INFRASTRUCTURE MANAGEMENT IN A METROPOLITAN CITY-KANPUR, INDIA

A THESIS

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CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **INFRASTRUCTURE MANAGEMENT IN A METROPOLITAN CITY-KANPUR, INDIA** in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the Department of Architecture and Planning of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during a period from July 2003 to May 2007 under the supervision of Dr. V. Devadas, Associate Professor, Department of Architecture and Planning, Indian Institute of Technology Roorkee.

The matter presented in this thesis has not been submitted by me for the award of any other degree of this or any other Institute.

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This is to certify that the above statement made by the candidate is correct to the best of my knowledge.

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ABSTRACT

The Indian sub continent is faced with increasing urbanization and a corresponding increase in the generated waste and the uncollected waste. Municipal solid waste management in the current Indian context is a complex problem on account of a number of factors like the limited resources, tendency to imitate the western counterparts for solutions irrespective of the different socio-economic, cultural and technological set up, absence of integration of land use and waste management (one of the infrastructures), low public-private and community participation, neglect of the informal sector engaged in waste recycling, lack of an integrated approach while tackling the waste management, poor implementation of the related legislation, etc. The methods employed usually follow a piecemeal approach and do not deal with the issue of municipal solid waste management in a holistic manner. This study attempts to approach the problem of municipal solid waste management in a metropolitan city in an integrated manner. Kanpur, a dirty and polluted metropolitan North Indian city has been chosen as the study area. The city does not have any data base except for few scanty data pertaining to waste generation. The objectives of the research are clearly stated with the main aim of converting the city into a dust-bin free clean city. Keeping in view the stated objectives, an extensive review of literature was carried out under three broad categories, solid waste management in developed countries, developing countries and India and the various prevalent models used in municipal solid waste management including the use of system dynamics approach for policy modeling. In this investigation, under the given constraints a System Dynamics model is developed to analyse all the six elements of solid waste management by using systems concept. The developed model is composed of several sub-models like, population and density, waste generation,

collection, treatment, transportation, disposal, manpower requirements in formal and informal sector, etc. Each sub-model is described in detail through stock and flow diagrams.

Various control parameters like socio-economic, environmental, institutional, etc., have been considered for calibration of the model. Field observations, literature survey and discussion with experts have been done to identify the important control parameters. Both primary and secondary sources have been used to fulfill the data requirement. Four largest generators of municipal waste in the study area have been considered for developing the waste generation sub-model, viz., household, industrial, commercial and market activity and hospital. The developed model has been validated and tested followed by long-range projections to understand waste generation by these four major sectors, the amount of waste collected, transported, treated and disposed of by the Authorities, the composite solid waste management efficiency and environmental stress in the overall system in the projected year 2031 A.D and the employment generated in the informal waste recycling sector. New concepts of composite solid waste management efficiency and composite environmental stress have been used to establish the interrelation amongst various system variables.

The functions of the system under various alternative conditions have been closely examined by developing various scenarios and tested by employing simulations to arrive at alternative policy decisions. Results for the impact of alternative policy scenarios have been presented for the year 2031 A.D., based on which the optimal policy was selected. A detailed phase-wise municipal solid waste management plan is thereafter prepared for the implementation of the selected optimal policy. General recommendations have also been given based on observations, analysis and discussion with experts. The study concludes with important conclusions and scope for future work.

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GLOSSARY OF TERMS

cal/kg:	calories per kilogram
CBO:	Community building organization
CDI:	City Development Index
CETP:	Common effluent treatment plant
CPCB:	Central Pollution Control Board
Dalaos:	a term used for Reinforced concrete (RC) bins used as collection point for storage of waste
GDP:	Gross Domestic Product
GNP:	Gross National Product
ICDP:	Institution and Community Development Project
IIT:	Indian Institute of Technology
INR:	Indian Rupees
ISWM:	Integrated solid waste management
Kabadi:	a local term used for waste –pickers and itinerant waste buyers
KDA:	Kanpur Development Authority
kg/hr:	kilogram per hour
kg/m^3:	kilogram per cubic meter
KNN:	abbreviation used for Kanpur Nagar Nigam (Kanpur Municipal Corporation), the main local Authority of Kanpur city
MIS:	Management Information System
mld:	million liters per day
MNA:	Mukhya Nagar Adhikari (Municipal Commissioner)
MT:	Metric tones
NGO:	Non-government organization
NH:	National Highway
SH:	State Highway
SK:	Safai karamcharis (municipal sweepers)
SPCB:	State Pollution Control Board
STP:	Sewage treatment plant

SWM:	Solid waste management
t/d:	tons per day
UASB:	Upflow Anaerobic Sludge Bed
Vikram:	diesel run six-seater highly polluting vehicles commonly used in Indian towns and cities as public mode of transport
WTE:	Waste-to-energy, a term used for various technologies for treating waste so as to extract energy in some form like fuel pelletisation, incineration with energy recovery, biomethanation, etc.

Chapter 1

INTRODUCTION

1.0 INTRODUCTION

Infrastructure is a very vital component of any settlement and is a prime necessity for its growth and development. A one per cent increase in the stock of infrastructure is associated with one per cent increase in Gross Domestic Product across all countries [342]. Both, quantity and quality of infrastructure is a direct indicator of the quality of life and the standard of living of the people. Infrastructure is in fact, an umbrella term used for many activities and is broadly termed as ‘economic infrastructure’ and ‘social infrastructure’ [341]. Economic infrastructure includes public utilities (power, piped gas, telecommunications, water supply, sanitation and sewerage, waste collection and disposal, etc.), public works and other transport sectors. Social infrastructure, on the other hand covers education and health care [342]. In spite of the best efforts on part of our various institutions, the gap between the demand and supply of required infrastructure seems to be ever widening. Some of the causes being, over dependence upon fiscal resources starved public sector for infrastructure provision, politicized decision making especially regarding location, pricing of services and lack of inter sector co-operation. A purview of the infrastructure status in urban and rural areas of the Indian sub-continent presents a grim picture. The problem becomes manifold in metropolitan cities. One of the components of the basic infrastructure services is waste management. Metropolitan cities, due to the enormous amount of population pressure, are facing an increasing pressure of managing the generated wastes and it remains a challenge in most cities.

In fact, a very startling difference made by the presence of *Homo sapiens* in any ecosystem is the huge quantity of waste generated and the mess created by his by-products of consumption.

In no other ecosystem is this imbalance between waste generated and waste treated/consumed seen. Nature has its own spectacular way of treating waste. Human being increasingly disturbed this nature's self-cleansing cycle and has reached to alarming proportions. His neglect, apathy and insensitivity towards a harmonious relationship with Nature have done a lot of damage, even endangering his own survival.

Today, management of waste is most often associated with urban areas where the life style and consumption pattern is different from that of the countryside. Hence, the problem of waste management is also more serious in urban areas. Urban people in developed countries generate two to three times more waste than their fellow rural citizens [165]. In developing countries, the rural citizens produce far less or no waste at all. The more inaccessible and remote a rural habitation, closer is its waste management similar to nature's, with all or most of its wastes going back to nature. Increase in accessibility especially to urban centres invariably takes the rural people away from their old traditional methods including their 'no-waste' attitude.

Cities in developing and developed countries alike face this problem of uncollected, untreated and burgeoning problem of waste management of different magnitude. Unlike the natural ecosystem where nothing is waste, urban systems follow an open cycle for waste disposal. A number of holistic methods have been attempted in developed countries to optimally manage municipal solid waste. Developing nations, however, have failed to come up with their own solid waste management methods suitable for their specific conditions. Attempts to blindly imitate the processes and methods followed in developed countries for collection, separation, transportation, treatment and disposal have often resulted in unsatisfactory results.

Integrated Solid Waste Management (ISWM) is the most widely accepted and practiced concept for the management of solid wastes. It has been defined as "the selection and application of suitable techniques, technologies and management programs to achieve specific waste management objectives and goals" [303]. The goals being to achieve environmental and health regulations, economic reliability and social acceptability. However, the holistic approach of sustainability has been added lately.

Indian cities have yet to adopt an integrated approach towards solid waste management. Currently, Indian cities like much of their counterparts in other developing countries are concerned only with collection and disposal of waste. Financial constraints and an inefficient management system that prevails give rise to poor collection and a further neglected disposal system without any treatment of waste whatsoever.

1.1 URBANIZATION AND SOLID WASTE MANAGEMENT

In India, the urbanization trend is not as high as in other countries of the world. The results of the 1991 and 2001 census indicate that the pace of urbanization has slowed down. The level of urbanization grew from 25.7 per cent in 1991 to 27.8 per cent in 2001 [1]. However, the process of urbanization is gradually shaping into *concentrated* urbanization. This phenomenon of increasing concentration of urban population is reflected through the increase in, not only the population but also the number of cities and urban agglomeration (UAs) having one million and above population, commonly known as 'million plus' or metropolitan cities/UAs. The number of such cities has increased from 1 in 1901 to 23 in 1991 and further to 35 in 2001. As per the Census 2001, the total population in these million plus cities constitutes 37.8 per cent of the total urban population as compared to that of 32.54 per cent in 1991. These indicates that more and more number of people from rural areas and also from smaller cities and towns are moving towards the million plus cities and UAs, putting an ever increasing pressure on the available infrastructure sub-system of these million plus cities [196].

Infrastructure comprises of many sub-systems like water supply, power, sewerage, drainage, roads, housing, waste management, etc. Solid Waste management is an important, yet most neglected subsystem of urban infrastructure. The per capita waste generation and the total waste generation is higher in million plus cities due to economic growth and change in life styles and consumption pattern. Management of solid wastes is the prime responsibility of the Urban local bodies (ULB) under the provisions of old municipal acts and also under the 74th Constitution Amendment Act, 1992. The Urban local bodies are however, not able to properly collect and manage the total solid waste generated. Indian cities generate an estimated 0.115 million MT of waste per day and 42 million MT annually [19]. The per capita waste generation ranges between 0.2 kg and 0.6 kg per day in the Indian cities, which is lower than that in developed countries. However, lifestyle changes due to economic growth and fast rates of urbanization have resulted in per capita waste generation increasing by about 1.3 per cent per annum. The Tata Energy and Resources Institute (TERI) has estimated that waste generation will exceed 260 million tones per annum by 2047-more than five times the present level [1].

It is observed that bigger the size of the city (population and density wise), greater is the quantity of waste generated. This is the phenomenon observed world over and India is no exception to this. Cities with population more than 0.1 million generate a major portion of this generated waste. They contribute 72.5 per cent of the waste generated in the country against the other 3955 urban centers producing only 17.5 per cent of the total waste. The collection of solid waste is inefficient (only 82.8 per cent of solid waste is collected in Class-I cities and less than 50 per cent in Class-IV cities), its transportation is inadequate and its disposal is unscientific. More than one-fourth of the municipal solid waste is not collected at all, and the landfills to dispose of the waste are neither well equipped nor managed efficiently. In fact, there is no scientific landfill in our country, only municipal dumps and controlled dumps are found. All these problems combine to make the condition of solid waste management in Indian cities quite grim. The current level of Solid Waste Management expenditure on waste treatment and disposal is found to be abysmally low, at less than 5 per cent. Central Pollution Control Board (2000) indicates that about 94 per cent of cities resort to indiscriminate dumping of domestic, commercial, industrial and medical wastes in low-lying areas [88]. During monsoons, the solid wastes are often found to be blocking the drainage movement leading to floods in the urban system. Improper/absence of waste management often results in serious pollution of surface and sub-surface water, resulting in supply of unfit water for drinking in the absence of a strong and efficient treatment system, leading to various health related problems ultimately affecting the economy. The solid waste management in Indian towns and cities, in general, presents a grim picture and needs urgent remedial measures.

The current practice of Solid Waste Management (SWM) in all urban centres of the country is biased towards achieving 100 per cent collection and its subsequent disposal, with partial or no treatment/processing. Thus, open cycle for waste management is being adopted unlike the waste management techniques of Mother Nature. To achieve the objective of sustainable development, there is therefore, an urgent need to shift the paradigm from open cycle to closed cycle of waste management to achieve the following: (i) to reduce the fast depletion of natural resources (ii) reduce the environmental stress caused by various elements of SWM (iii) to promote public health and avoid economic losses due to poor health on account of pollution caused by various Solid Waste Management practices.

The existing system of solid waste management in Indian cities is a Centralized one, both spatially and operationally. The system fails miserably when assessed for the criteria of Integrated Sustainable Waste Management. Integrated Sustainable Waste Management conceptually refers to a waste management system that best suits the society, economy and environment in a given location, a city in most cases. The concept of Integrated Solid Waste Management not only takes technical or financial-economic sustainability into account as is conventionally done, but it also includes socio-cultural, environmental, institutional and political aspects that influence overall sustainability of waste management [189]. Community initiatives, on the other hand, have found to improve the situation wherever it has been tried by involving the various stakeholders. There is, therefore, a need to find a way to achieve an optimal solution to this problem.

1.2 LITERATURE REVIEW

Solid waste management is one of the basic essential public services and its efficient management is indeed a challenging task with increasing levels of urbanization and consumption rates world over. The Author has gone through good amount of literature available and has selected for review only the most relevant cases. The practice of solid waste management is different in different countries; hence, an attempt was done to study solid waste management in developed countries, developing countries and in India to highlight the major differences in various aspects pertaining to solid waste management. To have an in-depth study on solid waste management, an extensive literature survey was done pertaining to this particular field of learning, grouped the literature into different segments based on literature focused on developed countries, developing countries and India; characteristics of wastes, sources of wastes, waste generation, waste collection, waste transportation, waste processing and waste disposal, various prevalent solid waste management models, costs of various components of solid waste management in different countries, regulatory and economic instruments in the field of solid waste management and role of institutions and informal sector in municipal solid waste management. Further, most important literature in the aforesaid aspects are chosen for in-depth study and their views, findings, etc., are presented [1, 4, 5, 7, 9, 10, 12, 14, 15, 16, 21, 22, 25, 26, 30, 38, 42, 45, 46, 51, 52, 53, 56, 87, 65, 72, 73, 78, 81, 88, 92, 103, 107, 109, 126, 132, 133, 141, 145, 146, 159, 162, 193, 210, , 236, 240, 245, 254, 273, 281, 298, 303, 317, 334, 335, 352].

1.2.1 Sources and Types of Solid Wastes

Municipal solid waste management is a complex task, which requires appropriate organizational capacity and cooperation between numerous stakeholders in the private and public sectors [278]. The knowledge of sources, types and composition of wastes is vital for designing a workable solid waste management system for any community, big or small. The most common classification for the sources of solid wastes can be given as: (1) residential, (2) commercial, (3) institutional, (4) construction and demolition, (5) municipal services, (5) treatment plant sites, (7) industrial, (8) agricultural and (9) hazardous [303, 335].

The generic term Municipal Solid Waste refers to all the solid wastes generated in the domain of a municipal body and comprises of all the above mentioned categories excluding industrial wastes. There is no consistent definition of Municipal Solid Waste across the countries [155]. In some cases it encompasses industrial and commercial waste and even construction and demolition debris which make its estimation incorrect [65, 273, 278]. According to the Ministry of Environment and Forests, Government of India, "municipal solid waste includes commercial and residential wastes generated in a municipal or notified areas in either solid or semi-solid form excluding industrial hazardous wastes but including treated bio-medical wastes" [231]. Solid waste expert Cointreau-Levine defines "Municipal solid waste to include: refuse from households, non-hazardous solid (not sludge or semisolid) wastes from industrial and commercial establishments, refuse from institutions (including non-pathogenic waste from hospitals), market waste, yard waste, and street sweepings" [78].

The composition of wastes can be at micro level or macro level. At micro level, the composition of waste means the percentage components of categories like plastics, paper, metals, glass, etc. Composition also refers to the amount of wastes coming from various sources in a community. It can also be termed as waste stream flow.

1.2.2 Functional Elements of Solid Waste Management

There are six functional elements that constitute Solid Waste Management systems [21, 30, 200, 278, 303]. They are:

1. Waste generation
2. Onsite handling, storage and processing
3. Collection
4. Transfer and Transport
5. Processing and Recovery
6. Disposal

Adoption of appropriate technology, by keeping in mind the socio-economic constraints, for handling various categories of wastes for each of the six elements of Solid Waste Management is a challenge to every municipality. Different countries adopt different policies and measures with regard to their waste generation, its contents, composition and various other socio-economic, technological and financial constraints. The literature has therefore, been discussed on these six functional elements separately for developed countries, developing countries and the prevalent situation in India.

1.2.3 Solid Waste Management In Developed Nations

Tchobanoglous, et. al. (1993), describes Solid Waste Management as that discipline associated with the control of generation, storage, processing and disposal of wastes in a manner that is in accord with the best principles of public health, economics, engineering, conservation, aesthetics and other environmental considerations, and that is also responsive to the public attitudes [303].

1.2.3.1 Waste Characterization

Waste characterization means characterizing waste streams by their source, types as well as generation rates and composition. It is important for optimal policy design formation and implementation of solid waste management program. Waste characterization studies are usually very expensive. Hence, only high-income countries are found to maintain a regular database with regard to waste characterization [165, 317].

1.2.3.2 Waste Generation

Waste generation varies from country to country, region to region, city to city and neighbourhood to neighbourhood. It is affected by factors like, socio-economic development, degree of industrialization, climate, cultural aspects, etc [161, 165, 352].

Waste generation and management data in most countries is poor in the context of availability, comparability, consistency and quality [105]. Most often, where data exists it is inconsistent or incomparable with similar data from other countries. Different definitions of wastes in different countries worsen the situation. Often, within the same country wide disparities are observed [105, 165, 317].

Waste generation is an activity that is presently not very controllable in most developed countries. Higher incomes lead to greater consumption of consumer goods, and therefore, waste generation rates in developed countries is much higher than in developing countries as shown in Table 1.1 [165, 344] and it clearly shows that USA has one of the highest per capita waste generation rate of 2 kg after that of Hong Kong whose exceptional waste generation rate of 5 kg per capita per day is probably due to inclusion of construction and demolition debris also in the municipal solid waste. The waste composition and income levels are generally found to be highly correlated in most countries. Lower GDP countries like Greece and Portugal have comparatively lower waste generation rates of 0.85 and 0.90 kg per capita per day, respectively. It has been observed that 40 per cent increase in the Gross Domestic Product of countries belonging to the Organization for Economic Cooperation and Development (OECD) since 1980 has been accompanied by 40 per cent growth in their municipal waste [249]. This however, does not hold true for all the countries. Studies done by Hoornweg, 1999 show the linkage between affluence and waste generation. Further, it is also observed that there is no correlation between private consumption in terms of income per capita and daily household and commercial waste. Increased income levels is often used to increase other types of waste like bulky waste or electrical and electronic equipment waste from households, construction and demolition waste [105, 165].

It is observed that municipal waste constitutes 14 per cent of the total waste generated in Western Europe* which is more affluent, whereas it is 4 per cent in Central and Eastern Europe**. The total waste generation per capita related to GDP per capita has decoupled in Western Europe, Eastern European countries in the last decade, whereas it has increased in Central Europe, Caucasian, and Central Asian countries [105, 317]. In total, an estimated 3,000 million tones of waste are generated in Europe every year. This means 3.8 tonnes per capita per year in Western Europe, 4.4 tonnes per capita per year in Central Europe, and 6.3 tonnes per capita per year in Eastern Europe [105].

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* Western Europe-Austria, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, United Kingdom

** Central and Eastern Europe-Bulgaria, Czech Republic, Estonia, Hungary, Poland, Romania, Slovakia, Slovenia

Table 1.1: Waste Composition as percentage of wet weight, Generation, GNP of major countries

S. No.	Country	Organic	Paper	Plastic	Glass	Metal	Others	MSW Generation rate Kg/cap/day 1992	GDP per capita(PPP US$) 2001
	High Income countries								
1	Greece	49	20	9	5	5	13	0.85	17440
2	Portugal	35	23	12	5	3	22	0.9	18150
3	Spain	44	21	11	7	4	13	0.99	20150
4	Singapore	44.4	28.3	11.8	4.1	4.8	6.6	1.1	22680
5	France*	25	30	10	12	6	17	1.29	23990
6	Finland*	32	26	0	6	3	35	1.7	24430
7	Hong Kong	37.2	21.6	15.7	3.9	3.9	17.6	5.07	24850
8	Japan	26	46	9	7	8	16	1.12	25130
9	Australia	50	22	7	9	5	8	1.89	25370
10	Canada*	34	28	11	7	8	13	1.8	27130
11	Netherlands*	43	27	9	4	5	8	1.37	27190
12	Switzerland	27	28	15	3	3	24	1.1	28100
13	Denmark*	37	30	7	6	3	17	1.26	29000
14	Norway	18	31	6	4	5	36	1.4	29620
15	USA	23	38	9	7	8	16	2	34320
16	Luxembourg*	44	20	8	7	3	17	na	53780
17	Israel	38	-na	35	na	na	na	1.73	

1995 data

Source: Compiled from Hoornweg et al, 1999 and World Bank data, 2001

1.2.3.3 Waste Composition

Waste composition describes the individual components that make up a solid waste stream and their relative distribution and is therefore, necessary to carefully study the waste composition characteristics before planning for solid waste management [213, 303].

Waste composition, generally, changes in accordance with the economic strength of the nation, and the purchasing power of the people of the particular nation. However, factors like socio-cultural, demographic, geographical aspects also influence the consumption pattern [55, 303].

Waste composition as percentage of wet weight in selected high-income countries is presented in Table 1.1. Wastes in USA, a country with highest GDP has one of the lowest organic content of 23 per cent while Japan has organic content of 26 per cent. The developed countries, in general, generate waste with higher paper and plastics content. Their wastes have lower moisture content and their calorific value is higher compared to that of developing countries. Higher income group people tend to have a higher percentage of inorganic materials like, metals, plastics, glass, textiles, etc., in the waste stream as they use more packaged goods.

As regards solid wastes, though the inherent characteristics of Municipal Solid Wastes remains consistent in location-to-location, the mix of those characteristics varies dramatically. Moisture is low in dry locations and high in coastal, sub-tropic, and tropic areas. Glass is higher in Europe than it is in North America. There are higher percentages of organics in Asia than in North America. Aluminium containers are higher in certain parts of the US than in others [159, 317].

1.2.3.4 Onsite handling, storage and processing

Onsite handling, separation, storage and processing of solid wastes at the source has a significant effect on the characteristics of the waste and on the subsequent functional elements. Developed countries, therefore, give a lot of importance to this elementary stage of solid waste management [303].

<u>Waste handling and storage</u>: Different types of equipments are used to collect, segregate, store and transport the wastes, which are generated in different areas like residential and commercial areas use equipments such as, compactors, service elevators, and pneumatic conveyors; vandal proof containers are required for open areas while special conveyors are used for treatment plant sites [303, 335].

Processing: Waste processing is done to reduce the volume of wastes, recovery of usable materials or to alter the physical form of the solid wastes. In developed countries, residences usually do shredding, grinding, sorting, compacting or composting at household level. Commercial and industrial facilities usually use compaction, shredding or hydropulping as an onsite-processing operation [21, 303].

1.2.3.5 Waste Collection

Collection means gathering of solid wastes from various sources, its haulage to the location where it is emptied and unloading of the collection vehicle. A collection system is a combination of collection method, container system, vehicles and personnel [53]. Collection of commingled and separated waste is rather a complex task in an urban setup, and is one of the costliest part of the various components of solid waste management. Estimates state that collection cost varies from city to city and it varies from 50 to 70 per cent of the total money spent on collection, transportation and disposal of solid wastes [303, 317].

An urban system is a complex of various land uses requiring different techniques to collect and segregate wastes in accordance with the local needs and requirements. Developed countries use very sophisticated automated collection vehicles and are either pneumatic or hydraulic. Both manual and mechanized vehicles are used for collection of wastes from residential areas and commercial-industrial facilities. The principal types of collection vehicles used for the collection of separated wastes are: 1) standard collection vehicles and 2) specialized collection vehicles like closed-body recycling trucks, recycling trailers, modified flatbed trucks, open-bin recycling trucks, and compartmentalized trailers [46, 303, 317].

The principal types of collection services prevalent in developed countries are curb collection, alley collection, setout-setback collection, setout collection, backyard collection and special collection systems like pneumatic and hydraulic types [303, 335]. Hydraulic transport is commonly used in United States, Switzerland but is uncommon in Europe [46]. Other than this, some cities use "just-in-time" collection systems, where residents bring out their wastes at the time when collection vehicle reaches a certain point and signals its presence [317]. This reduces the health hazards associated with wastes on streets and roadsides. However, this system requires someone to be at home at the time of collection. Waste collection systems are also classified into two categories namely hauled and stationary container systems, based on their mode of operation [303].

Industrialized countries have more anonymous and professionalized collection in contrast to that in developing countries [303]. Industrialized countries have a standard practice of using compacting vehicles of some type. Waste collection in Europe differs considerably among regions and countries, based on densities and degree of economic development. Most Western European countries organize waste collection twice in a week, weekly, or biweekly routes using 120 or 140 litre rolling carts, which are collected with semi-automated compactor trucks, usually having dual self-dumping lifts. In more Southern European nations, these compactor trucks may be loaded from ordinary garbage cans and/or bags. Scandinavian countries have a tradition of setting out and collecting household waste in tall 120 litre kraft paper bags in a stationary metal frame. The most common method in North America is curbside or alley collection. Collection usually occurs at least once per week and even more frequently in urban areas where storage space is limited. Drop-off and mailbox collection centres are also common in areas (e.g., rural), where individual collection is impractical. To promote recycling, dual or divided compacting vehicles and recycling trucks are used in US, Canada and Europe where vehicles do co-collection of waste and recyclables. As regard set-out containers used in collection system, industrialized countries usually use paper or plastic bag, or a metal or plastic garbage can. For recyclables, special containers are used like blue boxes in Canada and the US, and 120 litre rolling carts in Europe [21, 105, 303, 317].

1.2.3.6 Transfer and Transportation

Transfer and Transportation of solid waste management refers to the means, facilities, and accessories used to transfer waste from one location to another. In the process, the contents are usually transferred to larger vehicles, which are then used to transport the waste over long distances either to Materials Recovery Facilities (MRFs) or to disposal sites [325]. The transportation of recovered material to market or waste-to-energy facilities and transportation of residual materials to landfills also comes within the purview of transfer and transport. Factors like payload, distance to disposal or transfer stations, container systems, topography, traffic obstructions or limitations, road width on collection and transportation routes, daily work hours, routines, and break schedules of personnel and crew size are considered for determination of the size of collection and transportation vehicles [46, 317]. The various means and methods of transport practiced in the developed countries are:

a) Road transportation:

This is the most common means used to transport wastes. The principal types of vehicles used in conjunction with transfer stations for transport of wastes are truck, truck-trailer combination, tractor-semitrailer combination and tractor-semitrailer-pull trailer combination (also called doubles).

b) Waste transport by Rail:

Transport by rail requires a pre requirement of waste collection to the transfer stations by road transportation and is therefore, not much used. Rail transport generally uses compactor containers, rotary drum compactors, or open-top rail cars. It has the advantage of hauling large quantities of wastes like scrap metal, rubble, sludges, etc. It is, however, feasible where the landfill sites are remote and far off as the system is costly. The approximate cost per ton of garbage is about $6.88 by truck and $12.73 by train [46]. One of the largest rail haul operations in use is from the city of Seattle, WA to the Columbia Ridge landfill (300 miles away) [303].

c) Waste transport by Ship:

Waste can also be loaded on barges or containers for transport on container ships. Transport of waste by ship is relatively rare as it requires transfer stations, waste processing facilities, and landfills to be accessible to shipping docks. Besides, regular schedule of waste shipments is difficult and allows only non-decomposable waste shipping [46]. In United States, it is used for shipping waste over short distances at some places.

<u>Transfer stations</u>

Transfer stations are useful when haul distances to the waste processing centre or the disposal sites are large. In fact, transfer operations are an important part of all types of Materials Recovery Facilities (MRFs), a facility common in all developed countries. It can be used with all types of collection vehicles and conveyor systems. Larger quantities of wastes are transported to disposal sites in vehicles with greater capacity from the transfer station.

Transfer stations may be classified according to their capacities or according to the methods used to load the transport vehicles [146, 257, 303]. Transfer in most cases consists of the compactor truck or other type of collection vehicle like open truck, pickup truck, or wagon, arriving at the transfer facility and dumping its load of waste into a pit or onto a tipping floor. A front-end loader or bulldozer usually loads the waste onto a conveyor or a chute, from which it goes into a special compacting container. These are usually of large capacity and have high compaction ratios, and are used to densify the waste for more efficient long-haul transportation [325, 342].

1.2.3.7 Processing and Recovery

This element of Solid Waste Management includes recovery of separated materials, separation and processing of commingled waste, and transformation of solid wastes that occurs primarily in locations away from the source of waste generation.

A. Processing techniques

Processing of solid waste is primarily done to reduce volume with/without energy recovery. Developed countries employ many different types of unit operations to process and recover individual waste components. These operations employ advance technologies and state-of-the art equipment to get the exact configuration of the waste in terms of the size, weight density or physical and chemical properties required for further processing like thermal or biological [21, 46, 257, 303, 317].

Thermal Processing

It is the conversion of solid wastes into gaseous, liquid and solid conversion products, along with the release of heat energy. Thermal processing comprises of combustion, gasification and pyrolysis. The steam by combustion or gases or liquids by pyrolysis or gasification is converted to mechanical or electrical energy by using Steam turbine systems, Gas turbine Generator systems, Internal combustion engine systems or Cogeneration systems [303]. About 15 per cent of the total solid waste produced in the United States is processed in Waste-to-energy (WTE) facilities [323]. Fluidized-bed combustion (incineration) of municipal waste is extensively used in Japan which has some 167 such facilities whereas in Europe, mass-burn incineration is still the most popular [317]. In Europe, and Japan, Waste to Energy (WTE) incineration is primarily used for steam generation for heating and cooling purposes.

Although the technology of incineration has greatly advanced, the main problem in its implementation in the developed countries is the air pollution caused by the gaseous products of incineration. Studies from a variety of facilities in US, however, indicate that the best air pollution control equipments can potentially remove up to 99 per cent of dioxins and furans, more than 99 per cent of heavy metals, more than 99 per cent of particulate matter, hydrogen chloride, sulphur dioxide and up to 65 per cent of nitrogen oxides. However, the aforesaid air pollution control equipments are very expensive. Developed countries have stringent air pollution control regulations, which make incorporation of expensive equipment to keep the discharges to acceptable level necessary. Fabric filters, electrostatic precipitators and scrubbers are the major air emission control technologies used [257, 317].

Incinerators is the term used for combustion units of the past without energy recovery and usually characterized by high residual ash content, air pollution, inadequate engineering and poor design [323]. Japan, the world's second largest economy, has been actively using thermal treatment due to lack of available land for landfilling [46, 317].

Biological and Chemical Processing

Biological and chemical processes are used to transform the organic fraction of Municipal Solid Wastes into gaseous, liquid and solid conversion products [317]. The biological processes of waste treatment are broadly classified as aerobic and anaerobic decomposition. Aerobic decomposition is accompanied by generation of heat, whereas anaerobic decomposition is a cold process. Composting can be windrow (forced aeration-static piles, contained piles or mechanically turned bay type with forced aeration) or mechanically turned system.

Mechanically turned systems use mechanisms like (1) conventional earthmoving machines (2) side-cutting windrow turners, (3) straddle turners, and (4) pre-aeration in a rotating drum [213, 257, 303]. Anaerobic low-solids systems operate at a total solids percentage of less than 10 per cent. It has been in use to treat sewage effluent for over 100 years. Anaerobic high-solids systems are a recent innovation (last 20 years) and operate at a higher total solids percentage of 25-40 per cent [213].

Composting suffers from three practical serious problems even in developed countries [349], viz.,

a) lack of markets for the finished product;

b) small reduction in the total refuse volume requiring disposal;

c) environmental factors of composting plants, specifically odour.

Various biological processes, which are already in advanced stages of implementation and others in developmental stages are presented in Table 1.2 and the table illustrates the various aerobic and anaerobic processes like anaerobic digestion-low solids and high solids content, enzymatic hydrolysis and fermentation, the resultant conversion products from these processes and pre-processing requirements.

Chemical processes are used to recover products like synthetic oil, gas, methanol and cellulose acetate. It is not popular for processing the municipal solid waste. It is more commonly used for agricultural wastes and sugarcane bagasse [303].

Capital and operating costs of windrow composting is generally low, with only forced aeration types having a higher installation cost. Capital cost and the operating costs of sophisticated mechanical composting systems are high. An aerobic system costs between $90 and $150 per ton of waste to build, a low-solids anaerobic plant cost $120 to $180 per ton of waste while high-solids plant installation may even exceed $200 per ton [213].

Table 1.2: Biological processes for the recovery of conversion products from the organic fraction of MSW

S. No.	Process	Conversion product	Pre-processing	Remarks
1.	Aerobic conversion (Composting)	Compost (soil conditioner)	Separation of organic fraction	Popular types are windrow, aerated static pile and in-vessel forced aeration types; their performance is essentially same hence selection to be based on capital, operating costs, land availability, nuisance problems, etc.
2.	Anaerobic digestion (in landfill)	Methane and carbon dioxide	None, other than placement in containment cells	
3.	Anaerobic digestion (low solids, 4-8 per cent solids)	Methane and carbon dioxide, digested solids	Separation of organic fraction, particle size reduction	Not commercialized for energy recovery, most work going on in Europe; not much successful in USA except for agri-wastes.
4.	Anaerobic digestion (high solids, 22-35 per cent solids)	Methane and carbon dioxide, digested solids	Separation of organic fraction, particle size reduction	Not commercialized for energy recovery, most work going on in Europe; a prototype developed at Cornell Univ, USA under development
5.	Enzymatic hydrolysis	Glucose from cellulose	Separation of cellulose-containing materials	Bagasse, paper products and wood, agricultural wastes rich source
6.	Fermentation (following acid or enzymatic hydrolysis)	Ethanol, single-cell protein	Separation of organic fraction, particle size reduction, acid or enzymatic hydrolysis to produce glucose	Under development

Source: Compiled from Tchobanoglous, et. al., 1993; Haug, R.T., 1980 and Vesilind, et. al., 2002

Centralized composting is a successful, cost-effective environmentally sound waste management approach in Europe and increasingly in North America. Countries like Denmark, Germany, and the Netherlands use system approach to composting of separate kitchen and yard waste called 'biowaste'. It involves the use of a modular in-vessel composting system followed by a period of composting either in aerated static piles or active windrows [303, 317].

Some backyard composting programs have operated successfully in Northern Europe, North America, Australia and New Zealand with a participation rate of 30 per cent [317]. Anaerobic digestion used for composting mixed waste is successfully recovering compost and methane in France and Belgium. Europe has clear and enforceable compost quality standards with adequate government intervention. It is the world leader in its compost standard programs, identifying three grades of compost ranging from acceptable to very high quality based on levels of heavy metals [105, 317].

Inspite of the renewed interest to the importance of adoption of sustainable management of solid wastes, especially in the developed world, the amount of wastes being diverted to various waste recovery processes as shown in Table 1.3, is generally small. Composting is successful to some extent in countries like France, Portugal and Spain [202, 273].

Table 1.3: Waste management methods in developed nations (%by weight)

S. No.	Country	Landfilling	Incineration	Composting	Recycling	Total
1.	Australia	82	2.5	0	15.5	100.0
2.	Canada	80	8	2	10	100.0
3.	Denmark	20	58	0	22	100.0
4.	France	45	42	10	3	100.0
5.	Germany	46	36	2	16	100.0
6.	Greece	100	0	0	0	100.0
7.	Ireland	97	0	0	3	100.0
8.	Italy	74	16	7	3	100.0
9.	Japan	15	74.3	0	10.7	100.0
10.	Netherlands	45	35	5	16	100.0
11.	Portugal	85	0	15	0	100.0
12.	Spain	65	6	17	13	100.0
13.	Sweden	27	53	2	14	100.0
14.	UK	88	6	0	6	100.0
15.	USA	67	16	2	15	100.0

Source: Compiled from Sakai, et. al., 1996 and Williams, 1998

B. Recovery of Resources and Energy

Solid wastes contain components that may be of value as a source of raw materials for industry or fuel for production of power. Recovery of materials is important as it drastically reduces the materials left for final disposal, besides the additional benefit of conserving natural resources. Two terms are commonly used in this context, *viz.*, recycling and reprocessing. Recycling is the recovery of items or individual fractions from the waste in a way that they may be reused. Reprocessing, however, is the reduction of waste to one or more raw materials from which completely new consumer products are manufactured [213]. Both reprocessing and recycling end products need marketing. Reprocessed products have a potentially much larger market.

In developed countries, for recovery of source-separated waste materials curb-collection and homeowner delivery of separated materials to drop-off and buy-back centres is employed. Drop-off centres range from single material collection points to multi-material collection centres. Buy-back centres have the additional direct or indirect monetary incentive for participation. The commingled and separated waste is further processed at materials recovery facilities (MRFs) or at large integrated materials recovery/transfer facilities (MR/TFs). The materials recovered from Municipal Solid Waste can be reused directly, as raw materials for manufacturing and reprocessing, feedstock for production of biological and chemical conversion products, fuel source or land reclamation [257, 303, 317]. A number of methods like binary or polynary separators, picking, various types of screens, float/sink separators, jigs, air classifiers, magnets and electromagnetic separators, etc., are prevalent for materials separation at materials recovery facilities (MRFs) and materials recovery/transfer facilities (MR/TFs) [323].

1.2.3.8 Disposal of Solid Wastes and Residues

Safe disposal of solid waste residues is an important component of waste management. Solid waste residues are waste components that are not recycled, that remain after processing at a materials recovery facility (MRF), or that remain after the recovery of conversion products and/or energy [303, 323].

There are two main methods of ultimate disposal of wastes and post-treatment residues, viz., landfill and barging it out into the sea [130]. Landfills are one of the oldest and most primitive methods of disposal of solid waste. Tchobanoglous, et. al., (1993) defines landfills as the physical facilities used for the disposal of residual solid wastes in the surface soils of the earth [303]. The earlier crude methods of open dumping in the name of landfills have now given way to engineered sanitary landfills. Sanitary landfills is defined by the American Society of Civil Engineers as "*a method of disposing of refuse on land without creating nuisance of hazards to public health or safety, by utilizing the principles of engineering to confine the refuse to the smallest practical volume, and to cover it with a layer of earth at the conclusion of each days operation, or at such more frequent intervals as may be necessary*" [148]. All the developed countries of East Asia, Pacific, North America and Europe have engineered sanitary landfills, and developed countries like USA, UK and Canada landfill between 67 and 88 per cent of their municipal solid wastes. The developed countries, which use landfill as a major means of the disposal of municipal waste generated is presented in Table 1.3 and the table illustrates that the European countries have a comparatively lower rate of landfill due to the dominance of incineration. Japan, an advanced economy of the Asian zone incinerates most of its waste due to acute shortage of available land [317].

Landfill Planning, Design and Operation

The principle elements that must be considered in the planning, design and operation of landfill are landfill layout and design, operations and management, management of landfill gases and leachate, environmental monitoring, landfill closure and post closure care [12, 21, 303]. Zach, et. al, (1999) state that since landfills rank third in anthropogenic CH_4 emissions which are, beside CO_2, chlorinated and fluorinated hydrocarbons and N_2O, made responsible for global warming, "sustainable landfilling" should be promoted [347]. Simple biological pre- and aftercare measures like mechanical-biological pretreatment of wastes, using compost as cover layer and usage of plants like *Miscanthus* for stabilization of landfill cover, etc., are capable to reach the goal of a low emission waste disposal site at moderate costs. Recirculating leachate over waste in landfills (after taking proper precautions) can increase the quantity and quality of methane gas by a factor of 10 and enhance the settling of the waste. Such 'bioreactor' landfills are becoming popular in US, Europe and Brazil [21, 257, 317].

Stabilization of wastes in a landfill

Pichtel, J. (2006), Tchobanoglous, et. al., (1993) and Vesilind, et. al., (2002), suggest that the stabilization of wastes in landfills proceeds in five sequential and distinct phases. The rate and characteristics of leachate produced, gas generated and other parameters differ distinctly in all the phases [257, 303, 323].

Most developed countries, in particular, European countries, USA and Japan, have adopted a hierarchical approach to solid waste management, including final waste disposal. European Union policy includes environmental costs for landfilling, but only stresses environmental benefits for the other options. Landfilling is often considered to be the worst option, whereas incineration is generally thought to produce fewer externalities. In contrast, USA has not had a clear preference for incineration over landfilling for a long period [106]. The Environmental Protection Agency (EPA) explicitly mentions indifference between the final waste disposal methods. Existing final waste disposal is still dominated by landfilling, even if stated policy preferences suggest otherwise. The first column of Table 1.4 shows that fewer than half of the European Union countries and Japan incinerate over 50 per cent of their domestic waste. In contrast, Finland, Italy, Spain, the UK and the USA have a very low percentage of incinerated waste, while Greece, Ireland and Portugal incinerate no waste at all. It is widely thought that one of the major reasons for the dominance of waste incineration in general, and Waste to Energy in particular, is scarcity of land in some countries. Against the general belief that scarcity of land being the cause for waste incineration, Table 1.6 shows no clear correlation between population density or cultivated land and the percentage of domestic waste incinerated. For instance, the UK and Italy incinerate only small amounts of waste with relatively high population densities and levels of cultivated land. On the other hand, Sweden, France and Belgium incinerate a lot of domestic waste with much lower land scarcity indicators [106, 257, 317]. Gross private costs being very high for incineration, Waste to Energy (WTE) plants prove to be very expensive and need serious consideration by policy makers on social costs. However, Mendes, et. al, (2003) state that waste treatment from landfilling to incineration would decrease the overall environmental impact while also allowing energy recovery [223].

Landfilling, though the least environment friendly method for disposal, is still the most predominant option around the globe. Studies state that 57 per cent of municipal waste in Western Europe was landfilled in 1999, whereas 83.7 per cent in Eastern and Central Europe [105]. It is observed that the Western European countries are increasingly adopting policies to increase the recovery and reprocessing of wastes. Countries like Netherlands, Denmark, Austria, Sweden, Norway, etc., show a high recycling rate whereas France, Germany, United Kingdom, Portugal, Ireland, etc., landfill/incinerate most of their wastes [105, 317].

Table 1.4 : Waste incineration characteristics in some developed countries, 2001

S.No.	Country	Incinerated waste as a % of total municipal waste	Cultivated land as a % of total land[a]	Population density (people per km^2)
1.	Europe	33	22	122
2.	Austria	20	43	98
3.	Belgium	55	45	312
4.	Denmark	100	63	126
5.	Finland	5	9	17
6.	France	63	55	107
7.	Germany	72	50	235
8.	Greece	0	68	82
9.	Ireland	0	64	54
10.	Italy	13	53	196
11.	Luxembourg	47	na	166
12.	Netherlands	113[b]	58	466
13.	Portugal	0	43	109
14.	Spain	9	62	79
15.	Sweden	56	8	22
16.	UK	5	71	246
17.	Japan	75	13	336
18.	USA	16	47	30

[a] Figures for 1994.
[b] More than 100 per cent is possible as incinerated waste includes also firm waste, whereas due to statistical reasons this waste is not included in municipal waste

Sources: Elbert Dijkgraaf and Herman R.J. Vollebergh, 2004

Disposal of waste by barging into the sea

The other method used for disposal of waste is by barging it into sea rather than land. Wastes is carried at reasonable distance from the coast (16 to 20 kilometres) where the sea depth should not be less than 30 m , and the direction of the currents should be such as not to bring it back towards the shore. The system has become obsolete now with renewed environmental awareness and strict banning of disposal of wastes into the sea [130].

1.2.4 Solid Waste Management In Developing Nations

Third World cities have undergone a high urbanization rate in the past decades. The growth rates in these countries exceed 3 per cent a year, which is three times higher than that of the industrialized countries [221]. Increasing urbanization coupled with less attention to the provision of better solid waste related services and improper handling and disposal of solid wastes has led to a serious environmental and health crisis in these countries, especially in the urban centres [170].

Solid waste management in developing countries suffers from a number of problems. Some of the structural and institutional weaknesses of municipal solid waste management system and referred by different distinguished Authors include, secondary priority in municipal administration, shortage of resources, fragmented responsibilities borne by various departments, political pressures, lack of short-, medium-, and long-term solid waste management planning, lack of garbage collection route design, lack of supervision, with typical ratios of one supervisor per 10–30 vehicles, lack of equipment maintenance, lack of training for maintenance staff, inadequate funds for vehicle repair, lack of spare parts for vehicles, unsatisfactory onsite storage, insufficient supply of communal trash cans results in the storage area becoming a dump site, scavenging by rodents and stray animals eventually leaves the waste scattered all around the site, insufficient collection, widespread littering, crude dumping, haphazard tipping, shortage of suitable land for disposal, etc. [12, 73, 125, 198, 221, 278, 307, 314, 326]. It has been further stated that the trends in solid waste management in Asia indicate that methods used are outdated and show a lack of proper waste characterization, waste stream analysis, and landfill and dump site data [170, 171].

Another problem in developing countries is growing quantities of hazardous and toxic waste that hospitals and certain industrial and commercial establishments generate and the unchecked mixing of hazardous waste with the municipal solid waste. As per Asian Development Bank report, about 60 -65 per cent of the hazardous wastes generated in Asia is deposited in dumpsites or landfills, 5-10 per cent dumped in the ocean, and the rest incinerated or chemically treated. In most cases, proper safeguards are absent or largely ineffective [18].

Waste reduction by introduction of legislation like agreements to change packaging, landfill levies, charges on littering, user charges, extended producer responsibility, etc., are not common in developing countries and is a new emerging trend in few developing cities [76, 317].

1.2.4.1 Waste Generation

There is a strong correlation between the economic standing and the quantity of solid waste generated in an urban system world over [30, 352]. The waste generation rates for some Asian low and middle-income countries are presented in Table 1.5.

The table illustrates that there is an increase in waste generation rate with increase in Gross National Income (GNI), however the ranges observed are large which, shows the urban and rural divide. Studies undertaken by the Japan International Cooperation Agency (JICA) however, state that Gross National Product (GNP) and per capita waste collection in developing countries are correlated rather than the conventional notion of the link between per capita waste generation and GNP/GNI. The finding is based on the study of nine cities in eight developing nations [301]. Another noticeable feature with regard to estimations of waste generation, collection and disposal observed is the problem in comparing waste generation rates for various countries as global inconsistencies are observed in the way municipal solid waste is defined and quantified in various countries [165]. Waste generation in Latin America and Caribbean countries range between 0.3-1.0 kg/inhabitant/day (this includes commercial, market, and street-cleaning wastes), whereas the density of wastes vary between 150 and 200 kg/m [317].

Table 1.5: Waste generation rates of some Asian countries, sorted by ascending Gross National Income(GNI)

Sl No.	Country	GNI[a]	Waste generation (kg/cap/day)	Reference
1.	Nepal	240	0.2-0.5	UNEP,2001
2.	Cambodia	260	1.0	Yem,2001
3.	Lao PDR	290	0.7	Hoornweg,1999
4.	Bangladesh	370	0.5	Hoornweg,1999
5.	Vietnam	390	0.55	Hoornweg,1999
6.	Pakistan	440	0.6-0.8	World Wildlife Fund,2001
7.	India	450	0.3-0.6	Ahmed, 2000;Akolkar,2001
8.	Indonesia	570	0.8-1.0	Mukawi, 2001
9.	China	840	0.8	Hoornweg,1999
10.	Sri Lanka	850	0.2-0.9	Jayatilake,2001; Hoornweg,1999
11.	Philippines	1040	0.3-0.7	World Bank,2001
12.	Thailand	2000	1.1	Hoornweg,1999

[a] GNI 2000 per capita in $ based on Atlas method

Source: Christian Z., 2002

Although the waste generation rates in developing countries are substantially lower than those in industrialized countries, these rates are not proportionally lower relative to income as presented in Table 1.6. In fact, these rates are roughly 30 per cent to 50 per cent as high as those in industrialized countries, while income levels are 2 per cent to 10 per cent as high, as indicated below [78].

Table 1.6: Estimated waste generation rates and income

S. No.	Item	Low-income country	Middle-income country	Industrialized country
1.	Solid Waste Quantity (tonne/cap/yr)	0.2	0.3	0.6
2.	Average income $US/cap/yr(in1988)	350	1,950	17,500

Source: Cointreau-Levine, S., 1994

1.2.4.2 Waste Composition

The composition of solid wastes is similar in developing countries; nevertheless, there exists geographical, climatic, economic, racial, cultural, social and demographic differences. These variables have been reported as determinants of the quantity and the composition of the solid wastes [12, 55, 154, 218, 352]. The character of the waste is however, changing fast in recent years with increasing urbanization [248, 266, 278, 316]. The waste stream in Eastern Europe is similar to the Asian and African developing economies. They are high in putrescibles and lower in recyclables [317].

The typical waste composition in developing countries of Asia and South-East Asia is presented in Table 1.7 and it clearly illustrates that countries like China, Indonesia, Bangladesh and Nepal have very high percentage of organic or bio-degradable content in the municipal waste while countries like India, Pakistan and Thailand have comparatively lower bio-degradable content in the municipal waste. As evident from the table, inert materials also form the bulk of municipal solid waste in developing countries, making the waste density very high. Hence, collection vehicles successful in industrialized countries fail in these countries. High moisture and inert content of the waste makes it unsuitable for incineration as well, due to low calorific value of the waste [258, 352].

Table 1.7: Typical average waste characteristics in urban settings

	City	Bio-degradable	Paper	Plastic	Glass	Metal	Textile & Leather	Inerts
1.	Shanghai, China	67.3	8.8	13.5	5.2	0.7	4.5	-
2.	Indonesia	74	10	8	2	2	2	2
3.	Dhaka	70	4.3	4.7	0.3	0.1	4.6	16
4.	Kathmandu	68.1	8.8	11.4	1.6	0.9	3.9	5.3
5.	Bangkok	53	9	19	3	1	7	8
6.	Hanoi	50.1	4.2	5.5	-	2.5	-	37.7
7.	Manila	49	19	17	-	6	-	9
8.	India	42	6	4	2	2	4	40
9.	Karachi	39	10	7	2	1	9	32

Source: Compiled from Zurbrugg, C., 2002 and Terazono, et. al., 2003

Countries with lower levels of urbanization, such as Thailand, China, Indonesia, and Vietnam, generate relatively large quantities of organic kitchen wastes. The level of urbanization of a country affects the composition of organic waste as a result of the growing incomes and new lifestyles of people living in urban areas. Greater consumerism tends to generate more packaging materials, which have a higher paper and plastic content [304].

Waste generated in developing economies shows a higher percentage of organic materials than that in industrialized countries, which consume more packaged goods. Paper and plastics tend to increase with increase in GNP [159, 165]. Wastes in developing countries also consist of greater amount of ash, silt and other inert material. Accordingly, the municipal solid waste is invariably denser in these countries. These physical characteristics influence the treatment methods. These countries are often found to imitate the solid waste management practices of industrialized and developed economies, inspite of these differences in the amount, nature and composition of solid waste. As a result, most of these imitations often fail miserably [74, 317, 346].

1.2.4.3 Waste collection

Collection must be appropriate to the terrain, the type and density of generation areas, road, waste type, availability of the types of vehicles, capability of the collection crew, etc. of the particular community and neighbourhood [317].

The suggested frequency of collection for various climatic conditions are :

1. Tropics: Daily
2. Temperate: Summers-Every 2 days; Winters-Every 3 days
3. Cool climates: Summers-Twice a week; Winters-Once a week

It is observed that collection of municipal solid waste is poor in most developing countries, irrespective of the type of climate due to various reasons; the marginal and poor section being the worst sufferers as municipalities allocate their limited financial resources to the higher-income areas where citizens with more political power reside [27, 131, 197, 209, 317]. Similar findings are also observed in developing countries with regard to aspects such as the scarcity and insufficiency of planning, as well as non-scientific, disorganized, and informal solid waste management. Insufficient public and private funds and corrupt public sanitation management systems is also often reported in developing countries [8, 55, 99, 145, 157, 251, 250, 267].

The waste collection rates of few developing countries have been presented in Table 1.8 and the table clearly illustrates that the developing countries have varying collection rates and it varies between 8 per cent and 96 per cent, with an average collection rate of 60 per cent [141, 281].

Table 1.8: Collection rate in various developing countries

	City, Country	GNP per capita (US$/year)	Generation rate of MSW (g/person/day)	Collection rate of MSW (g/person/day)
1.	Vientiane ,Laos	330	970	105 (10.8%)
2.	Asuncion, Paraguay	1760	1312	834 (63.6%)
3.	Granada, Nicaragua	390	749	464 (61.9%)
4.	Dar-es-salam, Tanzania	210	873	70 (8.0%)
5.	Quezon, Philippines	1050	524	389 (74.2%)
6.	Tegucigalpa, Honduras	730	566	401 (70.8%)
7.	Adana, Turkey	3160	696	671 (96.4%)
8.	Chennai, India	-	1350	1242 (92%)
9.	Lima Metropolitana, Peru	-	1980	1188 (60%)
10.	Manila, Philippines	-	1718	1186 (69%

Source: Compiled from Shimura S. et. al , 2001 and Grafakos, et. al., 2001

The responsibility for managing solid waste primarily rests with the municipal authorities in most developing countries [27]. Collection accounts for 70-90 per cent of costs incurred by the local governments on municipal solid waste management in developing countries [317]. It involves face-to-face interaction between the generator and the collector. The service is low, with the poor getting no or little service. Collection is manual-labour based and vehicles like wagons, animal-drawn carts or rickshaws are common. Non-compactor trucks are found to be more efficient and cost-effective as wastes in these countries is usually very dense. Recoverable materials are often separated during the collection process at various stages [77, 317].

Three common types of primary collection vehicles are prevalent in developing countries, *viz.*, the handcart, which is manually pushed by the municipal worker or hired operator; the pedal tricycle with container or box(es); and animal-drawn carts, pulled by donkeys and buffaloes, etc. There are two basic approaches for collection system, *viz.*, shared system, in which the residents can bring out the waste at any time and individual system, in which the generators store the waste on their property till it is collected [146]. The conventional collection approach of individual system, as developed and used in the industrialized countries is often replicated in the developing countries. The vehicles used are sophisticated, expensive, and difficult to operate and maintain. As a result, after a short span of time only a small part of the vehicle fleet is operational [278, 352]. Poor maintenance of collection vehicles is a common problem in developing countries where one-third or more of the fleet is usually out of order at a time [317]. In many developing countries, like India and Pakistan, shared system of collection is prevalent. The generators of waste are required to dump their waste at a specified location or masonry enclosure or shared container, from where the wastes is removed or emptied [146]. Curbside collection is in practice in Brazil only among the Latin America and Caribbean nations. Side- or back-loaded compactor trucks carry out the collection process through pre-established collection routes. Waste collection is also carried out using other means, depending on finances, road conditions, and socio-economic level of the collection area, etc. Vehicles like trucks, front loaded tricycles, or carts (pulled by a tractor, animal, or person) are also used. Semi-motorized and manual collection systems are common in harder-to-reach areas of the cities, as well as in smaller towns. A parallel system of waste collection either by individuals who receive direct payment for their services, or, by waste collection cooperatives or small-scale enterprises is emerging in the Andean and Central American regions [221, 222, 317].

1.2.4.4 Waste Transfer and Transport

Transfer stations are centralized facilities where waste is unloaded from smaller collection vehicles and re-loaded into larger vehicles for transport to a disposal/processing site. Various types of transfer vehicles are used like trailers, trucks, carts, etc., depending on the terrain, climate, street layout, traffic, road surface and settlement pattern. Compactor trucks common in developed countries work poorly in extremely wet conditions and in developing countries where mostly the waste is very dense [72, 75, 157]. Cities in developing countries need to have several collection systems depending on the waste stream composition which varies with season and social division. Hybrid systems combining muscle and mechanical power are found to be more appropriate for these countries [278, 303]. Countries like South America, Mexico, and Costa Rica use trailers without compactors as transfer stations [317].

1.2.4.5 Waste Processing and Recovery

Waste recovery and recycling of inorganic wastes in developing countries is high even without any government or policy support as in industrialized countries [278]. The reasons for this are many like scarcity of virgin materials, cheap labour, presence of people who will accept minimal wages, the frugal values of the society, etc. The extent of formalization of these waste trading enterprises varies from country to country. Latin America and Asia have more formalized registration of waste recycling activities than Africa [221, 222, 317]. Recycling and recovery in developing countries is usually done by what is popularly known as 'informal sector' [126, 146, 336, 337, 343].

The informal sector engaged in waste recycling is entirely market driven and hence, subject to market fluctuations. This sector generally lack the technologies to optimize recycling methods due to poor financing and support by the government and private sector; poor working conditions exist especially for the lower rung of the sector whose services continue to be unrecognized [123, 215, 221, 222, 317].

Composting is the most promising area for the recovery of organic materials. In cities of developing countries, most large mixed-waste composting plants have proved to be complete failures or work at less than 30 per cent of capacity [278, 317]. Whereas, small and medium scale, informal and organized composting is successful in India and China while it is unsuccessful in Latin America, Caribbean and Africa due to technical and economic reasons.

Incineration in developing countries is difficult and inadvisable due to reasons like high capital and operating cost, high moisture content and low calorific value of the waste [113, 278, 317]. When incineration is done in a manner that has low adverse health and environmental impacts, it is expensive and when it is done poorly it can be expensive in terms of human health and environmental impacts [317]. Virtually, no incinerator operates in Latin America or Caribbean. Gupta, S., (2004) points that the more developed countries are doing away with incinerators because of high costs (due to higher standards of emission control) and developing countries have become potential markets for dumping such technologies [144]. Incinerators routinely emit highly toxic cancerous dioxins, furans and polychlorinated by-phenyls (PCB) [113, 144, 317].

Cities like Buenos Aires, Mexico, New Delhi, Sau Paulo, etc., have had to shut down their incinerators due to high costs or environmental impacts. It is however, successful in few middle income countries like Singapore which incinerates 90 per cent of the waste generated. It is, therefore, observed that a rational approach to planning is required for optimal municipal solid waste management and in the selection and adoption of technology due to the variations in waste stream and characteristics and local socio-economic conditions [159, 303, 317].

1.2.4.6 Waste Disposal

Open dumping is the most common disposal method practiced in middle and low income countries across the globe [12, 272]. Open dumping of solid wastes thrives because it is said to be the cheapest disposal method. Deposition along roads and riverbanks or in abandoned low-lying areas is common. The chemical and biological contaminants in wastes find their way back to humans to affect health, quality of life, and working activities. Soluble and suspended contaminants in water leaking from the site (leachate) enter surface watercourses and the groundwater. Contamination may then directly affect the drinking water supplies and/or the aquatic food chain. Grazing animals on dumps pass on diseases via the terrestrial food chain, as well as by pests through infestation. Those living on or near a dump are also at risk from direct hand-to-mouth transfer of contamination and from inhalation of volatile compounds and aerosols. Details on the common environmental health problems from poor waste management are presented in Cointreau- Levine, et. al. (1996) and WHO (1995) [79, 317]. People living and working in the vicinity of solid waste processing and disposal facilities are also exposed to environmental health and accident risks. These risks are substantially managed in high-income countries but remain mostly unchecked in developing countries [70, 74, 79, 170, 227].

Central America (except for Costa Rica), the Guyanas, and most Caribbean countries do not have landfills. All capital and other large cities in South America, Mexico, Costa Rica, and Trinidad and Tobago have landfills of some sort. Many of these landfills, however, are more like controlled dumps with some 60 per cent of the waste generated in the region going in such "landfills." Some large cities in the region like Buenos Aires, Mexico City, Santiago, and Sao Paulo, etc., do have state-of-the art landfills. Landfill design followed in the region consists of an initial clay layer, followed by a sand or ground stone layer. Synthetic liners are not usually used except for some new landfills in Argentina, Brazil, and Chile. Leachate collection systems are used, the landfills are subdivided into cells, and they have chimneys for gas ventilation [21, 317].

Manual landfills are common in Columbia, Chile, Costa Rica, Honduras and Peru. They are similar in design to mechanized landfills except for their size and the equipment they require; have a capacity to receive 10-50 tons per day. They are found to be a suitable option for small cities and towns. In many developing countries in Asia, the impact of open dumping of waste and unmanaged waste, in general, to human health and social welfare was not realized until much later when the waste dumps had grown into uncontrollable mountains of waste [12, 317].

1.2.4 Solid Waste Management Practices In India

India generates approximately 48 million tons of waste per annum, and is increasing by 1.3 per cent per year, against the annual urban growth rate of 3.5 per cent per annum [1, 113, 137, 165]. The urban waste generation is estimated to be two or three times more than the waste generated by rural residents [97]. There is a yearly increase of almost 5 per cent in the overall burden of solid wastes in Indian cities, thus pointing to the dismal situation of solid waste management in Indian cities and towns. The town planning documents also do not discuss in detail about the waste management issues in a comprehensive manner [217].

Indian cities usually do not have any formal house to house collection system; householders either deposit their waste in a communal container, or leave outside the house. It is removed by municipal sweepers who take it to a larger waste transfer point, from where it is lifted and transported to a disposal site, via another intermediate transfer point. The collection frequency of the waste varies from daily upwards, depending upon the resources available and the perceived importance of the locality. The municipal sweepers are organised into a system of 'beats', i.e., length of street, and there is a hierarchical system of supervision in the Health Department, which is usually based around council/corporation Wards. Vehicle crews are under the overall control of the Transportation Officer, who assigns their pick up routes [282, 290].

1.2.5.1 Waste Generation

Indian cities face a common problem of getting hazardous industrial and biomedical waste getting mixed with the municipal domestic and commercial waste. The latter is poorly collected and disposed of, creating great direct and indirect environmental consequences. Besides, the hazardous content is generally found to be quite high since the regulatory and enforcement system to control such waste disposal are usually non-operational [42, 79, 286, 287, 358].

The waste generation rate depends upon a number of factors like per capita income, standards of living, food consumption habits, cultural traits, degree of commercial and industrial activity, etc. The quantity of municipal solid waste generated from 23 metro cities on an average is rising by 23 per cent annually. The metros located in the major river basins show nine metro cities generate the maximum solid waste of 12,120 tonnes/day, which is about 40.3 per cent of the total waste generated from metro cities [87]. The total municipal solid waste generated and the per capita generation rate in the selected 23 metropolitan cities of India is presented in Table 1.9 and it illustrates that the per capita generation rate varies between 0.3 kg per day and 0.6 kg per day, with an average generation rate of 0.45 kg per capita per day.

Table 1.9: Status of MSW Generation in Metro Cities

	Metro city	*Municipal population*	*Municipal Solid Waste (t/d)*	*Per capita generation(kg/d)*
1	Ahmedabad	2876710	1683	0.585
2	Bangalore	4130288	2000	0.484
3	Bhopal	1062771	546	0.514
4	Mumbai	12288519	5355	0.436
5	Calcutta	10643211	3692	0.347
6	Coimbatore	816321	250	0.429
7	Delhi	8419084	4000	0.475
8	Hyderabad	4098734	1566	0.382
9	Indore	1091674	350	0.32
10	Jaipur	1458483	580	0.398
11	Kanpur	1874409	1200	0.640
12	Cochin	670009	347	0.518
13	Lucknow	1619115	1010	0.624
14	Ludhiana	1042740	400	0.384
15	Chennai	4752976	3124	0.657
16	Madurai	940989	370	0.393
17	Nagpur	1624752	443	0.273
18	Patna	917243	330	0.360
19	Pune	2244196	700	0.312
20	Surat	1498817	900	0.600
21	Vadodara	1031346	400	0.388
22	Varanasi	1030863	412	0.400
23	Vishakhapatnam	752037	300	0.399
	Total/Average	**66885287**	**30058**	**0.449**

Source: CPCB, 1998

A common problem observed in India is inadequate accounting of the waste generation, collection and disposition rates in Indian cities. Data available from various sources state varying figures with regard to quantity of waste generated, waste composition and the waste collected and managed in various cities of India, as presented in Table 1.10. The per capita generation of waste data given by the Municipal authorities is mostly found to be less than that given by the Central Pollution Control Board, a national level government organization, surveys. The percentage variation of Local Authorities data from CPCB data varies between 3.6 per cent and 47.9 per cent. Table 1.10 clearly illustrates that discrepancies occur in the generation rates given by various government agencies.

Table 1.10: Discrepancy in data from various sources, India

S. No.	City	*CPCB Survey, 1994-95*		*Local Municipality Data (1996)*		Percentage variation
		Municipal solid waste generated(MT/day)	Per capita generation (kg/day)	Municipal solid waste generated(MT/day)	Per capita generation (kg/day)	
1.	Ahmedabad	1683	0.585	1225	0.348	40.5
2.	Bangalore	2000	0.484	1716	0.381	21.3
3.	Bombay	5355	0.436	5500	0.336	22.9
4.	Calcutta	3692	0.347	na	na	-
5.	Delhi	4000	0.475	4557	0.333	29.9
6.	Hyderabad	1566	0.382	2200	0.398	-2.6
7.	Kanpur	1200	0.640	1000	0.333	47.9
8.	Chennai	3124	0.657	3200	0.498	24.2
9.	Pune	700	0.312	na	na	-

Source: Based on CPCB, 1994-95 and Various Local Municipalities Reports

As per the report of the Committee constituted by the Hon. Supreme Court of India, Solid Waste Management in Class I cities in India, March 1999, lower rates of per capita generation of solid wastes is observed in cities with lesser populations as presented in Table 1.11 and it clearly illustrates that the per capita waste generation in metropolitan cities varies between 270 grams per capita per day and 500 grams per capita per day.

Table 1.11: Per capita Waste generation rates in Indian cities

Sl. No.	Population range (in lakhs)	Average per capita waste generation (grams /capita/day)
1.	1 to 5	210
2.	5 to 10	250
3.	10 to 20	270
4.	20 to 50	350
5.	>50	500

Source: NEERI, 1996

The generation rate is dependent on the economic status of the population also. The higher income groups generate more solid wastes than the middle and lower income groups. As per a study done by the Tata Energy Research Institute, New Delhi, the lower income groups of Delhi were found to generate less than one-third of solid wastes than their higher income counterparts [309].

1.2.5.2 Waste Composition

Studies conducted by various agencies show that the composition of garbage in India has lower organic content and a high ash and dust content; with a low calorific value in general [1, 19, 88].

Variations are observed in physical and chemical characteristics in Indian cities. Cities with population higher than 50 lakhs have the highest moisture content in their municipal waste while cities with population range between 5 lakhs and 10 lakhs have drier waste with moisture content of 19.5 per cent. The nitrogen content of the waste generated in smaller cities is higher as compared to that of cities with greater population. The calorific value of the waste in smaller cities is also higher than that of cities with greater population [88]. It is also observed that increasing rate of urbanization gradually changes the consumption pattern, less industrial to more industrial goods, more packaged goods, etc., leading to the decline in ash content and increase in combustible content.

Waste density, a critical parameter for the design of a solid waste management system, also shows wide variations among various cities in India as presented in Table 1.12. The table clearly illustrates the difference in densities of waste, ranging between 369 and 537 kg per cubic meter.

Table 1.12: Density of municipal solid waste in selected cities in India

Sl. No.	City	Density (kg/m^3)
1.	Bangalore	390
2.	Baroda	457
3.	Delhi	422
4.	Hyderabad	369
5.	Jaipur	537
6.	Jabalpur	395
7.	Raipur	405

Source: MOUD, 2000

1.2.5.3 Onsite handling, Storage and processing

The Indians follow a common practice of throwing the wastes along roadsides, open drains, etc. They most often, do not even take the daily wastes to the communal collection points (which are quite often in a dilapidated state or altogether absent). The Municipal Acts of most Indian cities and the newly introduced Municipal Solid Wastes (Management and Handling) Rules, 2000 is silent on the requirements of onsite storage of solid wastes at various generation points [240]. The latter part only describes little about door-to-door collection and transfer to the secondary collection point.

However, the frugal values of our Indian culture bring some respite in the situation. Source separation of probable wastes and its storage is done even in the high income groups, which is later sold to the Itinerant waste buyers (popularly known as *Kabadiwalas* and *Raddiwalas*). Such wastes include wastes of all sorts like paper, magazines, old clothes, metals, glass containers, etc. Rest of the wastes find their way along roadside and open drains [90].

1.2.5.4 Waste Collection

The household waste is disposed of either via a door-to-door collection system, which is not so common, or in municipal facilities. Excluding posh residential and commercial colonies, most of the households, shops and other establishments throw waste as and when it is generated. At places where bins have been provided, the bins are found to be placed at great distances and bin sizes are usually small. The number of bins is also very little. In most cities and towns, waste collection is done at the ward level, with a minimum number of communal collection points. The secondary collection of municipal wastes is done by the respective municipalities of the cities [147]. The system is mostly erratic and inefficient due to a number of reasons. The collection efficiency of solid wastes few selected Indian cities is given in Table 1.13. Large metal bins and concrete bins (dhalaos) are kept in the collection points. More waste is often found littered all around these bins at the collection points rather than inside the dhalaos or waste bins [45, 137, 305]. The narrow bylanes and slum areas usually remain unserved or hand carts are used to bring the wastes to the nearest collection point or transport vehicle [172]. Street sweeping is another common method of collection of municipal wastes, especially since most of the waste is disposed off on the streets. However, street sweeping as a means to achieve cleanliness has also failed miserably in most places due to various reasons [45]. The collection efficiency of solid wastes in most Indian cities is very low and reflects the poor management and inadequate planning measures of the local authorities [1, 19, 90, 131, 252]. At secondary collection points, a major part of the recyclables is picked up by the rag-pickers and a part is eaten by the pigs, stray cattle, dogs, rats, etc.

Table 1.13: Collection efficiency of Solid Wastes in selected Indian cities

Sl. No.	City	Waste generated (t/d)	Waste collected	Collection efficiency (%)	Rank
1.	Calcutta	3500	3150	90.0	1
2.	Mumbai	5800	5000	86.20	2
3.	Bangalore	2130	1800	84.5	3
4.	Chennai	2675	2140	80.0	4
5.	Ahmedabad	1500	1200	80.0	5
6.	Surat	1250	1000	80.0	6
7.	Lucknow	1500	1000	66.7	7
8.	Delhi*	6500	4000	61.0	8
9.	Patna	1000	300	30.0	9

*Source: NIUA, 1997 and *Good Governance India, 2004*

1.2.5.5 Waste transfer and transport

From the collection points, wastes is periodically collected, transferred and transported by the municipalities using a fleet of vehicles. The vehicles used are of all sorts and types, ranging from hand carts, bullock carts, three wheelers, open tractors, trailors and trucks. The transportation system is often not synchronized with the collection and storage systems resulting in multiple manual handling of waste, which is unhygienic and hazardous for the workers as well. The wastes carried in the vehicles go uncovered leading to further littering enroute. Some large cities also use modern vehicles with hydraulic lifting mechanism and in-built compactors. The vehicles are mostly in poor shape due to lack of regular maintenance. Only a part of the whole fleet is found to be in use due to regular breakdowns. The cities, in general, have a very non-scientific and ill-managed system of transportation [19, 280].

1.2.5.6 Treatment and Processing

The treatment and processing of solid wastes has a peculiar problem in India due to variations in the generation rates, composition, physical characteristics and density. Municipal wastes in India have high organic content due to higher usage of fresh vegetables/fruits instead of tinned/pre cooked food as in developed countries. This makes the waste treatment options of incineration, pyrolysis, etc. unsuitable. Composting, on the other hand, is amenable due to high percentage of organic matter in the wastes. In most cities and towns of India, almost 100 per cent of the collected wastes is landfilled/openly dumped without any treatment/processing [42, 43]. Authorities in few urban areas are trying to have alternative waste management technologies [19].

Indian city refuse is generally not suitable for incineration, because of its low calorific value, high moisture content, and high quantity of non-combustibles [113, 145]. Burn techniques, such as, gasification, pyrolysis and incineration are technically inappropriate for Indian garbage which has a calorific value of about 800 cal/kg. Burning the waste requires at least 1,500 cal/kg, else auxiliary fuel is needed. This raises the probability of undesirable materials being used as fuel supplement, such as, plastics and other waste oils. Besides, Waste-to-energy plants are very costly apart from releasing highly toxic emissions like the carcinogenic dioxins and furans, particulate matter and Green house gases. The Delhi plant at Timarpur, Chennai WTE plant, Lucknow WTE plant, Vijaywada WTE and Hyderabad pelletisation plants all point to the inadequacy of the technology for Indian conditions [131, 310, 346].

Aerobic and vermin-composting are more popular forms of composting in India. Bin composting and pit composting is also widely practiced [174, 288, 289]. Centralized composting has proved to be a complete failure in the country. A study carried out in India (UNDP/WB RWSG-SA 1991), analysed 11 heavily subsidised mechanical municipal compost plants constructed between 1975 and 1985, ranging from 150 to 300 tons refuse handling capacity per day. The study concluded that in 1991 only 3 were in operating condition [315]. The past decade has seen the setting up of a number of small-scale composting plants initiated by NGOs, CBOs, often with some international assistance. Only few of them are able to continue functioning once the financial assistance is withdrawn. Besides, the community level small composting plants are often found to work improperly. Unsegregated waste is just dumped in a pit and allowed to decay. The entire operation is unhygienic, unscientific, foul-smelling and very slow. This leads to resistance by the people living in vicinity [45, 145, 353]. Technical and financial lacunas in absence of favourable market for compost are some of the reasons for failure of most composting plants [81].

1.2.5.7 Recovery and Recycling

An important feature of waste recovery and recycling is the involvement of the informal sector. Studies reveal that this sector is mainly engaged in the recovery and re-sale of most of the recyclables and is highly labour intensive [20, 27, 52, 76, 77, 90, 124, 126, 128, 265, 322]. However, notwithstanding their significant contribution to waste recovery and recycling process, their role in urban waste management is not recognized, and their earnings continue to be meagre Waste recovery and recycling processes is entirely guided by market forces in India [9, 77, 126, 127].

India has one of the highest growth rates in terms of plastic consumption as far as the plastic menace is concerned. It also recycles some 60 per cent of the plastic generated, the highest in the world [305]. However, though there is considerable in-house plastic recycling in industries that actually manufacture plastic goods; there is very little recycling of post-consumer plastic. Indian recycling is done by the informal small-scale sector which is capital-deprived and unable to adopt advanced safer technology. It is done in an uncontrolled and unmonitored way and is highly hazardous [305, 318].

1.2.5.8 Waste Disposal

The final destination of solid waste in India is disposal. Most urban solid waste in Indian cities and towns is landfilled or dumped or openly burned [49, 50, 86, 98, 144, 150, 160, 187, 333]. Disposal of solid wastes is the most ignored area among all the components of solid waste management in Indian cities. It is highly unscientific and unhygienic with serious health and environmental implications [12, 183, 230, 346]. The wastes collected and transported are simply dumped at any low lying area. There is no provision for leachate collection, gas extraction or any protective cover. There is nothing like sanitary landfill due to the high cost of construction and maintenance:

There is no adherence to any standards or norms for disposal and the site is not scientifically managed. Dumping waste in low-lying areas for land reclamation is commonly practiced, which results in contamination of the surrounding water resources by leachate. Only open dumps with or without the provision for daily cover exists in most Indian cities and towns. These landfills and open dumps are accessible to the dump pickers, animals and vectors. These legal and illegal open dumps are choking the land mass and pose a threat to health and the environment. As per an estimate by Tata Energy and Research Institute, dump sites occupy more than 20,000 ha [145].

Few dumpsite rehabilitation initiatives have however, been taken in the country like, the Pune Municipal Corporation adopted a strategy of rehabilitating the dumpsite by capping and construction of a sanitary landfill site over the capped site [261].

1.2.5.9 Legislative aspects of Solid Waste Management in India

The Planning Commission of the Government of India is an apex body that defines policies for the country as a whole. At the national level, the Ministry of Urban Development is the responsible agency for solid waste management in Indian cities and towns. It deals mostly with general issues such as conducting training programmes. There is an involvement of other ministries as well, but on specific aspects of waste management. For instance, the Ministry of Forestry and Environment established a task force to review plastic recycling industries and formulated guidelines for the same. It has also formulated guidelines for the storage and disposal of hospital waste. The Central Pollution Control Board is another central agency, which has formulated guidelines for hazardous (industrial) waste and is also responsible for the enforcement of those guidelines. At State level, solid waste management comes under the purview of the Municipal Affairs Department. Most of the Municipal Acts in Indian cities have some provision for the management of solid wastes. However, there is rampant abuse of the laws due to weak implementation mechanism and soft punitive measures. The Seventy-Fourth Constitutional Amendment Act (CAA) of 1992 provided more power, authority and responsibilities to the urban local bodies. At local level, the municipality is the responsible body for solid waste management. Municipalities of bigger cities have separate departments for solid waste management. For instance, the Conservancy and Sanitation Department of the Municipal Corporation of Delhi (MCD) is responsible for street sweeping, collection, transportation and disposal of garbage, while the Engineering Department is responsible for the technical and physical support such as, the provision and maintenance of vehicles and dustbins. In other metros, like Calcutta and Bangalore, the Health Department is responsible for the safe collection and disposal of solid waste, and the Engineering Department is responsible for the physical and technical support. Even in small towns the health officer of the municipal/local body is responsible for the waste management while vehicles and staff are under the control of the city engineer. Most municipalities lack a specific department exclusive for solid waste management. The respective departments are often headed by a Medical Health officer rather than any technical expert. Lack of inter-departmental co-ordination is universally observed in all Indian cities and towns, resulting in poor services.

The Ministry of Environment and Forests, Govt. of India, have come out with a number of statutory rules related to Solid Waste Management framed under the provisions of the Environment (Protection) Act, 1986 [286] and are:

(i) Hazardous Wastes (Management and Handling) Rules,1989;

(ii) Bio-medical Wastes (Management and Handling) Rules,1998 (*w.e.f.*July 27,1998);

(iii) Re-cycled Plastics (Manufacture and Usage)Rules, 1999 (*w.e.f.* September 2, 1999); and

(iv) Municipal Solid Wastes ((Management and Handling) Rules, 2000 (*w.e.f.* October 3, 2000).

(v) Batteries Management and Handling Rules of 2001

The Municipal Solid Wastes (Management and Handling) rules, 2000 lay down broad guidelines for Solid Waste Management including collection, segregation, storage, transportation and disposal of municipal solid waste [240]. It provides for setting up of certain mandatory infrastructure in respect of Solid Waste Management. Municipalities need to give annual reporting to State Pollution Control Boards (SPCB) who, in turn, are required to submit report to Central Pollution Control Board (CPCB). However, the implementation of various rules laid down in the Rule book is still seen to be a big problem and not much improvement is observed in the sanitary condition of most of the Indian cities and towns [325]. Besides, the rules are not comprehensive and need to lay down more detailed monitoring mechanism and implementation system for every aspect of Solid Waste Management. The responsibility of enforcement of the rules lay with the Secretary in charge of the concerned State while District Magistrate or Deputy Commissioners are responsible for the same in their respective districts. Further, a system of annual reporting by the municipalities to the State Pollution Control Boards (SPCB) exists, who in turn are supposed to report to the Central Pollution Control Board (CPCB). The CPCB is also required to prepare a consolidated report to document the implementation of these rules. The guidelines were to be fully implemented across the country by Dec 31, 2003 [240]. It is year 2007 and even part implementation of the rules is yet to be seen in Indian cities and towns [144].

1.2.6 Solid Waste Management Models

1.2.6.1 Integrated Solid Waste Management models

Integrated Solid Waste Management (ISWM) is the most widely accepted and practiced concept for the management of solid wastes. It has been defined as "the selection and application of suitable techniques, technologies and management programs to achieve specific waste management objectives and goals" [303]. The goals being to achieve environmental and health regulations, economic reliability and social acceptability. Developing and implementing an Integrated Solid Waste Management plan is essentially a local activity that involves the selection of proper mix of alternatives and technologies to meet changing local waste management needs while meeting legislative mandates. Integrated Solid Waste Management implies that decisions on waste handling should take into account economic, environmental, social and institutional dimensions. The integrative aspect lies in the trade-off between these four dimensions and can take place at various levels [199].

Integrated sustainable waste management is a much-discussed concept in international conferences but there is little evidence of integration of the socio-economic, environmental and public health aspects in local practice in developing countries [190].

The Waste Management Hierarchy is a key element of Integrated Solid Waste Management and is widely applied in industrialized countries. It is based on environmental principles and shown in Fig. 1.1. It became the internationally accepted standard for environmental assessment of solid waste management system as a whole [48, 313]. The attributes of the hierarchy move from preventive to ameliorative to assimilative [132].

Waste management hierarchy is an open system and faces a lot of criticism on the order of hierarchy. There are two major schools of thought on the hierarchy: one interpretation is that integrated waste management is a 'menu of options' and there is no such thing as a good or bad technology option and depends on the circumstances; the other interpretation is that the hierarchy should be strictly followed, i.e., one should maximise the amount of waste prevented at source, then maximise the amount recycled or composted, and only then burn or bury the rest [51, 277]

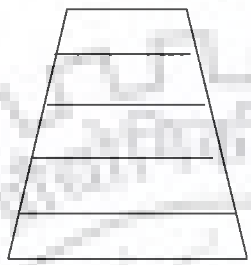


Fig. 1.1: Waste management hierarchy

Developed countries focus on adopting the waste management hierarchy as far as possible. Different countries adopt different strategies for Waste Management and variations in levels of adoption of the options are observed. This was universally strengthened at the United Nations Conference on Environment and Development in Rio de Janeiro, 1992 to reduce wastes and maximize environmentally sound reuse and recycling. Factors like topography, population density, transportation infrastructure, socio-economics, and environmental regulations should be considered for appropriate adoption of various options for Solid Waste Management [273]. Western Europe has largely endorsed and implemented integrated waste management system and follow waste management hierarchy. However, some variations are observed in this region. Northern Europe gives precedence to materials recovery over energy recovery with the exception of France [317].

Successful solid waste management frequently depends on accurate predictions of waste generation. Trend analysis, Life cycle analysis, Input-output model, Multi-sector equilibrium model and System Dynamics model are often used for these purposes [47, 53, 83, 109, 112, 173, 185, 234].

A number of models have been developed to achieve the best combinations of waste facilities for an optimal Solid Waste Management system. Earlier models focused on economic optimization functions [4, 201]. This gradually gave way to inclusion of environmental costs in 1990s after the UN Conference on Environment and Development in 1992. Chang, et. al., (1996) and Daskalpoulas (1998) combined economic and environmental costs to design an efficient Solid Waste Management system [66, 92]. Attempts were also made to deal with the micro-level issues like optimal siting for minimum cost for transfer stations and incinerators, siting for landfills, etc. [242, 284]

Tsiliyannis (1999) discussed the main environmental problems related to Municipal Solid Waste management, and in particular those concerning pollutant releases [312]. Chang and Wang (1997), proposed a fuzzy goal programming approach for optimal planning of Municipal Solid Waste management systems, in which they consider four objectives: economic costs, noise control, air pollution control, and traffic congestion limitations [67]. Another possible approach is based on life cycle assessment, which is a tool that can provide the data needed for choosing the best combination from an environmental standpoint [24, 94, 110, 111, 113, 219, 268, 331]. However, life cycle assessment does not predict actual impact, assess risk, safety, or whether a threshold may be exceeded by choosing an option [21].

Planning a Municipal Solid Waste management system is a very complex task, because it is necessary to simultaneously consider conflicting objectives; in addition, such problems are generally characterized by an intrinsic uncertainty as regards the estimates of costs and environmental impacts. Such reasons have led several Authors to introduce and apply multi-criteria decision techniques [67, 68, 71, 162, 184, 260]. The principles of Sustainable and Integrated

Solid Waste Management (SISWM) have been developed by WASTE*, based on project experience and studies conducted by different authors inside and outside WASTE [15, 42, 156, 199, 210, 235, 278]. The Sustainable and Integrated Solid Waste Management is supportive of good governance, provides economic service delivery, considers economies-of-scale in facility sizing and route designs, and seeks to decentralize or bundle services as needed to optimize such economics, establishes cost recovery mechanisms for long-term financial sustainability, conserves natural resources, embraces public participation, fosters environmentally appropriate technologies and sites, seeks appropriate levels of source segregation, recycling and resource recovery, conducts strategic facility planning and development, builds institutional capacity and invites private sector involvement. No model has however, been developed involving all the principles mentioned to achieve an optimal Sustainable Integrated Solid Waste Management. Hickman (1996) and Ham (1996) however, viewed that sustainability in waste management is an impractical idea [150, 158].

Di Nino and Baetz, 1996, tried to link the search for sustainable waste management systems to urban dynamics and observed that collection of waste in nodal city generates less pollution than in a spread city [98].

A number of models have been developed to achieve the best combinations of waste facilities for an optimal Solid Waste Management system. The first Solid Waste Management models were optimization models and dealt with specific aspects like vehicle routing, transfer station siting, etc. During the 1990s, the models developed tried to include aspects like recycling and other waste management methods. Some models also discussed the main environmental problems related to Municipal Solid Waste management, and in particular those concerning

* WASTE is an advisory company for research and practice pertaining to Solid Waste Management. They run the Urban Waste Expertise program, funded by the Dutch Ministry of Development Cooperation.

pollutant releases [162]. However, the models only considered economic and environmental aspects but missed social aspects. The current waste management models are mostly compromising models (unlike the earlier optimizing models) and can be categorized into three categories, those based on cost-benefit analysis, those based on life cycle analysis and those based on the use of a multicriteria technique. However, no model considers the involvement of all the stakeholders involved in waste management. An attempt has been made in this regard to combine multicriteria decision making (MCDM) and a consensus analysis model (CAM) for assessment of the degree of consensus between stakeholders for particular alternatives [166].

Waste minimization (reduction), which offers the best possibility for environmental aspects of sustainable development, is vigorously followed in developed countries like Netherlands [317]. It is based on households separating materials voluntarily with little or no compensation, and subsidies by government to reuse and recycle. There is active peoples' cooperation. The situation is very different in developing countries. Waste reduction is not usually applied as a matter of public policy. Waste reuse, recovery and recycling is extensive but not supported by the government, rather solely surviving on private commercial basis. Hence, waste recovery and recycling in these countries is susceptible to changes in external conditions [44, 221, 222].

Community based small-scale and micro-enterprises supported by the local governments in developing countries for collection, transport and disposal, and recycling have had mixed success [16, 26, 29, 56, 123, 127].

Sudhir, et. al., (1996) developed a non-linear lexicographic goal programming (NLGP) model for a planning period of five years highlighting the limitations of techno-managerial solutions and the scope of the informal sector in developing countries [297]. Sudhir, et. al., (1997) developed a dynamic version of Solid Waste Management planning model, capturing the dynamic nature of interactions among the various components of the urban Solid Waste Management system in Madras, a typical metropolitan city in India for a time horizon of 40 years [298].

Hokkanen and Salminen (1993); Chung and Poon (1996), used Multi-Criteria Analysis (MCA) to select the preferred waste disposal options [27, 162]. However, there are several problems associated with Multi-Criteria Analysis such as the selection of suitable criteria, appropriate weights, which may lead to biased results [131].

In India and other developing countries, the usage of integrated Geographic Information System-Geographic Positioning System (GIS-GPS) for the development of spatial and non-spatial database, routing optimization and decision-making is also underway [195, 228, 263].

McDougall, et. al., (2001) summarized 13 case studies where principles of Integrated Solid Waste Management have been attempted at [219]. However, any of the cited communities do not use any computer-based integrated model for choosing the waste management options and use of computer-based model at the local level is not common [21]. None of the existing developed/ing models in the field of Solid Waste Management are sustainable in real sense. Most of the models do not consider the complete waste management cycle; they do not cover all the three aspects of environment, economic and social considerations. Most importantly, no model considers the involvement of all the relevant stakeholders as given in the conceptual guidelines of Sustainable and Integrated Solid Waste Management.

1.2.6.2 Application of System Dynamics models in Solid Waste Management

Very few detailed studies are available in the field of solid waste management, which have employed system dynamics concept. Most of the available studies are at conceptual level. A conceptual Systems Focused approach was attempted at by Painter, J., et. al, 2001. It proposed to bring together group discussions and systems-analysis techniques that have been developed by employing systems concept for an efficient solid waste management system. It helped to evaluate problems comprehensively, arrive at solutions and effectively communicate with both internal and external stakeholders [254].

Sudhir, et. al., 1997, attempted to develop a generic model to study the potential and systemic consequences of various structural and policy alternatives for a sustainable urban solid waste management system. Chennai city, India was chosen as the case study for developing the model [298]. The model tried to capture the activities and interactions among the various actors, both formal and informal, involved in solid waste management. The proposed model however, considered only household waste generation whereas, municipal wastes comprises of other wastes as well.

Karen, M. Luken, 2004, used systems thinking concept to understand the prevalent advantages and disadvantages of the solid waste collection system in Chesterfield County, USA, to bring consensus among the various stakeholders (residential customers, private contractors, county government) for possible changes in the system after careful examination and promotion of strengths of the system [186].

Karavezyris, V. et. al., 2002, attempted to forecast solid waste management system using system dynamics concept along with fuzzy logic to enhance confidence in the validity of the model. It tried to incorporate phenomena of importance related to waste management but not measurable and tractable. In this investigation, Berlin was chosen for conducting the study [185]. The authors have evolved a Waste Management model (WMM), which is an abstract and conceptual model focusing on selected factors like facilities and costs of materials recovery, treatment and disposal schemes, production activities, environmental behaviour and legislative changes.

Wäger, P.A. and Hilty, L.M., 2000, developed a system called EcoSolver IP-SSK by using the system dynamics simulation software Powersim Constructor [Powersim Corporation 1996]. It has been conceived as a system, which allows simulating the ecological and economic effects of possible future developments in regional plastics waste management in Switzerland for time periods up to 15 years. When this model was however applied, a general need for improvement concerning the clarification of model structure, the assessment of parametric uncertainty and sensitivity, validation and robustness tests was felt [328].

Mayo, L, et. al., 2005, at Idaho National Engineering and Environmental Laboratory (INEEL) have build a model applying system dynamics to better understand the dynamic processes that affect the performance of waste-barrier caps [216] .

Thirumurthy (1992) employed system dynamics to study urban problems in developing countries [306]. He used the model to assess the investment requirement for various environmental services, including solid waste management in Chennai city for the time-period from 1990-2020. However, solid waste management was not dealt with in great details.

Masahyekhi (1993), made an attempt to analyze the problems of transition from landfill method of disposal to other forms of disposal for New York city [214]. Dyson, B. and Chang, Ni-Bin (2005) used system dynamics modelling for the prediction of solid waste generation in a fast-growing urban city-San Antonio, Texas, based on a set of limited samples [103]. Sufian and Bala (2005) used system dynamics modelling for analyzing electrical energy recovery from urban solid waste management for Dhaka, Bangladesh using the software Stella® [299].

All the above models, however, deal with one or few elements of solid waste management. There is therefore, a need to evolve a comprehensive model covering all the elements of solid waste management and aim at achieving sustainable integrated solid waste management in the context of developing countries requirements.

1.2.6.3 Zero Waste Approach

Recently, the Solid waste management hierarchy discussed earlier has led to a closed loop concept called "Zero waste" started at Canberra, New Zealand, which aims to eliminate rather than "manage" waste. It is a whole system approach that aims for a massive change in the way materials flow through society -resulting in NO WASTE and is both an end of pipe solution which encourages waste diversion through recycling and resource recovery, and a guiding design philosophy for eliminating waste at source and at all points down the supply chain [7, 21, 133, 356, 361].

Chronologically, the states/municipalities adopting/ed the concept of zero waste in a big way and making efforts at implementation level can be summarized as under:

- Canberra adopted 'No Waste by 2010' in 1996;
- Western Australia is in the process of adopting 'Towards Zero Waste by 2020';
- USA - Zero Waste targets have been adopted by Del Norte County, the city of Seattle, Santa Cruz County, San Luis Obispo County, and Boulder City Colorado;
- Toronto adopted 'Zero Waste by 2010' in January 2001;
- Zero Waste campaigns are also operating in South Australia, England, Wales, Ireland, India (Kovalam), Egypt, Asia, and the Philippines.

- Some of the major international businesses who have adopted Zero waste targets include big names like, Xerox, Honda Motor Corp, DuPont Inc., Hewlett-Packard, Toyota, Ricoh Group, Bell Canada, etc.

The key elements suggested by Wood and Tarman-Ramcheck (2002) to achieve zero waste are [339]:

a) Investment in community waste reduction and recovery systems
b) Citizens' participation in recycling
c) Product redesign to make it non-toxic and reusable after useful life
d) Extension of producers' responsibility beyond initial sale, which will provide incentive to buy back
e) End of subsidies to enterprises that use virgin resources only.

The core principles of Zero waste goals are to end cheap waste disposal, designing waste out of the system at all points of the supply chain, and to engage the entire nation/community. The concept is based on a very simple logical premise that anything that is extracted from the natural world as a useful resource should not be discarded, but should be repeatedly used. If a resource should finally become unusable then it should be processed in a way that ensures its value is returned to nature.

1.2.7 Solid Waste Management Costs

In high income countries, a major part of the municipal budget is allocated for intermediate treatment facilities and disposal whereas in low income countries, majority of the solid waste management budget goes to street sweeping, collection and transportation facilities and final disposal costs are minimal as the latter is accomplished through open dumping.

Solid waste service consumes a higher share of income in developing countries than in industrialized countries. Although labour costs are lower in developing countries, the purchase price of equipment is typically higher, and fuel costs are greater.

The per capita Solid Waste Management costs and per capita gross national product (GNP) have a strong relation worldwide [344]. It is observed that with increasing gross national product (GNP) of a country, the per capita expenditure on Solid Waste Management services also increases gradually. On an average, both developing and industrialized countries do not spend more than 0.5 per cent of per capita gross national product on urban waste services.

There are regional differences observed as regards the practices, the expenditure incurred and the recovery of cost for Solid Waste Management services all over the world. This variation can be briefly analysed as under:

1.2.7.1 Latin America and Caribbean

In most countries of the region, households pay for Municipal Solid Waste management services through property taxes. The costs are seldom recovered through this way, especially in poor areas. Frequent subsidies are common. Some cities in Bolivia, Columbia and Ecuador, charge fees through other utility bills as part of the bill (usually electricity bills). The system is found to be quite successful [317].

1.2.7.2 North America

Traditionally, funding for Solid Waste Management comes from a general fund whose primary source is a property tax. Other methods include municipal utility tax, special tax levies for specific facilities user fees, etc. Volume-based rates have increasingly become popular since 1980s. In this, average or marginal cost rate structure is adopted. The average cost structure is a flat rate for each volume disposed whereas marginal cost structure has a fixed cost for the first trash can, then a sliding amount for each additional can. Disposal site fees called 'tipping fees' are also charged at landfills and Waste-to-energy plants on a per-ton basis [38, 303, 317]. There are three prevalent types of capital financing used in North America viz., (a)current revenues (b) borrowed funds and (c) private financing [317].

1.2.7.3 Asia

1.2.7.3.1 East Asia/Pacific

Three sources of funds are prevalent in this region viz., fees charged for services, municipal taxes, and subsidies from municipal revenues received from government sources. Besides, deposit-refund system and volume-based fees are also being tried out at some places. Privatization is also on the rise in few countries like Korea, Malaysia, Singapore, Indonesia and Thailand [46, 197, 317].

1.2.7.3.2 South and West Asia

Most cities and towns in this region do not have adequate financial resources for efficient Solid Waste Management system. Indian subcontinent has municipal taxes mainly property taxes for the funds to provide services. Central or state grants are few and special-purpose. There is no direct user charge or fees or tax levied for Solid Waste Management. Financial reporting systems of the municipalities are very poorly organized. Privatization of various aspects of solid waste services is also on rise [165, 309, 310, 317].

1.2.7.4 Europe

Waste management is considered a public service and public health function. Europe follows either a tax-based or a flat-fee structure for waste management. Eastern Europe is however, increasingly turning to the private sector to finance Municipal Solid Waste Management activities, including collection and disposal. Tipping fees in Europe reflect both policy considerations and real cost. In fact, they are sometimes artificially inflated to support recycling, discourage disposal and improve the economics of other processing options. Volume based fees have not yet been tried [46, 65, 105, 317].

1.2.7.5 Africa

In Africa, Solid waste management services are financed by the Central government through taxes collected by the treasury. Direct municipal charges are an emerging economic instrument in Africa. Municipal user fees are prevalent in Accra; Conakry, Guinea; and some suburbs of cities in South Africa and provide only partial cost recovery for the service rendered. Full cost recovery exists only in places where the service is provided by the private sector. Special taxes are also levied sometimes as in Dakar where Municipal Solid Waste collection tax is imposed by the central government and in Bamako, a cleansing tax based on property value is levied [317].

Expenditure on various elements of Solid Waste Management depends on the per capita income of the people and is presented in Table 1.14 for various income-groups countries. The table clearly shows how the costs versus income vary among various income group countries [85, 86, 183, 272, 342]. Collection of solid wastes consumes a higher share of income in developing countries compared to the industrialized countries. Low income countries have low labour costs but higher fuel and equipments costs, which is often imported from industrialized countries.

Table 1.14: Comparison of Solid Waste Management versus Income in various income countries

S.No.		Low-income country	Middle-income country	High-income country
1.	**Waste generation**	0.2 tonne/cap/yr	0.3 tonne/cap/yr	0.6 tonne/cap/yr
2.	**Average income from GNP**	370$/cap/yr	2,400$/cap/yr	22,000$/cap/yr
3.	**Collection cost**	10-30$/tonne	30-70$/tonne	70-120$/tonne
4.	**Transfer cost**	3-8$/tonne	5-15$/tonne	15-20$/tonne
5.	**Sanitary landfill cost**	3-10$/tonne	8-15$/tonne	20-50$/tonne
6.	**Total cost without transfer**	13-40$/tonne	38-85$/tonne	90-170$/tonne
7.	**Total cost with transfer**	16-48$/tonne	43-100$/tonne	105-190$/tonne
8.	**Cost as % of income**	0.7-2.6%	0.5-1.3%	0.2-0.5%

Note:

1. Income based on 1992 Gross National Product data from the World Development Report 1994 published by the World Bank.
2. Costs are for owning, operation , maintenance and debt service in 1992, assuming no equipment provision through grants.

Source: Sandra Cointreau-Levine and Gopalan, P., 2000

1.2.8 REGULATORY AND ECONOMIC INSTRUMENTS

This part of the review deals with the most widely used strategies and policy instruments (that is, regulatory and economic) that address urban environmental problems especially solid waste management and are in use in developed and developing countries. The two principal widely practiced approaches to pollution control and waste management are the command-and-control and economic strategies. The first approach generally requires a government to set specific environmental objectives and specify the standards or amount of pollutants that can be discharged or the technology by which polluters should meet those objectives. The responsibility for defining and enforcing the standards and other requirements is shared in legislatively specified ways between the national, state, and local governments. The approach has however, been found unsuitable to address non-point pollution sources like solid waste disposal. The latter approach of Economic instruments includes pollution charges, marketable permits, subsidies, deposit and return systems, and enforcement incentives, etc. Most of these instruments operate as incentives to polluters who can determine the most efficient and cost-effective means for achieving environmental targets. To various degrees, they incorporate the polluter-pays and user-pays principles [38, 50, 105, 108, 149, 320].

Command and Control/Regulatory instruments

Command and Control/Regulatory instruments are used either for facilitating the use of specific technologies for environmental management or for the realization of specific environmental standards [260]. The standards include technical and operational standards for various aspects of solid waste management like storage of waste, collection, transfer, transportation, resource recovery and final disposal. It also governs the siting, design, construction, and closure of solid waste facilities. In the United States, for example, the Resource Conservation and Recovery Act (RCRA) bans open dumps and has standards for sanitary landfills, which include leak detection systems (for certain land disposal units), ground-water monitoring, location restrictions, and corrective actions. In France, technical standards relate to site layout, landscaping, control and management of water, management of fermentation gases, leachate management, and post-operational landscaping and control [21, 38].

Most countries have also introduced some form of financial mechanism in addition to direct regulatory measures. Instruments like landfill levies in France, The Netherlands, Italy, Denmark and U.K, contribution paid by firms using packaging to business oriented organizations in France and Germany, Fees for collection and treatment in Norway, etc., are some of the instruments used in different countries to achieve the desired objectives [65, 105, 317].

Extended Producer responsibility (EPR) is a policy principle being widely promoted in various countries. It promotes "total life cycle environmental improvements of product systems by extending the responsibilities of the manufacturer of the product to various parts of the entire life cycle of the product, and especially to the take-back, recycling and the final disposal of the product" [50, 105, 225, 271, 317].

Economic Instruments

Economic instruments like taxes or subsidies are advocated to determine the right balance between recycling, disposal and incineration [65].

a) **Charges**: Three types of charges apply to the collection and disposal of solid wastes, viz., user charges, disposal charges, and product charges. User charges are commonly applied to the collection and treatment of municipal solid waste. They are considered normal payments for such services and rarely act as incentives. Some countries apply charges ("tipping fees") on waste disposal. The rate depends on the type of waste and the method of treatment before dumping and is basically intended to encourage recycling [38]. Tax on landfilling is a common economic instrument used in Europe. It is in use in nine Western European countries. The design and the level of the tax vary greatly. The tax has been applied to stimulate waste reduction, reuse and recycling, to raise revenue and internalize landfill costs [105]. Product charges on waste are applied to nonreturnable containers, lubricant oils, plastic bags, fertilizers, pesticides, feedstock, tires, and car fuels.

   Studies report that initial introduction of user and disposal charges causes only a modest reduction in waste disposal due to a third factor of illegal dumping and open burning [5, 122, 176, 229].

b) **Virgin Material Taxes and subsidies**: Taxes on virgin materials and Subsidies are provided to waste management authorities and the private sector for various aspects of solid waste management. Another approach to subsidization is to afford preferential tax treatment to bond issues of state and local governments for the construction of solid waste treatment plants or development of plants capable of burning municipal solid waste for the generation of heat or power [38]. Koplow, 1993, and Ackerman, 1997, however, observed that virgin material taxes work only for specific industries and fail as a general policy instrument [5, 194]. Virgin material tax must be supplemented with a subsidy on final goods [65].

c) **Advance disposal fee (ADF) and Deposit-refund systems**: Advance disposal fee is a tax on goods levied at the time of sale, based on the cost of ultimate disposal of goods. Calcott and Walls (2000) suggest that Advance disposal fee is the optimal policy for only non-recyclable items [57]. A Deposit-refund system is a two part instrument where the deposit is set equal to the social marginal cost of disposing of the materials and the optimal refund is set equal to the difference between the marginal external cost of garbage and the marginal external cost of recycling which impose special taxes, charges, or fees on consumers-are designed to encourage recycling and prevent pollution [65]. They are applied most often to beverage bottles, beer cans, automobile batteries, and other recyclable items [38, 57].

Germany has the controversial Duales System Deutschland (DSD), which adds a second bin for packaging waste to the German household. Packaging bearing the now-famous "Green Dot" logo is collected, sorted and recycled, with costs borne by the producer. Green Dot spread to the 15 member states of the European Union in 1994 with the adoption of a less-stringent Packaging Directive [239, 317]. Variations of the Green Dot and Extended Producer Responsibility (EPR) are in place all over the world, including programs in Poland, Hungary, Korea, Taiwan, Japan, Finland, etc. More than two dozen countries now require companies to take back their packaging, including Belgium, France, Sweden, and the Netherlands [317].

In Western European countries, producer responsibility has been implemented for various waste streams like packaging, batteries, waste electrical and electronic equipment, paper and tyres. Voluntary agreement between Authorities and industry has also been made to some extent in some countries [50, 105, 317]. The most commonly used instruments in Central and Eastern Europe are municipal waste user charges and waste disposal charges, which apply to municipal, hazardous, and non-hazardous waste. Besides, several Central and Eastern European countries also use deposit-refund systems on beverage containers and product charges on batteries. Taxes on waste are used only in two European countries of Estonia and Romania [105]. Japan also uses laws in line with Extended Producer Responsibility (EPR) to promote waste recycling and reduce waste generation [301].

There is a 'third generation of policy instruments' also where countries (European) have intended to use decentralized choices to promote the recycling of materials and develop cooperation between the generators and disposers of waste [54, 65]. Various regulatory instruments, which can be employed at production level, at neighbourhood and city level for waste generation and collection and disposal of wastes, are presented in Table 1.15.

Policy instruments in the field of Solid Waste Management are strong in most developed countries. On the contrary, developing countries, in general, have yet to incorporate market-based regulatory and economic instruments in the field of Solid Waste Management. Adoption of the various economic instruments in these countries needs caution and should be driven by the existing socio-economic, cultural and environmental constraints. Economic instruments are capable of reducing waste generation but they may also affect the informal sector, which is an integral part of the waste recycling sector in all big cities of these countries. Hence, social considerations need to be given more attention along with economic and environmental aspects before implementation of market-based instruments in developing countries.

Table 1.15: Available Policy tools for waste reduction and recovery

S. No.	Production patterns	Household consumption patterns	Waste generation and collection	Waste management systems
1.	*Economic tools*	*Economic tools*	*Economic tools*	*Economic tools*
	Packaging levy	Deposit-refund schemes	Waste fees and taxes	Taxes on landfilling and incineration
	Economic incentives for cleaner production	Taxes on disposable products and packaging	Pay as you Throw (PAYT)	
2.	*Regulatory tools*	*Regulatory tools*	*Regulatory tools*	*Regulatory tools*
	Environmental standards	Eco labeling	Extended Producer Responsibility	Environmental regulations
	Eco labeling		Regulation on waste collection and recycling schemes	Bans on landfilling, landfill levies, incineration fees
			Provision of infrastructure for recycling	Recycling incentives, subsidies, rebates, etc.
3.	*Technology innovation*	*Social tools*	*Social tools*	*Technology innovation*
	Eco-design LCA concept	Community level environmental education	Support to recycling initiatives	Energy recovery incinerators with cleaner technology
	Dematerialization	Green purchasing information	Information on recycling schemes	
	Shift from products to services	Support to voluntary initiatives		

Source: Compiled from OECD, 2000 and Zero Waste New Zealand Trust, 2000

1.2.9 Role of Institutions and Informal Sector In Municipal Solid Waste Management

1.2.9.1 Role of Institutions

Innovative urban waste management experiments are being initiated in India both by the governmental (municipality) and non-governmental institutions [19, 28, 279, 280] . Three distinct sectors are identified who work in various capacities to meet the various needs of society viz., Public, Private and Non-profit, with each sector working in its own distinct sphere. However, a new spirit of inter-sectoral co-operation is seen in recent times [10].

Different sectors are involved in dealing with different aspects of Solid Waste Management. Some of the agencies/institutions other than the public agencies, involved for various activities of Solid Waste Management are as follows:

a. Primary collection-Informal sector (Itinerant Waste Buyers, rag pickers)
b. Primary collection and transportation- Private contractors, NGOs/CBOs
c. Secondary collection and transportation- Private contractors, NGOs/CBOs
d. Treatment, Energy recovery, recycling and reuse-Private contractors, NGOs/CBOs, informal sector, Micro and Small Enterprises, etc.
e. Disposal- Private Contractors, dump pickers, etc.

All these agencies can be broadly categorized under public sector, non-profit sector and private sector and are discussed in the following sections:

1.2.9.2 Public Sector

The local government is the main provider of solid waste management service under this sector in most countries. Municipal Officers are responsible for the provision of waste management services along with other associated administration like, finance, personnel, etc. They either operate and maintain the service or engage the private sector on contract or concession basis.

1.2.9.3 Non-Profit Sector

Non-government Organizations/Community Building Organizations (NGOs/CBOs) come under the non-profit sector. The term NGO can refer to such diverse organizations as churches, universities, labour organizations, environmental organizations and even donor organizations. Generally, Non-Governmental Organizations (NGOs) are intermediate organizations which are not directly and continuously involved in community projects. They often serve as the link between Community Building Organizations (CBOs) and Municipal Governments, or serve the ideological interests of international organizations.

There are more than 10,000 NGOs in India out of which some 45 are engaged in solid waste management activities [124, 127]. In general, non-government organizations and community building organizations working on waste management issues can be broadly divided into two categories: those with a more labour-market/socially oriented agenda, such as working with street children and women, and ones with a more environmental focus which are involved in education [127, 265]. There are, however, also certain combinations of these types of non-government organizations and community building organizations that exist, such as those involved in working with children waste pickers and at the same time in community based schemes to solve the problems in waste collection.

Community-based organizations (CBOs) are informal institutions that are formed by members of a community to address a need of the community [10]. Social service is the main motive and such initiatives in the field of solid waste management may or may not be financially sustainable. Groups of citizens, including those from middle and high-income areas, may start Community-based organizations aimed at improving the waste situation in their neighbourhood. They generally deal with primary waste collection systems, separation at source experiments and implementation and so on.

A Community-based organization can organize solid waste management services in a neighbourhood by different ways. They can:

- petition the local government for improvement or extension of solid waste services in the area;
- organize volunteers to provide the services (like, primary collection, street and drain cleaning, etc.);
- engage a private enterprise to carry out the service, on behalf of the residents;
- stimulate local entrepreneurs to take on the task;
- carry out the services (by employing Micro and small enterprises or ragpickers) with payment from residents.

The difference between Non-government organization and Community-based organization is that non-government organizations usually operate on a larger geographical scale, at city, regional, national or even international level [14]. Non-government Organizations/Community Building Organizations usually work in partnerships with the local government, in which they are more sustainable. However, instances of Non-government Organizations/Community Building Organizations working on their own are also found. In India, the Muskan Jyoti Samiti (MJS), is a good example of this which gets assistance from State Urban Development Agency and not from the Lucknow Municipal Corporation [309].

1.2.9.4 Private Sector

Private sector comprises of micro-enterprises, formal sector and informal sector. All these work for money making only. They often offer advantages in terms of lower costs in the field of solid waste management not only in developed countries but also in developing nations [16].

1.2.9.4.1 Micro and Small Enterprises (MSEs) and Cooperatives

Micro-enterprises are for-profit business operations [59]. Micro and small enterprises are defined as "enterprises with fewer than 20 employees, having small capital and using low-cost technologies". Micro-enterprises have 1 to 10 people while small enterprises have 11 to 20 people, with capital investments ranging from US $100 to US $10,000 and from US $5,000 to US $50,000. Micro and small enterprises are suitable for activities which have small economies of scale [146, 317]. Studies reveal that Micro-enterprises can be categorized as [146]:

1. **Private Micro-enterprises**: In this type of arrangement, the entrepreneur organizes employees and resources for the provision of solid waste management services for generating profit.
2. **Cooperatives:** It contains an element of "collective" action. Cooperatives are common in Brazil and Columbia, engaged in primary collection, transportation and recovery and recycling of wastes.
3. **Community-based enterprises**: These are also collective enterprises but originate from community interest and efforts.
4. **Labour contracted by a local organization**: This involves direct labour contracting by community leaders, Community Building Organizations, Non-government organizations, etc. This arrangement is common in Indonesia for door-to-door collection.

Micro-enterprises are cooperative enterprises with eight to twenty-five members who share responsibilities and income and who operate together a waste collection scheme, street sweeping, etc. Sometimes members of a micro-enterprise live in the neighbourhood where they operate a service, but this is not always the case. Cooperatives, micro and small-scale enterprises are most successful in Latin America [221, 222]. There are more than 300 waste collection service providing micro-enterprises, more than 100 cooperatives in Columbia and more than 100 small enterprises in Peru [199]. Studies suggest that Cooperatives usually achieve stability in cities where the decline of informal networks of waste buyers and traders has left gaps in recovery systems [317]. However, small enterprises and cooperatives need some sort of *external support* to start up and to be successful. It works best when this support comes from the local government. This external support is however, not necessary as is the case in Guatemala, where the role of the municipality is almost absent. It has been observed that there are 300 to 400 trucks providing waste collection services. The municipality's role is no more than a quick inspection of the vehicle, after which it receives a stamp.

In Peru and Bolivia, the partnership works differently. The micro and small enterprises were initiated by the Non-government organizations at the request of either the community or the municipality. In this system, the enterprise provides the service; the beneficiaries pay taxes to the municipality and the municipality contracts and pay the enterprise. The role of Non-government organizations is very strong: they provide financial, technical and institutional advice and manage to obtain small loans from the banks [199, 317]. There have been many attempts to form cooperatives and small enterprises in waste recovery elsewhere. The best documented case is of the recovery and composting enterprises run by families of Zabbaleen in Cairo [317]. It is worth noting that Micro and Small enterprises are registered and formal in Latin American countries while they are informal in Asia and South-Asia [146].

1.2.9.4.2 Formal Sector in Solid Waste Management

Formal sector of solid waste management refers to private sector corporations and registered businesses, with an organized labour force governed by the labour laws, and with capital investment and modern technology [49, 124]. Privatization may be done partly or fully. They are also termed as medium and large scale enterprises.

Indian cities are seeing more involvement of private sector involvement in provision of solid waste management services in recent years. Such initiatives envisage promotion of energy generation through appropriate waste management operations. This includes involvement of M/s Gadgil Co. in collaboration with M/s Global Environmental Engineering Ltd. (GENL) through an SPV named Bio-Power and Compost, Pune Ltd (M/s BPCL) in Pimpri Chinchwad; CECON Environmental Technologies in Nagpur; and initiative to establish an RDF Power Plant in Delhi by M/s MS Associates Subba Ltd. M/s Excel Industries has set up bio degradation of solid waste units in Vijaywada, Calcutta, Mumbai, Bhopal, Bangalore, Gwalior, Cochin and Calicut together disposing more than 1750 tons per day. M/s Future Fuels in collaboration with ECO technology JVVOY (ECOTEC) of Finland have developed a process for anaerobic digestion for treatment of municipal solid waste and have signed an agreement with Kalyan Municipal Corporation for setting up 150 tons per day garbage unit for the city. In addition M/s CELCO, Hyderabad has taken up initiatives for solid waste management in that city.

1.2.9.4.3 Private (Informal) Sector in Solid Waste Management

Informal sector implies "unregistered, unregulated, or casual activities carried out by individuals and/or family or community enterprises that engage in value-adding activities on a small-scale with minimal capital input, using local materials and labour intensive techniques"

[126]. The informal sector engaged in waste recycling mostly refers to those employees who are classified as "own account" workers, e.g. unpaid family workers and those who collect and treat mostly unregistered waste material [343].

The informal sector engaged in waste industry has two sub sectors:

- Organized : The segment of the informal sector wherein the establishments have some formal relationship with the state and are subject to state regulation
- Unorganized: Enterprises that are not only small in size but also do not have any formal relationship with the State

There is an active Informal sector engaged in solid waste management process in Indian cities and it is found to exist as a parallel system to the formal waste management process. It is highly labour intensive with low capital inputs. The recycling, recovery and reuse activities usually take place in semi-legal conditions with many enterprises remaining unregistered [50, 35]. There are varying estimates of the quantity of waste recovery taking place in the informal sector. Bhide (1990) estimates that on an average waste-pickers recover between 6 to 7 per cent of waste generated [45].

Organizational structure and size of Recycling waste sector

The Waste Recycling industry in India is entirely private and has both formal and informal sectors engaged in it. The formal sector heads the informal sector and gets the required raw materials and services from the informal sector. Waste-pickers and rag pickers form the bulk of this waste recycling sector as presented in Fig 1.2. This section lives in very poor living conditions and it continues to remain unrecognized and unregulated. It is the most vulnerable section. They collect wastes (recyclables) from street dumps and municipal and/or open dumps. As one moves up the waste recycling pyramid, the affluence increases and number of people engaged in recycling decreases. The sector overall is however labour intensive. The technology penetration is very poor especially at the lower ends of the pyramid.

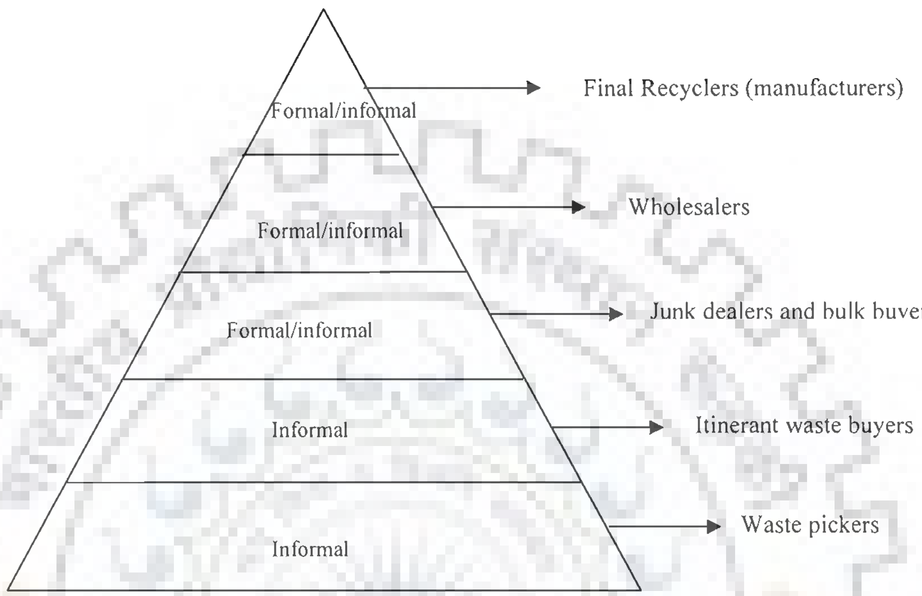


Fig. 1.2: Pyramidal structure of waste recycling sector

The source/producers of waste can be kept under following major categories:

- Enterprises (factories, industries)
- Institutions (hospitals, clinics, offices, etc.)
- Commercial centres, shops, etc.
- Households/individuals

The above producers of waste have two ways to dispose of this so called waste:

1. One part of the waste is straight away taken to collection bins for further disposal without any returns to the user
2. Another part is often stacked for a period of time and later disposed off to itinerant buyers for a price

The general structural pattern and flow of wastes in the waste recycling industry can be depicted as follows (Fig.1.3):

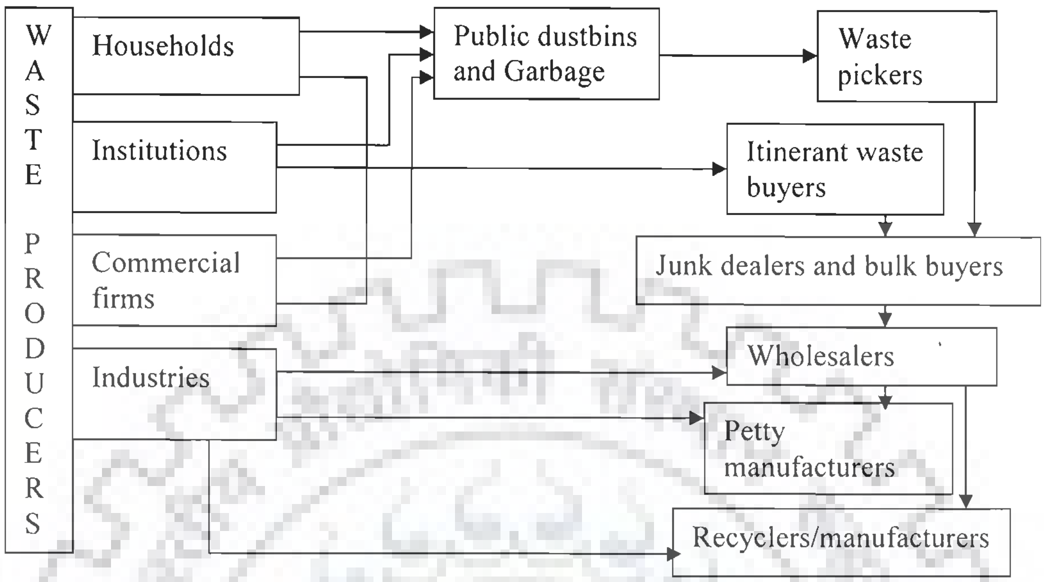


Fig. 1.3: Flow patterns in waste recycling

There are no estimates or studies evaluating the correct size of the total population involved in waste recycling industry. Rosario (2004) estimates that over a million people in India find livelihood opportunities through waste picking, which encompasses retrieving waste, transportation, recycling, reuse of waste, etc [265]. The informal sector is not included in any census category, and hence there are no reliable data available at national/state/city level. It is however noted that waste recycling is a big income and employment generator in this country. An estimated 20,000-50,000 waste-pickers live and work in and around Calcutta municipal dumps alone [221, 265]. Over 20,000 women work as paper pickers in Ahmedabad city [274]. An estimated 150,000 waste pickers are active in Municipal Corporation of Delhi area handling between 9 to 15 per cent of the solid waste generated and saving the municipality minimum of Rs 6 lakhs daily [9, 10]. Bangalore has 25,000 waste pickers making their living out of collecting and selling wastes (recyclables) [42]. Bombay has an estimated 35,000 waste pickers [41] while Pune has some 10,000 waste pickers [221, 222]. Various studies indicate that there is approximately one waste picker for every 200 to 450 citizens [26].

The Indian waste recycling industry is market driven and is subject to fluctuations [10]. Seasonal variations in consumption pattern due to various reasons lead to fluctuation in recovery and recycling. The worst sufferers of market fluctuations are the segment of people working on the lower side of the pyramid.

Partnerships observed of Informal Waste sector in an Indian city

The informal waste recycling sector works in partnership with various stakeholders. Typically, three types of relationships viz., Informal-informal, Informal-formal and Informal-consumers are found to have strong mutual ties. The remaining two i.e., Informal-govt. and Informal-Non-profit has weak partnerships (Table 1.16)

Table 1.16: Partnerships of informal sector in an Indian city

	Partnerships	Agents involved	Relationship	Incentives
1.	Informal-Informal	Waste pickers/IWBs- Junk dealers and wholesalers	Commercial	Subsistence and profit
2.	Informal-formal	Junk dealers & Wholesalers- small and large recycling units	Commercial	Profit
3.	Informal-Consumers	HHs/Institutions/commercial firms/industries- IWBs/junkdealers and wholesalers	Commercial	Profit
4.	Informal-Govt.	Waste pickers/IWBs/Junk dealers and wholesalers-Municipality	Usually weak relationship observed	No incentive
5.	Informal-Non-profit	Waste pickers/IWBs/ Junk dealers and wholesalers-NGOs,CBOs	Experimental stage in few pilot cases	Service motivation

IWB: Itinerant Waste Buyers

Source: Based on Beukering, P. et al, 1999

1.2.9.5 Different combinations of Community-based Solid Waste Management

i) Micro-enterprises and Community based organizations working together

Micro-enterprises and Community based organizations can work together to manage a solid waste service in a neighbourhood. In such partnerships, the community based organization generally looks after management and supervision tasks, while the micro-enterprise is responsible for operating the service. E.g. GIE-`groupes d'intérêt économique'- and neighbourhood committees in Bamako, Mali [190].

ii) Governmental institutions assisting Non-government organizations/community based organizations

Community managed solid waste collection in Chennai. A partnership between a local non-government organization (Exnora international) and neighbourhood organizations (Civic Exnora units) have developed community-managed solid waste collection services for several hundred thousand inhabitants whose costs are covered by fees collected from those who are served. To be effective, this also depends on a partnership with the local government, as these local organizations need transfer stations to which they deliver the collected solid waste [311].

1.2.9.6 Partnerships/Alliances

A number of definitions of partnerships pertaining to urban governance prevail [29, 96]. Partnerships is the association of two or more individuals or organizations, sharing common resources or/and decision making authority, etc. Partnerships have the potential to achieve what individual organizations can not do especially in the field of provision of infrastructure services like water, sanitation, solid waste management, etc. They are more than the sum of their parts. By working together, partnerships often result in more comprehensive analysis of sustainable development challenges than otherwise organizations achieve by working on their own [60]. The salient features of a partnership can be identified as [29]:

- It involves two or more actors;
- All actors benefit in some way from the alliance (without assuming quality or equal benefit among actors);

- It refers to a more or less enduring relationship between the actors.

The following major types of partnerships are observed in the field of solid waste management, *viz.*,

1. Public-private partnerships
2. Public-community partnerships
3. Public-Private-Community partnerships: an emerging one and not tested much

Ahmed, et. al, 2004, rightly emphasize the need to have a clear role demarcation to make partnerships work in the solid waste management sector [10]. Efforts must be made to make the best use of the potentials of each sector. Studies indicate that private sector is generally found to do better in primary collection. Non-profit sector excels in creating educational campaigns and inviting public support for policy implementation. Whereas, financial and management inputs for operating secondary collection, treatment and disposal are domains of public sector. One of the most crucial aspects for any partnership to be successful is that the alliance or partnership should be financially viable for the consumers, local authorities and private sector [141].

1.2.9.6.1 Public-Private Partnerships

From the late 1980s through the 1990s, private sector participation was actively promoted worldwide to improve management of water and sanitation services. In India, it is rather a new entry in the field of solid waste management. Table 1.17 summarizes several of the options of private sector participation as practiced across the world. The table shows the increasing role of privatization on moving towards right.

Table 1.17: Allocation of responsibilities for private-public partnerships

Increasing private participation →							
	Service contract	Mgt contract	Affermage	Lease	Concession	BOT-type	Divestiture
Asset ownership	Public	Public	Public	Public	Public	Private / public	Private
Capital investment	Public	Public	Public	Public	Private	Private	Private
Commercial risk	Public	Public	Shared	Shared	Private	Private	Private
Operations/ maintenance	Private / public	Private	Private	Private	Private	Private	Private
Contract duration	1–2 years	3–5 years	8–15 years	8–15 years	25–30 years	20–30 years	Indefinite

Source: Jessica Budds and Gordon McGransham, 2003

Service implementation is usually contracted out with the government usually keeping the decision making powers. Public-private partnerships often result in saving of costs, little political interference, and lower levels of coercion [10, 25, 259]. In an ideal public private partnership, the advantages of the private sector namely, innovation, access to finance, knowledge of technologies, managerial efficiency, and entrepreneurial – are combined with the social responsibility, environmental awareness, and local knowledge of the public sector in an effort to solve the vast gamut of urban problems [37].

Public-Private partnerships is catching world over primarily to overcome the financial backlog that most cities face for the provision of better infrastructure. Following models are popular for Public-Private partnerships:

1. Contracting
2. Concession
3. Franchise
4. Open competition

1. Contracting

Contracting is usually in the form of operation, maintenance and service contracts. In this type of model, the public body awards a finite-term contract to a private firm for any of the SWM components like the delivery of solid waste collection service, street sweeping, collection of recyclables, transfer station operation, disposal site operation, or fleet maintenance. The contract award is usually made after a competitive procurement process. The private firm is paid for service delivery by the government under the terms and conditions of the contract [37, 317].

2. Concession

In this mode, the government awards a concession to a private firm to set up a facility that utilizes the government-owned resource-refuse. The concession given is in many forms. It may enable the private firm to recycle; to recover resources (compost, heat, electricity) from refuse; or to transfer or dispose of refuse. The concession is in the form of a long-term contractual agreement. The private firm builds the facility, and/or operates it for a certain term or may maintain indefinitely the ownership and operation. Build-Operate-Transfer (BOT), Build-Operate-Own-Transfer (BOOT), Build-Operate-Lease-Transfer (BOLT), Rehabilitate-Operate-Transfer (ROT), Design-Build-Finance-Operate-Transfer (DBFOT), etc., are some forms of concession [300].

i) <u>BOOT:</u> Build-Own-Operate-Transfer. In this type of arrangement, the private sector finances the facility, runs it for a certain time period and then transfers the facility to the government. The time period should be for a minimum duration to at least recover investments.

ii) BOO: Build-Own-Operate. This type of arrangement is similar to BOOT with the only difference that the facility is not transferred to the government at the end of the contract period.

iii) BOT: Build-Own-Transfer. The ownership is not with the private party and investment transferred to the government after a specified period.

iv) BOLT: Build-Own-lease. In this type of arrangement, risk is borne by the private party. The infrastructure is given to the government on lease.

3. Franchise

The government awards a finite-term monopoly to a private firm or community organizations for the delivery of solid waste collection service. The franchise award is made usually after a competitive procurement. The private sector pays a license fee to the government. The private firm, in turn, gains through direct charges to the households and establishments that are served. Government provides control over the tariff charged to the consumer through: a) development of adequate competition, or b) price regulation.

The local government in some developing countries works with the NGOs/CBOs under this arrangement, particularly for recovery of materials from waste, while in others the local government has given exclusive franchise to recover and recycle from the waste generated.

4. Open Competition

In this type of public-private arrangement, the government freely allows qualified private firms to compete for refuse collection, recycling, or disposal services. No firm holds a monopoly, and there is no restriction on the number of competing firms. The government grants a license to qualified firms for the private provision of disposal services. The government's role in open competition is to license, monitor, and, as needed, sanction private firms. Costs are directly billed by the private firms to their customers under open competition. Hence, it is only suitable for private goods or else the lower-income group people might be left out from getting any service. This arrangement is applied in cases where standards have been evolved and enforcement laws are strict. This can be applied for private goods or maintenance and repair cases.

Contracting and Franchise are the two more popular models adopted for waste collection. Private sector has apprehensions in both situations due to expected risks of non-payment/delays, high default values, etc. [33, 35]. Contracting and Concession are suitable for collective goods whereas open competition is suitable for private goods. Suresh V. (2004) however, states that in Indian context various softer options like Service contracts, Management contracts, Lease and concessions should be first tried before trying the full-blown BOT modes [300].

As regards Financing and Recovery system for Solid waste Management in various countries, Table 1.18 presents a short list of Public-Private partnerships (PPP) models that have been found successful.

Table 1.18: PPP models and the mode of financing

S.No.	Country	Agency	Financing Requirement
1.	Sri Lanka	Secretariat for Infrastructure development and Investment (SIDI) Joint Venture Private Sector	BOT Contract
2.	Philippines	BOT Centre under the office of the President, NGOs	Concession, BOT Contract
3.	Thailand	Urban Community Development Office	BOT
4.	Indonesia	Jakarta authority	Private Contracting
5.	Thailand	Bangkok Municipal Authority	Private contracting

Source: Kanpur Development Authority, 1997

Public-private partnerships (PPP) are not easy achievable and requires enabling environment to foster trust and workable relationship [10]. Some of the barriers for meaningful Public-private partnerships in developing countries include weak structural, financial and legal framework. These weaknesses provide outlets for lack of transparency, fairness and accountability. There is also a possibility of resistance by the public workers' union.

- In *Dakar,* the municipal authorities entrust all waste collection services to private operators, who in turn delegate preliminary collection jobs to micro and small enterprises (MSEs). There are 140 of such organizations in charge of sewer and street cleansing, and preliminary collection in informal housing areas; they have joined to form a federation.
- In *Bamako,* in some areas, refuse collection is directly entrusted by the municipality to the micro and small enterprises, under the terms of a municipal ordinance defining collection zones and fees. Bamako has 60 micro and small enterprises in the field of cleansing alone, only half of which are reported to be operational. They, too, have formed a federation.
- Community-based and private micro and small enterprises in Ouagadougou: The city is served by three community-based micro and small enterprises and six private micro and small enterprises. Community-based micro and small enterprises are involved in primary-collection service to residential areas and work with the support of municipal government, while private micro and small enterprises provide primary-collection services to residences, commercial establishments, companies and embassies [146].
- In Seychelles, there are more than 170 licensed waste pickup truck owners who do primary collection of waste generated by industries and commercial establishments. They also trim the vegetation along road sides and bench cleaning.

- Besides the collection services, micro and small enterprises are actively involved in waste recycling in some form or other in most developing countries. They process the recyclables into intermediate products or products.
- In Guatemala city, Central America, 300 to 400 micro and small enterprises operate collecting wastes from high-income residents and tourist businesses without any kind of contract [16].

There are two mechanism observed for the payment of micro and small enterprises - they are either paid by the client (municipality or private contractor) or they may collect fees directly from the beneficiaries. The first type of arrangement can be direct contracting, franchise or open competition. Direct contracting to micro and small enterprises is prevalent in South American countries like, Peru, Columbia and Bolivia. It has also been tried in Dakar (Senegal) and Accra (Ghana) but with less success [161]. Franchise contracts are not commonly observed. Open competition in micro and small enterprises is prevalent in Central America, West Africa and India.

Solid Waste Management has long been privatized in Bangalore but nearly a decade after privatization, most of the *pourikarmas* (sweepers) work under abysmally discriminatory conditions [212].

1.2.9.6.2 EMERGING PUBLIC-PRIVATE SECTOR PARTICIPATION ARRANGEMENTS IN SOLID WASTE MANAGEMENT IN INDIA

Some of the emerging Public-Private sector participation arrangements in Solid Waste Management in India are listed below:

1. Contracting for vehicular fleet maintenance and repair: Municipal bodies often contract with local garages for maintenance and repair of vehicles.

2. Contracting for Leasing vehicles: When the capital investment is limited, vehicles are usually leased in which the lessor, also provides the fuel and maintenance. Bombay has leased vehicles for more than 15 years for waste transportation.
3. Contracting for waste collection and transportation: A number of local bodies are now contracting for collection and transportation of waste. Contracts are usually fee based.

   Example: Following a competitive bidding process, the Chennai Municipal Corporation entered into a seven-year agreement in November 1999 with M/S C.G.E.A. Asia Holdings, Singapore. Operations began in March 2000. The private operator is responsible for sweeping, collecting, storing, and transporting waste (garbage, construction, and garden waste), and for creating public awareness. It will deploy more than 1,800 employees, 30-35 compacter and hook lift trucks, 170 auto rickshaws, 800 modified bicycles, and 5,300 mobile garbage bins. It will also modernize two vehicle depots and two transfer stations. The waste to be removed is more than 1,000 tons per day (TPD). The rate for the first year is Rs. 648 per ton, which is to be escalated annually at five percent. This is much lower than the Corporation's own estimated cost of Rs. 1,050 per ton [113].
4. Concessions for Resource-recovery projects: Long term concessions like BOOT or BOO or DOB contracts are being increasingly used. The local bodies provide the private sector a fixed amount of waste with or without land on lease for the facility.

   - Composting projects: More than 35 projects have so far been developed on BOO or BOOT structure. Capital investment required for such facilities (capacity 100 to 700 tons per day) typically ranges from Rs. 30 to 75 million, and project financing has predominantly been driven by promoter equity. Under the DOB (Design, Build and Operate) model, funds, land and garbage are provided by the municipal authorities whereas the private firm is responsible for designing, building, and operating the facility, whereas the ownership remains with the urban local body. Cities like Mysore, Calicut, Kochi, Shillong and Puri have adopted this model for setting up compost plants [19]. Key risks associated with such projects include demand for compost and sustainability of operations. In the absence of market support by the government, the quality of compost produced must be closely monitored, since, without waste segregation at the source, compost may become contaminated.

- WTE projects: Waste-to-energy project technologies include incineration, pelletization, and bio-methanation. Such plants get an interest subsidy of up to Rs 2 crore per megawatt for commercial WTE projects. Examples are few like Enkem Engineers established a 5 MW bio-methanation plant at Lucknow while SELCO Industries is running a pelletization plant at Hyderabad, which is facing a lot of public ire of lately [346].

1.2.9.6.3 PUBLIC-COMMUNITY PARTNERSHIPS

In this type of alliance, the Non-government organizations/Community based organizations manage some kind of solid waste management service with the assistance of municipalities, e.g., Exnora Green Cross, Vellore and Jan Chaitnya in Vishakhapattanam. The support from the local government comes in the form of land allocation for segregation/composting, the issuance of identity cards to the waste collectors, etc. They usually collect some sort of 'user fee' from the community to sustain themselves.

1.2.9.6.4 PUBLIC-PRIVATE-COMMUNITY PARTNERSHIPS

In this type of alliance, all the stakeholders work together for better management of solid waste generated. It includes participation of the waste generators, community organizations, private operators (formal and informal) and the local government.

Some of the most commonly observed problems in community-based solid waste management include low willingness to participate, public apathy for a cleaner neighbourhood, low willingness to pay, management problems, lack of accountability to the community, competition from private sector, poor working conditions, inadequate fee collection, cost recovery problems, problems with the local government/municipality, etc.[26, 311].

1.2.9.7 Alliances/partnerships in various Indian cities

There are various kinds of alliances observed in the field of Solid Waste Management in India. An attempt has been made to study these alliances in various Indian cities based on secondary data and is presented in Table 1.19 and it reveals a brief overview of the various alliances/partnerships working in various Indian cities and the kind of services they are involved with.

Table 1.19: Alliances in various Indian cities

City	Bangalore	Delhi	Calcutta	Chennai	Bombay
1	2	3	4	5	6
NGO involved	-Centre for Environmental Education; -Mythri Sarva Sewa Samiti (project:Wastewise) -Residents Association for a safe environment (RISE)	-Vatavaran (through Cleaning Brigade Scheme);covers 27 projects including JNU, NOIDA, Vasantkunj, Asiad Village -Srishti -Development Alternatives -ACORD			Stree Mukti Sanghatan, Aakar Mumbai (both help in convincing ragpickers for training) Mumbai Environmental Action Group
Activity	- -Door-to-door primary collection of source segregated waste, vermin-composting - Bin composting	-Door-to-door primary collection, segregation, anaerobic composting of organic waste(resi), vermi-composting for schools -vermi-composting, biomethanation;installed a bioreactor in a slum to treat wastes from 600HHs -waste recycling management -awareness bldg, facilitating primary collection			
Service charges		-Rs 30/month/HH -each rag picker is paid Rs 500/month - -			
Level of action		-Neighbourhood, Zone level -Neighbourhood level - -			
CBO involved	Scientific Handling of Waste Society (SHOW)		FOCUS	Civic Exnora (1000 CEs); on an avg each CE covers 75-80 families	-Advanced Locality Management(ALM)(643 ALMs)
Activity	Segregation at source, bin-composting with active aeration		Segregation, collection	Segregation at source, vermin-composting	Source segregation, waste collection, bin-composting, pit composting, vermin-composting; 276 vermicompost pits; covers residential, commercial areas and slums

Table 1.19 (Continued)

City	Bangalore	Delhi	Calcutta	Chennai	Bombay
1	2	3	4	5	6
Service charges				Rs 10 per HH per month; Rs 650 paid to each street beautifier(rag picker)	
Level of action	HH, Neighbourhood		Neighborhood level	HH, neighbourhood level	HH, Neighborhood
Pvt. Org. involved	- Excel -Terrafirma Biotechnics		Excel	CES Onyx	Excel
Activity	- Biodegradation of solid waste - Marketing vermin-compost		Biodegradation of solid waste	Sec. Collection, transfer, transport & dumping	Biodegradation of solid waste
Service charges				2 crores/month paid by corporation	
Level of action				Zonal level; 3 zones	

Table 1.19 (Continued)

City	Nagpur	Bhopal	Vijaywada	Gwalior	Calicut	Hyderabad
	7	8	9	10	11	12
NGO involved						-SPEQL -sukuki exnora
Activity						-vermicomposting -primary collection, segregation,vermin-composting
Service charges						-compost sold at Rs2/kg -
Level of action						-neighbourhood -neighbourhood
CBO involved	None					
Pvt. Org. involved	CECON Enviornmental Technologies	Excel	Excel	Excel	Excel	Selco Int.
Activity		Biodegradation of solid waste	Biodegradation of solid waste	Biodegradation of solid waste	Biodegradation of solid waste	Pelletisation from mixed waste
Service charges						
Level of action						City

Table 1.19 (Continued)

City	Cochin	Lucknow	Allahabad	Ahmedabad	Agartala
	13	14	15	16	17
NGO involved		MJS	MJS	-Clean ahmedabad abhiyan; -SEWA	Open national Service Scheme
Activity		Door-to-door collection, segregation, transportation, disposal, vermi composting	Door-to-door collection	-awareness campaign, door-to-door meetings for source segregation -	Primary kitchen waste collection
Service charges		* Given at the end of table			
Level of action		Zonal level; 20,000 HHs in trans-gomti area	Neighbourhood, 5000 HHs		
CBO involved	Exnora International				
Activity	Segregation at source, primary collection, aerobic composting using 'garbactum';takes only 20 days, no smell				
Service charges	Rs 10-15 per HH per month				
Level of action	Ward level; 4 wards have composting, rest in the process of primary collection				
Pvt. Org. involved	- The Institution of Engineers · The leading English and Malayalam dailies - Indian Express, Mathrubhumi · Rotary Clubs				
Activity					
Service charges					
Level of action					

* Rates of the MJS (per HH): monthly garbage collection charge

1. Slum dwellers Rs. 15
2. Economically weaker HHs Rs. 20
3. Middle income HHs Rs. 25
4. Higher Income HHs Rs. 30

List of NGOs, CBOs engaged in Solid Waste Management sector in India:

Some of the important NGOs, CBOs working in the field of solid waste management in India are given as follows:

- CES: Chennai Environment Services Onyx is a subsidiary of Onyx Asia Holdings pvt. Ltd. which is a subsidiary of the $39 billion French multinational Vivendi
- EXNORA: **Ex**cellent **No**vel **Ra**dical Innovative ideas: EXNORA International Established by Mr. M.B. Nirmal in 1989 in Chennai, it has now more than 5000 branches, 2,00,000 members
- SPEQL: Society for Preservation of Environment and Quality of Life
- Srishti, a New Delhi based NGO
- Indian environmental Society(WMI): Delhi based NGO: has set up three demonstration projects:

- recycling urban waste in Agra,
- recycling marble industrial waste in Udaipur
- recycling paper waste in Delhi.

- ACORD: Asian Centre for Organization Research and Development: did a pilot project in Harkesh nagar, a low-income colony in Delhi :currently doing "Upgradi Environment Quality of Delhi" covers following
  - Markets and institutional areas:21
  - Authorised colonies:95
  - Unauthorised colonies:50
  - Slums:34
- MJS: Muskan Jyoti Samiti, established in 1994
- SEWA: Ahmedabad based Self-employed Women's association
- Jan Sewa Ashram (NGO, Jabili, Solan based): Garbage management in two cities through door-to-door segregated waste collection and its processing.
- SPARC: Society for Promotion of Area Resources, a Mumbai based NGO

1.2.9.8 Municipal Solid Waste (Management and Handling) Rules, 2000 and role of institutions and informal sector

It has been observed that the recently enforced Municipal Solid Wastes (Management and Handling) Rules, 2000 by the Govt. of India do not discuss much about private sector participation. A sheer mention of the efforts made to call for private firms for processing of waste utilizing technologies like, composting, vermiculture, pelletisation, etc., is given in the format of annual report to be submitted by Municipal Authority. A casual mention of non-profit sectors' (NGOs and CBOs) role is given in the manual for municipal solid waste management. No attempt has been made to encourage various kinds of public-private-community partnerships. The vast force of informal waste recycling sector has been conveniently left out and no attempts, whatsoever, have been made for their formalization. There is therefore, an urgent need to involve all or few of the stakeholders for various activities of solid waste management under the current crisis as the involvement of various stakeholders can reap in rewards in various ways as evident from the earlier discussion.

1.2.10 Important findings

The important findings based on the literature review pertaining to solid waste in developed countries, developing countries and India are presented as follows:

1.2.10.1 Developed Countries

1. Higher economic growth in these countries is often observed with high rates of waste generation. The waste composition invariably has a higher percentage of packaged goods, and hence the waste has high calorific value. Besides, it is lighter than that in developing countries.
2. Collection is mostly 100 per cent, anonymous, professionalized and even covers the poorly accessible and low-income areas.
3. Most of these countries have municipally sponsored source separation and collection systems.
4. Land value and labour cost is often very high and hence, the municipal authorities focus more on methods to reduce the waste to be deposited in landfills.

5. Source separation and curb side separation programs are heavily subsidized by municipal governments, private industries or foundations. Local and regional waste management plans are well integrated contrary to the situation in developing countries.
6. Composting and Materials recovery facilities are centralized, formalized and technically strong. Few European countries have legal provisions for good compost standards.
7. Informal sector engaged in Solid Waste Management hardly exists in these countries. Recycling is therefore, institutionalized in these countries in the form of Materials Recovery Facilities and Recycling Centres.
8. Street sweeping is mechanical in few countries like USA, Canada while in others it is predominantly manual. It is however, seen as a separate function and not related to waste collection.
9. A lot of emphasis in these countries is being given to waste reduction at source and recycling, including measures taken at manufacturing and packaging levels.
10. Public-private participation is quite strong and the government more often, acts as a facilitator and regulator for the provision of efficient solid waste management services. Legal and administrative support encourages a lot of private participation.
11. Public awareness of the environmental consequences of ill-managed solid waste disposal is higher and hence, community participation is stronger in these countries.
12. Various laws governing different aspects of Solid Waste Management are efficiently enforced and implemented, unlike the case of most of the developing countries.

1.2.10.2 Developing countries

1. The moisture content and organic content of the waste is generally high, as compared to the developed nations. The calorific value is also found to be low.

2. The waste is generally very dense and often has high amount of silt, ash and other inert materials also in the waste. Hence, the vehicle and equipments replicated/imported from developed nations often fail to deal with these waste types.
3. Collection is mostly manual, inefficient and with smaller coverage.
4. Incineration of waste and waste-to-energy recovery have often failed in these countries. Recycling is informal and has a long tradition. Private participation is less and being tried only recently. This privatization is however, limited to collection of wastes only. Centralized composting has mostly failed in these countries. Decentralized composting is however, popular at many places. It is mostly subject to manual pre-processing unlike developed countries. The quality of the end product is however, not consistent and good. Disposal of waste is in the form of open or controlled dumps. Sanitary landfill is a rarity in these countries.
5. In developing countries, the traditional network and practice of waste recovery and recycling is quite strong. It is mostly Informal and not supported by the government institutions and often harassed by the local authorities.
6. Informal sector is frequently found to lack the technologies to optimize recycling methods. Working conditions is mostly very bad, especially the people working at the lowest level of waste recovery hierarchy.
7. There is an inadequate management of hazardous and healthcare waste in these countries. Biomedical and hazardous waste often get mixed with municipal waste and pose health problems apart from a number of environmental ill-effects.
8. Cost recovery by the local government for the provision of solid waste management services is either absent or poor, putting extra burden on their financial sustainability.

9. Public-private partnerships and Public-Private-Community partnerships are being attempted at in various developing countries in the field of solid waste management. Micro and small enterprises and cooperatives are running successful in some countries.

1.2.10.3 India

1. The density of waste generated is generally high in Indian cities and there are wide variations in the composition of waste among various cities and different income-groups of people. The sophisticated compaction equipments, therefore, work poorly in such conditions.
2. The moisture content and organic content of wastes is high, while the calorific value is generally low. Incineration and other Waste-to energy projects would not be self-sustaining and require external energy input. Methane generation and composting techniques are more feasible for such waste characteristics.
3. Decentralized composting holds more promise rather than centralized composting plants.
4. There is a substantial presence of inert material due to the presence of sweepings and open ground storage of wastes.
5. A large section of people works in the informal waste sector and renders important service, though unrecognized and unacknowledged by the society and the government. They need to be supported by the government.
6. Collection of wastes is generally poor in almost all Indian cities and needs vigorous measures to improve the situation.
7. Municipalities are unable to cope up with the growing problem of increasing solid waste generation due to financial constraints, no cost recovery, absence of financial

accounting, absence of effective monitoring system, inadequate work norms, lack of expertise, low productivity of Solid Waste Management staff and equipment, organizational constraints, lack of co-ordination among various departments involved in providing infrastructure services, etc.

8. The constraints and inefficiencies experienced in Solid Waste Management are mainly due to an undue emphasis on technology, while ignoring the related social, ecological and economic characteristics.
9. Various laws and rules rightly point to the various problems and plausible solutions to the municipal solid waste management but their implementation and enforcement is very poor.
10. Community participation in the solid waste management service is generally, low. Sanitation and solid waste management has a low priority for the people. Public-private and Public-community partnerships have started to emerge in some cities with mixed results.

1.2.11 Summary

The review of literature reveals the various important aspects regarding waste management practices in India and abroad. It is observed that Waste management is more or less dealt with in an integrated approach in developed countries and is not so in developing nations. The local governments in India though spend a major portion of their expenditure on waste management; there is a complete lack of any technical, professional guidance and integrated approach towards dealing with this service. Discrepancies in data pertaining to waste management are frequently observed in almost all towns and cities in India. The study further led to understand the waste characteristics and waste management practices in prominent developed countries and developing countries, application of appropriate tools and techniques, models in waste management, and prominent economic instruments, which could be used to achieve an integrated sustainable waste management system in an urban system. The Investigator has also attempted to study the various possible alliances between private, public sectors, and community and their different combinations existing in various developing countries in the field of solid waste management. It also brings an insight into the emerging alliances in this field in India by citing examples of few cities.

The Investigator further attempts to summarize the findings pertaining to Solid waste management in developed countries, developing countries and India, and are presented in Table 1.20.

Table 1.20: Comparison of MSW management practices in Developed and Developing Countries

S. No.	Item	Developed countries	Developing countries	India
1.	Quantity of waste generated	High	Low to medium	Low
2.	Quality of waste generated			
	- Moisture content	Low	High	High
	- Organic content	Low	Medium to High	High in suburbs and small urban centres, less in metros
	- Volume	High	Less	Less
	- Mass	Less	High	High
	- Caloric value	High	Low	Low
3.	Collection cost	Low	Maximum	Maximum
4.	Transfer and Transportation cost	Low	Less	Medium
5.	Treatment and Processing cost	High	Low to Medium	Not practiced
6.	Landfill cost	High	Minimum	Low
7.	Public awareness	High	Low	Low
8.	Public-private partnership	Strong	Weak; started on experimental basis	Experimental stage in few cities; partnerships primarily for waste collection

Table 1.20 (Continued)

S. No.	Item	Developed countries	Developing countries	India
9.	Informal sector participation	Weak	Strong; weak in few countries	Strong
10.	Success rate of various SW treatment technologies			
	- Incineration	Successful; but with environmental costs	Failure	Failure
	- In-vessel composting	Successful	Failure	Experimental stage
	- Decentralized composting & windrow composting	Failure	Successful	Mixed results
	- Biomethanation	Successful	Experimental stage	Failure for municipal waste; successful for industry waste
	- Formal Materials Recovery facilities(MRFs)	Present	Absent	Absent
	- Informal recycling	Absent	Strong	Strong
11.	Environmental laws	Strictly implemented	Poorly followed and implemented	Strong but poorly implemented
12.	Capital cost	High	Low to medium	NA
13.	Labour cost	High	Cheap	Cheap
14.	*Recommended SOLID WASTE MANAGEMENT*	*Capital intensive, labour saving*	*Low cost, labour intensive*	*Low cost, labour intensive with formal-informal sector integration*

Source: Compiled by the Investigator

The Investigator understood the problems and prospects of solid waste management in detail through the above presented literature review and selected Kanpur city to conduct the present investigation. To conduct the present investigation, a set of plausible objectives are framed.

1.3 OBJECTIVES

The following objectives are framed in this investigation. They are:

1. To assess the existing physical, socio-economic and environmental conditions of the urban system (study area).
2. To assess the available infrastructure facilities pertaining to solid waste management in the system.
3. To identify the control parameters, which decide the functions of the system in connection with socio-economic, solid waste management and environmental conditions of the system and their functions.
4. To forecast the Municipal Solid Waste generation, collection, infrastructure requirements for solid waste management and the cost of the services in the year 2031 A.D.
5. To evolve a set of policy guidelines, and to prepare a feasible integrated solid waste management plan for Kanpur city.

1.4 SCOPE OF THE STUDY

The study area of Kanpur city has the distinction of one of the most polluted cities of Northern India. Unlike other metropolitan cities, there are not many efforts taken in giving it a cleaner urbane and international look. This study is an attempt to plan and manage the municipal solid waste generated in the city. The Investigator hopes that if the recommendations are implemented systematically in time in the study area, the city could soon turn out to be a dust-bin free clean and healthy city. Sustainable integrated solid waste management is anticipated in the system if the policy recommendations and strategic management plan is implemented properly.

1.5 CONCEPT

In this present investigation, systems concept is employed. A system functions as a whole with the interaction of several sub-systems. All the sub-systems are interlinked and interdependent on each other and functions as a whole with dynamic characteristics. If one of the sub-systems functions with advancement or defunct or partly function during its function, its effects can be observed in the whole system over a period of time.

An urban system is one such complex, soft, social system with dynamic characteristics. Kanpur city is found to have all such complex dynamic characteristics and hence, can be regarded as a system. The city has many generators of waste. Generators of waste can be considered as sub-systems, which are dependent on socio-economic and cultural conditions of the study area. Collection, storage, transportation and final disposal are other sub-systems of formal waste management sector. Another sub-system of recycling is entirely handled by the informal sector. All these sub-systems together create environmental stress. Thus, all these sub-systems are interlinked and interdependent on each other. The Systems concept is, therefore, employed in this present investigation to assess the functions of the system in different alternative conditions, to evolve a set of plausible guidelines and to prepare a feasible integrated solid waste management plan, which is sustainable and conducive to the socio-economic conditions of the study area.

1.6 RESEARCH DESIGN

Survey research methods have been employed in this present investigation. A detailed methodology, which has been followed to conduct this investigation, is presented in Fig. 1.4.

1.6.1 METHODOLOGY

The present investigation follows a systematic and step wise methodology as presented in Fig. 1.4. The various steps followed in the investigation are problem identification, formulation of goals and objectives, followed by collection of data, analysis and identification of the control parameters, which decide the functions of the system. This is followed by development of model, its validation, forecasting, simulation, drawing of inferences, policy analysis, development of a strategic waste management plan, and evolving a set of policy guidelines and recommendations.

1.6.2 DATA

Two types of data, i.e., secondary and primary sources of data pertaining to this present investigation are collected and employed. The details of data collected are presented in Table 1.21.

Table 1.21: Details of Data collected

S. No.	Levels	Source of Information	Types of Information
1.	Local bodies	Kanpur Municipal Corporation, Kanpur Development Authority, and experts	Secondary and Primary
2.	Households	Household persons	Primary
3.	Informal sector	Waste-pickers, Itinerant Waste Buyers, retailers, wholesalers	Primary
4.	Institutions	Indian Institute of Technology-Kanpur, Common Effluent Treatment Plant, State Pollution Control Board	Secondary

Secondary Sources of Data: Required data from the published and unpublished literature, documents from various sources are collected pertaining to this investigation.

Primary Sources of Data: Sample survey at household level, informal sector level and experts' level are conducted for obtaining requisite data at the grassroots level.

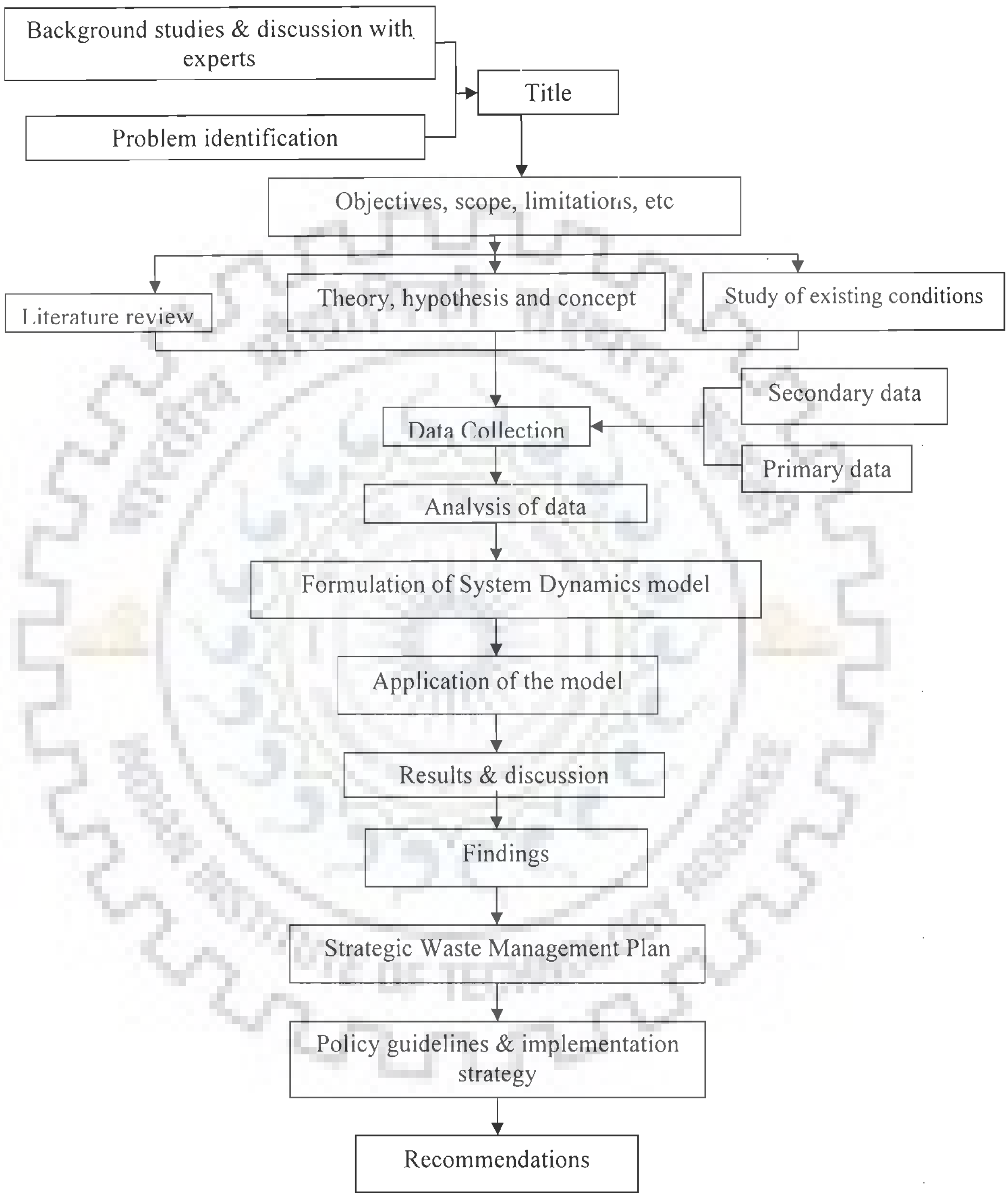


Fig.1.4: Methodology Chart

1.6.3 SAMPLING DESIGN

The city is sub-divided into six zones for administrative purpose (Fig. 1.5). All the six zones have their own special features. These six sub-divisions together have 110 wards (Fig. 1.6). An attempt was made to select households from selected wards from all six zones. Purposive sampling technique has been employed for the selection of wards whereas simple random sampling technique was employed for the selection of households from the selected wards. The selected wards for conducting the primary household survey in each of the six zones are presented in Fig. 1.7.

1.6.3.1 Selection of the Sample Households

Zonewise selection has been done for the selection of wards and households for conducting the primary survey as the city is divided into six zones for rendering the municipal solid waste management services by the Local Authorities. An attempt has been made to select wards from each zone to get an equitable representation from each zone and presented in Table 1.22, 1.23 and 1.24. Each zone has its own features. The selected wards from each zone represent the salient features of that particular zone. Purposive sampling was thus done for selection of wards since the Investigator has an in-depth knowledge regarding the study area. Characteristics of each zone with details of the selected wards are discussed in the following sections for further clarity.

Table 1.22: Details of the selected wards

Sl. No.	Zone	No. of wards	Selected wards
1.	Zone 1	15	5
2.	Zone 2	18	8
3.	Zone 3	18	6
4.	Zone 4	16	5
5.	Zone 5	25	6
6.	Zone 6	18	4
	Total	110	34

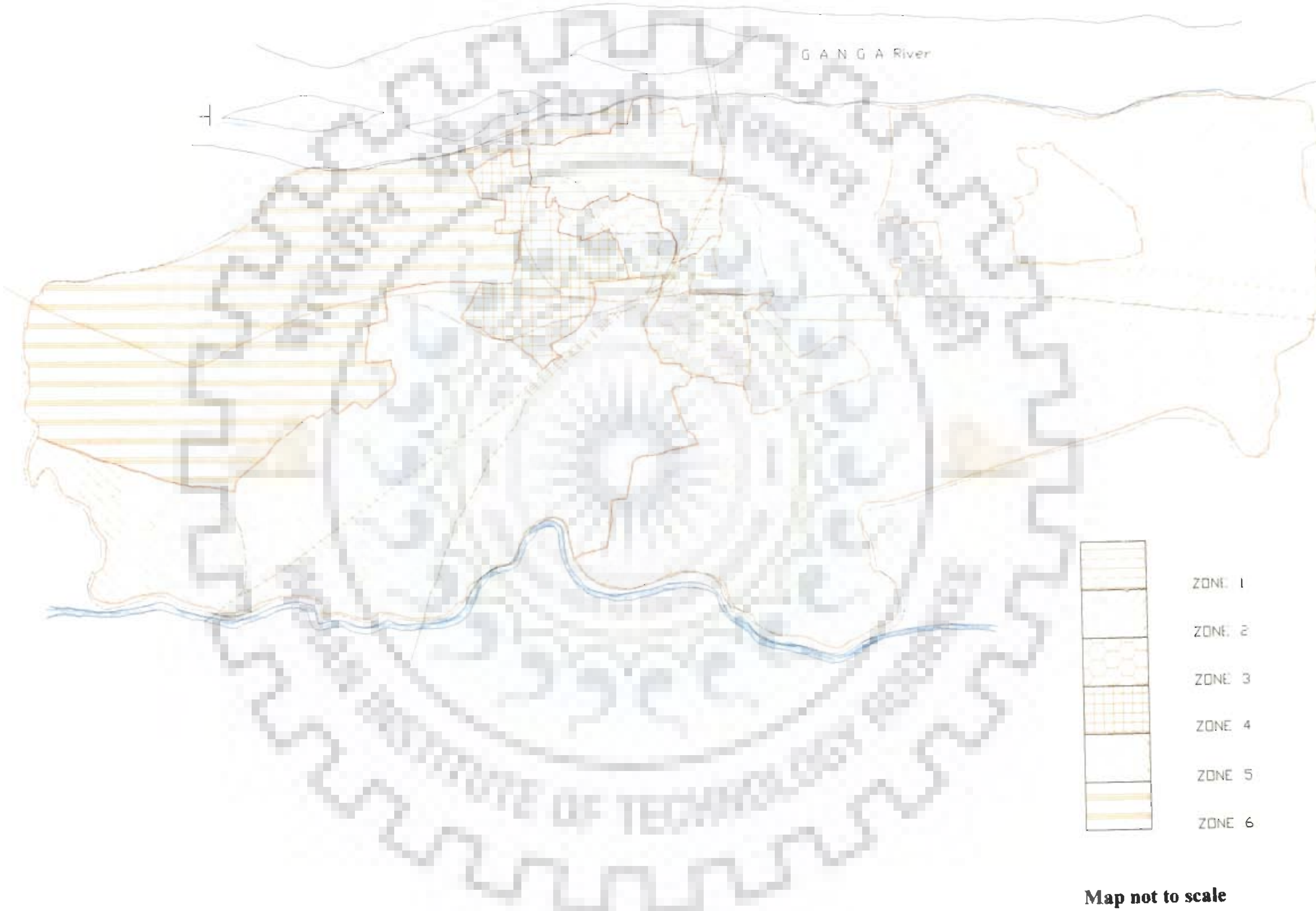
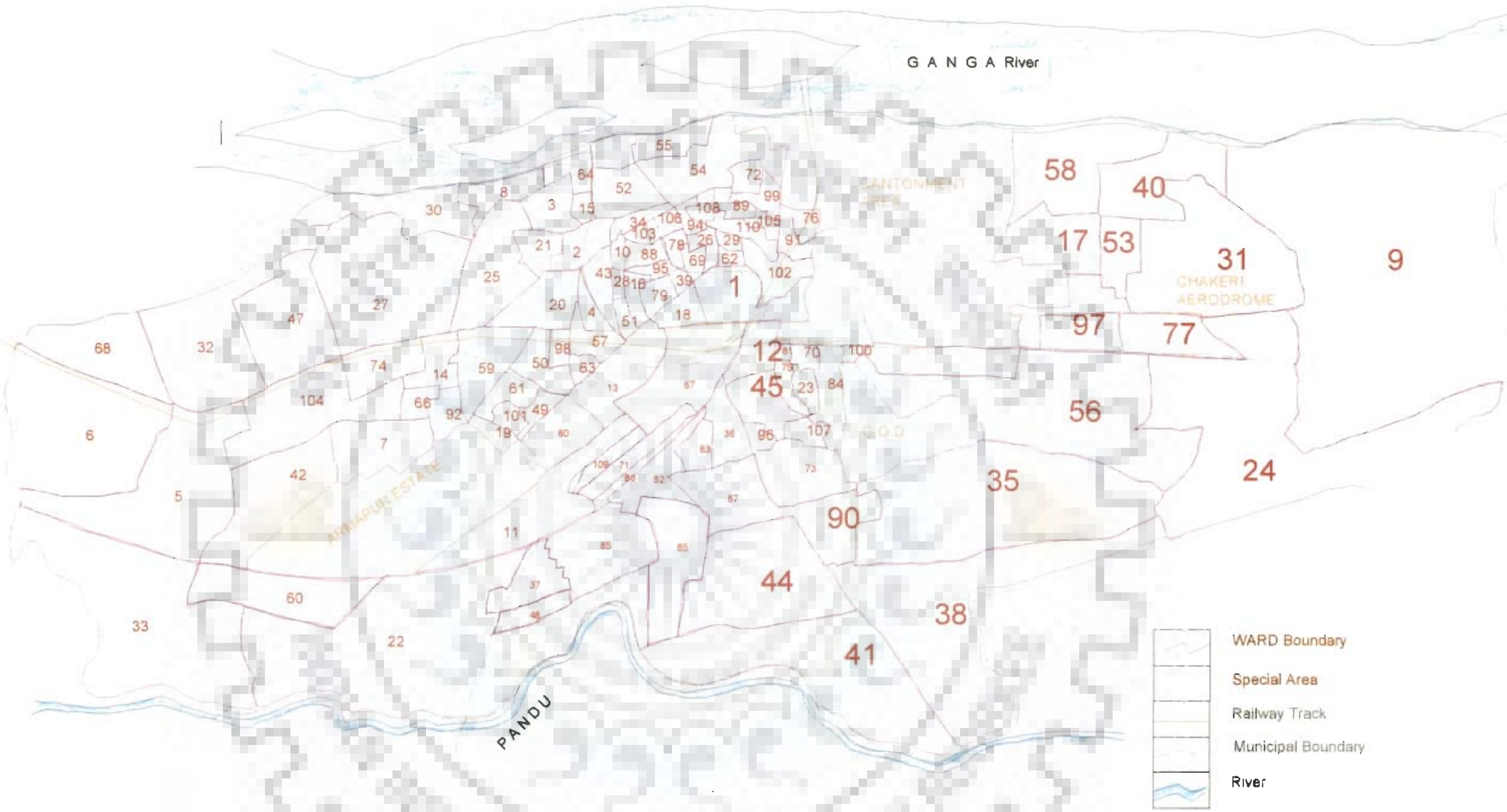


Fig. 1.5: Sub-divisions based on zones and used for selection of wards for primary survey in Kanpur



Map not to scale

Fig. 1.6: Ward map of Kanpur

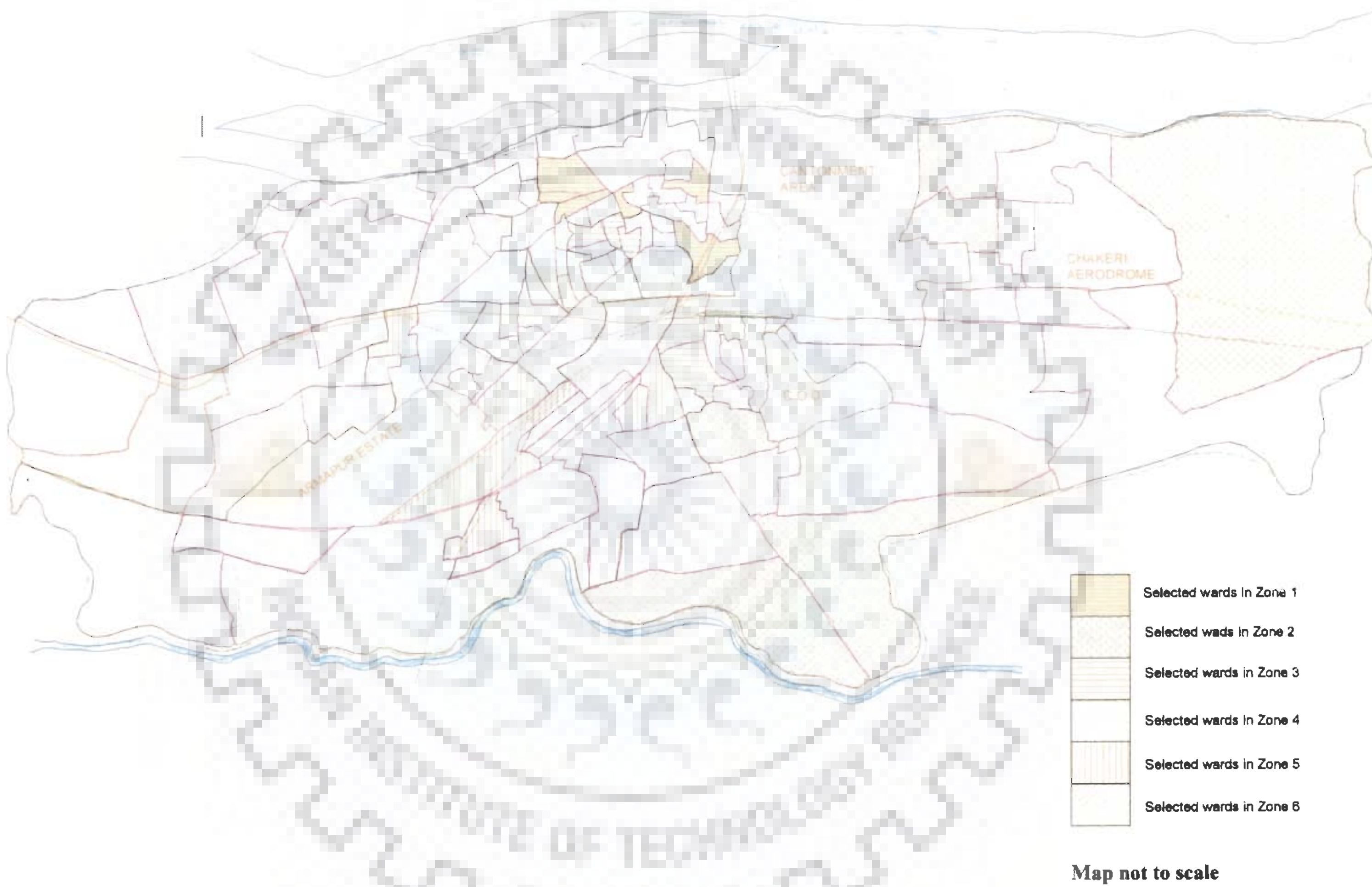


Fig. 1.7: Selected wards in each zone for primary survey

Table 1.23: Details of the selected households for primary survey

Sl. No.	Zone	Selected wards	Total no. of HHs in selected wards	Selected HHs	Percentage of selected HHs to the total HHs
1.	Zone 1	5	90476	45	0.30
2.	Zone 2	8	257471	70	0.15
3.	Zone 3	6	131355	45	0.20
4.	Zone 4	5	88926	35	0.23
5.	Zone 5	6	129549	50	0.21
6.	Zone 6	4	135627	55	0.23
	Total	34	145235	300	0.21

Note: HHs-Households

Table 1.24: Details of the selected wards in each zone

Sl. No.	Zones	Zonewise selected number of wards and their names	
		Ward No.	Ward name
1.	Zone 1	34	Chunniganj
		52	Civil Lines
		94	Parade
		99	Chatai Mohal
		102	Collector ganj
2.	Zone 2	9	Chakeri
		17	Ompurwa
		38	Naubasta(East)
		41	Jarauli
		53	Harjendranagar
		58	Jajmau
		73	Qidwainagar (two)
		97	Krishnanagar
3.	Zone 3	12	Transportnagar
		45	Sabzimandi
		69	Dalelpurwa
		78	Heeramanpurwa
		88	Becunganj
		100	Begumpurwa
4.	Zone 4	4	Jawaharnagar
		15	Gwaltoli
		16	Sisamau-two
		43	Rambagh
		51	Gandhinagar
5.	Zone 5	11	Govindnagar
		14	Ambedkarnagar
		36	Juhi-Hamirpur road
		37	Dabauli
		83	Juhi-kalan
		80	Fazalganj
6.	Zone 6	5	Kalyanpur
		7	Rawatpur
		27	Nawabganj
		47	Vikasnagar

Zone 1: Zone 1 represents the oldest area of the city and contains the Central Business District. This zone has fifteen wards, of which five wards have been selected and the selected wards represent the features of this zone, like, Parade and Collectorganj wards are one of the largest wholesale markets of the area. The selected wards are characterized by mixed land use, high density, narrow roads, etc. From these wards, a total number of 45 households were randomly selected for conducting the survey.

Zone 2: This is the largest zone of the city. One of the salient features of this zone is the presence of a number of small and big tanneries and the effluent treatment plants. This part of the city developed in the later stages and is in growing stages. It has medium to low density of population with mixed land use and few planned colonies. It has eighteen wards, of which eight wards have been carefully selected. Wards like Chakeri, Jajmau, Qidwainagar, Krishnanagar and Harjendranagar represent the typical characteristics of this zone with population from all classes. A number of slums are also found in this zone. Two peripheral wards with more rural characteristics and not served properly by the local Authorities namely, Jarauli and Naubasta, have also been selected for survey to have a proper representation of the zone. From these eight representative wards, a total number of 70 households were randomly selected for conducting the survey.

Zone 3: Zone 3 is a high density area with lot of commercial activities due to the presence of a number of wholesale and retail markets. This zone has eighteen wards, of which six wards, which represent the characteristics of this zone, have been carefully selected. Transportnagar ward is a very congested residential cum commercial ward with frequent sewerage breakdown and has poor roads. Sabzimandi ward has big vegetable market. Dalelpurwa and Begumpurwa are congested residential areas with narrow roads. Dalelpurwa is primarily a slum area, whereas Becunganj has a big textile market, is congested and has very narrow roads. From these selected wards, a total number of 45 households were randomly selected for conducting the primary survey.

Zone 4: Zone 4 is a medium density area with a mix of planned and unplanned areas. It has sixteen wards, of which five wards have been carefully selected representing the salient features of this zone, like, Jawaharnagar, Gandhinagar and Rambagh wards are planned residential colonies while Gwaltoli is a big retail market and is very congested. Sisamau ward has wholesale market and slums. From these five wards, a total number of 35 households were thereafter randomly selected for conducting the primary survey.

Zone 5: Zone 5 lies towards the western-southern part of the city and has medium to low density of population. It has twenty five wards, of which six wards have been carefully selected by the Investigator representing the characteristics of this zone, like, Juhi-Hamirpur road ward and Juhi kalan wards are very congested, have low income households, and poor infrastructure services whereas Fazalganj ward has a big retail market and is congested. Govindnagar and Ambedkar nagar are more planned residential areas whereas Dabauli has more suburban characteristics and poor infrastructure services. A total number of 50 households were thereafter, randomly selected from the shortlisted wards for conducting the survey.

Zone 6: Lying towards the western part of the city, this zone comprises of new and old areas. It has eighteen wards, of which four wards have been selected. Kalyanpur ward is a busy educational centre with concentration of coaching centres and a number of small and big institutes. This ward is prone to flooding during the monsoons due to improper sewage and drainage. The other ward namely, Rawatpur ward has a number of government and private offices, besides residences whereas Nawabganj ward is a well planned residential area with large expanses of green area. Vikasnagar ward has also planned residential colony. A total number of 55 households were thereafter, randomly selected from these wards for conducting the survey.

For household survey, the Investigator collected a list of households prepared by the Municipal Corporation for each ward. Requisite number of households were randomly chosen from the selected wards and marked for conducting the survey.

1.6.3.2 Selection of the Sample Respondents from the Informal Sector

There are six types of people working in informal waste recycling sector in the study area. Each type is found in specific areas, like the small traders are mostly located along the highways and major roads, Waste pickers are found nearby the railway lines and small settlements nearby dump sites. Random sampling technique has been employed to select the respondents to conduct the survey from each of the segment in the absence of any data base as to their number or whereabouts. The number of respondents selected from each segment is presented in Table 1.25. Survey was conducted among the informal sector people who were willing to participate in the survey.

Table 1.25: Details of the selected samples (informal sector)

S. No.	Type of respondents	No.
1.	Waste-pickers/dump-pickers	20
2.	Itinerant waste-buyers	5
3.	*Jogies*	3
4.	Retailers/small traders	7
5.	Bone merchants	2
6.	Wholesalers	3
	Total	40

1.7 SURVEY TOOLS

Appropriate survey tools, such as, pre-tested schedule, questionnaires, etc., are employed in this present investigation. They are as follows:

1.7.1 SCHEDULES

Two types of schedules were prepared to carry out the primary survey at the grassroots level, such as household schedule and informal waste recycling schedule; pre-tested in the study area, modified accordingly and then employed in this investigation to conduct the survey. They are as follows:

1.7.1.1 Household Schedule

This is an important source of collecting information at the grass-roots level. The schedule was designed in consultation with experts, tested by taking pilot studies, discrepancies were corrected and the final schedule was prepared. The schedule has good number of variables covering various aspects like socio-economic, housing conditions, income, expenditure on various commodities, level of education, energy consumption, specific details about the quantity and quality of solid waste generated, mode of cleaning, sewerage, drainage, willingness to pay more if better waste collection services are provided, ranking of various infrastructure related problems faced by the respondents, etc. The Household schedule used in this investigation is presented in Appendix-I.

1.7.1.2 Informal sector schedule

This is an important source of collecting raw data and valuable information about the various actors engaged in waste recycling. It covers information about waste-pickers, dump-pickers, itinerant waste-buyers, traders and wholesalers. There is a serious data gap about information of this sector. The informal nature of this sector adds to the problem. The schedule contains details such as, place of living, work, living conditions, household size, quantity of waste collected, selling price, lean seasons, health hazards, etc. The schedule used in this investigation for carrying out the survey of Informal Waste recycling sector is presented in Appendix-II.

1.7.2 METHOD OF ADMINISTRATING THE SURVEY AT THE HOUSEHOLD LEVEL

Preparation of schedule in consultation with experts was followed by conducting a pilot survey in the identified households. The collected data during the pilot survey was analyzed thoroughly, gaps were identified and final schedule was developed for conducting the investigation. This was followed by actual survey of the households. The households were approached directly, and detailed discussions were done with the members of the households after obtaining prior appointments from the respondents for conducting the final survey at the household level. An attempt was made to cover households from different income-groups living in different localities to have a better representation of all sections of the people living in the city. The survey was conducted by the Investigator herself which gave an opportunity to have a better understanding of various issues based on observations.

1.7.3 METHOD OF ADMINISTRATING THE SURVEY AT THE INFORMAL SECTOR LEVEL

Pre-tested schedule was used to conduct the survey at the Informal sector level. The Investigator first approached the waste-pickers for survey and could extract information for further links to the small traders and wholesalers. Waste-pickers were found to be initially reluctant to give any information. This was followed by random selection of Jogies, bone collectors, small traders and wholesalers' survey. A lot of insight was gained about the living conditions, social seclusion, health hazards of these people as the survey was done by the Investigator herself.

1.8 ANALYSIS

The collected data were checked for completeness and correctness, and errors or bias in the results was eliminated by crosschecking, and subsequently, carefully transferred the data into code sheets and further fed into computer for analysis. Detailed analysis is done by employing various tools and techniques as discussed below:

1.9 ANALYTICAL TOOLS AND TECHNIQUES

1.9.1 Analytical Tools

Analytical tools, such as, code sheets and software such as, EXCEL, SPSS, GeoMedia and PowerSim have been used in this investigation for data processing, modelling and analysis.

1.9.2 Analytical Techniques

Relevant statistical techniques, such as, tabulation, correlation, multiple regression; and system dynamic models, etc., were employed in this present investigation.

1.10 APPLICATION OF THEORY

System Dynamics theory based on systems concept has been employed in this present investigation [128]. In this investigation, the study area has been considered as a system having the major objective of achieving an integrated municipal solid waste management in the system.

1.11 MODELLING

Correlation analysis has been used to analyze the primary survey data to understand the correlation between monthly income and various other variables, while Multiple regression models have been developed and used to understand the relationship between various controlling parameters. Urban System Dynamics model was developed and employed to understand the causal relationships among the subsystems of the system and the dynamic functions of the urban system as a whole. PowerSim® 3.1 software has been employed to develop the urban system dynamics model.

1.12 VALIDATION OF MODEL

Validation is done for the evolved System Dynamics model to understand the reliability of the model for further investigation.

1.13 FORECASTING

The validated Urban System Dynamics model thus evolved has been used for forecasting various control parameters such as, population, the demand and supply of land requirement for disposal of generated municipal solid waste, total quantity of generated waste, manpower requirement, environmental stress, etc., which decide the functions of the solid waste management sub-system and the same are used in the model.

1.14 SIMULATION

Alternative plausible scenarios have been developed based on historical development, trend analysis, assumptions, etc., and the same have been tested in the projected year model for arriving at different feasible decisions.

1.15 RESULTS AND DISCUSSIONS

Results of all types of analysis, such as, (i) Literature survey (ii) Primary household survey (iii) Primary survey of informal sector engaged in waste recycling (iv) Field survey of the city (v) Model results and (vi) Simulation results have been discussed in detail to arrive at plausible recommendations.

1.16 INFERENCES

Plausible inferences were drawn for evolving a strategic waste management plan and for evolving a set of feasible policies.

1.17 STRATEGIC WASTE MANAGEMENT PLAN

A Strategic waste management plan has been proposed based on the results of the recommended policy. The plan has been made for phase wise collection, treatment and disposal of municipal solid waste.

1.18 RECOMMENDATIONS

A set of policy guidelines is prepared based on the results, discussions and findings of this investigation for integrated sustainable solid waste management of the study area.

1.19 SIGNIFICANCE OF THE PRIMARY DATA

Secondary data is completely absent on the waste recycling sector pertaining to the study area. This sector comprises of workers engaged at many levels, like waste pickers, small traders, wholesalers, itinerant waste buyers (Kabadi), etc. In the absence of any data base pertaining to this sector, it was essential to get the necessary information by conducting the primary survey.

The secondary data available from various sources was not found sufficient to understand the required details at the household level. The data pertaining to waste generation, linkages to the income-expenditure pattern, willingness to pay user fees for better facilities, etc., were completely absent. Data pertaining to spatial qualities, income, expenditure, solid waste generated, etc., are not available in any form of secondary data. Thus, the required amount of data for this present investigation at micro-level was not available from the secondary sources of data. These data were, therefore, colleted by conducting an extensive primary survey by using pre-tested schedules. The data obtained from the primary survey was essential to understand the functions of the system. The survey was conducted in the year 2004, which is considered to be the base year of the study.

1.20 NEED FOR THE PRIMARY SURVEY

Planning for integrated solid waste management requires an in-depth understanding of various parameters-formal and informal sector, peoples' perception and behaviour with regard to waste, relationship of socio-economic conditions with waste generation, treatment, etc., and various issues, problems, pertaining to municipal solid waste management in the system. For the said purpose, the study area is divided into six administrative zones for rendering waste management services by the Corporation. It is observed that these six zones differ in access to basic services including waste collection frequency, availability of bins, etc. Representative wards have therefore, been carefully selected from these for carrying out primary household survey.

The development and implementation of an integrated municipal waste management plan depends on spatial, socio-economic and public policy factors. Public participation, aspirations and perception of environmental stress play a major role in development and implementation of such plans. Involvement of community based organizations, NGOs and informal waste recycling sector also play a strong role in managing waste in a sustainable manner. These aforesaid factors forced the Investigator to collect detailed information for the investigation in two broad aspects, such as, socio-economic conditions of the system and of the informal waste recycling sector, details like average waste being collected by this sector and the sale price differentials of retrieved products, etc. The information regarding socio-economic conditions was collected through surveys conducted at the household level and information pertaining to informal waste recycling sector was collected through surveys at the waste recyclers' level. Such surveys brought a lot of first hand information and insight to understand the dynamics of the system, factors that influence the functioning of the system pertaining to waste recycling, environmental stress, etc.

1.21 JUSTIFICATION OF THE STUDY AREA

Kanpur city is the largest metropolitan city of Uttar Pradesh State. It is also the chief industrial and commercial centre of the State. Despite its economic well-being, the city is one of the dirtiest and most polluted cities in the Northern India. The city also has a big waste recycling sector, recycling of leather wastes, plastics, paper, etc., is very common in the city. The Investigator has often been visiting the study area for personal reasons, which led to an increased interest to study the problems of the city at micro level. The city is already a hotbed of Tuberculosis and various other broncho-respiratory diseases. The city is littered with municipal, industrial and biomedical wastes. The city is continuously degrading environmentally, over the years. Even a small amount of rainfall results in flooding of many areas in the city; reason being clogging of drains by uncollected and littered waste. This environmental degradation results in loss of working man-hours, increased expenditure on medical expenses and economic and environmental loss. Under the circumstances, there is an immediate need to evolve an integrated solid waste management plan considering all aspects, such as, waste generation, collection, transportation, disposal, recycling, ecology and environment for making the city a healthy city in real sense. Having the above knowledge, the Investigator has chosen this particular city for investigation in this particular field of learning. The existing condition of the study area is presented in the Study area profile in the second chapter.

1.22 PROBLEM IDENTIFICATION

A clean and healthy built environment is of paramount importance to achieve sustainable development. All the Indian metropolitan cities are currently facing tremendous population pressure due to which there is a geometrical increase in the demand and supply of various infrastructure facilities, including waste management. The introduction of various manuals on Waste Management by the Central government has not been able to achieve much specially in North Indian cities. The local government as well as the people have not yet realized the various ill-effects of unhealthy environment. This is very much evident in Kanpur city, which has a distinction of being called a TB city, a polluted city and a city full of littered waste.

A number of models have been developed to achieve the best combinations of waste facilities for an optimal solid waste management system. The first solid waste management models were optimization models and dealt with specific aspects like vehicle routing, transfer station siting, etc. During the 1990s, the models developed tried to include aspects like recycling and other waste management methods. Some models also discussed the main environmental problems related to municipal solid waste management, and in particular those concerning pollutant releases. However, the models only considered economic and environmental aspects but missed social aspects. The current waste management models are mostly compromising models (unlike the earlier optimizing models) and can be categorized into three categories, those based on cost-benefit analysis, those based on life cycle analysis and those based on the use of a multi-criteria technique. However, no model considers the involvement of all the stakeholders involved in waste management, and hence cannot be termed sustainable. The proposed model tries to involve various stakeholders and prepare an integrated solid waste management plan for the study area.

1.23 LIMITATIONS

The following limitations are observed in the study:

a. Solid waste management is the only infrastructure dealt with in this study.
b. The study only covers the municipal solid waste. The hazardous, industrial and construction waste flows are not covered in this study. A fraction of the industrial waste (leather industry) is however, considered as it forms a substantial part of the municipal solid waste in the study area.
c. The contribution by bulk generators in municipal waste generation are not field tested and assumptions are made based on previous studies.
d. Sampling techniques are employed in this investigation due to the non-availability of resources for conducting a detailed comprehensive household survey.
e. The study is limited to only Municipal Corporation area.
f. Slums are excluded from the grassroots level investigation as they have features different from rest of the city.
g. Estimates about the number of persons in each segment of the waste recycling sector is based on similar studies for other cities.
h. Time limit, i.e., Ph.D research is time based.

1.24 CHAPTER SCHEME

The thesis is organized in the following chapters:

Chapter 1: This chapter consists of introduction, statement of the problem, literature review, objectives, scope of work, research methodology, limitations, etc.

Chapter 2: This chapter deals with the study area profile.

Chapter 3: This chapter discusses in detail the existing situation of Solid Waste Management in Kanpur.

Chapter 4: This deals with the analysis of the physical, socio-economic, infrastructure and environmental condition of the study area, based on the primary survey of households. It also discusses the socio-economic, living and working conditions of the informal sector.

Chapter 5: This chapter deals with control parameters, which decide the functions of the system pertaining to solid waste management, application of theory, development of functional models, its application under various alternative conditions, forecasting the various parameters in 2031 A.D., and functions of the system under various alternative conditions.

Chapter 6: This chapter deals with results, discussion and important findings based on literature survey, primary survey of households and informal sector and model based findings.

Chapter 7: This chapter deals with preparation of Strategic management plan for integrated sustainable solid waste management in the study area and also covers evolving planning policies, recommendations and conclusions.

Chapter 2

STUDY AREA PROFILE

2.0 INTRODUCTION

A settlement is an integration of culture and society, a harmonious interaction between man and nature. The modern urban settlement is a dynamic organism working in active interactions with its various systems and sub-systems. This close working of systems and sub-systems is often disturbed directly or indirectly due to various reasons leading to the so-called urban problems. One of these overwhelming problems of modern cities all over the world is the ever-increasing unattended heaps of municipal, biomedical and hazardous waste and/or their unsustainable treatment and management. It is imperative for a better understanding of this problem to study the selected area/city in a holistic manner, right from the start of the city's evolution over time. An attempt has therefore, been made in this chapter to have a close look at the cityscape of Kanpur city, its demographic profile, its existing infrastructure, functional structure, socio-economic, administrative, financial, environment aspects, etc.

2.1 PHYSICAL SETTING

The district of Kanpur is situated in the lower part of the Ganga and Yamuna *doab*, between the parallels of 25^0 26' and 26^0 58' North latitude and 79^0 31' and 80^0 34' East meridians of longitude in an irregular quadrilateral shape (Fig 2.1). The creation of the district Kanpur Nagar has taken place after 1981 Census and was earlier a part of Kanpur district.

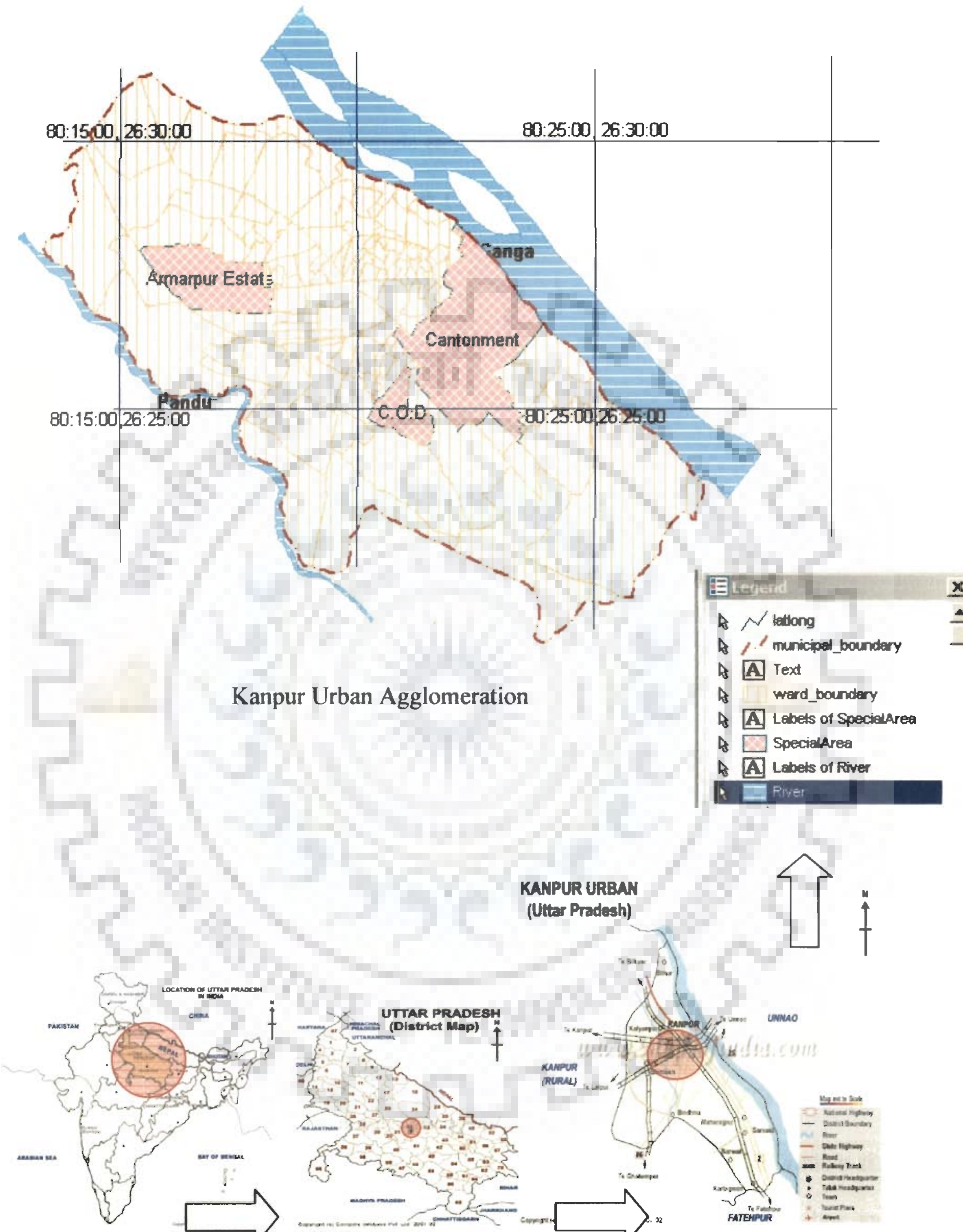
On its South-east is the district of Fatehpur, to the North-east lie the districts of Hardoi and Unnao and surrounded by the district of Kanpur-rural (Kanpur-Dehat) in the West. The Ganga river forms the North-eastern boundary. The area is a very fertile well-cultivated area and lies at an altitude of 126 m above sea level.

The study area of Kanpur Urban Agglomeration lies towards the North-eastern part of District Kanpur Nagar. It has a total area of 298.98 sq km. It is the most populated metropolitan city of Uttar Pradesh and the State's chief industrial city. It is located on the right bank of the river Ganga. It enjoys a central position in Uttar Pradesh and is at a distance of 63 km from Lucknow and 425 km from the national capital Delhi.

2.2 TOPOGRAPHY AND CLIMATE

Topography of the district bears a slightly sloping form of an alluvial plain tapering away from North-west to South-east direction. The coverage of Ganga lies in wide and sandy bed, the shores often changing. Apart from the sand, the bed is formed by new deposits of alluvial. The soil is extremely fertile like the other districts. The part lying between the river Ganga and the river Pandu is a level expanse of good loam.

The climate is tropical in the study area. The study area is characterized by a hot summer and general dryness except in the South-west monsoon seasons. The year may be climatically divided into four seasons. The period from March to about the middle of June is the summer season, followed by the South-west monsoon season, which lasts till about the end of September. October to first half of November is the transition period. The cold season spread from about the middle of November to February. The average maximum and minimum temperatures in the study area are 33.8 ^{0}C and 18.2 ^{0} C respectively. The average rainfall in the city is 447.6 mm per annum.



Map of India | Uttar Pradesh State | Kanpur Urban District

Fig. 2.1: Location of the Study Area: Kanpur City

2.3 PHYSIOGRAPHY

The area constitutes an alluvial plain sloping gradually from North-west to South-east, following the line of rivers Ganga and Pandu, as shown in Fig 2.2. The area has an average level of 120 meter above mean sea level (MSL). Spot heights, however, vary from 113 to 127 meter above mean sea level in the area.

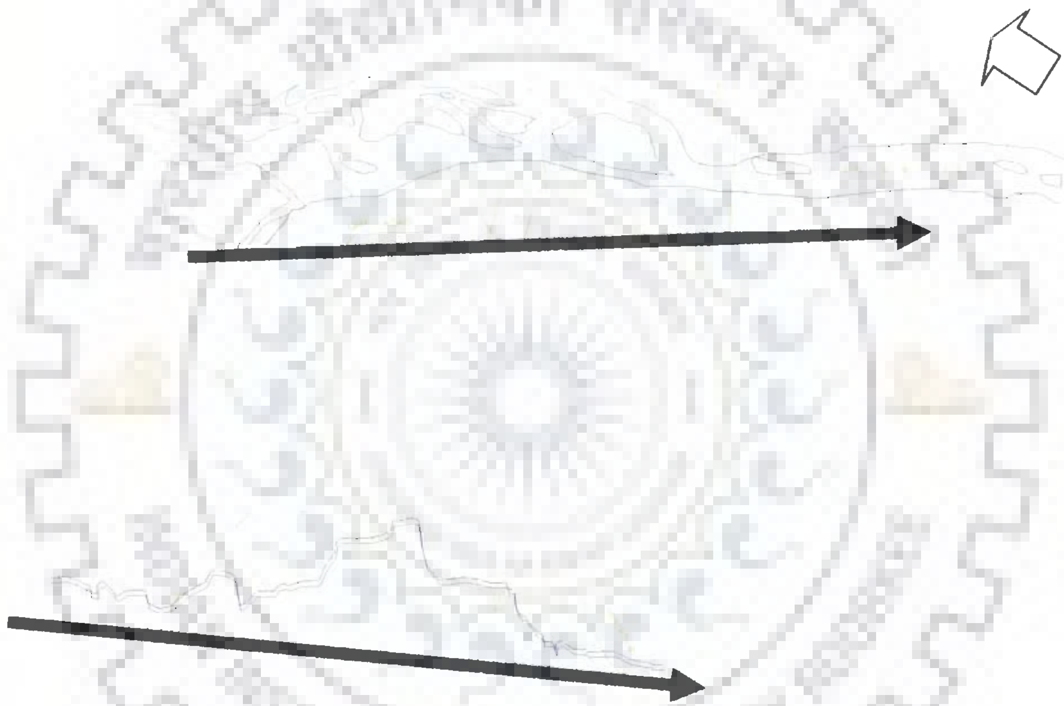


Fig. 2.2: Physiography of Kanpur

2.4 GEOLOGY AND SOIL

Soil is mainly light and fertile loam in the area. It is relatively hard and gritty along the river Ganga and gradually becomes softer towards the river Pandu. It further becomes sandier gradually towards South-east. Thus, the bearing capacity of soil gradually decreases towards South and South-east direction.

There are three seismic fault lines in the vicinity of Kanpur, *viz.*, the great Himalayan boundary fault (280-480 km), the Lucknow fault (140-160 km) and the Moradabad fault (280-360 km).

2.5 WATER BODIES

Kanpur Urban agglomeration has two major water bodies in the form of rivers Ganga and Pandu in North and South respectively. Other than these, there are small water bodies (area ranging between 2 and 5 hectare) like, the Zoo, Motijheel, Chandari, near Railway Bazar and Railway Colony, Naukhera, etc. Ganga is the major source of surface water supply to the city, while Pandu has small water flow and is in a deplorable condition due to draining of ash slurry from Panki Power Thermal Plant and effluents thrown by a number of industries and tonnes of domestic sewage.

2.6 HISTORICAL GROWTH

There are different stories with regard to nomenclature of the city. One legend says that the place draws its name from ear-piercing ceremony of Lord Kanhaiya. The town however, seems to have been founded by King Chandel of Sachendi in 1750 A.D. It was earlier called Kanhaiyapur, which later became Kanpur.

The area comprising of district Kanpur Nagar has imprints of one of the earliest existence of human culture going as far back as to the Neolithic cult, as gleaned by archaeological finding in Moosanagar on the left bank of river Yamuna. Traces of further stages of development are evident from major findings in the form of spear heads, arrows, stone images, terracotta objects, pottery and remains of fort and temples at many places in the district. It was part of the

Panchal kingdom in the sixth-century B.C. and was a part of Kannauj empire later during the medieval period. Later on, it passed under the rule of Mughals. The death of Aurangzeb in 1707 triggered off the process of disintegration of Mughal empire and in its wake many battles were fought, with the territory finally going to the Nawabs of Awadh. The area had some eleven rural settlements till eighteenth century with names like, Old Kanpur, Kursawan, Juhi, Sisamau, Pathakpur [285]. It remained with the Nawabs till 1801 when it was made over to the British. It soon became an important military station and was strongly garrisoned. In late 19th century, it developed into an industrial centre and came to be known as 'Manchester of East'.

2.6.1 EVOLUTION OF KANPUR

The townscape of Kanpur in various stages of development is analyzed and presented as below:

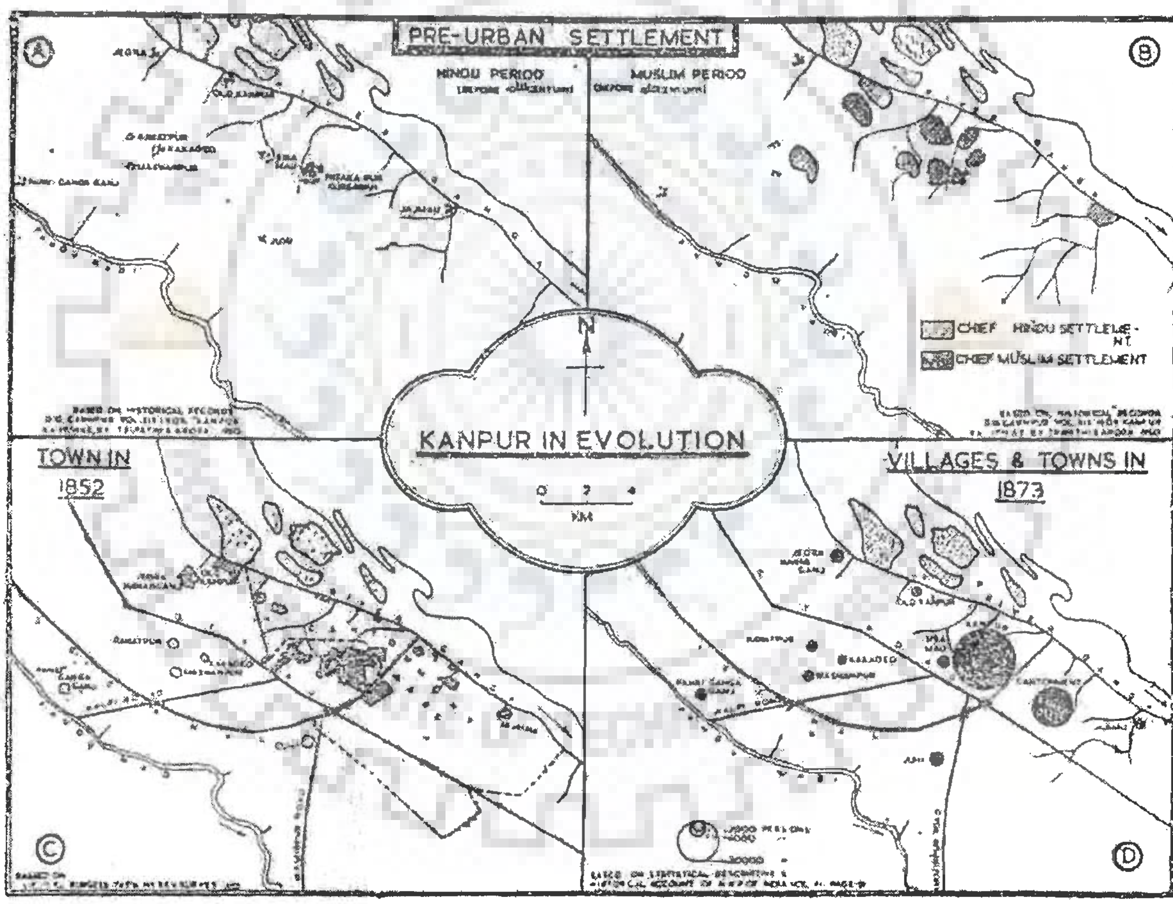
2.6.1.1 Kanpur before the first war of independence (1801-1857)

Kanpur passed into British hands under the treaty of 1801 with Nawab Saadat Ali Khan of Awadh. It was declared a district on 24th March, 1803. Subsequently, it became one of the important military stations of British India.

Kanpur before 1857 had only two prominent features, viz., a hypertrophied Cantonment and an atrophied Civil lines (Fig 2.3.1 and 2.3.2). The Cantonment, stretching along the river from the eastern limit of old Kanpur to Jajmau covered an area of 25.92 sq. km, with an inhabitant population of 48,975. The Civil lines was located in the west of the Cantonment with a total area of 14.23 sq. km. It consisted of the district courts, revenue offices, jail, and tehsil buildings. The city proper was enclosed by the Cantonment and Civil lines on three sides and hence, had possibility of expansion only in one direction. The City proper with a population of

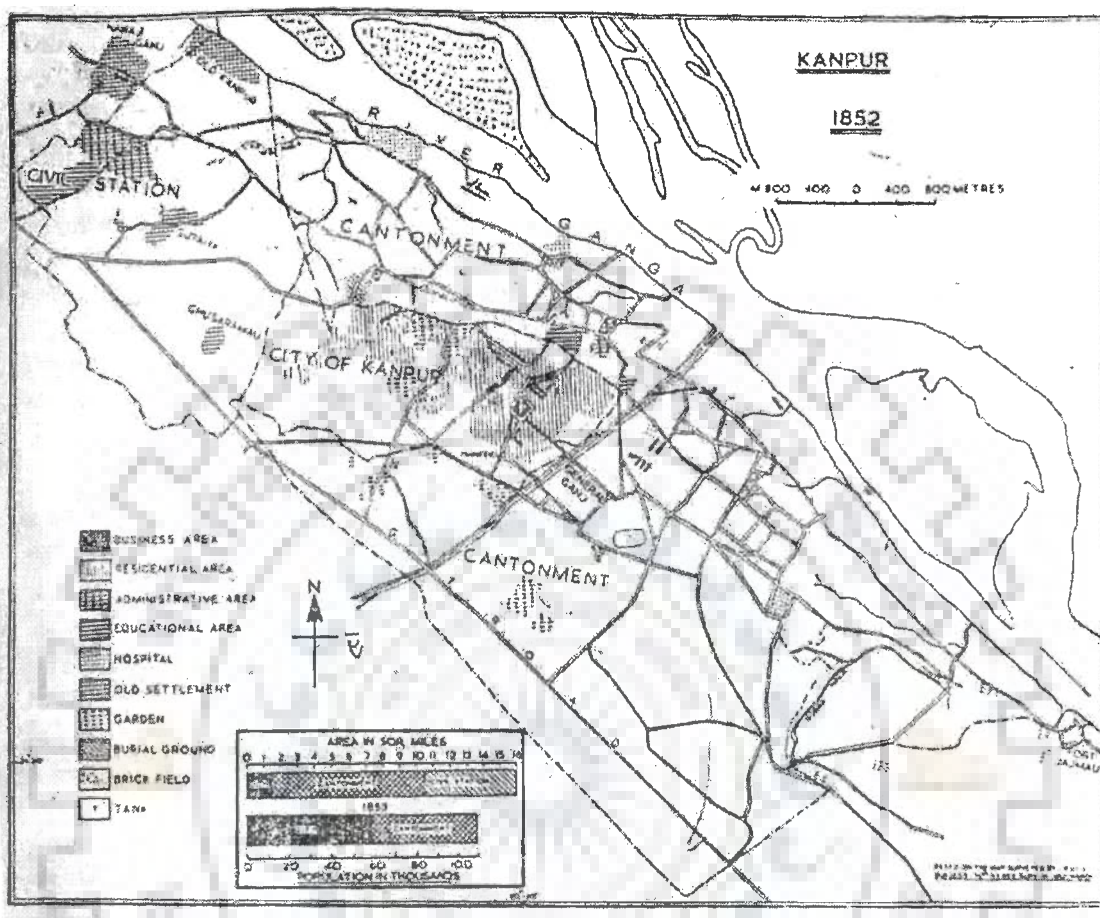
85,821 (1847) occupied a very small area of 2.72 sq. km. It was characterized by unplanned development, crowded lanes and poor drainage.

The townscape was thus, characterized by three types of settlements, viz., the Cantonment, Civil lines and the city proper. Besides, few indigo and cotton industries also formed a part of the townscape. The Grand Trunk road and Lower Ganga Canal also got completed during this period giving further impetus to the establishment of industries and firms.



Source: Singh, H.H., 1972

Fig. 2.3.1: Kanpur before 1857



Source: Singh, H.H., 1972

Fig. 2.3.2: Kanpur before 1857

2.6.1.2 Kanpur during uprising of 1857

Kanpur became the epicenter of the uprising of 1857 struggle. Freedom fighters like Nana Sahib, Tantiya Tope, Azimoolah Khan and Brigadier Jwala Prasad hailed from this place. The three strategic events of the 1857 war at Kanpur were the fight at 'wheeler's entrenchment', the 'massacre at Sati Chaura Ghat' and the 'Bibighar massacre'. The uprising brought a lot of destruction to the town as well as the Cantonment. The population declined from 1,18,000 in 1853 to 1,13,601 in 1865.

2.6.1.3 Kanpur after 1857

There was a distinguished change in the city's morphology. The whole city had to be rebuilt. The western boundary of the Cantonment shrunk, leaving the portion between the city and the river for the new civil station. Its boundary has not changed much since then. The morphological changes in the city can be assessed as follows:

i) *The Cantonment*

The Cantonment, which earlier occupied a major portion of the city was truncated and its western boundary considerably shifted to the east of the Ganga canal. It is characterized by ample open spaces and scattered settlements of varied nature. Roads are wide and follow a planned pattern.

ii) *The New Civil Station*

The land gained by the shrinking of Cantonment became the new Civil Station. The District and Tehsil courts, the district jail, the collector's house, and many other administrative offices were shifted to this area. The two parks- Nana Rao park and the G.S. Vidyarthi Park also beautify the eastern part of the Civil lines. A number of educational buildings, banks, old parade ground, Corporation building, etc., are a part of Civil lines.

iii) *The City Proper*

The city proper was earlier an ugly, unplanned and a small part of the entire settlement. The actual growth of the city proper took place after the 1857 uprising. The Collector Ganj area with Naya Ganj, Dalmandi, Nachghar, etc. developed as an important business sector. The Chowk came up to the east of Meston road. A number of cotton factories, presses, godowns, foundries and mills came up in the western part of the city.

2.6.2 EVOLUTION OF THE CITY STRUCTURE

The growth and development trends of the city on the basis of three traditional theories of Urban Growth can be explained as follows:

1. Development of the city in Concentric Zone form
2. Development of the city in Sector zone form
3. Multiple Nuclear development

2.6.2.1 Development of the city in Concentric Zone form

The city depicted the concentric zone form in the early stage of its developmental process being a principal centre of wholesaling and retailing (Fig. 2.4). Before 1857, the city of Kanpur was encircled by the Cantonment and Civil station from the three sides and the Ganga in the North. Consequently, in the earlier period up to 1900, the city grew around the old settlement in a more or less concentric form. With further expansion in the present century, it assumed a semi-circular form as river Ganga restricted the expansion of the city in the North and the Cantonment limited its growth in the East.

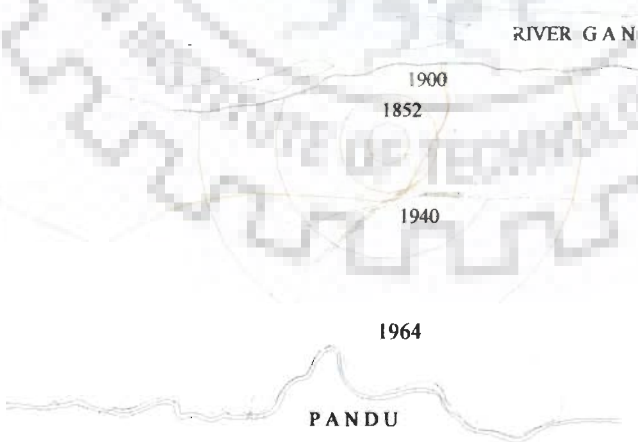


Fig.2.4: Concentric zone development of Kanpur

2.6.2.2 Development of the city in Sector Zone form

The segregation trend in the growth pattern became more prominent in the beginning of the twentieth century with increase in urban complexes. Morphologically, the city may be divided into three distinct sectors, which have been separated by two limiting forces of land uses.

- The first delimiting line is marked by large enclosures of different factories and mills in the civil lines. These enclosures continue eastwards and are marked by the district administrative centres, the Government Harness and Saddlery factory, Green park, Waterworks, Slaughter house, Idgah and two big burial grounds;
- The second delimiting barrier is determined by the Cantonment, extensive railway yards and a few other defence areas, which are out of bounds for civilians.

  These barriers, thus, explain the existence of three distinct sectors in the city and are presented in Fig. 2.5.

  i) The River front sector in the North

  ii) The Middle sector

  iii) The later developed Southern sector

i) THE RIVER FRONT SECTOR IN THE NORTH

This is characterized by a large number of open spaces, wide roads, parks, playgrounds, high-class residential bungalows and a number of administrative, educational and other cultural centers. A few labour colonies and some residential areas of Vishnupuri, Azad nagar and others developed after independence, have filled-in gaps lying in the form of open spaces or shabby areas of the sector.

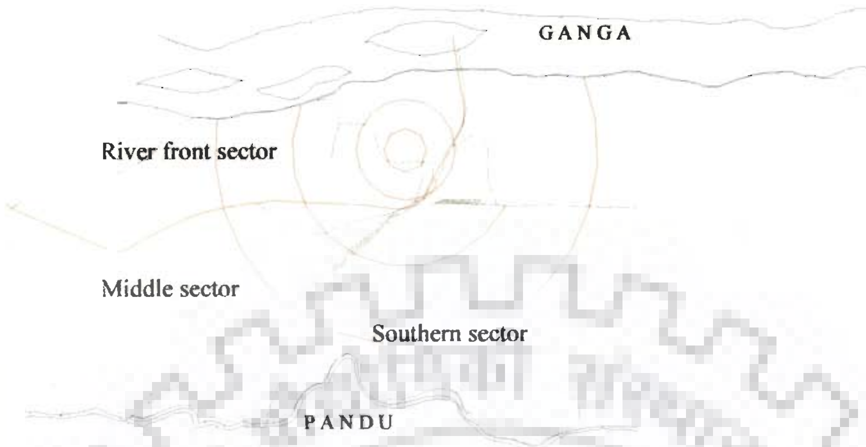


Fig.2.5: Sector zone development of Kanpur

II) THE MIDDLE SECTOR

This sector, lying between the two limiting lines, contains the old congested part of the city with its extension in the West up to the Armapur Estate. All the business and trade centers of the city lie in this multifunctional area. Open spaces and parks are conspicuous here by their absence. The majority of the roads are narrow. Most of the wholesale marketing centers like Collector ganj, Nawgarha, General Ganj represent the indigenous character of the city, with narrow and winding lanes and old types of buildings with little opening in them. This is also credited with typical slums and blighted areas. The business thoroughfares like Meston road, latouch raod and Birhana road lie in this sector. Ashok Nagar, Lajpat Nagar, Pandu Nagar, Rama Krishan Nagar, etc., are later additions. Further extension is marked by the well planned labour colonies of Harihar Nath Shastrinagar in the West and the Vijay Nagar residential colony developed for the slum dwellers. The Industrial estate and the factory area in the Southwest, the administrative area and the office area along the G.T. road and the hospital zone also come under this zone.

III) THE SOUTHERN SECTOR

This sector, developed beyond the railway yards in the South, is a later extension of the city. Areas like Kidwai nagar, Govindnagar, Swaroopnagar etc., that have developed into prime commercial areas lie in this sector.

2.6.2.3 Multiple Nuclei Development

The present growth and development of the city is associated with several discrete nuclei away from the city proper (Fig. 2.6). This is largely due to outward migration of the people from the main city and the specialized nature of the functions of these nuclei. Heavy industries, at first localized along the Ganga river in the civil lines, migrated eastward and westward, are working as nuclei for new urban development. The new industrial sites towards the periphery in the South and the West and the separate township of Jajmau beyond the cantonment in the far East noted for its many leather tanneries are the main examples of such developments. Further, in the extreme West, the big institutions like Indian Institute of Technology, Institute of Sugar technology, Kanpur University, are the important nuclei added at later stages.
Thus, the multi-functional industrial metropolis has got concentric and semi-concentric (in the West) zones. Outside the inner zone, the three sectors of the city are distinctly noticeable.

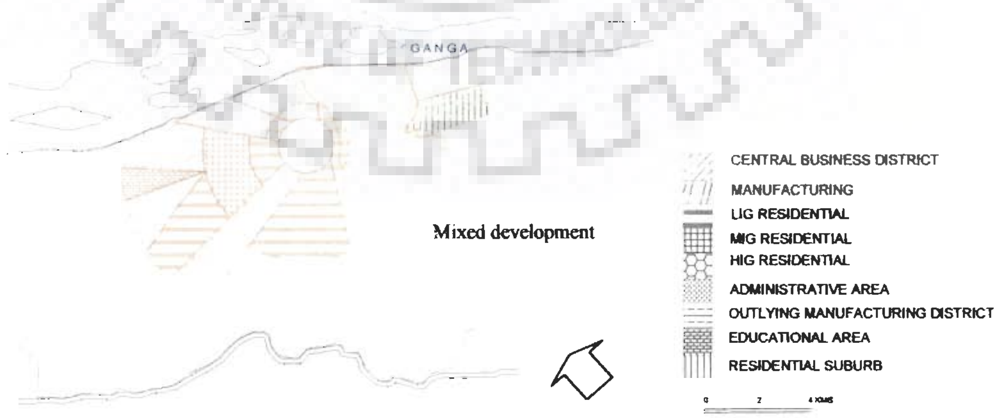


Fig. 2.6: Multiple Nuclei Theory

2.7 AREA

Kanpur Municipality was established in 1861. Kanpur Urban Agglomeration comprises of Kanpur Municipal Corporation, Cantonment, Armapur Estate, Northern Railway Colony, Chakeri, etc. and together covers an area of 298.98 sq. km (Table 2.1). The area under Kanpur Development Authority (KDA) extends beyond the Municipal Corporation limits and covers an area of 829.04 sq. km. Kanpur Urban Agglomeration is presented in Fig. 2.7.

Table 2.1: Area under Kanpur Urban Agglomeration

S.No.	Area	Area in sq. km
1.	Kanpur Municipal Corporation	262.52
2.	Kanpur Cantonment	16.08
3.	Armapur Estate	6.29
4.	N.R. colony	4.66
5.	Chakeri	5.21
6.	IIT Kanpur	4.22
	Total	*298.98*

Source: Kanpur Development Authority, 2001

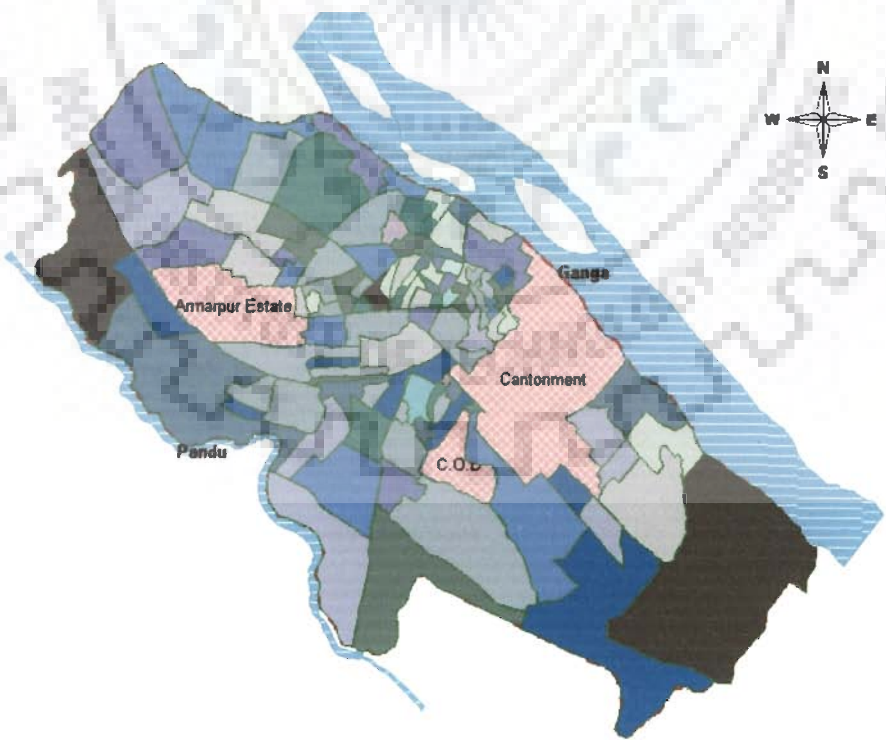


Fig. 2.7: Kanpur Urban Agglomeration

2.7.1 DYNAMICS OF URBAN SPRAWL

Urban centres are dynamic in nature continuously experiencing change in land use patterns and city limits. Kanpur city is no exception to this process of urban sprawl. Increase in urban sprawl results in need for wider coverage of waste collection, transportation and disposal facilities. An attempt has, therefore, been made to study the spread of Kanpur for various years, based on data from various sources. The results are presented in Table 2.2. The city of Kanpur has undergone extremely fast expansion in recent years due to various reasons. The rapid changes in the urban land use and their expansion need to be monitored frequently for effective and realistic physical planning of the urban sprawl (an important component of the Master Plans) and to check uncontrolled growth of the city.

Table 2.2: Urban growth of Kanpur in different years

S. No.	Year (1975 has been taken as base year)	Urban area (sq km)	Urban growth (sq km)	% of urban growth
1.	1975	114.22	-	-
2.	1986	170.59	56.37	49.35
3.	1989	211.40	97.18	85.08
4.	1991	298.89	184.67	161.67
7.	2001	298.89	0	0
8.	2021(proposed)	340.23	226.01	197.87

Source: Based on various reports of Kanpur Development Authority (KDA)

The urban extent of Kanpur metropolis in 1975 was 114.22 sq km, while in 1986 it was 170.59 sq km. Thus, the urban growth recorded during the 11 years period of 1975-86 is 56.37 sq km, an average annual urban growth rate of 4.48 per cent. The rate of growth between 1975 and 1989 is 97.18 sq km, which amounts to an increase in growth by 85.08 per cent. The period 1989-1991 experienced a tremendous growth of 20.7 per cent per annum.

Increase in the built-up area has obviously led to adverse effects on other land use categories. It has been noticed that the urban sprawl has extended along the East-west transportation network. Furthermore, specific growth has been identified in the South of city. The city, at present, is therefore facing a lot of infrastructure related problems like housing shortage, unplanned road networks, traffic related problems, water supply, sewerage related problems, poor management of wastes, shortage of power supply, etc.

2.8 LAND USE

Kanpur grew in a linear pattern due to the presence of natural barriers in the form of river Ganga and Pandu in North and South respectively. The Central Business District forms a dense core of the city in the north-central part. Table 2.3 and 2.4 show the land use distribution in 1990 and 1997-98 respectively. The tables clearly show that there is a decline in residential and institutional area. Fig. 2.8 shows the land use of Kanpur Urban Agglomeration.

Table 2.3 : Land use of Kanpur Urban Agglomeration, 1990

S. No.	Land Use	Area (Ha.)	Area (%)
1.	Residential	4150.41	31.57
2.	Commercial	127.32	0.97
3.	Industrial and Warehousing	1378.14	10.43
4.	Institutional	871.43	6.63
5.	Mixed built-up areas	273.15	2.08
6.	Recreational	332.14	2.53
7.	Urban infrastructure	2131.63	16.22
8.	Public utilities	30.62	0.24
9.	Undefined use	2758	20.98
10.	Miscellaneous	1091.58	8.3
	Total	13144.42	100.0

Source: Kanpur Development Authority, 1997

Table 2.4 : Land use of Kanpur Urban Agglomeration 1997-98

S. No.	Land use	Area (ha.)	Area (%)	UDPFI
1.	Residential	8813.38	29.59	45-50
2.	Commercial	460.35	1.55	4-5
3.	Industrial	970.42	3.27	5-7
4.	Institutional	298.62	1.01	-
5.	Public services and utilities	966.55	3.26	12-15
6.	Recreational	959.08	3.23	16-20
7.	Traffic and Transport	1452.85	4.89	6-8
8.	Water bodies	82.60	0.23	-
9.	Green belt	15679.15	52.82	-
		29683.00	100.00	

Source: Kanpur Development Authority, 2001

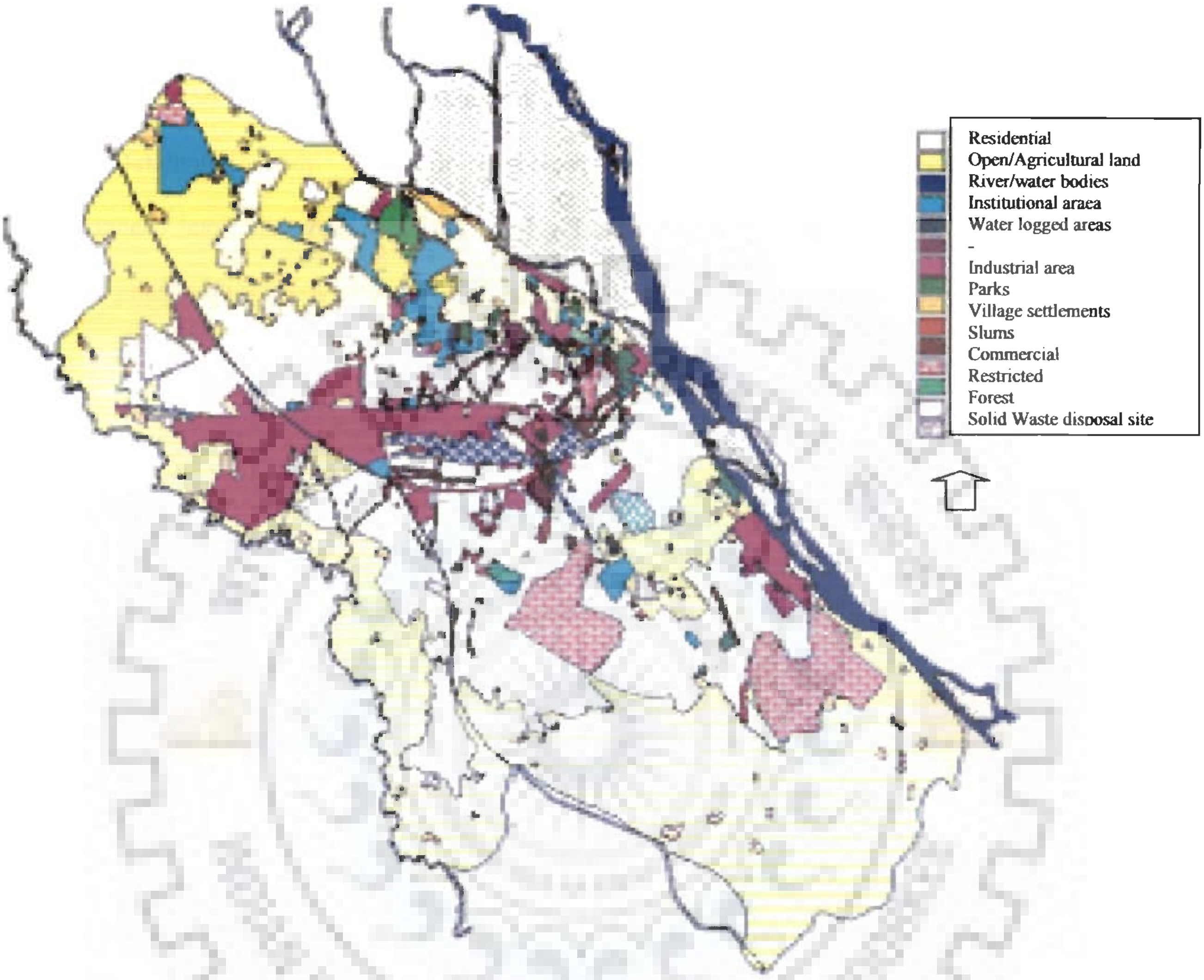


Fig.2.8: Land use pattern of Kanpur Urban Agglomeration

2.9 DEMOGRAPHIC CHARACTERISTICS

Demography is one of the vital factors responsible in shaping up the structural form and cultural life of a city. Kanpur, a place which grew up from few small villages into a metropolis (million plus city) within a span of 200 years, is no exception. The demographic characteristics of the city has therefore, been carefully studied.

2.9.1 GROWTH OF POPULATION

The earliest published report related to population record of the city is Montgomery's Statistical report of 1849, stating the population of the Cantonment and city to be 49,975 and 58,821 respectively. Table 2.5 shows the total population of Kanpur Urban Agglomeration in various census years and the decadal change. Fig.2.9 graphically shows the total change in population in each census year. The population change is further analysed for three categories *viz.*, 1881-1931, 1931 -1960 and 1961-2001.

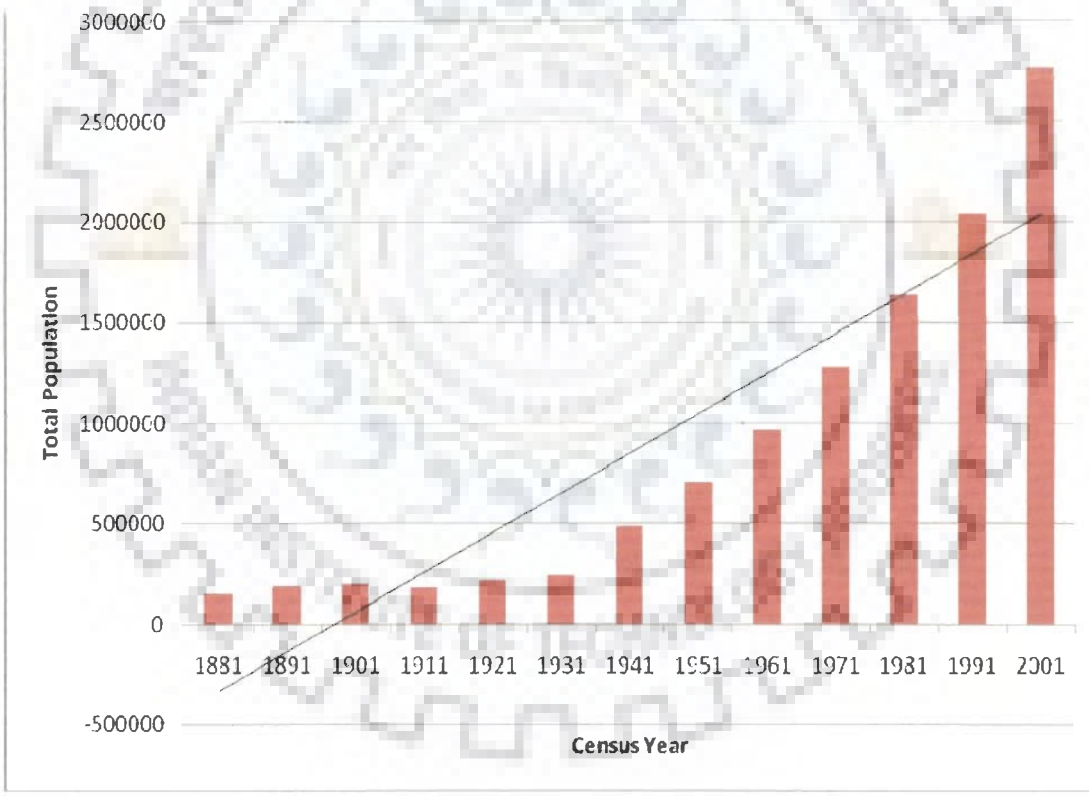


Fig. 2.9: Decadal Change in population of Kanpur Urban Agglomeration

Table 2.5: Growth of Population in Kanpur Urban Agglomeration (1881-2001)

S. No.	Census Year	Total Population	Changes in % during the preceding decades
1.	1881	1,51,444	-
2.	1891	1,88,444	+24.4
3.	1901	2,02,797	+7.6
4.	1911	1,78,557	-11.9
5.	1921	2,16,436	+21.2
6.	1931	2,43,755	+12.6
7.	1941	4,87,324	+99.9
8.	1951	7,05,383	+44.6
9.	1961	9,71,062	+37.9
10.	1971	12,75,242	+31.3
11.	1981	16,39,000	+28.5
12.	1991	20,37,333	+24.3
13.	2001	27,72,212	+36.1

Source: Singh, H.H., 1972 and Census of India reports

2.9.1.1 Population growth during 1881-1931

Table 2.5 clearly indicates that the city underwent a sluggish growth during the period 1881-1931. The reasons being recurring famines, outbreak of epidemics like cholera, plague and chicken pox.

2.9.1.2 Population growth during 1931-1960

This period shows a very rapid growth in population. In fact, the decadal growth during 1931-41 was a record 99.9 per cent, much greater than the population increase in the metropolitan cities like Bombay, Calcutta, etc., during the same period. This tremendous growth is attributed to two governing factors, viz., immigration from rural areas during the Word War II and post-partition days, and decrease in death rate due to improvement in health facilities.

2.9.1.3 Population growth during 1961-2001

This period shows a stabilized growth compared to the earlier decades. The graph of decadal percentage variation in population does not show much variation. In this period, the highest average annual growth of 2.7 was recorded between 1961 and 1971. It dropped to 2.5 in 1971-81, to 2.1 in 1981-91 and to 2.2 in 1991-2001[1].This is the period when the industrial growth consolidated. In the last two decades of this period, a number of industries and factories were forced to close down due to lack of adequate infrastructure facilities. Even today, most of the surviving factories and industries are in a dilapidated state and lack technological advancement.

An attempt is further made to compare the decadal variation in population of Kanpur with other major metropolitan cities of Uttar Pradesh State and is presented in Table 2.6 and Fig. 2.10.

Table 2.6: Decadal Variation in Population of major metropolitan cities of Uttar Pradesh

Sl. No.	Million plus city/U.A	Period				Total Population
		1961-71	1971-81	1981-91	1991-2001	2001
1.	Agra	24.76	17.76	26.86	39.38	12,59,979
2.	Allahabad	19.11	26.71	29.92	24.28	10,50,000
3.	Lucknow	24.14	23.79	65.66	35.81	22,07,340
4.	Meerut	29.93	41.74	56.50	37.37	10,74,229
5.	Varanasi	25.54	25.50	29.32	17.55	11,00,748
6.	Kanpur	31.32	28.53	23.84	36.07	27,72,212

Source: Census of India, Government of India, Various years

[1] *Annual growth rate has been computed by the help of the formula r=200(P2-P1)/Y*(P2+P1),where P2=Population at the end of the period; P1= Population at the beginning of the period; Y=No of years in the period*

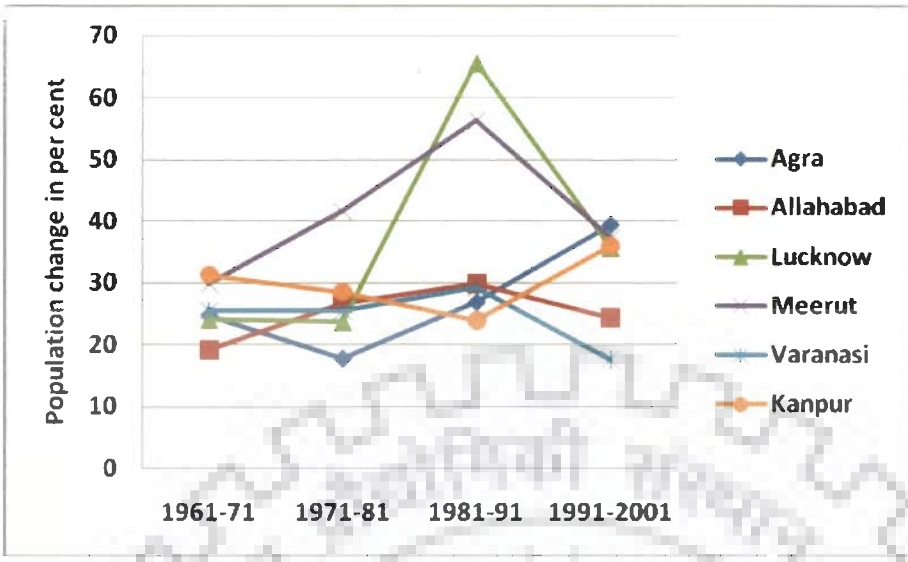


Fig. 2.10: Decadal variation in population of metropolitan cities of Uttar Pradesh State

It is evident from the above graph that Kanpur underwent a decrease in decadal variation in population between 1961 and 1991, and again showed a slight increase in 1991-2001. Compared to cities like Meerut, Allahabad and Lucknow, which went through a tremendous increase in population during 1981 to 1991 due to better employment opportunities, Kanpur shows a decline in population in that period. As far as the absolute population size is concerned, Kanpur is the most populated metropolis of Uttar Pradesh State.

2.9.2 RANK OF KANPUR CITY

Kanpur was the 12th largest Indian city in 1881. It moved up to 6th rank in 1891 but again slipped to 14th and 12th ranks in 1901-1931 and 1931 respectively. It again ranked the 8th largest city between 1941 and 1971. It slipped to 9th rank in 1981 and 1991 and to 10th rank in 2001. This clearly shows that the growth of population is not as it was earlier. The other cities like Pune and Surat have bypassed Kanpur owing to better employment opportunities and improved infrastructure facilities.

2.9.3 DENSITY OF THE POPULATION

The density of population in Kanpur Municipal Corporation shows an increasing trend and is presented in Table 2.7. The table clearly shows that the population density was 3274 persons per sq. km in 1961 and gradually increased to 9275 persons per sq km in 2001. A decadal increase in population density of 36.62 per cent is observed in the period 1991 to 2001. Table 2.8 presents the density of population in Kanpur Agglomeration in the year 1991 and 2001.

Table 2.7: Population Density in Kanpur Municipal Corporation (1961-2001)

Sl. No.	Year	Density (per sq.km)	Percentage decadal change in density
1.	1961	3274	-
2.	1971	4265	30.27
3.	1981	5482	28.53
4.	1991	6789	0.24
5.	2001	9275	36.62

Source: Compiled by Investigator based on secondary data

Table 2.8 : Density of Kanpur Urban Agglomeration

S. No.	Title	Area (Hectare)	% of urban agglomeration	Population (1991)	% of Urban Aggl. Population	Density Persons per hectare (1991)	Population (2001)	Density persons per hectare (2001)
1.	Kanpur Municipal Corporation	26169	88.23	1958282	92.75	74.83	2551337	97.49
2.	Rawatpur Railway Yard	54	0.18	3192	0.16	59.11	3017	55.87
3.	Central Railway Colony	39	0.13	1276	006	37.71	1457	37.36
4.	Northern Railway Colony	466	1.57	25162	1.19	53.99	29783	63.91
5.	Cantonment	1718	5.79	93109	4.41	54.19	100796	58.67
6.	Armapur Estate	692	2.34	20604	0.97	29.77	20584	29.74
7.	Chakeri	521	1.76	9659	0.46	18.53	8581	16.47
	Total	29659	100.00	2111284	100.00	71.18	2715555	183.11

Source: Census, 1991, 2001

The above table illustrates that the Corporation area has the highest density of 75 (74.83) persons per hectare, followed by Rawatpur Railway Yard where the density was 60 persons per hectare in Census year 1991. Chakeri was sparsely populated with a density of 19 persons per hectare. The average density of Urban agglomeration was 71 persons per hectare in 1991. The overall density of Kanpur Urban Agglomeration increased from 71.18 persons/hectare in 1991 to 183.11 persons /hectare in 2001. The density increased much in Kanpur Municipal Corporation and Northern railway Colony while it declined in other railway colonies.

2.9.4 LITERACY

The literacy rate is considered as one of the major indicators of quality of life and raises the human development index of a place. The literacy rate of Kanpur Municipal Corporation is 78.7 per cent, which is higher than the national literacy rate (65.38 per cent). The detailed literacy rate of Kanpur Urban Agglomeration is presented in Table 2.9.

Table 2.9: Literacy Status in Kanpur Urban Agglomeration (2001)

S. No	Name	'Total Literates'	'Literacy Rate'	'Male Literates'	'Female Literates'
1.	Kanpur (M Corp+OG)	1762138	78.8	999005	763133
2.	Kanpur (M Corp.)	1758807	78.7	997001	761806
3.	Kanpur (Cantonment)	65285	73.9	38237	27048
4.	Chakeri	7140	95.5	3982	3158
5.	Northern Rly Colony	19528	75.3	11965	7563
6.	Armapur Estate	15430	83.8	9110	6320

Source: Census, 2001

Among the total literates, 56.69 per cent are males while the remaining 43.31 per cent are females. Thus, female literacy is still not equal to male literacy in the city. The ward-wise literacy rate in Kanpur Municipal Corporation area is further presented in Fig. 2.11.

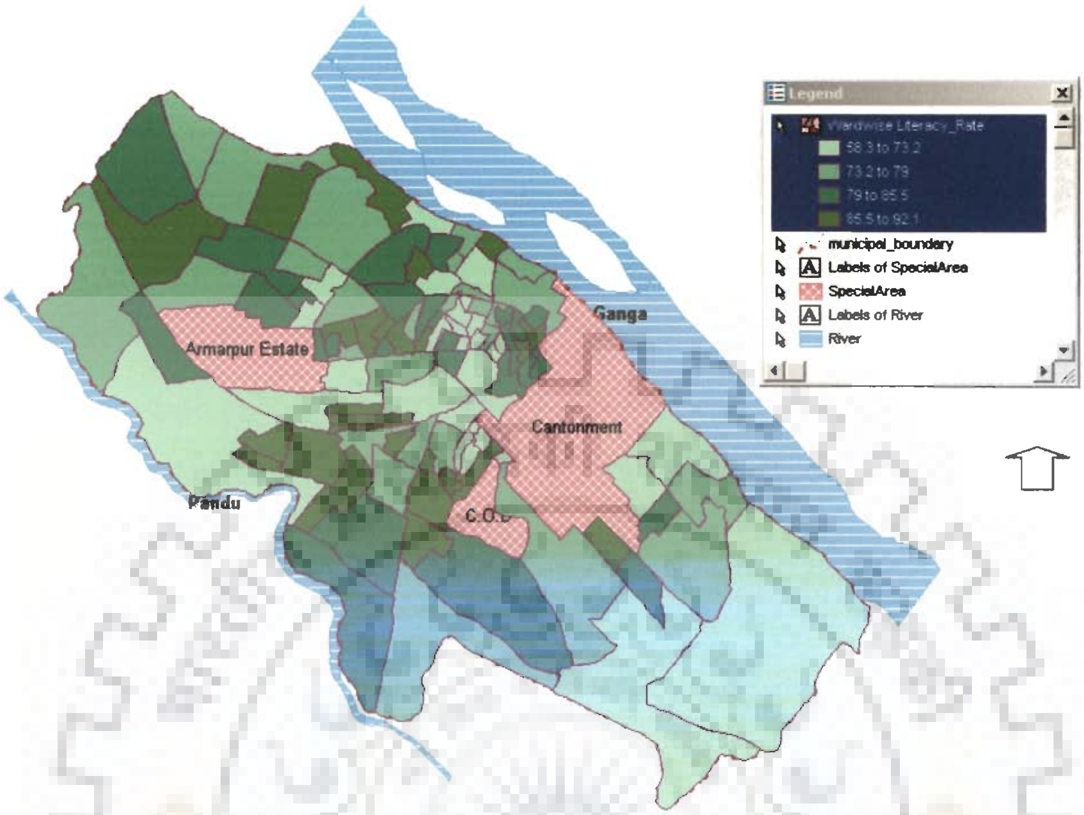


Fig. 2.11: Wardwise literacy rate in Kanpur (2001)

The figure clearly shows that eastern wards primarily have low literacy rate. The wards with highest literacy rates are spread in the central core, western and southern parts of the city.

2.9.5 SEX COMPOSITION

The demographic structure of Kanpur shows a distinct masculine character. The number of females per thousand males has always been lower as evident from the following Table 2.10.

Table 2.10: Changes in sex ratio

	1901	1911	1921	1931	1941	1951	1961	1971	1981	1991	2001
Kanpur U.A.	770	728	668	696	645	699	739	762	804	822	857
Kanpur Urban District	871	836	806	813	781	770	788	803	825	832	869
U.P State	938	916	908	903	907	908	907	876	882	876	898

Source: Census of India, Government of India, various years

The table shows that male-female ratio regularly declined from 770 per thousand in 1901 to 645 per thousand in 1941, but started improving after independence. The disparity in earlier decades is more because of large immigration in search of employment opportunities. These immigrants usually came alone due to lack of shelter and poor economy. The sex-ratio is still low as compared to the District statistics and also to that of the State statistics. The areas having worker colonies had a very poor sex-ratio compared to the influential and prosperous parts of the city. Fig. 2.12 further illustrates the wardwise sex ratio in Kanpur city.

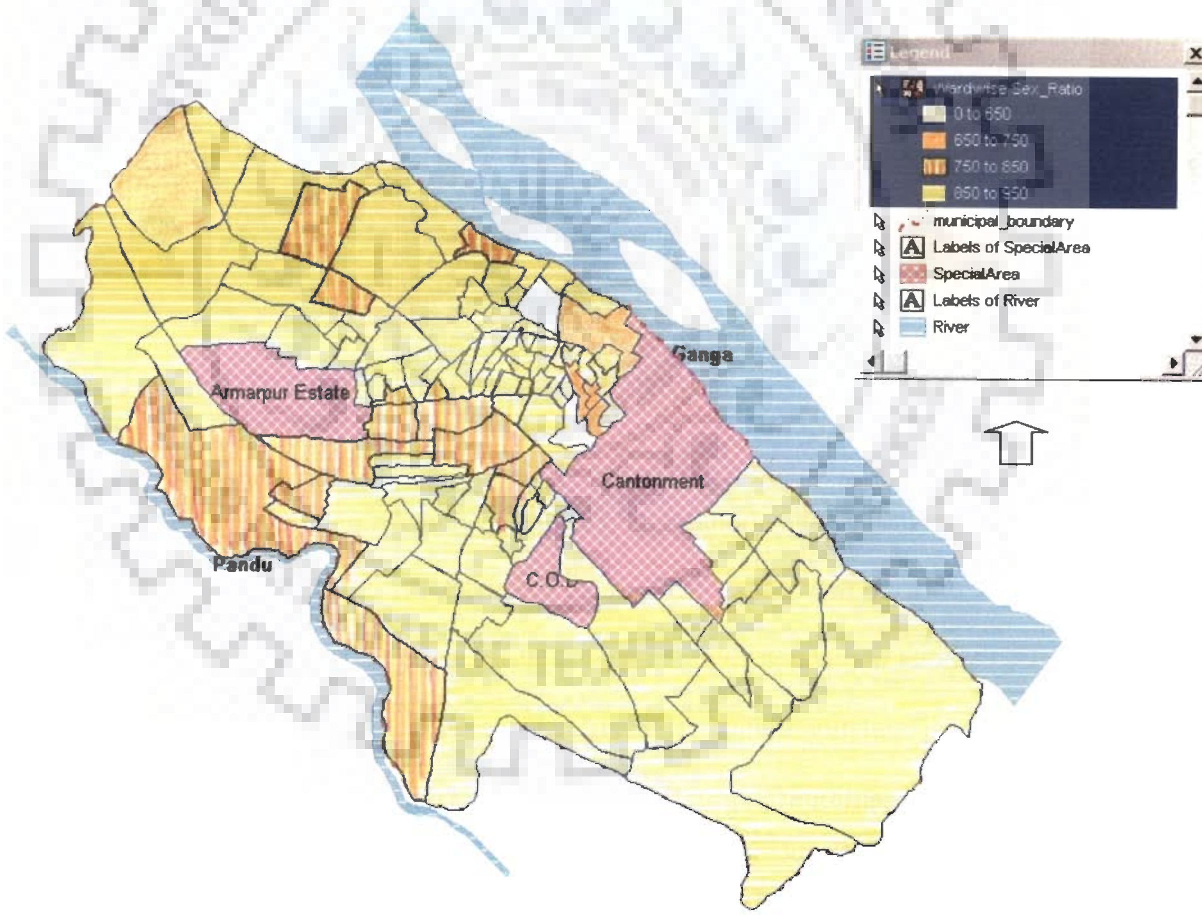


Fig. 2.12: Wardwise sex ratio in Kanpur City (2001)

2.9.6 POPULATION LIVING IN SLUMS

Kanpur, like all other metropolitan cities suffers with housing shortage and the resultant proliferation of slums spread all over the city. Table 2.11 shows the population living in slums for years 1948 (immediately after independence) and in years 1981, 1991 and 2001. Although the total slum population is increasing, the percentage of slum population as part of the total population shows a decreasing trend. The prime reason for this is the decaying industries of Kanpur city due to poor infrastructural facilities. Slums are often occupied by people working at low wages in industries and factories. Their decay leads to low immigration to the city from nearby places and hence, a comparatively slow growth trend.

Table 2.11: Population living in Slums in Kanpur Municipal Corporation

Sl. No.	Year	Total population (in lakhs)	Slum population (in lakhs)	%age
1.	**1948**	6.190	1.238	20.0
2.	**1981**	16.391	6.140	37.5
3.	**1991**	20.299	4.172	20.6
4.	**2001**	25.321	3.688	14.6

Source: Census of India, 1996

The composition of the population living in slums in Kanpur is presented in Table 2.12, for the census year 2001. It shows that there are 855 females per 1000 male population living in slums. Of the total population living in slums, 60.1 per cent is literate while 66.1 per cent of the total literate population living in slums is males.

Table 2.12: Composition of population living in Slums in the Census year 2001

Sl No.	Year	Total Population in Slums			Literate Population in Slums		
		Persons	Males	Females	Persons	Males	Females
1.	2001	3,68,808	1,98,805	1,70,003	2,21,841 (60.1%)	1,31,362 (66.1%)	90,479 (53.2%)

Source: Census of India, 2001

This population resides in 296 identified slums in the city, especially in areas adjoining the industrial estate and is not supported by proper infrastructure. Zonewise population of slums and their location is presented in Table 2.13. The table shows that the Zone 5 has the highest number and population of slums, followed by Zones 6 and 2 respectively. The slums are thus, spread all over the city and is presented in Fig. 2.13.

Table 2.13: Zone wise name, location and population of slums in Kanpur

Slums		
Zone	Name & Location	Population of Slums
Zone-1	Hasiya Hata, Gammu Khan Hata, Fakhrruddin Hata, Kaliddin Ka Hata, Chaval Mandi, Chainsukh ka hata, Ramdas, Salalu mistri, Dhobi ka hata, Omar Vaisya, Kaosik, Rammohan, Kailash mandir, Shiwala, Navrang, Kaitha, Sirki Mohal, Civil line railway,.	50780
Zone-2	Jagatapur, Bibipur, Patel Nagar, Ahirawa, Mawaiya, Sadanand Nagar, Sukhlalpur, Chheda Tatiya, Gandhi Gram Harizan Basti, Suzat Gunj, Balla Tatiya, Ara, Pirambi, Khejpur, Baktori, Vairamapur, Dalanpur, Baba Nagar, Tikapur, Karrhi, Lalpur, Gangapur, Simra, Bhurepur, Sakrapur, Hanspur, Goverdhan Purwa, Sanjai Nagar Machharia, Ganjupur, Ramrai Sarai, Makdum Nagar, Wazidpur, Sanjai Nagar, Chhabiley Purwa, Jaggai Purwa, om Purwa, Shiv Katra, Kali Badi, Ganga Ganj, Safipur, Pokharpur, Chrari, Kazi Kheda, Naubasta, Todhakpur, Budhapur Machariya, Delhi Suzanpur, Tatiya Bagwant, Bingawan, Hanspur, Nithura, Madiyana, Tatiya Jhanku, Paibandi, Kul Gaon, Ruma, Ahirawan, Chatmara, Kalyanpur Narval, Tikra.	95370
Zone-3	Dakana Purwa, Silpi Nagar, Rattu purwa, Baba Kutia, Khatikana Babu Purwa, Talwa Mandi, Dalil Purwa, Sakarmill Kaluwa, Lakshmi Purwa, Katikana Karnal ganj, Jangamal, Bakar Ganj, Baghi, Ajeet Ganj, Naya purwa, Muncipurwa, Sukhapurwa, Chaman ganj	74750
Zone-4	104/334,104/327-331,104/336, 104/302 Prem nagar Sisamau, 104/299, 12/485 Harjan basti, Omprakash, shivnarayan, lalamaharaj, Ambedkar Nagar, Tara chand, Jagai Purwa, Kali deen, Baghawan deen, Ram Swaroop, Radhey shyam, Hanumand Nagar	41150
Zone-5	Kabir Nagar, Sevagram, Lohia Nagar, Shiv Nagar, Q Block, Sanjay Nagar, Vivakanand nagar, Harmendra Nagar, Sakera estate, Chabalal ka hata, 84/172A, 83/168, barra, M block kaka dao, J2 ambedkar Nagar, Jayaprakash Nagar, Tulsi Nagar, Sarvadoya Nagar, BM market, Prachalsabha, Juhi Gada, Natwan toli baradevi, Anwar Ganj, Ganga Ganj panki, Gujaini Malin Basti, SivaRajsingh ka purwa, Raja ka purwa, Bara Devi, Juhi Baburia, Juhi Parampurwa, Kachi Basti Govindnagar, Gadrian Purwa, Pratap ganj, Ambedkar Nagar –Vijaya Nagar, Rani Ganj, Kaka deo, Navin Nagar, Dabouli, Budwa Purwa, Sarai meeta, Gambir pur, Paratap pur, Kapali, Nonian purwa, Panki kala, Jamoi, kanjaranpurwa, panki katra	107975

Table 2.13 (Continued)

Zone	Name & Location	Population of Slums
Zone-6	Kachi Basti Medical College, Chapeda, Ludheria, J.K Cancer Kachbasti, Nankari, Khera kalyanpur, Madarpur, Katkana Gawaltoli, Benazabar kachi basti, Machuwa basti purana Kanpur, Benazabar Batta, Sani dev Mandir chunniganj, Hospital ghat parmat, Badi kana Nawabganj, Tiwari Ghat Gadhyana, Alenganj, Bhairo ghat, Parmat Dobhiyana, Kachi Sarai, Kuriyana, Kheora, Jheoera, Kalanpur kurdh, Kalyanpur kala, Bara sarhoi, Devi Sahai Nagar, MaswanPur, Bairy Akabar pur, Brijan Swaroop ka hata, Choti Gutia, Gudhad basi aklabya nagar, Makhari kera, Sukaw purwa, Ujayari purwa, Rawatput gaon, Vinayakpur	97685

Source: Kanpur Municipal Corporation, 2001

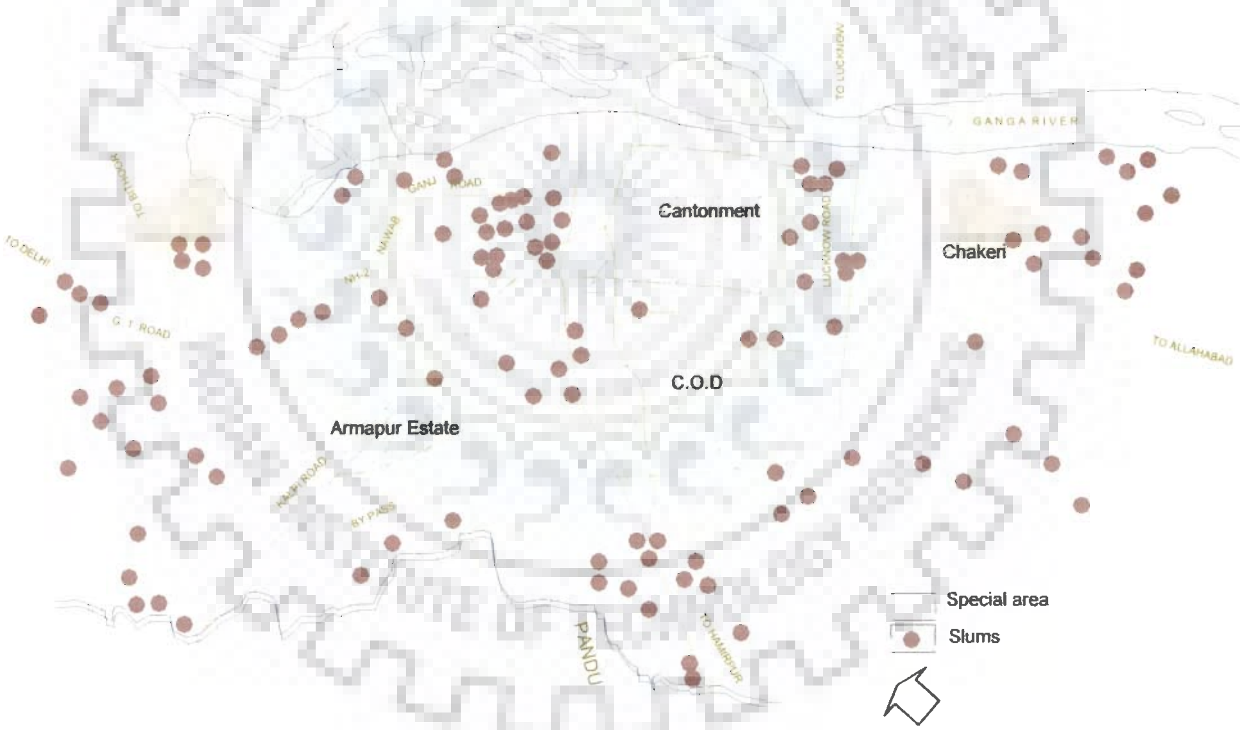


Fig. 2.13: Location of Slums in Kanpur City

2.10 ECONOMIC PROFILE

Kanpur has a very prominent industrial character. In Kanpur, manufacturing, services, trade and commerce dominate the occupational structure of the city. It can, therefore, be rightly classed as a MST city i.e., a city where manufacturing, services, trade and commerce provide the maximum employment opportunities. The occupational structure of the main workers has undergone tremendous variations over the years and is presented in Table 2.14 and 2.15. Table 2.14 clearly shows that the percentage of workers is gradually declining in the manufacturing sector since 1951, whereas it increases substantially in Trade and Commerce sector in the period 1981 to 1991. For other services, the percentage of workers is almost constant. Table 2.15 further elaborates this and shows that the total number of main workers increased by 10.73 per cent in the period 1981 to 1991.

Table 2.14: Occupational structure (Percentage of workers) in Kanpur Urban Agglomeration

Sl. No.	Year	Agriculture & other primary activities	Manufacturing, processing, etc. (household industry)	Manufacturing, processing, etc. (other than household industry	Construction	Trade & Commerce	Transport	Other services
1.	1901	5.0	-	27.0	NA	15.9	5.0	47.1
2.	1911	4.9	-	27.2	NA	15.9	6.7	45.3
3.	1921	4.1	-	28.0	NA	17.3	6.4	44.2
4.	1931	3.0	-	31.4	NA	18.1	6.3	41.2
5.	1941	2.6	-	35.4	NA	2.05	6.2	35.3
6.	1951	1.3	-	42.6	NA	22.7	5.7	27.7
7.	1961	4.0	3.6	34.1	2.5	18.0	8.0	29.8
8.	1971	4.0	4.2	30.1	1.2	20.9	8.6	31.0
9.	1981	6.1	3.7	31.4	2.2	19.2	7.9	29.5
10.	1991	4.2	0.6	27.8	2.0	27.4	7.6	30.6

Source: Census of India, various years

Table 2.15: Occupational trend in Kanpur Urban Agglomeration

S. No.	Category	Number of workers				% Increase		
		1961	1971	1981	1991	1971	1981	1991
1.	Agriculture & other primary activities	10655	15007	28686	21317	40.84	91.15	-25.69
2.	Mining & Quarrying	1992	168	317	92	-91.57	88.69	-70.98
3.	Manufacturing, processing, etc. (household industry)	11463	15957	17794	3417	39.2	11.39	-80.77
4.	Manufacturing, processing, etc. (other than household industry	101909	1144063	149050	146085	11.93	30.67	-1.85
5.	Construction	8004	4577	10398	10506	-42.82	127.18	1.04
6.	Trade & Commerce	57085	79452	91428	143874	39.18	15.07	57.36
7.	Transport, Storage & Communication	25343	32561	37517	39821	28.48	15.22	6.14
8.	Other services	94130	117469	139962	160817	24.79	19.15	14.9
	Total Main Workers	316581	379249	475132	526129	19.79	25.28	10.73

Source: Census of India, various years

Another feature of Kanpur city's population is its high percentage of dependents. The dependency in Kanpur was 67.3 per cent in 1961 which increased to 74.17 per cent in 1991. Among the dependents, 43.95 per cent were found to be females. In the productive group, males and females constitute 95.5 and 4.5 per cent (Census 1991) respectively and is a very unbalanced proportion.

2.10.1 SPATIAL VARIATION IN THE OCCUPATIONAL STRUCTURE WITHIN THE CITY

Studies reveal that the nearness to the place of work is often the basis for selection of residence. Thus, persons engaged in trade and commerce is generally clustered together in the

Central Business District while the industrial workers occupy the areas in River front, the Middle and the Southern sectors. Persons engaged in service sector are found scattered in different parts of the city. A segregation of functions and occupational zoning is therefore, seen in the Kanpur city.

2.11 POPULATION DISTRIBUTION IN WARDS OF KANPUR MUNICIPAL CORPORATION AREA

There were 50 wards in Kanpur Municipal Corporation till the year 2000 when there was a redistribution of wards and their number increased to 110. Table 2.16 presents the ward wise population and respective density in Census years 1981 and 1991.The ward map as in 2005 is presented in Fig 2.14. The ward wise population of Kanpur city in the census year 2001 is presented in Appendix-III.

Table 2.16: Wardwise population and density in Kanpur Municipal Corporation

S. No.	Ward name	Area (hectare)	1981		1991		Decadal increase in density
			Population	Density	Population	Density	
1.	Kalyanpur	1948	41,914	22	54,700	28	+6
2.	Panki	3070	47,544	15	80,817	26	+11
3.	Rawatpur	1218	46,639	38	65,508	54	+16
4.	Nawabganj	1642	27,024	16	47,712	29	+13
5.	Kakadeo	321	28,837	93	59,469	185	+92
6.	Tilaknagar	293	28,734	98	29,712	101	+3
7.	Old Kanpur	179	36,659	205	30,250	169	-36
8.	Sutarganj	73	24,941	342	29,442	403	+97
9.	Khalasi line	206	30,952	150	26,600	129	+21
10.	Ashok nagar	214	25,714	120	20,083	94	-26
11.	Lajpat nagar	121	19,294	159	33,557	277	+118
12.	Hariharnath Shastrinagar	60	21,584	360	32,777	546	+186
13.	Vijay nagar	115	31,155	271	39,666	345	+74
14.	Darshan purwa	65	33,302	511	33,625	517	+6
15.	Nehru nagar	31	20,567	663	30,738	992	+329
16.	Gandhinagar	29	33,739	**1163**	21,683	748	**-415**

Table 2.16 (Continued)

S. No.	Ward name	Area (hectare)	1981		1991		Decadal increase in density
			Population	Density	Population	Density	
17.	Rambagh	82	30,538	372	24,525	299	+73
18.	Gwaltoli	131	23,838	182	35,218	269	+87
19.	Colonelganj	64	19,474	309	32,376	506	+197
20.	Baconganj	65	31,851	490	34,072	524	+34
21.	Chamanganj	69	32,194	467	26,472	384	-83
22.	Sisamau	34	20,954	646	45,193	**1329**	**+683**
23.	Civil lines	21	24,650	59	31,823	76	+17
24.	Parade	69	26,663	386	31,971	463	+77
25.	Dalalepurwa	47	26,371	561	35,254	750	+189
26.	Raipurwa	76	21,565	284	25,939	341	+57
27.	Jareebchawki	673	26,988	40	46,479	69	+20
28.	Govindnagar-1	609	27,786	40	46,561	76	+36
29.	Govindnagar-2	270	24,375	90	68,326	253	+163
30.	Juhi	1081	18,704	17	**1,23,867**	115	+98
31.	Transport nagar	159	21,315	135	39,607	250	+115
32.	Lakshmipurwa	179	20,789	116	38,652	216	+100
33.	Anwarganj	47	22,704	483	27,859	619	+136
34.	Chowk Sarrafa	49	22,242	454	31,521	643	+189
35.	Chatai Mohal	40	28,759	719	24,493	612	-107
36.	Patkapur	66	22,327	338	27,975	424	+86
37.	Generalganj	85	29,893	352	24,252	285	-67
38.	Harbansh Mohal	25	**15,740**	630	22,612	905	+275
39.	Moti Mohal	26	19,201	739	23,269	895	+156
40.	Munshipurwa	84	23,611	281	46,125	549	+268
41.	Ajitganj	58	23,860	411	33,365	575	+164
42.	Kidwainagar-1	72	20,704	288	18,752	268	-20
43.	Kidwainagar-2	312	30,843	99	36,619	117	+18
44.	Babupurwa	135	76,527	567	34,737	257	-310
45.	Sujatganj	1189	23,913	20	38,973	33	+13
46.	Naubasta	3440	46,830	14	71,956	21	+7
47.	Krishna nagar	403	**61,518**	154	25,547	64	-90
48.	Harjinder nagar	740	45,973	62	51,526	70	+18
49.	Jajmau	547	33,727	62	41,708	76	+14
50.	Chakeri	5237	35,842	**7**	40,903	**8**	+1
	Total	*26169*	*14,86,522*	*57*	*19,58,282*	*75*	*+18*

Source: Kanpur Municipal Corporation

The above table clearly shows that in the year 1981, the highest density of 1163 persons per hectare was observed in Gandhinagar ward while Chakeri had the lowest density of 7 persons per hectare. Chakeri had lowest density of 8 persons per hectare even in 1991, while highest density of 1329 persons per hectare was observed in Sisamau. This shows a very heterogeneous development of the city with such wide variations in population density.

Fig.2.14: Wardwise map of Kanpur City

Based on the population density in Kanpur Municipal Corporation area, the city can be easily delineated into three distinct zones, *viz.*, areas with very high, intermediate and low population densities and referred to as Core zone, Intermediate zone and Peripheral zone respectively and is presented in Fig. 2.15. The Core zone comprises of densely populated wards like Parade, Chamanganj, Bekanganj, Lajpat nagar, Shastri nagar, Civil lines, Chowk Sarrafa, Transport nagar, Gandhi nagar, etc., with densities ranging between 116-739(1981) and 216-1329 (1991) persons per hectare. The Intermediate zone comprises of wards like Kaka deo, Tilak nagar, Purana Kanpur, Govind nagar, Kidwainagar, Jareb Chowki, Babu Purwa, etc., with densities ranging between 40-342(1981) and 69-403(1991) persons per hectare, while the Peripheral zone comprises of wards with low population like Kalyanpur, Panki, Rawatpur, Juhi, Harjendar nagar, Jajmau, Naubasta, etc., with densities ranging between 7-62(1981) and 8-78 (1991) persons per hectare.

On close study of population studies in 1981 and 1991 for the three delineated zones, it is observed that in some of the Core wards and Intermediate wards like Gandhinagar, Generalganj, Old Kanpur, Kidwainagar-1, etc. there is decline in density indicating out migration to other wards. All the wards in Peripheral zone, except for Krishna nagar ward, show a positive growth especially in the North-west, South-west and South. Population growth is more pronounced in western direction in the Intermediate zone.

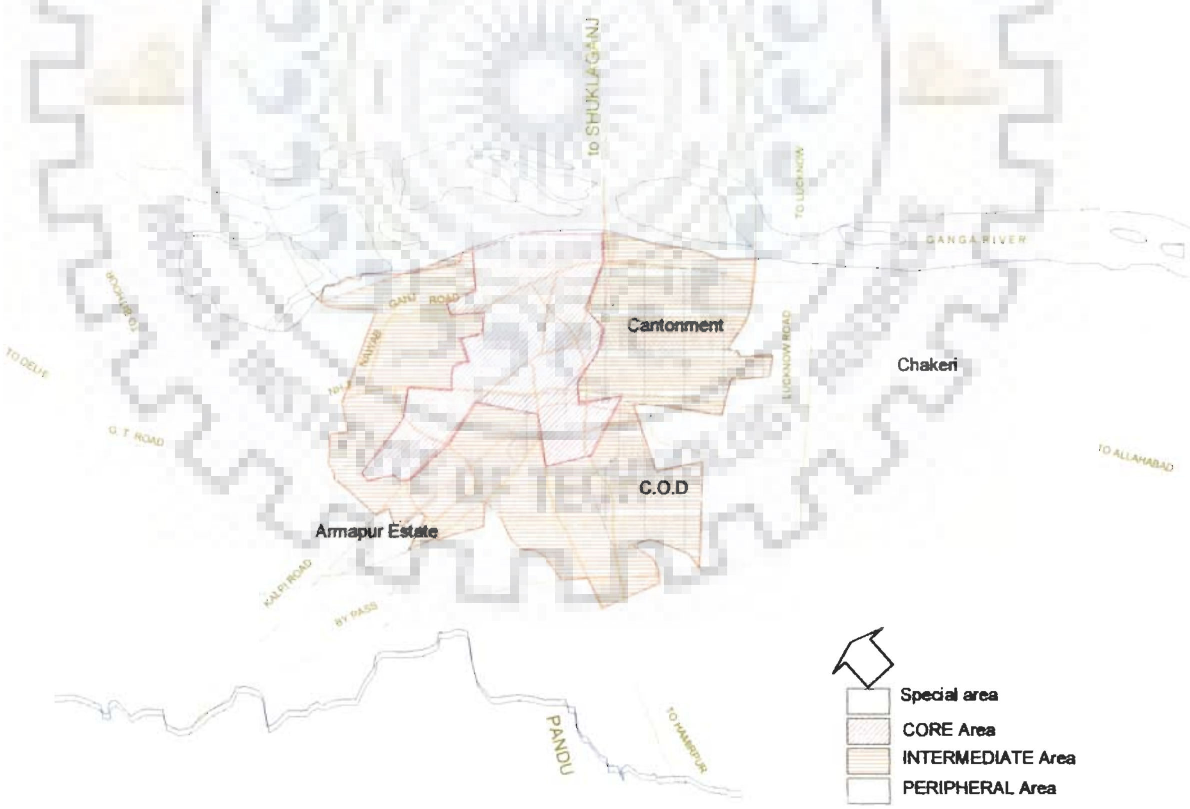


Fig. 2.15: Sub-divisions in Kanpur Corporation Area based on density

2.11.1 Future Population Growth pattern in Kanpur

If the present growth pattern of population continues without any deliberate planning interventions, the trend suggests that there will be maximum growth of population in the Intermediate zone, followed by the Western and South-western part of Peripheral zone. The core areas will continue to have natural growth of population or may be even some shifting of population to other less congested areas. Restricted areas like Kanpur Cantonment, Armapur Estate, Northern Railway Yard, etc., shall continue to have natural growth of population and this projected growth pattern is presented in Fig 2.16.

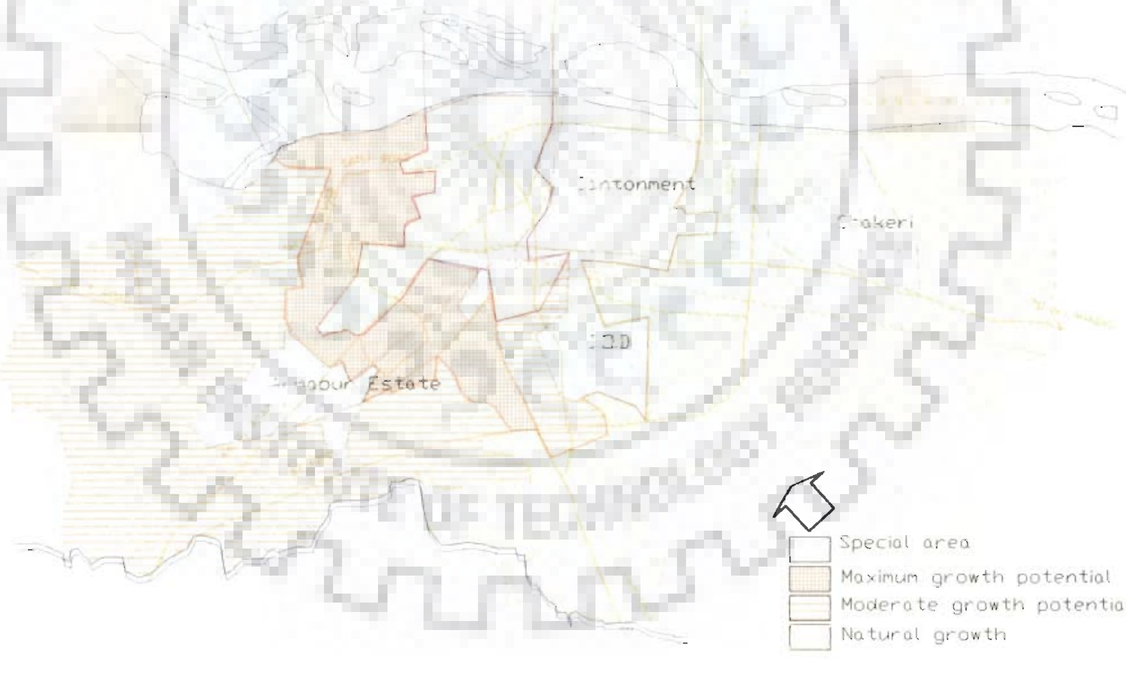


Fig. 2.16: Structure of Future population growth in Kanpur

2.11.2 POPULATION PROJECTIONS

The amenities for a city are planned as per the expected growth levels of population of that city. Hence, it is a very crucial task to rightly establish the expected population of a city in future. An attempt has been made to project the population based on the observed population figures in various Census years, from 1881 to 2001.

Based on the population figures of Kanpur Urban Agglomeration of the last twelve decades, regression analysis has been done to estimate the form of population growth pattern as observed during the period 1881-2001. The relationship thus established was further used to project the population for the next 25 years and presented in Table 2.17. The table shows that as per Scenario-1, the population will increase to 47.10 lakhs in 2025 while it will increase to 40.40 lakhs in Scenario-2. Mathematical relationships between the population as a dependent variable and time as an independent variable were established using the Census data for years from 1881 to 2001, for both linear and non-linear functions. The best fit curve was tested by using the MS-Excel package. The results of regression analysis show that the linear form did not give a 'good' fit of the population trend and hence was discarded. The results of exponential and polynomial (two degree) show a better fit of the population trend and are presented in Fig.2.17. The regression coefficient (r^2) for exponential curve is 0.95 while for polynomial curve (two degree) is a favorable 0.99.

Table 2.17: Population Projection Scenarios

S No	Year	Scenario 1(Exponential)	Scenario 2 (Polynomial)
		Population(in lakhs)	Population (in lakhs)
1	2001	25.10	26.30
2	2005	28.00	28.50
3	2010	31.80	31.30
4	2015	36.20	34.20
5	2020	41.40	37.30
6	2025	47.10	40.40

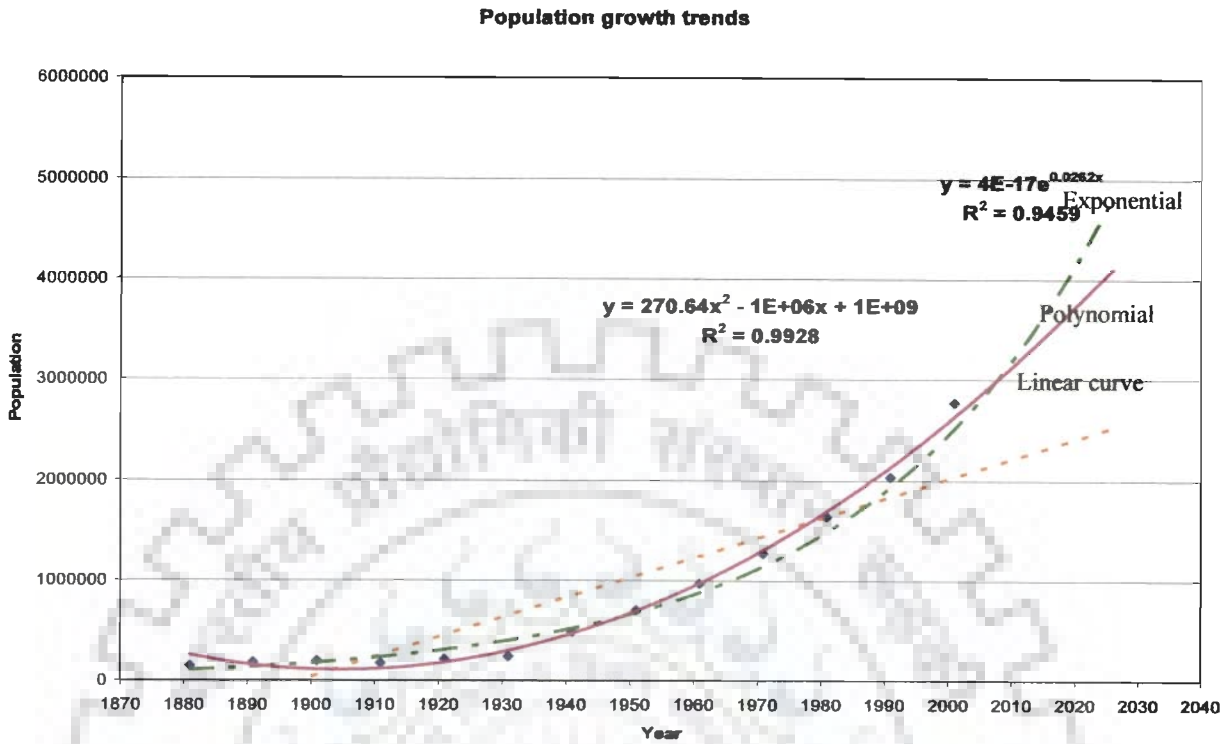


Fig. 2.17: Population Growth trends

2.12 INFRASTRUCTURE

Physical and social infrastructure is one of the most important infrastructure components and an essential necessity for smooth functioning of a settlement. Kanpur city, though a megapolis lacks adequate civic amenities as the population grew at a much faster pace than the facilities. Expenditure per capita on urban services is extremely low and inadequate for efficient service delivery. The trend over the past decade shows a declining trend. It is observed that 80 per cent of the Kanpur Nagar Nigam's expenditure is earmarked for establishment costs (mainly salaries). Investment in maintenance and extension of services is therefore, very limited. The Municipal Corporation is not able to raise enough funds from taxes, etc., and is dependent on the State subsidies to as large as 80 per cent for expenditure coverage.

2.12.1 HOUSING

The city is not able to cope with the increasing demand of housing and suffers from housing shortage.

2.12.1.1 Housing Stock

The housing stock condition is presented in Table 2.18. The table illustrates that the population grew by 23.84 per cent between 1981 and 1991, whereas the growth in housing stock was only 14.18 per cent. The difference between decadal increase in houses and number of households is evident in the table. As per the Census data 2001, the average annual rate of formation of new households is 8641.

Table 2.18: Housing shortage in Kanpur Urban Agglomeration

Year	Total population	No. of Households	Housing Stock	Housing shortage (No.)	Housing shortage (%)	Decadal increase in HHs(%)	Decadal increase in houses (%)
1971	1275242	268515	249378	28142	10.48	-	-
1981	1639064	305882	282106	23776	7.77	13.92	13.12
1991	2029889	353203	322129	31074	8.79	15.48	14.18
2001	2532100	439619	373229	66390	15.10	24.47	15.86

Source: Census of India, GOI

2.12.1.2 Housing Supply

Kanpur Development Authority is the main public agency for provision of housing in Kanpur. The following agencies supply housing stock in Kanpur:

- Kanpur Development Authority

- Private sector builders, developers and promoters

- Co-operative Societies, and

- Private individual owners.

The housing supply situation in Kanpur between 1981-1991 by Kanpur Development Authority and non- Kanpur Development Authority agencies is summarized in Table 2.19.The table shows that 47.6 per cent of the housing supply is by Kanpur Development Authority while 52.4 per cent is by non- Kanpur Development Authority agencies. Thus, the average annual rate of effective addition of houses is only 4002. The non- Kanpur Development Authority agencies are supplying almost half of the total housing supply.

Table 2.19: Housing supply between 1981 and 1991 in Kanpur

S. No.	Item	No.	% to Total supply
1.	Housing stock supplied by KDA	45902	47.60
2.	Housing stock supplied by non KDA agencies	50542	52.40
3.	Total Housing stock supplied	96444	-
4.	Dilapidation of Housing	56421	-
5.	Effective supply of housing stock	40023	-

Source: Kanpur Development Authority, 1997

2.12.1.3 Housing Characteristics

Apart from the housing stock shortage, it is also important to study the housing characteristics which are defined by features such as, occupation rate, accommodation space, income-wise distribution of population and services. The distribution of households by their size is presented in Table 2.20 and it shows that 44.01 per cent households have 3 to 5 members in the family while 31.59 per cent households have 6 to 8 members. Table 2.21 further presents the accommodation space in Kanpur. The number of rooms per dwelling unit in 1991 was 1.59, which has slightly improved to 2.21 in the year 2001. The level of basic services like drinking water availability, toilet and electricity give an overview of the housing conditions and is presented in Table 2.22. The table states that only 84.52 per cent households had some sort of toilet facility available and only 86.19 per cent households had electricity and drinking water supply.

Table 2.20: Distribution of Households by their size and percentage

Year	Households by their size				Total No. of Households	Percent HHs by their size			
	Size					Size			
	1-2	3-5	6-8	9+		1-2	3-5	6-8	9+
1991	45190	146540	115030	52165	358925	12.59	40.83	32.05	14.53
2001	34948	166009	119135	57058	377150	9.27	44.01	31.59	15.13

Source: Census of India, 1991, 2001

Table 2.21: Accommodation space in Kanpur

Year	1-room dwellers	2-room dwellers	3-room dwellers	Greater than 3 room dwellers	Room stock	Rooms/DU
1991	216471	76767	21625	19822	514168	1.59
2001	128234	130762	54296	57340	833789	2.21

Source: Complied from Census of India, 1991, 2001

Table 2.22: Distribution of Households by availability of facilities (percentage)

Year	Electricity	Drinking water	Toilet	Electricity & Drinking water	Toilet & safe drinking water	Electricity &Toilet
1991	75.49	88.74	74.14	68.63	67.69	68.19
2001	90.49	94.08	84.51	86.19	81.49	84.51

Source: MOUDPA, 2002

2.12.1.4 Land Value

The land values within the municipal limits of Kanpur vary from Rs. 61 to Rs. 2800 per sq m. The core city wards have higher market price for land as compared to the peripheral wards. Outside the city limits, the land price range between Rs. 16.10 and Rs. 24.70 per sq. m. (Office of the District Magistrate, Kanpur).

2.12.2 Traffic and Transport

Transportation and communication serve as the arteries of a settlement, providing links among various parts, inter-urban links and regional linkages. Kanpur is well linked by rail, waterways and roads to various parts of the country. In fact, the early industrial development was due to the presence of transportation through Ganga river. The coming of railways in 1859 brought a new dimension and scope to the industrial growth of the city. Today, it is an important junction and tracks from many directions under as many as three railways namely; Northern, Central and North-eastern railways make their ways through the district. Moving along the entire length of National Highway 2- Sher Shah Suri marg, the electrified track under the Northern railways connects Kanpur with Calcutta and Delhi while Bombay is linked through tracks under Central railways. North-eastern railways connect Agra and Mathura on the West and Lucknow and Gorakhpur on the East.

There is an aerodrome at Chakeri, East of Jajmau near the Grand Trunk road. For air connectivity, the city has to however, depend on the Amausi airport, 65 km away towards the capital city of Lucknow.

Kanpur is well connected by roads to major cities, towns and villages of the region. The regional road network comprises of two National Highways and two State highways. National highway NH-2 connects Kanpur with Delhi and Calcutta, NH-25 connects with Lucknow and Jhansi, while State highway SH-22 connects Kanpur with Etawah and SH-17 with Hamirpur respectively.

The major network in the city is along East-west direction due to geographical constraints- Ganges in the North and Pandu river in the South, and is shown in Fig. 2.18. The major roads in the East-west direction are G.T. road, Kalpi road, Mall road, Parvati Bangla road and Ambedkar road, while those in the North-south direction are Hamirpur road, Canal road, Meston road and Kidwai nagar road.

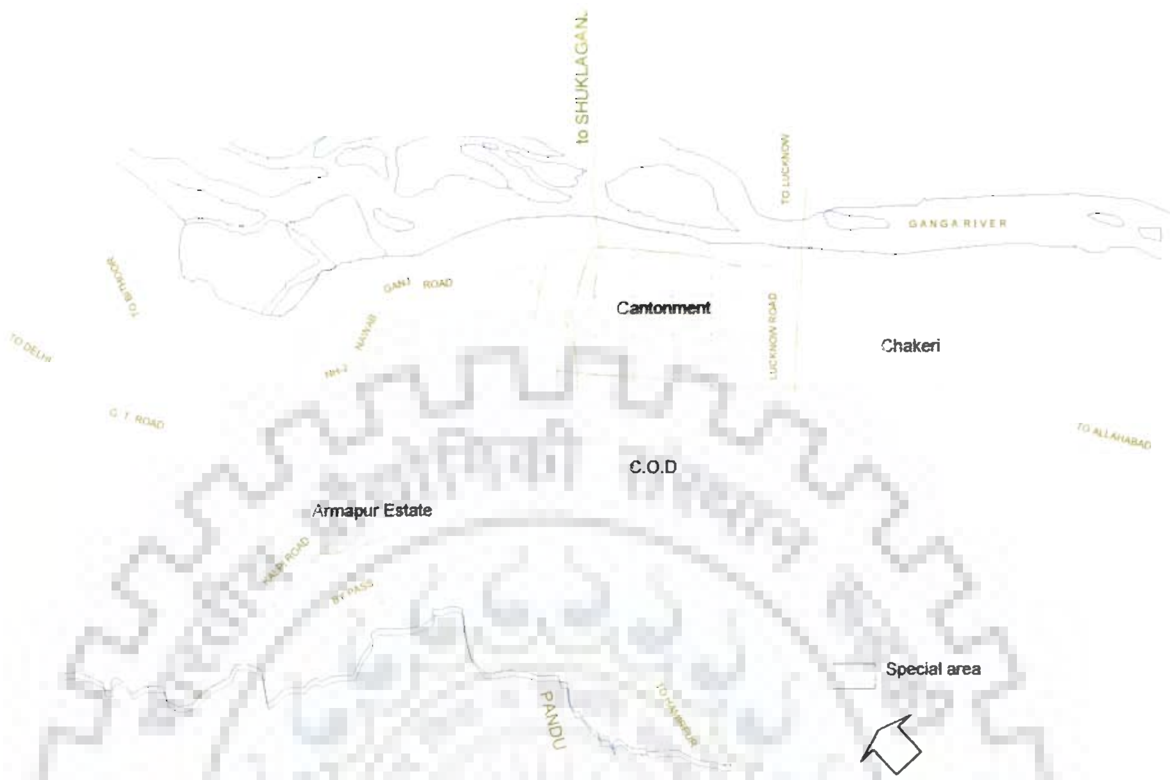


Fig. 2.18: Major and minor roads of Kanpur city

2.12.2.1 Growth of vehicles

The number of registered vehicles in Kanpur grew from 1.69 lakh in 1991 to 2.29 lakh in 1995. It further grew to 2.50 lakh in 2001. The growth of vehicles in the period 1991 to 1995 is presented in Table 2.23.

The table states that the overall annual growth of vehicles between 1991 and 1995 stood at 7.2 per cent. Taxis show a substantial growth rate of 28 per cent per annum. Two-wheelers and tempos show an average growth rate of 7 per cent and 11.9 per cent respectively. Mini buses show a substantial annual growth rate of 46 per cent whereas standard buses grew slowly at 2.3 per cent only.

Table 2.23: Growth of Registered vehicles in Kanpur

S. No.	Type	Year		Annual Growth rate (%)
		1991	1995	
1.	Car/Jeep	11981	14643	5.1
2.	Taxi	203	558	28.0
3.	Two-wheelers	145468	190484	7.0
4.	Auto rickshaw/Tempo	1851	2904	11.9
5.	Buses			
	- Mini	52	236	46.0
	- Standard	787	862	2.3
6.	Trucks			
	- LCV	543	916	14.0
	- HCV	6626	7539	3.3
7.	Tractor	574	561	-
8.	Trailers	348	399	3.5
9.	Others	633	727	3.5
	Total	169066	222907	7.2

Source: RTO, 1991, 1995

These vehicles contribute to 3550 kg/hr of pollution load. These vehicles are a major source of air and noise pollution. The break-up of the load is SO_2 33.7 kg/hr, Particulate Matter 42.2 kg/hr., NOx 408 kg/hr., CO 2307 kg/hr and HC 757 kg/hr. The volume/capacity ratio on a road is a direct indicator of the service rendered by a city's road network. The volume/capacity ratio on important roads is presented in Table 2.24. It is observed that there is heavy traffic flow on Lucknow road, Kalpi road, Canal road, Mahatma Gandhi road, Meston road, G.T. road and Station road, where peak hour traffic volume is greater than the respective road capacity. Heterogeneity is another characteristic feature observed in Kanpur city. Lane discipline is completely absent on most roads. Slow moving vehicles like cycle rickshaw, bicycle, etc., dominate on the roads of inner city while fast vehicles form the major part of traffic composition on the outer roads.

Table 2.24: Volume capacity ratio for important roads

S. No.	Location	Capacity of Road(PCUs)	Peak hour traffic volume	V/C ratio
1.	G.T. road (Delhi side)	3000	1978	0.66
2.	G.T.road (Allahabad side)	2250	1536	0.68
3.	Lucknow road	1500	1109	0.74
4.	Kalpi road	1500	1479	0.99
5.	Hamirpur road	1500	1216	0.81
6.	Lucknow road	1500	1637	1.09
7.	Canal road	1800	1741	0.97
8.	Hamirpur road	2400	1710	0.71
9.	M.G.road	2900	3295	1.14
10.	Meston road	1800	4276	2.38
11.	Nawabganj road	2400	1381	0.58
12.	G. T road (inner city)	1200	2145	1.79
13.	Station road	1800	3099	1.72

Source: Kanpur Development Authority, 1997

2.12.2.2 Public Transport

The public transport system in the city is poor and comprises of private buses, tempos and auto rickshaws. The tempos are most common and ply on fixed routes and are available at frequent intervals. In the year 1997, a total of 7839 tempos plied in Kanpur [181]. The major tempo stands are located at Parade, Railway station, Rawatpur, Bara Devi, Jajmau, Gomti No. 5 and Kalyanpur. Besides, there are 319 buses which run on 43 routes in the city and are operated by private operators.

2.12.2.3 Road network

The road patterns of the city can be divided in three groups:

- Roads of the City Proper
- Roads of the Civil lines and the Cantonment
- Roads of the Newly planned areas

i) <u>Roads of the City Proper</u>

This constitutes the core old area of the city with a mix of regular and irregular pattern, not suited to the volume, intensity and variety of traffic. In general, the road pattern in the outer part of the core area is somewhat rectangular. The Halsey road with the Latouche and Meston roads exhibit radial pattern in the inner part. These roads are the main business thoroughfares and the business arteries of the city. Mall road, Sisamau, Kalpi and Birhana roads produce a rectangular pattern. This area suffers from acute congestion, capacity problem, level crossing, poor traffic management, poor quality, etc.

ii) Roads of the Civil Lines and the Cantonment

The roads of this area were laid on rectangular pattern. The Cantonment is open with wide and straight roads.

iii) Roads of the Newly planned areas

The western and southern planned areas of the city have followed a rectangular pattern.

2.12.3 Water Supply

The city had an installed capacity of water supply of 300 million litres per day (for 17 lakhs population) with average daily rate of supply of 147 litres per capita per day. The distribution of water supply from various sources is as under:

a) River Ganga: 150 mld (50 %)

b) Lower Ganga canal: 40 mld (14 %)

c) Ground water (tube wells): 110 mld (36 %)

Thus, of the total water supply, 64 per cent is being met from surface water source, while the rest (36 per cent) is met from the ground water (private dwellings, defence establishments, industry and Jal Sansthan) sources. The underground water is easily available at a depth of 60 to 80 feet. The ground water is drawn from 82 tubewells and 6179 handpumps, located all over the City. Besides, private boreholes mounted with electrically driven pumps to supply housing colonies, industries or households are also common in Kanpur. The water supply network was laid way back in 1892 and designed to cater 2 lakhs population soaring the water from Ganga river at Bhairo ghat. The water after treatment at Benjhabar water works is distributed to 6 zones, from there after disinfection it is fed to local network through 26 Zonal Pumping stations.

2.12.3.1 Water Demand and Supply

The city has been divided into four districts for proper supply and distribution of water, *viz.*,East, West, South and City and is presented in Fig. 2.19. East service district is the largest in area and gets its supply from ground sources while the other three districts get their water supply from ground, river and canal.

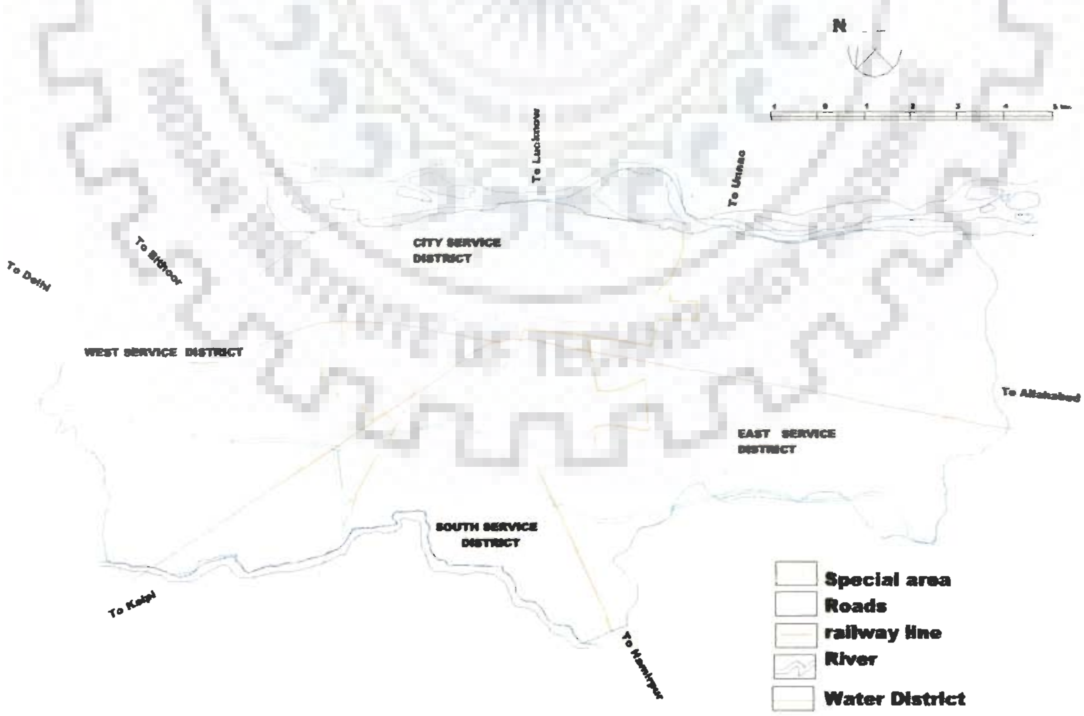


Fig. 2.19: Districts for Water Supply

At present, the city faces shortage of drinking water. The district wise per capita water demand and the deficit/surplus is presented in Table 2.25. The table illustrates that there is shortage of water in all the districts except for the City. There is an average deficit of 122.4 million litres per day. The average supply in the city is 147 litres per capita per day.

Table 2.25: Water demand and supply in Kanpur Urban Agglomeration (1991)

S.No.	Districts	Population (in lakhs)	Water		Deficit/Surplus
			Demand(mld)	Supply (mld)	
1.	East	2.70	54	24	-30.0
2.	West	2.48	49.6	21	-28.6
3.	South	4.97	99.4	65	-34.4
4.	City	9.31	186.2	190	+3.8
5.	Others	1.65	33.2	-	-33.2
	Total	21.11	422.4	300	-122.4

Source: KJS, 1991

The water supply treatment and distribution network is in need of renovation and extension. Piped water supply has not reached all over the city. The distribution of water supply by different sources in Kanpur city is presented in Table 2.26.

Table 2.26: Distribution of Households classified by source of Drinking water

S. No.	Water supply type	No. of Households	Percent
1.	Tap	174,649	46.3
2.	Hand pump	180,179	47.7
3.	Tube well	16,185	4.5
4.	Well	2,824	0.8
5.	Others	2683	0.7
	All sources	377,150	100.0

Source: Census of India, 2001

The table illustrates that only 46.3 per cent households have piped water supply, while 47.7 per cent households get their drinking water supply through hand pumps. Assuming a per capita water consumption for domestic needs, 15 per cent and 30 per cent of the domestic demand for industrial requirement and fire demand, respectively, the current water demand and shortage is calculated as under:

1. Domestic water demand in 2005: 28, 50, 000* 200=570 mld
   (assuming polynomial growth of population)
2. Industrial demand (15% of Domestic demand): 85.5 mld
3. Fire demand/wastage (30 % of Domestic demand): 171 mld
4. Total water demand in year 2005: 826.5 mld
5. Existing supply in year 2005: 386 mld
6. Shortage in year 2005: 440.5 mld

Thus, there is an immediate need to take appropriate measures for augmenting the water supply of the city in a sustainable manner.

2.12.4 Sewerage and Drainage

The existing sewerage network in Kanpur covers a small area of 40 sq. km out of the total corporation area of 298.98 sq. km. The city sewerage network was laid in the year 1904 and has not been upgraded in proportion to the rising population of the city. Besides, lack of periodic maintenance, has further deteriorated the sewerage network resulting in poor sanitary conditions. The network is of about 700 km length at present.

The city is being administered under five different zones/districts for proper drainage and sewerage management and is as follows:

- City drainage district
- East drainage district
- South drainage district
- West drainage district
- North-West drainage district

The division of the above mentioned five drainage districts is presented in Fig. 2.20.

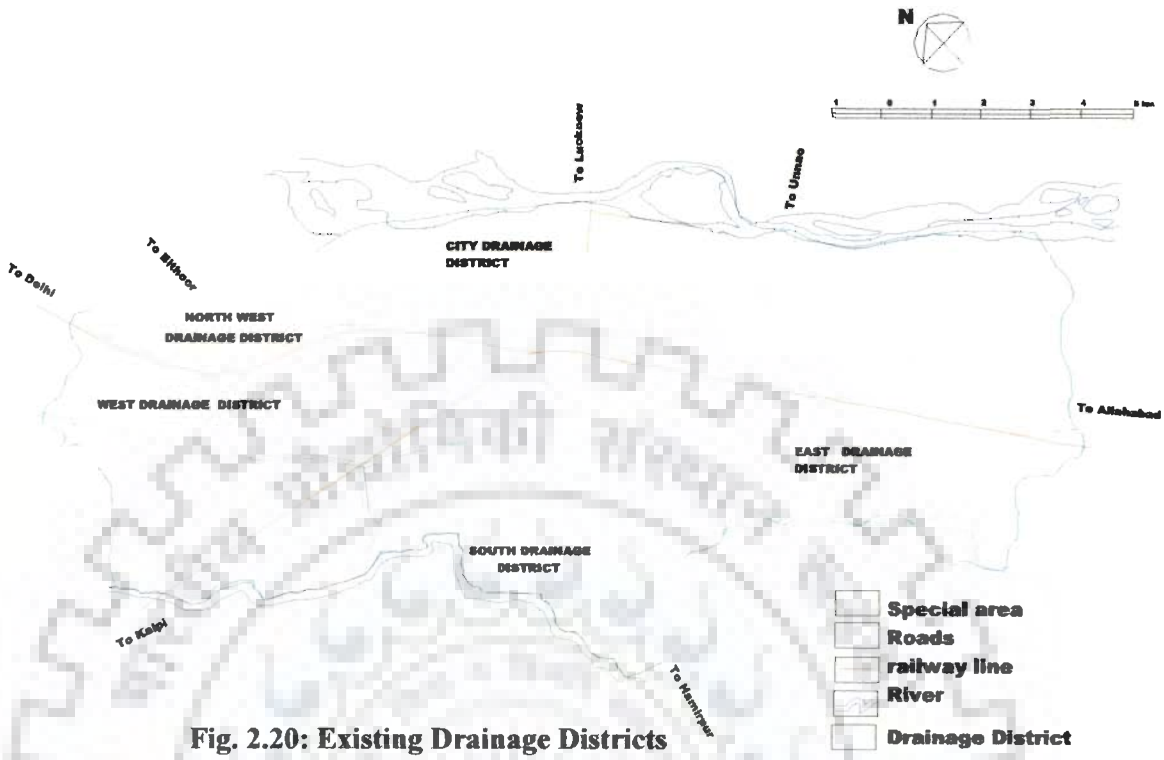


Fig. 2.20: Existing Drainage Districts

The major zone of sewerage system 'city drainage district' with its underground sewerage system covers 10 lakhs population and generates 260 mld waste water, with its out-fall at Jajmau into river Ganga. The system has carrying capacity of 160 mld and other 100 mld of sewage meeting river Ganga without any treatment. The 'east drainage district' which is primarily the developing areas has also no sewerage network. The collection/treatment of wastewater has been proposed to be discharge into river Pandu. In the 'south drainage district' only some pockets are sewered and rest is collected in open nallahs. The Industrial effluent from Panki area meets the river separately through industrial drain. The 'west drainage district' has no sewerage facilities and the wastewater leads through open nallah to Pandu river. The North-West district is also partly sewered.

2.12.4.1 Treatment facilities

The city has total installed treatment capacity of 171 mld for domestic/industrial wastewater. The sewage treatment plants (STP) with UASB technology and bio-gas recovery with 65 to 80 percent efficiency commissioned in 1987, has the capacity to treat 5 mld and is located at Jajmau under the Indo-Dutch project. The city also has Common Effluent Treatment Plant (CETP) commissioned in 1994 with its capacity of 36 mld (for 9 mld of tannery effluent in conjunction with 27 mld domestic sewage). The conventional sewage treatment plant commissioned in 1996-97 under Ganga Action Plan has the capacity of 130 mld.

The various treatment plants were developed under the aegis of Ministry of Environment and Forest and were later taken up by the State government in 1997, which is not able to finance the operation and maintenance costs of the plants. As a result, the plants are not running at full capacity.

At present, the 130 mld STP is running at only 60 mld capacity, the resultant sludge being sold to farmers. The 130 mld treatment plant was designed for domestic sewage but it is getting tannery/industrial waste, illegally driven along with the domestic sewage. The UASB reactor was designed for chromium free waste water but the plant is currently getting an intake rich in chromium.

Status of Domestic Sewage

Major Drains of the city: There are 11 major drains in the city which carry domestic sewage. They are as under:

1. Bhaironghat (Raw water source for Kanpur)
2. Sisamau nala
3. Parmath ghat nala
4. Jail nala
5. Police lines nala

6. Bhagwat das ghat nala
7. OEF nala
8. Gola ghat nala
9. Massacre ghat nala
10. Dabka nala
11. Nalas in Jajmau

There are 4 Intermediate Pumping Stations (IPS), one each at Nawabganj, Parmat Ghat, Baba Ghat and Guptar Ghat. These pumping stations pump the sewage to Sewage treatment plants or irrigation fields. Frequent power cuts and low supply of diesel results in under utilisation of these intermediate pumping stations. It was observed that drains emerging from Azadnagar, Dandiwada, Pehelwaan purwa, KDA colony, Malin Basti, TB hospital drain, Mainawati Marg, Shivadeen purwa, Rani ghat and Machuwa Nagar reach the water intake point and contaminate the prime raw water source for Kanpur [358].

Drains from COD, Ganda Nala, Halwa Khanda etc., directly fall into the river Pandu. These drains also carry effluent from industries in the Panki and Dadanagar industrial areas.

2.12.4.2 Drainage

Inadequate drainage has become a characteristic feature of almost all parts of the city except for the special areas, which are not managed by the Kanpur Nagar Nigam and also few posh colonies. Flooding of even important commercial/residential areas like Swaroopnagar, Kalyanpur, Transport nagar, Fazalgnaj, etc., is common. Drainage is completely absent or in a very poor condition in peripheral areas.

The city has thirteen main drainage outfalls carrying storm water to the river Ganga and three to river Pandu. The drains are commonly affected by blockades due to throwing of debris, garbage, dung, dead carcass of livestock, earth, etc. The drains are annually desilted before monsoons, but the places where the sides and beds of drains are kutcha, earth again flows into the Nallas in rainy season.

The break-up of estimated waste water generated in various districts is presented in Table 2.27. The total waste water generated in the city is 426 mld, with maximum waste water generated in the City drainage district.

Table 2.27: Estimated waste water generation in various districts (Year: 1995)

Sl. No.	Area	Population (lakh)	Waste waster generated(mld)
1.	City drainage district	15.10	307
2.	South drainage district	1.37	28
3.	West drainage district	2.52	51
4.	North-West drainage district	0.55	11
5.	East drainage district	1.42	29
	Total	20.96	426

Source: Kanpur Development Authority, 1997

The sewerage and drainage systems are not able to cope with the increasing load. There is no systematic cleaning of sewers. At places, even industrial waste from tanneries joins with sewage causing treatment problems. Regular blockades in storm water drains cause a lot of problems to the residents. The treated and untreated waste water is finally disposed in Ganga, causing water pollution.

2.12.4.3 Surface Water Quality

The lack of adequate sewerage system has adversely affected the city's sanitary conditions. Accumulation of stagnant sewerage or industrial effluent is observed along the roads in open plots and in many low-lying areas in the city.

2.12.5 Solid Waste Management

Kanpur generates approximately 1500 tonnes/day of solid waste from domestic and commercial sources, apart from 250 to 350 tonnes/day of industrial waste. The responsibility of solid waste management is entrusted to Kanpur Nagar Mahapalika (Municipal Corporation). For the purpose of solid waste management, the city was divided into six zones covering 110 wards. Collection efficiency varies from very poor to poor all over the city. Areas owned by other agencies like Cantonment, HAL colony, Armapur, IIT, etc., have efficient waste collection. Peripheral areas, newly developed colonies and slums have very poor waste collection. A detailed analysis of the present solid waste management scenario is presented in Chapter 3.

2.12.6 Power

Transmission and distribution of electricity in Kanpur is undertaken by U.P. State Electricity Board (UPSEB). The works relating to the supply of electricity in the city comes under the purview of Kanpur Electricity Supply Corporation (KESCO). The total consumption of electricity in the district amounts to 1061961 KWh as per the figures of 1989-90. The major consumption of power is in the industrial sector amounting to 773687 KWh. Thermal power is generated in Panki power station, which caters not only to the demands of the urban agglomeration and the district, but that of the state also. The per capita consumption of electricity in the district is 626 KWh. The city gets its power supply mainly from the U.P. state grid. The power requirement of the city is estimated at 640 MW in the year 2005. The supply is however very low and not able to cater to the growing demands of the city. Besides, transmission losses and thefts, which are as high as 30 per cent further, deteriorate the situation. Poor electricity supply is one of the reasons for the declining industrial growth in the city. The city faces power cuts for as long as 10 to 12 hours daily. There are also, high voltage fluctuations, causing a lot of problems to the gadgets and appliances run by electricity.

2.12.7 EDUCATION

One of the important functions of Kanpur city is its educational role played in the area. The city boasts of educational institutes of national repute like the Indian Institute of technology and Ganesh Shanker Vidyarthi Medical College. There are a number of institutes like National Sugar Institute, Central Leather Research Institute, National Textile Institute, Kanpur University, etc.

There are a number of schools and colleges scattered throughout the city. The percentage of population enrolled in different educational institutes/schools to the total population was 25.44 per cent in 1992 and is presented in Table 2.28. There were 784 primary schools, 213 junior high school and 28 technical institutes in the year1992.

Table 2.28: Educational enrolment and number of institutes in Kanpur (1992)

S. No.	Institute/Schools	Enrolment (No.)	% of Enrolment to total population	No. of Institutes
1.	Primary Schools	162592	7.80	784
2.	Junior High School	163476	7.85	213
3.	Higher Secondary Schools	86828	4.17	108
4.	Degree colleges & Technical Institutes	117075	5.62	28

Source: NIC UP State, 1992

2.12.8 HEALTH SERVICES

There are 407 odd hospitals and nursing homes in the city, of which there are 43 government and semi-government hospitals, 360 private nursing homes and 4 defence hospitals. The combined bed capacity of these is 11,140. The important hospitals are Lala Lajpat Rai hospital, U.P.S.R. maternity hospital, Kanpur eye hospital, Ganesh Shankar Vidyarthi Medical college hospital, Cancer Research Institute, Ursula Maternity hospital and Mariampur hospital. The hospitals are however, not evenly distributed in the city. They are mostly located in the outer zones away from the congested area of the city. The number of beds per 1000 population is only 0.63 as per Census 1991, which is a very low figure. The city attracts a huge number of patients from the whole region. The high incidence of diseases in the city, an outcome of the high level of pollution, adds pressure to the already scarce medical facilities in the city.

2.12.9 Fire Services

The city has only 3 fire stations to cater to the Urban Agglomeration and is not sufficient. The expansion of industries and of the city calls for the need to upgrade the facility.

2.12.10 Recreational areas

Kanpur lacks in parks and open spaces. The dearth of open spaces adds to the chaos of the already congested and polluted city. There are three big parks, all located in the river front sector, with no green open spaces in the middle and southern sectors. The Ganesh Udyan (Phool bagh) is near the Government Harness factory, while the Brijendra Swaroop Nagar Park is in the Arya nagar and Swaroop Nagar locality. There is only one playground in the Green Park in Civil lines. There are some playgrounds in the newly developed colonies but the grounds are not maintained. There are some 39 cinema halls and 4 auditoria/community halls in the city, with some new modern multiplexes also coming up like Rave -I and II.

2.13 ENVIRONMENT

Kanpur, a major metropolitan city of Uttar Pradesh is an active industrial city. The city in its march for urbanization has not developed in a sustainable manner and as a result, the environment has gradually become degraded in the city. All sorts of pollution are observed in the city and needs immediate remedial measures.

2.13.1 AIR POLLUTION

Kanpur is one of the major polluted cities in India. The estimated air pollution loads in Kanpur is 5500 kg/d from domestic sources, 2550 kg/h (142 t/d) from vehicular sources and 12,000 kg/hr from industrial sources [73]. The major problem in case of air pollutants in the city is due to high levels of Suspended Particulate Matter (SPM), which is exceeding the prescribed norms in most places in the city. Respirable dust concentrations are alarmingly high in many locations in the city due to loose surface soil and lack of vegetation in most parts of the city. The SPM levels in different parts of the city and the generators of such pollutants are presented in Table 2.29. The table illustrates that the Central Business District area and Panki industrial area has the highest SPM level of 501 to 800 μm^3 followed by Dadanagar and Govindnagar industrial area where SPM level of 350 to 500 μm^3 were recorded. Jajmau area also has high SPM levels due to stack emissions from the numerous tanneries.

Table 2.29: Ambient air quality in Kanpur

Ambient Air Quality in Kanpur			
S. No.	**Area in the city limits**	**SPM in ug/m3**	**Factors effecting air quality**
1	Central Business District area comprising commercial areas of Deputy ka Padao, General Ganj, Parade, Gwaltoli etc., Panki Industial area, Power house and the immediate adjoining areas including ash pond.	501 to 800 (occasionally exceeding 800)	• The commercial areas are characterized by unclean roads and traffic congestions. • In industrial areas low level emission from DG sets. Small boiler emissions, small foundries • Fly ash from ash pond and operation of small boilers in Panki Power plant also affects air quality of adjoining areas
2	Mixed use areas in the south,south west and east side of CBD area covering Dada nagar ,Govind Nagar,Industrial state etc. Areas adjoining to power house	350-500	• Impact of adjacent industrial emissions • Impact of power house fly ash
3	Areas in the south-east,south and south-west side to CBD area like Naubasta ,Ratanlal Nagar,Barra,Lalbangla etc.	250-350	• Commercial and residential areas being affected by industrial areas during leeward wind flow. • Most of the areas are under developing stage with uncovered open areas, leading to dust problem. • Vehicular emissions

Table 2.29 (Continued)

Ambient Air Quality in Kanpur			
S. No.	**Area in the city limits**	**SPM in ug/m3**	**Factors effecting air quality**
4	Jajmau Industrial area	350-500	• Emissions from small boilers being liberated through stacks of height 15 to 30m.height
5	Area to the left of CBD consisting Rawatpur village, around the Allen forest, Swaroop Nagar, Vikas Nagar and Sharda Nagar etc.	250-300	• Natural sources of dust, dust due to vehicular movement, use of coal/cow dung in adjoining slum areas if any
6	Areas with more vegetation and low population density like Cantonment, IIT, villages and agricultural land along the western periphery of the city	200-300	• Natural source of dust • Industrial influence during leeward wind direction and other favorable meteorological conditions.
7	Agricultural land along the eastern boundary of the city	< 200	• Natural source • Distant traces of emissions from main city.

Source: CPCB, 2001

2.13.1.1Vehicular pollution loads

In the absence of a good public transport system, the city is undergoing a tremendous vehicle growth like most of the other metropolitan cities. The city has more than 5 lakh vehicles plying on its roads, and almost 50,000 new vehicles are added every year. The pollution load due to these vehicles is 3547.9 kg/hr. Table 2.30 presents the break-up details of distribution of vehicular pollution load in the study area.

Table 2.30: Vehicular pollution load in Kanpur

S. No.	Parameter	Load in kg/hour
1.	SO_2	33.7
2.	PM	42.2
3.	NO_x	408
4.	CO	2307
5.	HC	757

Source: CPCB, 2001

2.13.1.2 Impact of Air pollution in Kanpur city

There are numerous ill-effects of air pollution on the flora, fauna and the human beings. Kanpur, also known as "Capital of Tuberculosis", is also turning out to be a high-risk city for asthma. The city had the highest count of respirable suspended particulate matter (RSPM) in the country as per CPCB survey, January to April 2002. The RSPM levels varied from 119 to 257 micrograms per cubic metre as against the National Ambient Air Quality Standard (NAAQS) of 60 micrograms per cubic metre. The pollutant triggers a lot of respiratory ailments like, asthma. Currently, the number of asthma patients exceeds 10 per cent of the total population against the norm of two to five per cent for a normal city. According to the World Bank Study (1995), the annual environmental health cost for every citizen in Kanpur owing to ambient air pollution is US $50. Thus the total annual environmental health cost due to air pollution for Kanpur is approximately Rs 600 crore [380]. An estimated annual health incidence due to ambient air pollution in major cities of India is presented in Table 2.31.

Table 2.31: Estimates of annual health incidences in India cities due to ambient air pollution levels

S. No.	Cities	Premature death	Hospital admissions and sickness requiring medical treatment	Incidence of minor sickness
1.	Ahmedabad	2979	1,183,033	72,177,644
2.	Bangalore	254	135,887	8,326,282
3.	Calcutta	5726	2,022,786	179,479,908
4.	Delhi	7491	2,990,012	241,958,219
5.	Hyderabad	768	420,947	31,708,958
6.	Jaipur	1145	520,947	31,708,958
7.	Kanpur	1894	812,381	49,247,224
8.	Madras	863	416,966	27,859,485
9.	Mumbai	4477	2,57,210	156,452,916
10.	Patna	725	319,242	19,561,109

Source: Gadhok, T.K.

The table clearly illustrates that the incidence of premature death due to ambient air pollution levels is very high in Kanpur city as compared to other cities of similar and bigger size like Bangalore, Madras, Hyderabad, etc. The number of hospital admissions and sickness requiring medical treatment is very high at 8.1 lakh cases in a year, while 492 lakh cases of minor sickness are reported annually. This figure is growing drastically due to increasing air pollution and lack of proper remedial measures to check the root cause of this problem.

2.13.2 WATER POLLUTION

Kanpur gets 64 per cent of its water supply from Ganga river and the rest 34 per cent from tube wells. Both surface water and ground water is severely polluted and not fit for consumption without thorough treatment. Escheerichia Coliform and faecal coliform were found in water samples collected in the city and its suburbs. The water samples from Bhairon ghat pumping station (the primary source of drinking water) and Motijheel raw intake point were found to be highly contaminated [384]. Samples collected by the State Pollution Control Board at Bithoor, Ranighat and Jajmau pumping station with their observed ph value and coliform count are presented in Table 2.32.

Table 2.32: Characteristics of Water samples in Kanpur

S. No	Sampling Points	SamplingDate	TotalColiform	pH	Faecal Coliform	BOD	Use Based Class
1	Bithoor	04/01/2005	7500	8	3900	2.2	B
2	Ranighat	09/11/2005	4300	8	900	1.6	B
3	Jajmau pumping station	04/01/2005	93000	8.1	28000	8.6	B
4	Jajmau pumping station	06/05/2005	43000	8.6	15000	6.9	B
5	Jajmau pumping station	09/11/2005	46000	8.2	23000	4.3	B

Source: Prepared by the Investigator based on results by State Pollution Control Board

The defined use is B type use based class as observed in Table 2.32. For B type, the criterion is that the total coliform count should be less than 500. In all the above cases however, it is far exceeding. Even for C type usage (drinking water source after conventional treatment and disinfection), the defined total coliforms count is less than 5000 (Ministry of Environment and Forests). It has been observed that in many places in the city, electroplating and bleaching waste contaminates the ground water, rendering it unfit for drinking and cooking. Improper disposal of municipal solid waste, biomedical and industrial waste is also contaminating the ground and surface water in the city.

Status of Domestic Sewage

Domestic sewage with or without treatment is usually disposed off in the available surface water in Kanpur city, which has a direct impact on the pollution load of the surface water. The status of drains carrying domestic sewage in Kanpur is presented in Table 2.33 and Fig 2.21.

Table 2.33: Status Report of Drains (nalas) carrying domestic sewage

Name of the drain (name given according to the place of discharge)	Actual status as on June, 2003
Bhaironghat-Raw water source for Kanpur	Bhaironghat raw water intake point, which is the primary source of drinking water for at least 60 % of the population of Kanpur, is now suffering from severe contamination from at least 15-20 drains in the upstream of water intake point. Azadnagar, Dandiwada, Pehalwaan purwa, KDA colony Malin Basti and a TB hospital drain, instead of being diverted to Nawabganj IPS, are being allowed to flow in Binda Shiwala (new basti) nala which finally reaches Intake point. Similarly Mainawati Marg, Shivadeen purwa, Rani ghat, Machuwa Nagar drains also reach raw water intake point. Besides, open defecation, washing of clothes, bathing, use of detergents etc. at raw water intake point go on unabated.

Table 2.33 (Continued)

Name of the drain (name given according to the place of discharge)	Actual status as on June, 2003
Sisamau nala	**It's like a tributary meeting Ganga. It discharges more than 100 MLD of raw sewage directly into river Ganga.**
Parmath Ghat nala	Parmat ghat nala is situated just along the Parmat temple. It receives some sewage from Sisamau Nala, sewage from Jail, Parmat colony, Khalasi line and Gwal Toli area. It still discharges sewage directly into Ganga. The capacity of the Parmat IPS is 18 MLD and it receives around 20 MLD of sewage from Sisamau nala, around 8-10 MLD from Jail, Parmat colony, Khalasi Line and Gwal Toli area. Parmat ghat area is highly polluted and completely filled with dirt and filth along Ganga side. No measures have been taken to collect the waste produced from the temple and also to stop the drain carrying raw sewage directly into Ganga.
Jail nalas	Small drains carrying sewage from the Jail premises find its way to Ganga. These drains are along Sarsaiya ghat area. Beside these drains, also the sewer lines of this locality remain choked most of the time, as a result of which all the sewage overflows and bypasses into Ganga.
Police Lines nala	Police personnel who are living in barracks have constructed toilets on these drains which are carrying all the sewage to Ganga. Also their backyard has become a dumping ground for their garbage and a huge volume of garbage can be seen littered in the backyard.
Bhagwat Das Ghat nala	**Bhagwat Das Ghat nala receives maximum sewage from the Guptar ghat IPS. The capacity of this IPS is 3 MLD but the waste which reaches here is approximately double Thus around 3-4 MLD of raw sewage is being bypassed directly into Ganga.**
OEF nala	There are two drains from OEF, which are discharging their waste into Ganga. One carries industrial effluent and the other one sewage from their colonies. The industrial effluent is treated and then bypassed into the river, say OEF officials.
Gola Ghat nala	This is in the Cantonment area. The drain discharges its load of raw sewage into the Ganga. People have made house connections directly into this nala. There is a big dhobi (washing) ghat functioning here.
Massacre ghat nala	No sewage flows through this drain.
Dabka nala	There are two drains, one carries domestic waste and the other one industrial effluent. These nalas discharge their load of raw sewage and effluent into the Ganga.
Nalas in Jajmau	Many small nalas from the settlements on the edge of the river discharge raw sewage into the Ganga. These settlements also dump their solid waste into Ganga.

Source: www.ecofriends.org

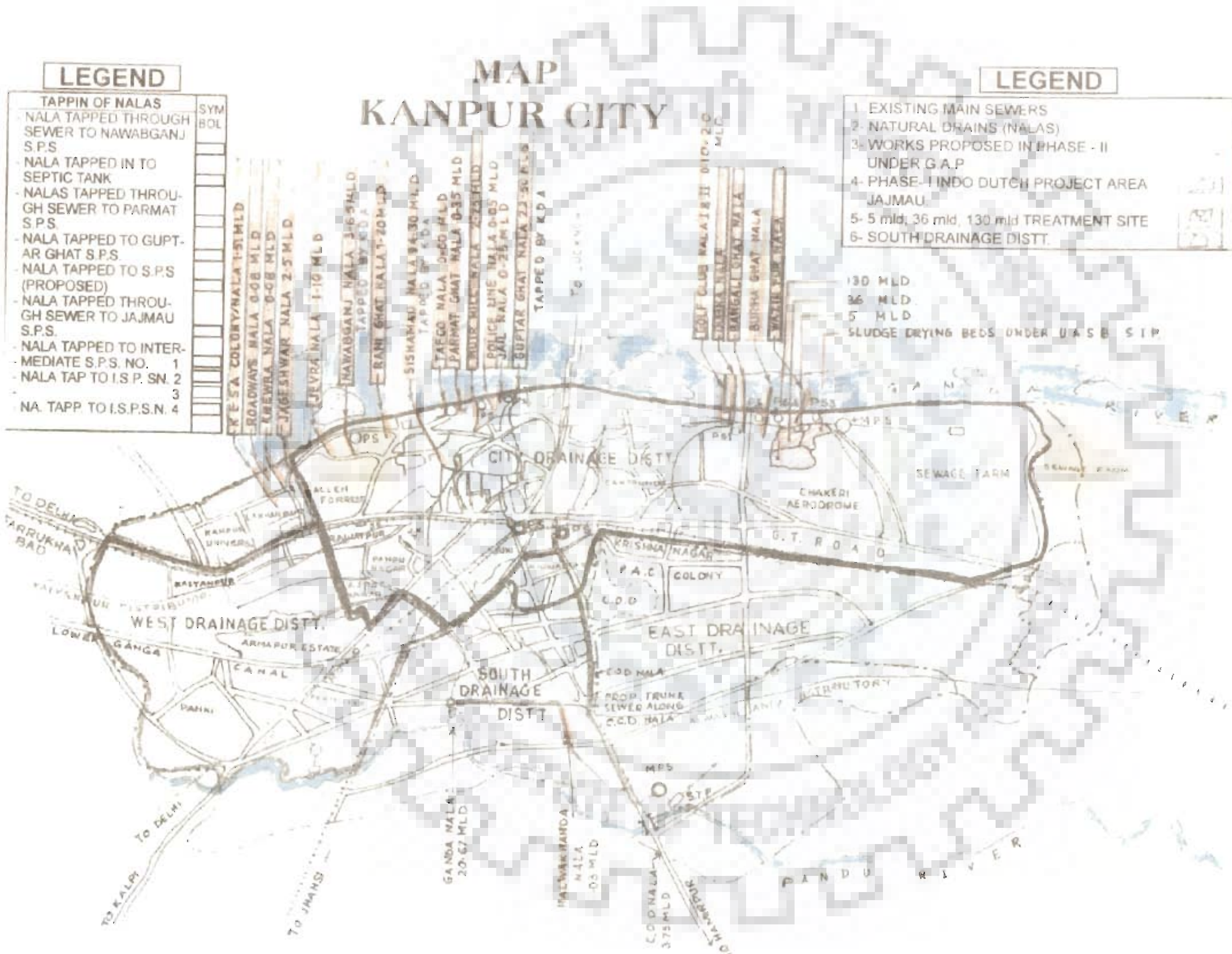


Fig. 2.21: Location of various Nalas and sewage treatment plants in Kanpur City

Status of Tannery Sewage

Reports by an NGO Ecofriends' state that some tanneries situated at some height along Ganga have constructed underground drains from their factory to the Ganga. They are fearlessly discharging their hazardous waste directly into Ganga and as a result, the colour of the water in that stretch looks dark brown.

Status of Intermediate pumping Station, Tannery effluents

There is power breakdown on an average for 7 hours every day. The supply of diesel remains irregular, erratic, and insufficient which hampers the efficient functioning of the pumping station. This ultimately leads to bypassing of the raw sewage and tannery effluent to the river. During monsoon the Intermediate pumping Station become dysfunctional and the entire sewage and tannery effluent is allowed to flow directly into the river Ganga.

Besides Ganga, Pandu river is also severely contaminated with domestic and industrial effluents. Some of the drains such as COD, Ganda Nala, Halwa Khanda ,etc., falling into the river Pandu carry effluent from industries in the Panki and Dadanagar industrial areas and pollute the river Pandu.

One of the biggest woes of the city is its underground aquifers are getting extremely polluted due to the pollution of river Ganga and leachate penetration from numerous legal and illegal dump sites. A four-member team of scientists from the National Environmental Engineering Research Institute (NEERI) has found the quality of underground water in many of the localities of the city and suburbs totally unfit for domestic use (www.HindustanTimes.com). Water samples were collected from two classes of respondents (higher and lower income groups) from different parts of the city, analyzed and found that the water samples collected from the higher income groups in the city and suburb areas for the pre monsoon and winter seasons contained faecal coliform. The water samples of tubewells collected from the people belonging to the lower income group had faecal coliform and Escheerichia Coliform contamination. The water samples collected from the Bhairon Ghat pumping station and the Motijheel raw water intake point were found grossly contaminated. Similarly, all water samples collected in winter months from the highest income group indicated high rate of contamination. The report suggested that raw water resources needed thorough treatment before being consumed. The ground water of Panki industrial area has been found to be contaminated with alarming levels of ammonia due to contamination from Duncans Fertliser factory. The underground water in areas such as Baburia, Rakhimandi, Nauriyya Khera, Fazalganj, Juhi and Jajmau is highly contaminated. The chromium level in the groundwater of these places was between 0.132 and 10 milligram per litre, which is far beyond the permissible level of 0.05 milligram per litre.

2.14 FUNCTIONAL STRUCTURE

Functional character of a settlement is an outgrowth of a number of factors like topographical features, economic, historical, socio-economic and political factors. These features finally lead to functional specialization, especially in the case of an urban settlement and shape the urbanscape.

In Kanpur city, the high and level ground in the heart of the city first got the attention of the early businessmen and traders. It soon became the Central business District of the city. The city grew around this core and later the business district expanded with increasing population. The industrial establishments were aptly placed near the higher land on the bank of Ganga, an important artery of transport. Railways brought the industries towards the South, close to the railway station. Administrative offices, courts, police lines, etc., developed in the northern part of the city.

2.14.1 Trade and Commerce

The city is one of the greatest business centres of the area. It deals in a variety of goods, materials and services. There are specialized wholesale and retail markets, for all kinds of goods like, iron, jewellery, articles of daily needs, milk, sugar, stationery, books, etc., in Kanpur. Most of these specialized markets are located in the Central Business District. Popular examples of such specialized markets are Collectorganj (grain market), Sabjimandi (vegetable market), Lohai bazaar (iron goods and utensils), Chappal bazaar (footwear market), etc.

Trade and commerce activity is spread over the entire city. The locations of major wholesale markets are presented in Table 2.34. Most of these wholesale markets are located in core areas of the city, causing much congestion.

Table 2.34: Location of major wholesale markets

S. No.	Market type	Location
1.	Food grains	Collector gunj, Coopergunj
2.	Pulses	Lal Bangla, Panki, Fazal ganj, Bhandana Purwa, Canal road, Baker ganj
3.	Fruits and vegetables	Kidwai nagar
4.	Skin and hides	Jajmau, Farash Khana
5.	Edible Oil	G.T. road, Panki, Bhandana
6.	Kirana	Naya Ganj
7.	Sugar and Khandsari	Shakarpatti
8.	Iron and Steel	SAIL depot, Bhauti, Kalpi road, Latouch road

Source: Kanpur Development Authority

The Central Business District lies in the core of the city and occupies the most advantageous location in the inner zone. The area is crossed by Halsey, Meston and Latouche roads which are the main arteries of the city. The area deals in a variety of goods and commodities. Most of the city's trade is carried out through this area and meets all the consumable goods of the surrounding areas. The shape of the Central Business District is unlike that of the city, which is elongated in East-west direction. The Central Business District on the other hand, is elongated in the North-south direction.

The *Chowk* is the main hub of the city from where specialized markets radiate in different lanes and streets. It shares a big part of the trade of Central Business District. It deals in general merchandise, leather goods and gold and silver ornaments. Other parts of the Central Business District like Collectorganj, Generalganj, etc., deal with wholesale grain market and cloth market. Meston, Birhana and Latouche roads are very busy commercial streets and a part of the Central Business District. Besides the main commercial markets, there are Commercial arteries in all residential districts, with variations in intensity and potential of business as per the locality. They can be broadly identified as *planned* and *unplanned* commercial arteries/ribbons. Examples of unplanned commercial arteries are Generalganj, Nawgraha, Parmat, Shakkarpatti, Misribazar, Anwarganj, Gwaltoli and Jajmau. Planned commercial arteries are P P N market, Govind Nagar, Swaroopnagar, Gumati No 5, Kidwai Nagar, Arya Nagar, etc. Unplanned commercial ribbons are often marked by congested streets, haphazard arrangement of shops mixed with residences on the upper floors. The planned commercial ribbons are sophisticated and more planned, and usually have functional variety.

2.14.2 Industrial Areas

The total land under industrial use is about 1407 acres, approximately 6.5 per cent of total built-up area. The industries first started coming up in the River front sector on the bank of Ganga river but gradually spread to different parts of the city. The industries are located in the thickly populated residential localities like Parade, Parmat, Latouche road, Rail Bazar, Anwar Ganj, Darshanpurwa and Phool Bagh as a result they suffer from a lot of air and noise pollution. The industries of later origin came along the Kalpi road in Fazalganj and Jajmau, of which the former is again sandwiched between residential colonies. The existing industrial estates in the city are presented in Table 2.35. The table clearly exhibits that Panki industrial area is the largest in area and number of sheds, followed by industrial estate at Dada Nagar.

Table 2.35: Industrial Estate in Kanpur

S. No.	Industrial Estate/Area	Area (acres)	No. of plots/sheds	Type of units
1.	Government Industrial Estate (situated on Kalpi road, Fazal ganj)	38.00	104	Cotton clothes, cycle sheets, confectionary, hosiery, bread, machine parts, rubber slippers, plastic goods, etc.
2.	Educated Unemployed Industrial Estate, Panki	7.00	31	Biscuits, slippers, electric appliances, chemicals, etc.
3.	Co-operative Industrial Estate, Dada Nagar	235.60	311	Machine Rolling Mills, iron casting, steel/PVC pipes, furniture, electric goods, spring, auto parts, tin containers, plastic goods, soap, chemicals, machinery, confectionary, agricultural machinery, etc.
4.	Industrial Areas under UPSIDC			
	a. Panki Industrial Area I	234.05	261	-
	b. Panki Industrial Area II	112.57	192	-
	c. Panki Industrial Area III	200.00	353	-
	d. Panki Industrial Area IV	25.00	131	-
	Total	852.22	1383	

Source: DIC, 1994

Kanpur, which was once an important industrial growth centre of the development in the region face the problems of uncontrolled growth coupled with decline in industrial production. The industrialization era marked the city with about 71 large and medium scale industries which followed western direction of expansion along the railway line and G.T. road. These industries include famous units like, Elgin mills, Muir mills, Cawnpore woolen mills, ordinance factories, New Victoria mills, M.P. Udyog and Lalimli. All these mills suffer from old technology problems, gigantic work force, high input cost with low output. It is however, still an important industrial centre with few operating textile mills, defense establishments, power plant, fertilizer unit, automobile industry, Vanaspati oil mills, and tanneries.

Apart from the large scale industries, there are some 5457 mixed type of Small Scale Industries which grew as ancillary to the major units. The existing status of these heavy and small-scale industries in terms of number of units and employment is presented in Table 2.36. The table clearly depicts that the Small Scale Industries produce variety of goods and products, ranging from metal products to leather goods, paper and textiles, etc. There are 830 metal products Small Scale Industries, 819 leather producing industries, 443 food products based industries, 416 units producing rubber and plastics, 396 units producing machinery parts, 387 units of garments, 337 units of chemicals, 318 units producing paper products and 246 units producing cotton textile. The total employment in both heavy and small-scale industries is 89,968, with cotton textiles employing the maximum number of people. Most of the industries are located in Government industrial estate (Kalpi road and Fazalganj), Industrial Estate, Co-operative estate (Dada Nagar), Panki Industrial Area and Jajmau Industrial area. Kanpur is also very (in)famous for its leather tanneries. There are more than 175 tanneries in Jajmau area on the bank of the river Ganga.

Table 2.36: Industry-wise units and Employment in Kanpur (upto March 1994)

S. No.	Industry	No. of Units			Employment		
		HI	SSI	Total	HI	SSI	Total
1.	Food products	7	443	450	1355	2021	3376
2.	Beverage, tobacco & tobacco products	-	5	5	-	35	35
3.	Cotton textiles	9	246	255	37037	1230	38267
4.	Wool, Silk, Synthetic fibre textiles	4	52	56	4214	276	4490
5.	Jute, Hemp & Mesta textiles	2	16	18	5290	80	5370
6.	Hosiery & Garments	-	387	387	-	1146	1146
7.	Wood products	-	191	191	-	716	716
8.	Paper products and printing	4	318	322	636	1157	1793
9.	Leather products	10	819	829	3773	3463	7236
10.	Rubber & Plastic products	4	416	420	750	2124	2874
11.	Chemicals & Chemical products	10	337	347	3934	2119	6053
12.	Non-metallic Mineral products	1	111	112	41	700	741
13.	Basic metal industries	7	138	145	939	1079	2018
14.	Metal products	-	830	830	-	3736	3736
15.	Machinery & Parts except electricity	7	396	403	1434	2093	3527
16.	Electrical Machinery & Apparatus	1	181	182	87	1063	1150
17.	Transport Equipment & Parts	3	89	92	4210	635	4845
18.	Miscellaneous Manufacture	2	145	147	187	756	943
19.	Repairs & Servicing Industries	-	337	337	-	1652	1652
	Total	71	5457	5528	63887	26081	89968

Note: HI-Heavy Industries; SSI- Small Scale Industries

Source: DIC, 1994

The industries can be broadly grouped under six categories, based on locational attributes:

a) Ubiquitous industries, whose market area is essentially co-extensive with the city or its part. Such industries are concentrated near the perimeter of CBD.

b) Communication economy industries, which are based on the accessibility to the purchaser prior to the actual process of manufacturing, e.g., printing and publishing works located on the Mahatma Gandhi road and Civil lines.

c) Local market industries, which are dependent on locally available raw materials, like brick and concrete works, metal plating, polishing, etc. These are mostly scattered throughout the city.

d) Non-local market industries, which cater to a bigger area than the city itself, like chemical and pharmaceutical, plastic works, machine parts, electrical accessories, etc.

e) Industries oriented towards national and international markets, like textiles, leather, metal and engineering works. These are found to be usually located on the river side and in the south by the railway sidings. Jajmau and Panki area also have a bulk of such industries.

f) Defense industries, like C.O.D in the south and the Armapur estate, provide defense equipments and products.

2.14.3 Administrative Areas

The administrative areas in Kanpur city can be classified as follows:

2.14.3.1 District Administrative Office areas

This area is a rectangle of 90 hectares located in the river front sector, bordered in the south by Mahatma Gandhi road. It houses a number of government offices and the district courts. The offices are mostly scattered and the area houses offices like District sub-division office, Revenue offices, District Census offices, etc.

2.14.3.2 State Administrative Office areas

State offices are mostly located on the Grand Trunk road near Medical College. The area seems to be more planned compared to the district administrative office area. It houses offices like Uttar Pradesh Government Industrial Offices, Regional Employment Exchange Offices, Labour Commissioner's office and Transport office.

2.14.3.3 City Corporation Offices

The Corporation offices are located in a big block on the Benajbhar road, near Moti-Jheel. The Kanpur Jal Sansthan and Kanpur Development Authority office is also located in this area.

2.15 URBAN MANAGEMENT

A smooth functioning of the overall developmental activities in an urban system requires a good Urban Management system. The task of implementation of various policy guidelines also falls on the Urban Managing bodies, besides providing other basic services and amenities. The agencies, which have a direct role in managing urban development in Kanpur are as follows:

a. **TOWN AND COUNTRY PLANNING DEPARTMENT**

The Town and Country Planning Department mainly deals with matters of urban planning. It prepares Development Plans and Master Plans for metropolitan and other cities under the provision of U.P. Regulation of Building Operations Act, 1958 and U.P. Planning Development Act, 1973, while the onus of enforcement lies with Development Authorities and U.P. Housing and Development Board.

b. **KANPUR DEVELOPMENT AUTHORITY**

Kanpur Development Authority promotes and secures the development of the Kanpur Urban Agglomeration according to the master plan. It has been given the power to acquire, manage and dispose off land and other property; to carry out building, engineering and other operations; to execute works in connection with the supply of water and electricity; to dispose off sewage and to provide and maintain other services and amenities and to take necessary actions for purposes of such development.

c. **U.P. HOUSING AND DEVELOPMENT BOARD**

This agency is headquartered at Lucknow and is primarily responsible for launching and developing housing colonies and building housing stock in major cities of the state. The activity of the Board in Kanpur is however, limited.

d. CO-OPERATIVE HOUSING FEDERATION (U.P. AVAS SANGH)

The U.P. Co-operative Housing Federation, popularly known as U.P Avas Sangh primarily obtains loans form LIC for housing and makes it available to the members of the affiliated Cooperative Housing Societies.

e. KANPUR JAL SANSTHAN

This organization was set up under section 19 of U.P Water Supply and Sewerage Act, 1975 to look after the water and sewerage system, previously taken care of by the Municipal Corporation. In 2001, the Kanpur Jal Sasthan was officially merged into the Kanpur Municipal Corporation. Administratively, it however continues to function as an autonomous entity.

f. KANPUR MUNICIPAL CORPORATION (KNN)

The local government was upgraded in 1960 from a Municipal Board to a Municipal Corporation. The specific duties of the Corporation includes the following:

- Town planning, slum improvement and urban poverty alleviation;
- Provision and maintenance of roads, sanitation, solid waste services, fire services, urban forestry, street lighting, parking lots, parks and burials;
- Protect the environment, promote cultural, educational, aesthetic, ecological activities;
- Maintenance of public hospitals, dispensaries and other public heath functions including veterinary services;
- Regulation of land uses, building, markets, slaughterhouses and tanneries;
- Safeguarding the interest of weaker sections of the community;
- Provision of vital statistics;
- Prepare development plans.

g. DIRECTORATE OF LOCAL BODIES

This agency acts as an intermediary between the Secretariat and the local authority. It streamlines the flow of financial assistance to urban local bodies and enables the State Government to exercise control over them.

h. OTHER AGENCIES

In addition, a number of other agencies of the State Government like State Urban Development Authority (SUDA), State Pollution Control Board, Public Works Department (PWD), Industries Directorate, etc., operate in the urban area and contribute to the development programmes and projects directly or indirectly.

A list of various departments and their functions is summarized and presented in the adjoining Table 2.37.

Table 2.37: Relevant government departments and their functions

Sl. No.	Name of the Department	Function	Brief description of function
1.	Kanpur Development Authority	Town Planning	Responsible for development of Kanpur and to approve the maps
2.	State Pollution Control Board	Pollution control and environmental protection	Control the air, ground and water pollution
3.	Provincial medical and health services	Public health	Control epidemic treatment and all sorts of public health activities
4.	Jal Sansthan & KNN	Sewerage	Cleaning and maintenance of sewers
5.	Jal Sansthan & Kanpur Nagar Nigam	Storm water	Construction, maintenance and cleaning
6.	Jal Sansthan	Water supply	Supplying water to the city
7.	Kanpur Nagar Nigam	Garbage/solid waste	Primary collection and disposal
8.	KNN, PWD, KDA	Roads	Repair, maintenance
9.	Industries Directorate	Industry	Issuing licenses, loans, etc
10.	SUDA, DUDA	Slums	Up gradation of the slums
11.	Forest department, KDA and KNN	Green belts, horticulture	Plantation

Source: Compiled by the Investigator based on secondary data

2.16 REGIONAL INTERACTION

Kanpur is one of the most important industrial centers of Northern India, especially Uttar Pradesh state and is an upcoming busy trade and commerce centre. Such big urban nodes have a strong regional presence by the extent of services provided to surrounding and distant areas. Traffic volumes and goods traffic movement-both inbound and out bound, are often strong indicators of the level of regional interaction of a place. This hold true for the city of Kanpur also and is presented in Table 2.38 and Table 2.39. Table 2.38 presents the traffic volume on major regional roads in the year 1987 and 1994 respectively. Maximum traffic is observed on Unnao Road across old Ganga bridge in 1987 which decreased by 45.6 per cent in 1994.The other five cordons show an equitable distribution of traffic in 1987. The traffic volume data for the year 1994 shows that maximum traffic is observed on NH-2 leading to Delhi. A maximum increase of 191 per cent was observed on this cordon. Traffic volume also increased considerably on Lucknow-Jajmau corridor. The traffic volume data on the six cordon points comprise of only 25 per cent of inter-city traffic, the remaining 75 per cent of traffic shows the level of regional interaction.

Table 2.38: Traffic Volume (vehicles/day) on major regional roads

S. No.	Road	Traffic volume In 1987	% of the total traffic	Traffic volume (1994)	% of the total traffic	%Change in traffic
1.	To Unnao-Lucknow	32086	42.82	17452	17.10	-45.6
2.	To Lucknow (on Jajmau corridor)	7420	9.90	15202	14.90	+104.9
3.	To Allahabad	8982	11.99	17012	16.67	+89.4
4.	To Hamirpur	9893	13.20	12513	12.26	+26.5
5.	To Kalpi	8567	11.43	16617	16.29	+93.9
6.	To Delhi	7983	10.66	23238	22.78	+191.1
	Total	**74931**	**100.00**	**102034**	**100.00**	**+36.2**

Source: Compiled from Kanpur Development Authority, 1997

Table 2.39: Goods Traffic volume (truck/day) on major regional roads

S. No.	Road	Traffic volume In 1987	% of the total traffic	Traffic volume (1994)	% of the total traffic
1.	To Unnao-Lucknow	46	0.50	NA	0
2.	To Lucknow (on Jajmau corridor)	2684	29.04	2096	12.23
3.	To Allahabad	1506	16.29	5816	33.96
4.	To Hamirpur	1056	11.43	NA	0
5.	To Kalpi	2368	25.62	4280	25.00
6.	To Delhi	1582	17.12	4933	28.81
	Total	**9242**	100	**17125**	100

Source: Compiled from Kanpur Development Authority, 1997

Table 2.39 clearly illustrates that Lucknow road (Jajmau corridor) carried the maximum goods traffic in 1987 but has come down in due course of time. The goods traffic increased tremendously in 1994 on Allahabad cordon, followed by Delhi NH-2 and road to Kalpi.

2.17 FINANCES

Good financial health of a city is the key to better and smooth functioning of the city and is a pre cursor for its growth and development. In India, the local governing bodies deal with the financial aspects of the various urban services. They are empowered by the Central and State government to collect revenues in the form of taxes and duties, from the people to incur expenditure for providing various services. It is however, observed that the expenditure exceeds the income very often and the local bodies have to borrow from the State governments.

As discussed earlier, Kanpur is governed by various organisations providing various essential services, chief among them are Kanpur Municipal Corporation (Kanpur Nagar Nigam), and Kanpur Development Authority. A brief overview of their income from various sources and the expenditures incurred over the past few years are presented as below:

2.17.1 KANPUR MUNICIPAL CORPORATION (KANPUR NAGAR NIGAM)

Kanpur Nagar Nigam is the local governing body functioning as the third tier of government. Its role and responsibilities have been increased with the passing of 74th Constitutional Amendment Act. Accordingly, the expenses have also increased tremendously but there is no well defined scheme for the income to meet the required expenditure. The main functional aspects of Kanpur Nagar Nigam are related to medical and health facilities, solid waste management, sanitation, education, roads and street lights, social security and welfare, traffic management, slum up gradation, parks development, urban development, etc. Some major sources of income and their coverage are presented in Table 2.40.

Table 2.40: Sources of income and their coverage in Kanpur

S. No.	Source of Income	Coverage
1.	Taxes	General tax, vehicle tax, animal tax, advertisement tax, entertainment tax.
2.	Income from property and other sources	Houses, shops, open land, moveable property, higher education, medical institutes, laboratories, vendors, etc.
3.	Income from land	Sale, rent, etc.
4.	Sanitation and sewage farm	Water tax, sale of water, industrial sewage disposal, etc.
5.	Grants and aids	General provision, secondary schools, other education, medical, foreign aid, road construction, grants lieu of octroi, slum, environment, etc.
6.	Capital accounts	Loan from government, International Institutes, etc.

The budget statements of the Kanpur Nagar Nigam has been carefully studied for the last few years (1990-91 onwards)and is presented in Table 2.41.

Table 2.41: Income-expenditure of Kanpur Municipal Corporation

S. No.	Item	1990-91 (in lakhs)	Percentage	1991-92	Percentage	1992-93	Percentage
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	INCOME						
1.	Taxes	1159.9	25.5	560.4	11.9	693.8	14.7
2.	Receipts from KNN property and other	102.8	2.3	287.8	6.1	263.2	5.6
3.	Income from Nazul	0.9	0.0	0.7	0.0	1.6	0.0
4.	Income-Water & Sanitation services	1.3	0.0	4.3	0.1	3.6	0.1
5.	Receipts under special acts	3.6	0.1	5	0.1	3.5	0.1
6.	Grants & contribution	2616.4	57.4	3342	70.8	3190.5	67.5
7.	Income & interest	40.7	0.9	59.4	1.3	3.7	0.1
8.	Miscellaneous income	69.4	1.5	155.9	3.3	54.7	1.2
9.	Capital account receipt	179.3	3.9	224.6	4.8	416.2	8.8
10.	Suspense account receipt	117.8	2.6	1	0.0	77.9	1.6
11.	Recoveries and advance	265.2	5.8	78.4	1.7	20.4	0.4
	TOTAL INCOME	4557.3	100	4719.5	100.0	4729.1	100.0
	EXPENDITURE						
1.	Central Administration	385.6	7.9	324.2	6.6	344.5	7.5
2.	Sanitation	1580.6	32.4	1541	31.3	1741.6	37.7
3.	Public health	265.5	5.4	353.9	7.2	299.4	6.5
4.	Public Safety +Facility	517.5	10.6	468.2	9.5	422.2	9.1
5.	Public works	960.8	19.7	596.1	12.1	562.5	12.2
6.	Primary education	229.5	4.7	277.2	5.6	283.6	6.1
7.	Other	310.3	6.4	781.9	15.9	531.5	11.5
	Total Revenue account	*4249.8*		*4342.5*		*4185.2*	
8.	Capital Account	539.6	11.1	415.5	8.4	281.1	6.1
9.	Suspense account	85.2	1.7	169.2	3.4	151.4	3.3
	TOTAL EXPENDITURE	4874.6	100.0	4927.2	100.0	4617.7	100.0

Table 2.41 (Continued)

S. No.	Item	1993-94 (in lakhs)	Percentage	1994-95	Percentage	1995-96	Percentage
		(10)	(11)	(12)	(13)	(14)	(15)
	INCOME						
1.	Taxes	763	15.4	586.3	12.3	635.8	10.4
2.	Receipts from KNN property and other	257.5	5.2	223.9	4.7	133.9	2.2
3.	Income from Nazul	0.7	0.0	0.3	0.0	0.4	0.0
4.	Income-Water & Sanitation services	7.8	0.2	5.5	0.1	5.9	0.1
5.	Receipts under special acts	4.1	0.1	4.2	0.1	3.8	0.1
6.	Grants & contribution	3620	73.0	3751.9	78.9	4252.4	69.4
7.	Income & interest	-	0.0	20.3	0.4	0	0.0
8.	Miscellaneous income	125.2	2.5	101.6	2.1	684.6	14.5
9.	Capital account receipt	73.2	1.5	-	0.0	350	7.4
10.	Suspense account receipt	90.4	1.8	61.5	1.3	59.7	1.3
11.	Recoveries and advance	19.5	0.4	-	0.0	0	0.0
	TOTAL INCOME	4961.4	100.0	4755.5	100.0	6126.5	100.0
	EXPENDITURE						
1.	Central Administration	376.7	7.5	382.1	8.2	439.9	8.8
2.	Sanitation	1887.8	37.4	1926.3	41.2	2104.7	42.2
3.	Public health	308.8	6.1	351.1	7.5	365.6	7.3
4.	Public Safety +Facility	396	7.8	366.2	7.8	444.3	8.9
5.	Public works	439.9	8.7	589	12.6	506.1	10.1
6.	Primary education	311.4	6.2	317.3	6.8	322.2	6.5
7.	Other	627.4	12.4	591.7	12.6	672.4	13.5
	Total Revenue account	*4348.0*		*4523.8*		*4855.3*	
8.	Capital Account	572.5	11.3	53.1	1.1	48.3	1.0
9.	Suspense account	130.6	2.6	103.3	2.2	86.5	1.7
	TOTAL EXPENDITURE	5051.1	100.0	4680.2	100.0	4990.1	100.0

Table 2.41 (Continued)

S. No.	Item	1996-97 (in lakhs)	Percentage	1997-98	Percentage	1998-1999	Percentage
		(16)	(17)	(18)	(19)	(20)	(21)
	INCOME						
1.	Taxes	771.6	12.8	844.2	12.9	975.6	12.6
2.	Receipts from KNN property and other	264.4	4.4	265.3	4.1	419.8	5.4
3.	Income from Nazul	0.6	0.0	0.3	0.0	0.2	0.0
4.	Income-Water & Sanitation services	9.1	0.2	12.2	0.2	9.8	0.1
5.	Receipts under special acts	4.6	0.1	5.1	0.1	5.1	0.1
6.	Grants & contribution	4647.6	77.0	5039.5	77.0	5537.9	71.5
7.	Income & interest	27.2	0.5	25	0.4	1.2	0.0
8.	Miscellaneous income	50.1	0.8	100.9	1.5	78.4	1.0
9.	Capital account receipt	0	0.0	0	0.0	0	0.0
10.	Suspense account receipt	258.9	4.3	253.1	3.9	586.9	7.6
11.	Recoveries and advance	0	0.0	0	0.0	132.4	1.7
	TOTAL INCOME	6034.1	100.0	6545.6	100.0	7747.3	100.0
	EXPENDITURE						
1.	Central Administration	450.9	7.3	467.2	7.1	510.2	7.1
2.	Sanitation	2420.6	39.1	2801.3	42.4	3306.2	45.9
3.	Public health	352.7	5.7	344.8	5.2	372.7	5.2
4.	Public Safety +Facility	481.5	7.8	532.8	8.1	533.4	7.4
5.	Public works	853.4	13.8	917.8	13.9	669.8	9.3
6.	Primary education	391.5	6.3	428.5	6.5	453.3	6.3
7.	Other	764.3	12.3	880.1	13.3	1000.9	13.9
	Total Revenue account	*5714.9*		*6372.5*		*6846.5*	
8.	Capital Account	382.3	6.2	35	0.5	3	0.0
9.	Suspense account	91.9	1.5	196.3	3.0	346.5	4.8
	TOTAL EXPENDITURE	6189.1	100.0	6603.8	100.0	7196	100.0

Table 2.41 (Continued)

S. No.	Item	2002-03 (in lakhs)	Percentage	2003-04	Percentage	2004-05	Percentage	2005-06	Percentage
	INCOME	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)
1.	Taxes	1718.3	14.9	2935	18.2	2935	18.7	3160	18.9
2.	Receipts from KNN property and other	1056.7	9.2	2334.8	14.5	2384.5	15.2	2392.5	14.3
3.	Income from Nazul	0.02	0.0	1.1	0.0	1.1	0.0	1.1	0.0
4.	Income-Water & Sanitation services	6	0.1	6.5	0.0	6.5	0.0	6.5	0.0
5.	Receipts under special acts	4.9	0.0	6.5	0.0	8.5	0.1	14.5	0.1
6.	Grants & contribution	0.4	0.0	2	0.0	2	0.0	100	0.6
7.	Income & interest	7944.1	69.1	9125	56.5	9725	61.9	10125	60.6
8.	Miscellaneous income	169.4	1.5	150	0.9	150	1.0	150	0.9
9.	Capital account receipt	0	0.0	0	0.0	0	0.0	0	0.0
10.	Suspense account receipt	221.5	1.9	190	1.2	190	1.2	190	1.1

Table 2.41 (Continued)

S. No.	Item	2002-03 (in lakhs)	Percentage	2003-04	Percentage	2004-05	Percentage	2005-06	Percentage
	INCOME	(22)	(23)	(24)	(25)	(26)	(27)	(28)	(29)
11.	Recoveries and advance	382.7	3.3	1395.5	8.6	315.8	2.0	567.6	3.4
	TOTAL INCOME	11504.02	100.0	16146.4	100.0	15718.4	100.0	16707.20	100.0
	EXPENDITURE								
1.	Central Administration	676.1	6.7	737	4.7	745	4.9	745	4.6
2.	Sanitation	3883.6	38.5	4056	25.6	4506	29.7	4621	28.5
3.	Public health	521.8	5.2	640.7	4.0	640.7	4.2	820.7	5.1
4.	Public Safety +Facility	949.9	9.4	2335.8	14.8	1847.8	12.2	1943.8	12.0
5.	Public works	1720.1	17.0	1910	12.1	2410	15.9	2825	17.4
6.	Primary education	659.7	6.5	710.5	4.5	710.5	4.7	710.5	4.4
7.	Other	1214.7	12.0	4532.7	28.6	3532.7	23.3	3584.7	22.1
	Total Revenue account	*9625.9*		*14922.7*		*14392.7*		*15250.7*	
8.	Capital Account	337.4	3.3	702	4.4	552	3.6	752	4.6
9.	Suspense account	127.6	1.3	206	1.3	206	1.4	206	1.3
	TOTAL EXPENDITURE	10090.9	100.0	15830.7	100.0	15150.7	100.0	16208.7	100.0

Note: Data for the year 1999-2000, 2000-01, 2001-02 are not available.

Source: KNN, Municipal budget reports for various financial years

The earnings from Kanpur Nagar Nigam property and others, has increased considerably from 2.3 per cent in 1990-91 to 14.3 per cent in 2005-06. Expenditure was more than income in 1990-91, 1991-92, 1993-94, 1996-97, and 1997-98. However, the recent trend 1998 onwards show that expenditure is less than or almost equal to the income generated. Income from grants and aids reduced drastically from 2002 onwards. The reason is the end of GAP-phase 1 and phase 2 in the year 2001, aided by the Dutch government.

Sanitation takes away the maximum spending and has been consistently increasing every financial year. Expenditure on public health is a meagre 4.2 per cent in the year 2005-06. However, the major share of expenditure is on wages and salaries of all the concerned departments under the Corporation.

2.17.2 Kanpur Development Authority

The primary function of Kanpur Development Authority is development of land and houses, industries, trade and commerce, repair and maintenance of roads, green belts, parks ,etc. and approving maps.

The main income of Kanpur Development Authority is accounted by capital income from sale of land, sale of houses, loans from government and financial institutions while the primary expenditure is on development and construction work and payment of loans. The details of income and expenditure statement for the financial years 1994-95 and 1995-96 is presented in Table 2.42.

Table 2.42: Income-expenditure of KDA for 1994-95 and 1995-96

S. No.	Item	Actual 1994-95			Actual 1995-96		
		Amount (in lakhs)	%	Per capita (Rs.)	Amount (in lakhs)	%	Per capita (Rs.)
	INCOME						
1.	Income from rent of colonies and lease	145.00	1.32	6.36	175.00	1.39	7.47
2.	Income from Transfer of immovable properties	80.00	0.73	3.51	85.00	0.68	3.63
3.	Income from Housing department	125.10	1.14	5.49	66.60	0.53	2.84
4.	Income from Registration	450.00	4.11	19.75	450.00	3.58	19.21
5.	Income from Other Revenues	155.50	1.42	6.82	155.50	1.24	6.64
	Income under Revenue A/C	955.60	8.73	41.94	932.10	7.42	39.78
6.	Income from sale of land	5001.00	45.67	219.49	4189.25	33.34	178.79
7.	Income from sale of houses and shops	2923.00	26.69	128.29	2969.95	23.64	126.76
8.	Income from Govt.-Grants - Loans	25.00 867.40	0.23 7.92	1.10 38.07	45.20 433.10	0.36 3.45	1.93 18.48
9.	Income from HUDCO bank and other financial institutions	796.60	7.28	34.96	3633.00	28.92	155.06
10.	Income from adjustments of advances given to employees	100.00	0.91	4.39	100.00	0.80	4.27
11.	Income from Deposit Works	200.00	1.83	8.78	200.00	1.59	8.54
12.	Income from enchasing deposits	60.00	0.55	2.63	25.00	0.20	1.07
13.	Other Capital income	21.50	0.20	0.94	36.50	0.29	1.56
	Income under Capital A/c	9994.50	91.27	438.66	11632.00	92.58	496.45
	TOTAL INCOME	10950.10	100.00	480.60	12564.10	100.00	536.23

Source: Kanpur Development Authority

2.19 SUMMARY

The study area enjoys a central position in the Uttar Pradesh State and is blessed with perennial sources of surface water in the form of rivers Ganga and Pandu and has rich alluvial soil. It is well connected by roads and railways to all important cities, towns and rural areas giving it leverage for developing into a prime industrial, trade and commerce centre. The growth of the city from a small town to its current form has three distinct phases. The first phase is its structure before 1857 when there was only Cantonment and Civil Lines. During the rising of 1857 before the war of independence, it became the epicenter of the struggle for freedom in the region. Post independence, the city grew sporadically in some parts and in a more planned manner in others. The Urban Agglomeration has a total area of 298.98 sq km. As far as demographic growth is concerned, Kanpur underwent a decrease in decadal variation in population between 1961 and 1991, and again showed a slight increase in 1991-2001. However, in terms of absolute population it is the most populated city of Uttar Pradesh State. The overall population density in the city was 183.11 persons/hectare in 2001 while the overall literacy rate in the Corporation area was 78.7 per cent. It has a sex ratio of 857 males per 1000 females, a rate lower than the State average. The city has a huge population living in slums and 14.6 percentage of the total population is estimated to be living in slums. Zone 5 has the highest number of population living in slums. Based on the spatial density of population, the city can be delineated in three areas, viz., core area, intermediate and peripheral area. An attempt is also made to project the future population growth pattern spatially. Physical and social infrastructure is also carefully studied. Public transport is poor in the city leading to high growth in personalized vehicles. The city paradoxically faces drinking water supply shortage of 122 mld (1991). Only 13.4 per cent of the total area in the city is connected to sewer line. For the treatment of waste, there is an existing installed capacity of 171 mld but the plants are

3. Health = (Life Expectancy-25)*50/60 + (32-Child mortality) * 50/31.92

= (70-25)*50/60 + (32-45)*50/31.92

= 37.5 + 20.36

= 57.86

For U.P. the male life expectancy is 63.54, hence for urban city like Kanpur it has been assumed as 70.The Child mortality at birth for urban India (Census 2001) is 45.

4. Education = Literacy *25 + Combined enrolment*25

= 0.7*25 + 529970/2037333*25

= 17.5 + 6.5

= 24

5. Product = (log City Product-4.61) * 100/5.99

Where City Product is not given, it is calculated by following:

City Product*Household size = 0.45 * Mean Household Income(annual)

CP = 0.45*25000/6.1

= 1844

C. P is close to per capita SDP hence, it is correct.(Per capita net State Domestic product for Uttar Pradesh State is Rs. 2000-3000)

Product = (log1844-4.61) * 100/5.99

= 49.7

City Development Index = (Infrastructure Index+Waste Index+Education Index+Health Index+City Product Index)/5

= 39.2

For Bangalore city, CDI is 58;

Stockholm, = 97.4

2.18 CITY DEVELOPMENT INDEX (CDI)

The City Development Index is an index to compare the performance of a city. It is considered to be the best single measure of the level of development in cities. It is a composite index made of five sub-indices for infrastructure, waste management, health, education and city product. The sub-index Infrastructure depends on the number of water connections, sewage, electricity and telephone connections. The rest of the sub-indices cover other infrastructure. Each sub-index is a combination of several indicators that have been normalized to give a value between 0 and 1. It is defined at the city level and could also be taken as a measure of average well-being and access to urban facilities by individuals and it is a proxy for the capital and physical capital assets of the city.

City Development Index is also quoted as a good index of urban poverty and urban governance [338]. Infrastructure, waste and city product components (sub-indices) are indicators of measuring the effectiveness of governance in a city whereas health, education and infrastructure components show the poverty outcomes of a city.

The formulae used for calculating City Development Index are as under:

1. Infrastructure = 25 *Water connections +25*Sewerage+25*Electricity+25*Telephone

   = 25* 0.6955(for year 1991) + 25*40/262 + 25*228510/353203 + 25*71192/353203

   = 17.3875 + 3.8168 + 16.1741 + 5.039

   = 42.4

2. Waste = Wastewater treated *50 + Formal solid waste disposal *50

   = 171/390 * 50 + 0*50

   = 21.9

Note: Actual waste water treated is lesser as the plants are not running to their full capacities

Table 2.42 (Continued)

S. No.	Item	Actual 1994-95			Actual 1995-96		
		Amount (in lakhs)	%	Per capita (Rs.)	Amount (in lakhs)	%	Per capita (Rs.)
	EXPENDITURE						
1.	Expenditure on Administration	650.00	5.95	28.53	650.00	5.19	27.74
2.	Miscellaneous	300.00	2.75	13.17	300.00	2.40	12.80
	House maintenance works	87.00	0.80	3.82	18.50	0.15	0.79
	Expenditure on advances given to staff for house building and land procurement	25.50	0.23	1.12	10.50	0.08	0.45
	Expenditure incurred for returning other fixed deposits and earnest money	460.00	4.21	20.19	147.00	1.17	6.27
	Total Revenue Expenditure	1522.50	13.95	66.82	1126.00	8.99	48.06
3.	Expenditure on Stores Material	25.00	0.23	1.10	66.00	0.53	2.82
4.	Expenditure on Procuring land	300.00	2.75	13.17	400.00	3.19	17.07
5.	Expenditure on						
	- Development works	2751.00	25.20	120.74	3175.00	25.36	135.51
	- Construction works	1392.80	12.76	61.13	403.60	3.22	17.23
	- Construction of parks and other community centres	152.50			1150.20		
6.	Expenditure on - Payment of instalments	987.10	9.04	43.32	1017.10	8.12	43.41
	- Payment of interest	939.10	8.60	41.22	1094.20	8.74	46.70
	- Payment of new agreed loans	80.00			200.00		
	- Payment of loans and interest	2465.90			3777.70		
7.	Expenditure on Deposit works	200.00	1.83	8.78	10.00	0.08	0.43
8.	Expenditure on Temporary Advances	100.00	0.92	4.39	100.00	0.80	4.27
9.	Other expenditures	0.00	0.00	0.00	0.00	0.00	0.00
	Expenditure under Capital A/C	9393.40	86.05	412.27	11393.80	91.01	486.28
	TOTAL EXPENDITURE	10915.90	100.00	479.10	12519.80	100.00	534.34

Source: Kanpur Development Authority

The table illustrates that the main income of Kanpur Development Authority is from capital income through sale of land, sale of houses, loans from government and financial institutions. Expenditure is mainly on development and construction work and payment of loans and interest. The total revenue accrued from all sources is not found sufficient to meet the expenditure.

running below capacity and face a lot of operational and financial problems. Drainage is poor in most parts of the study area. Surface water quality is abysmally poor due to various reasons. Solid waste management is also poor. The quantity and quality of power supply is not good in the city. Education wise, the study area is blessed with the presence of number of institutes of repute. The area lacks in public places and well maintained parks. The study area is a prime centre for industries and a number of wholesale and retail markets. A number of agencies are involved in urban management. The city faces all kinds of pollution and needs immediate remedial measures. The City Development Index of the city, which is a good indicator of a city's performance, is also calculated and comes out to be a low 39.2.

2.20 CONCLUSIONS

In this Chapter, the Investigator has attempted to have an in-depth knowledge about various aspects of the study area, like, climatological factors, physiography, historical growth, dynamics of growth pattern, demographic characteristics, various infrastructure including housing, water supply, sewerage, solid waste management, education facilities, traffic and transport, built environment, pollution loads, various government agencies involved in the management of city and the overall City Development Index for actual assessment of the city development wise.

Chapter 3

SOLID WASTE MANAGEMENT IN KANPUR: EXISTING STATUS

3.0 INTRODUCTION

Kanpur, the largest metropolitan city of Uttar Pradesh represents the typical North Indian industrial city, characterized by narrow roads and lanes, environmental pollution, public apathy towards cleanliness and poor waste management. Kanpur lies in the composite zone with an average rainfall of 860 mm/year. It has hot summers and cold winters. The climate is conducive to make the waste decompose faster. This makes it essential to frequently clean the waste from the numerous generation points. The city however, continues to be one of the dirtiest cities and need systematic planning, implementing and monitoring of an integrated solid waste management plan.

This section systematically studies the existing scenario of Solid Waste Management in the industrial city of Kanpur based on secondary data sources, discussion with experts and field observations.

3.1 LEGISLATION ON SOLID WASTE

There are a number of legislations at National, State and Local level, which govern the management of municipal solid waste in Kanpur city. They are as follows [167]:

- The Uttar Pradesh 'Municipal Corporation Act of 1959' gives a description of few aspects of solid waste management, but is not comprehensive and detailed in nature.
- The Municipal Waste (Management and Handling) Rules, 1999 by the Central government describes certain parameters and compliance criteria for various elements

of solid waste management. The District Magistrate or the Deputy Commissioner is the enforcing agency.

- A draft 'Manual on municipal solid waste management', 2000 issued by the Ministry of Urban Development, Government of India, is a practical tool for guiding the planning and designing the solid waste management services .
- At State level, the Uttar Pradesh 'Plastic and other non-biodegradable garbage Ordinance of July, 2000', prohibits the littering of non-biodegradable waste in public drains and use of recycled plastics for food packaging purposes.
- Bio-Medical Waste (Management and Handling) Rules, 1998: Issued by the Ministry of Environment, this prescribes ten categories of bio-medical waste generated from health care facilities, different ways of their storage, treatment and disposal methods.
- Hazardous Wastes (Management and Handling Rules), 1989: Issued by the Ministry of Environment and Forests, this covers waste generated from manufacturing units like chemicals, dyes, paints, glues, tannery, etc., to ensure that the hazardous wastes produced are properly handled and disposed off. The State Pollution Control Board is the enforcing agency.

3.2 THE MUNICIPAL CORPORATION OF KANPUR

Kanpur had Municipal Board till 1925 when Improvement Trust was also created to supervise the developmental activities of the city. Improvement Trust Development Board was formed in 1935 and it continued up to 1959. In 1959, the same was replaced by Nagar Mahapalika Act and followed by the creation of Nagar Nigam (Municipal Corporation).

The Municipal Corporation is the local body for maintaining sanitary and hygienic condition (including health and solid waste management) of the city including birth-death registration, cleaning of roads (bye lanes), construction and maintenance of kaccha/ pacca roads, maintenance of surface drains, management of lower level education, water supply by means of bore wells / hand pump, etc. The revenue is generated from house tax, sale of unused municipal properties, business tax, tax from Tehbazar, etc.

It is headed by the Mayor and a board of 12 corporators. The administrative head of the Corporation is the Mukhya Nagar Adhikari (MNA), also called Municipal Commissioner. The organogram of the Corporation is presented in Fig 3.1.

Three departments of Kanpur Nagar Nigam are involved in solid waste management.

1. Health Department: Primary collection of waste comes under the purview of Health department.
2. City Cleansing Department: Secondary collection, transportation and disposal of waste come under the purview of this department.
3. Engineering Department: This section deals with the repair and maintenance of vehicles.

The three departments work on their own without any co-ordination among them.

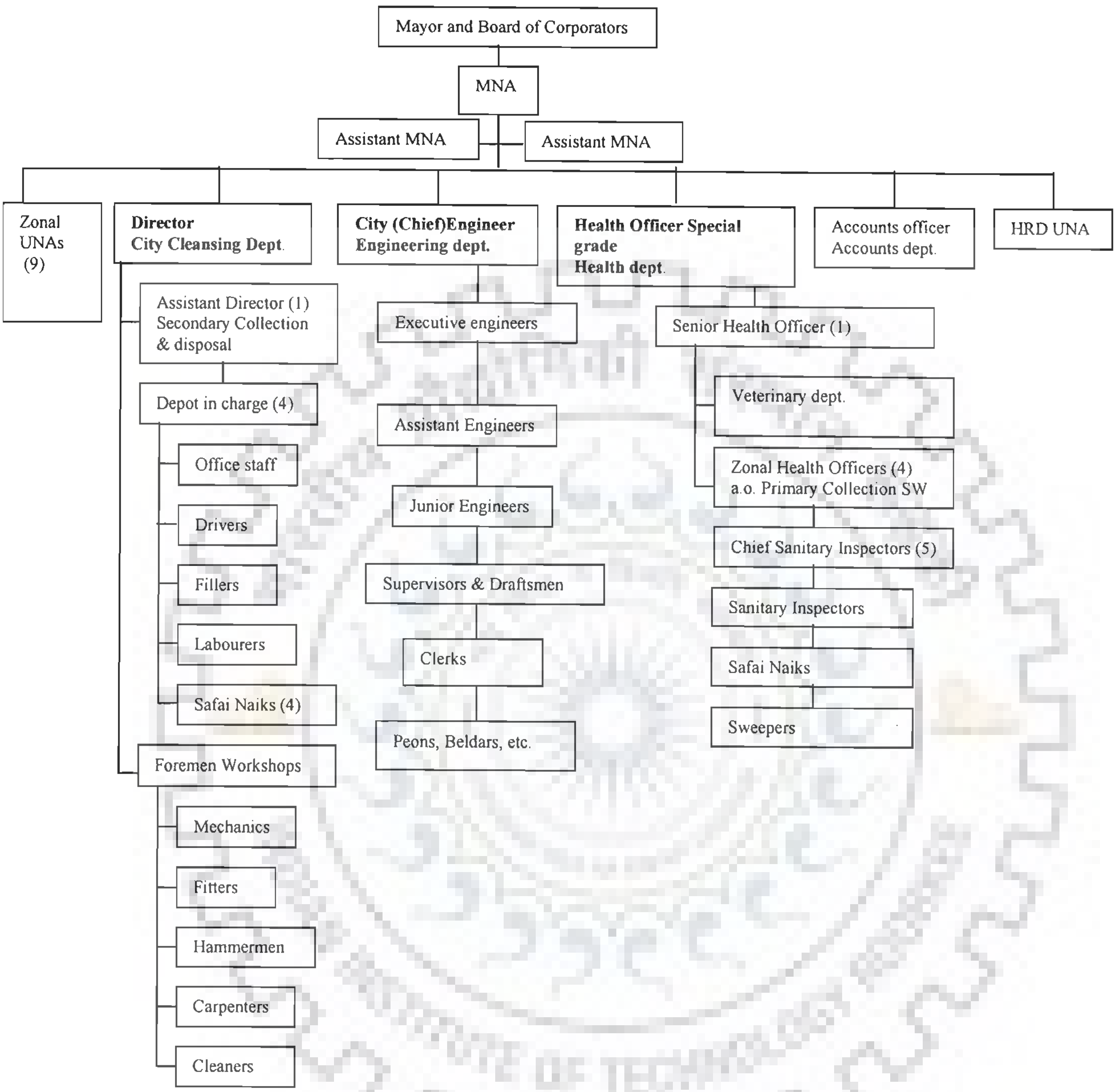


Fig. 3.1: Organogram of Kanpur Nagar Nigam (KNN)

3.3 WASTE CHARACTERISTICS

3.3.1 WASTE GENERATION POINTS

The generators of waste can be categorized as (1) households and institutions (2) commercial establishments (3) health-care facilities (4) industries (5) slaughterhouses (6) animal husbandry and dairies (7) wastewater treatment plant and (8) others.

1. Households and institutions

This includes waste generated by the households and comprise of kitchen waste, plastics, paper, glass, metals, garden waste and inert materials along with some hazardous waste like batteries, paint residues, fluorescent tubes, etc. Certain types of waste like old magazines and newspaper, glass, metals, and thick plastics, cans, etc., are stored and directly sold to the itinerant waste buyers. Rest of the mixed (unsegregated) waste is either dumped on the streets or brought to the communal collection point (bins of some form). A common practice observed in Kanpur during the study is that the middle and high-income group monthly pay to the municipal sweepers or their servants to daily collect waste from their houses and transporting to some collection point.

2. Commercial establishments

Wastes from commercial establishments include both biodegradable and non-biodegradable wastes. Vegetable markets, restaurants, small food-processing businesses, vegetable vendors and the numerous informal sector food-dhabas (small eateries), bakeries, etc., produce bio-degradable wastes. The commercial establishments on the other hand, mainly produce paper and plastic wastes too.

3. Health-care facilities

Health-care facilities generate infectious and non-infectious waste. Infectious waste comprises of pathological waste like, tissues, organs, blood, body fluids and items like, IV tubing, blood bags, items contaminated with blood, and sharps. Non-infectious waste comprises of general office waste and kitchen waste. Most of the health-care facilities in Kanpur do not segregate their infectious and non-infectious waste. It often gets mixed with municipal waste, posing threat to health and environment. Open burning of such waste is also observed in the city. There is a rampant illegal recycling sector which recycles and reuses the infectious waste. Table 3.1 presents a list of existing health-care facilities in Kanpur city.

Findings of Central Pollution Control Board (CPCB) however, indicate that there are 407 odd hospitals and nursing homes (43 government and semi-government hospitals, 360 private nursing homes and 4 defence hospitals) in Kanpur. The combined bed capacity of all the above health-care facilities is estimated to be 11,140 and the bio-medical waste generated is 3,550 kilograms per day [169]. There is no proper disposal system for infectious waste. Even reputed hospitals such as Lala Lajpat Rai (LLR) hospital burn their medical waste along with ordinary garbage in their premises while Murarilal Chest Clinic which, primarily deals with tuberculosis (TB) patients drains down its hospital waste at the Bhaironghat; such waste thereby gets mixed with the Ganga water, the main raw water source for the city. Only 50 nursing homes have some kind of combined incinerator facility, which also remains underutilised. The four defence hospitals also have incinerator facility.

Table 3.1: Existing Healthcare facilities in Kanpur

S. no.	Healthcare facility	No.	Name	Beds
1.	Government hospitals	1 2 3 4	UHM KPM T.B. Clinic, Doodh wala bangla AHM Dufferin	450 90 NA 210
2.	ESI hospitals	5 6 7 8 9	Chest hospital, Pandu nagar Maternity Hospital, Sarvodaya nagar Azad nagar Kidwai nagar Jajmau	312 144 180 100 100
3.	KNN hospitals	10 11 12 13	Jan hitkari eye hospital, Govind nagar Chacha Nehru Children hospital,Cooperganj B.N.Bhalla Hospital, Babupurwa 9 Maternity centers	100 100 24 90
4.	LLR & Associated hospitals	14 15 16 17 18	LLR Children hospital IDH Upper India Sugar Exchange Maternity Hospital Murari Lal Chest Diseases Hospital	1055 100 87 225 210
5.	Private hospitals	19 20 21 22	Mariampur hospital Laxmipati Singhania Cardiology Institute J.K.Cancer Institute J.L.Rohtagi Eye hospital	200 100 106 272
6.	Nursing homes	23-63 63-163	Member of Association Non-member of Association (100 approx.)	1000 2000
	Total	*163*		*7255*
	Pathological labs and Blood banks	NA		
	Defense hospitals	4		
	Railway hospital	NA		

Source: ICDP, 2001

A summary of the estimated generation of biomedical waste and its collection in Kanpur city is presented in Table 3.2. It has been observed that only 1350 kg of the estimated 6750 kg of biomedical waste is treated in the incinerator. The rest is recycled by the informal sector or gets mixed with municipal waste or is illegally burned.

Table 3.2: Details of biomedical waste in Kanpur

S.No.	Quantity Generated per day	Collected	Frequency of Collection	Treated	Place of Disposal
1.	6750 Kg	1350 Kg	Daily	1350	site at Bhowti

Note: An estimated 5400Kg recycled per day.

Source: Kanpur Nagar Nigam

4. Industrial Waste

Kanpur, an industrial city, has 75 large and medium scale industries along the railway line and Grand Trunk road. It is also famous for its leather tanneries. The official count of small and big tanneries is 364 but latest findings (2005) put the figure at 400. Besides this, there are approximately 5457 mixed small-scale ancillary manufacturing units listed in Kanpur and are presented in Table 3.3 [87].

Table 3.3: List of Small-scale industries in Kanpur

S. No.	Type of Small-scale industry	Number
1.	Metal Products	830
2.	Leather products	819
3.	Food products	443
4.	Rubber & Plastics	416
5.	Machinery parts	396
6.	Hosiery and garments	387
7.	Chemical units	337
8.	Paper products	318
9.	Cotton textiles	246
	Total	*4192*

Source: CPCB, 2001

About 1, 35,000 metric tones of hazardous industrial waste generated annually, which needs to be safely and scientifically disposed off, is left out in the open to damage the ecology and seep into the ground aquifers [358]. The details of the hazardous waste generated are presented in Table 3.4.

Table 3.4: Details of hazardous waste generated in Kanpur

S. No.	Type	Quantity Generated (annually) MT	Collected	Frequency of Collected	Treated	Place of Disposal
1.	Industrial waste	64000	NA	Irregular	No treatment	Ganga, Pandu rivers (the portion mixed with municipal waste dumped at Panki); illegal open dumps
2.	Coal ash	71000	NA	Irregular	No treatment	Pandu river
3.	Total	135000				

Source: CPCB, 2001

Though the disposal of industrial waste is not the responsibility of municipality, but field study shows that the mixing of industrial waste (directly or indirectly) with municipal waste is rather a rule and not an exception. The specific highly voluminous and toxic industrial wastes generation points are as follows:

(1) Panki Thermal Power Station: It is a 274 MW installed capacity, operating at 55-60 per cent Plant load factor and uses 40 per cent ash-content coal. It produces 600-800 tons of fly ash every day, which is transported as slurry in Ganga canal water and discharged onto a 104.4 hectare ash pond with a depth of 5-6 meters. The ash-pond water has a pH between 6.5 and 7.5 and enters municipal drains, thereby often blocking the drains.

(2) Tannery Solid wastes: Four types of solid wastes are generated by the tanneries besides the toxic sludge (Kanpur Municipal Corporation). They are:

i. Fleshings, scraped from the inside of hides before processing;

ii. Blue fleshings, if scraping is done after chrome-tanning;

iii. Shavings and buffings, produced after hides are tanned and split or shaped or finished to produce leather. Most of this is reused for manufacturing leather board; and

iv. Finest fractions, often seen as large heaps of waste along road sides. These have to be either cleaned by the municipality or taken away by the rag-pickers.

The solid waste of the tanneries is collected by the Kanpur Nagar Nigam against payment.

5. Slaughterhouses

There are five slaughterhouses in operation generating waste like intestines, carcasses, blood, bone, etc. The skin and bones have market value and hence, collected and resold. The available slaughterhouses located in the city are presented in Table 3.5 and their spatial positions shown in Fig. 3.2. These slaughterhouses generate an approximately 2000 kg of waste daily, of which some is collected by the Corporation daily and the rest is dumped and littered, causing lot of problems to the residents.

Table 3.5: Existing Slaughterhouses

S.No.	*Animal*	*Location*
1.	Buffalo	Colonelganj
2.	Goat	Colonelganj
3.	Goat	Babu Purwa
4.	Goat	Fazalganj
5.	Pig	Fazalganj

Source: Kanpur Nagar Nigam

6. Animal husbandry and dairies

There are some 900 registered dairy farms in Kanpur city. The actual number is much higher. Apart from cattle, pig rearing is also prevalent in the city. According to a study, the Khatiks (scheduled caste community) and Valmik sweepers, the main pig-breeders own some 75,000 pigs to 100,000 [36, 167]. Pigs represent a source of cheap protein for certain social groups which consume pork, as the pigs rely on low-cost sources of feed – street rubbish, waste from hotels and restaurants, soil and vegetation. Pigs are sold for Rs 15-20 per kg liveweight and Rs 35-50 per kg pork*. While almost all pigs roam the streets by day, only about 25 per cent sleep on the roads at night and the remaining 75 per cent spend the night in a covered pig-sty. Some of the areas having pigs on large scale are Govindnagar, Barra, Juhi, Ompurwa, Tatmill, Bakarmandi, Jajmau*. Waste generated by cattle and pigs include dung and used straw, *kanaa* (used to feed pigs) and mainly ends up on the streets and in the drains.

7. Waste water treatment plant

There are three wastewater treatment plants in Kanpur and are as follows:

i) one 5 mld domestic sewage treatment plant based on Upflow Anaerobic Sludge Bed (UASB) principle,

ii) one 130 mld domestic sewage treatment plant based on consecutive pond system, and

iii) one 36 mld domestic and tannery waste water treatment plant (3:1 mix) based on UASB principle.

There is 53 tons of toxic sewage sludge (the daily production of sludge shows a wide variation as per the ICDP-II [168] produced from these treatment plants at Jajmau, which is transported

* Field study conducted by the Investigator between 2003-2005

by the Kanpur Nagar Nigam's garbage trucks to the 12.4 hectare site at Rooma. Rooma site is the approved hazardous-waste disposal site but it completely lacks the required infrastructure. The waste is carelessly deposited along the roadside. The waste burns easily and often taken by the people to their home to burn in winters. The burning converts the trivalent chromium to hexavalent chromium, causing environmental damage. The generation of hazardous waste containing chromium is about 10-15 MT per day.

8. Others

This includes wastes generated in temples as a result of offerings of flowers and fruits, construction and demolition of debris, wastes from forest department, gardens and parks, marriage parties and ceremonies and silt from city drains.

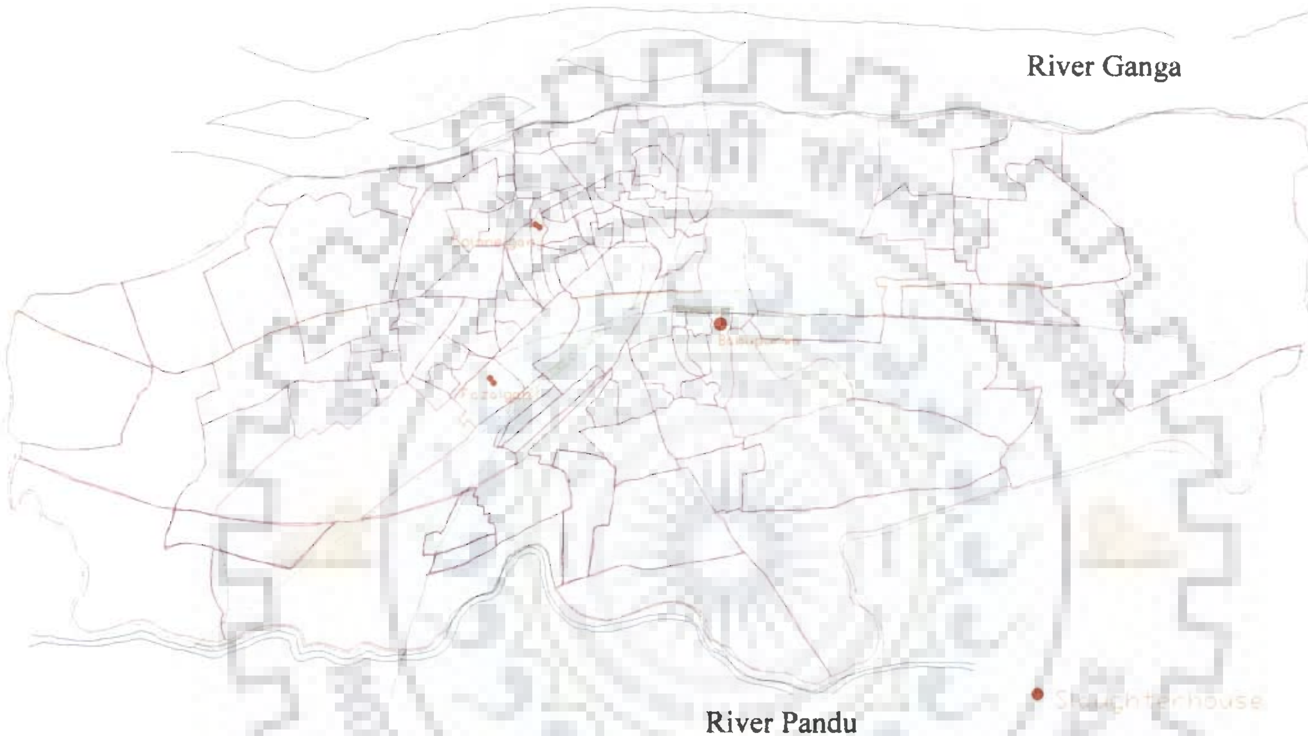


Fig. 3.2: Location of Slaughter houses in Kanpur city

3.3.2 WASTE CHARACTERISTICS

It is important to study the physical and chemical characteristics of the municipal waste generated by a city as it helps in proper planning, designing and managing the waste. The physical characteristics of the municipal waste generated in Kanpur city are presented in Table 3.6 and Fig. 3.3, 3.4, 3.5 and 3.6. The table clearly shows that biodegradables constitute a major part in the waste generated in residential and industrial areas. The quantity of inert materials is also observed to be very high.

Table 3.6: Physical Analysis of Kanpur City Refuse **(Dry weight by per cent)**

S.N	Item	Mixed	Door to Door HIG	Resi HIG	MIG	LIG	Veg. M	Comm Area	Indus Area	Collection depot	Disp site
	Sample	1	2	3	4	5	6	7	8	9	10
1	Biodegradable	34.94	58.60	59.96	38.65	29.27	34.94	29.27	58.60	59.96	38.65
2	Paper	3.69	5.12	5.77	4.80	0.59	3.69	0.59	5.12	5.77	4.80
3	Plastics	6.22	5.40	5.91	5.10	4.18	6.22	4.18	5.40	5.91	5.10
4	Rubber & Leather	2.69	2.46	2.90	2.10	0.95	2.69	0.95	2.46	2.90	2.10
5	Rags	5.10	7.55	5.59	3.95	2.27	5.10	2.27	7.55	5.59	3.95
6	Metal	-	-	-	0.01	-	-	-	-	-	0.01
7	Ceramic	-	-	-	0.01	-	-	-	-	-	0.01
8	Inert & Fine Earth	38.8	17.12	16.3	37.22	51.46	38.8	51.46	17.12	16.3	37.22
9	Fine Organic	8.51	3.75	3.57	8.16	11.28	8.51	11.28	3.75	3.57	8.16

Source: Kanpur Nagar Nigam, 1999

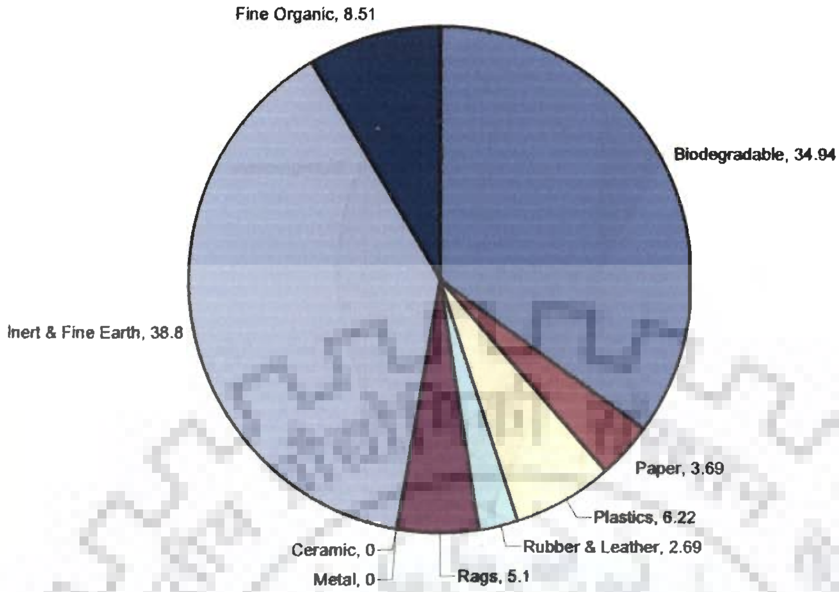


Fig. 3.3: Composition of mixed waste in Kanpur

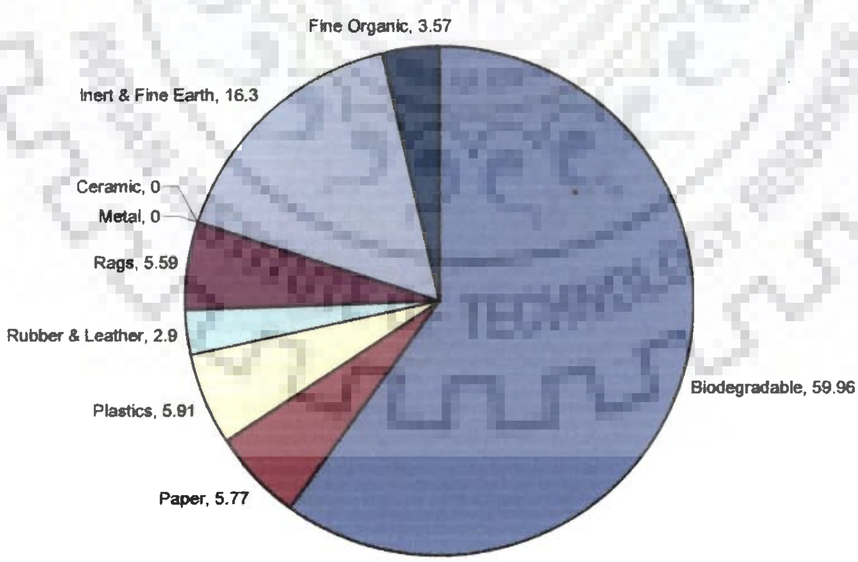


Fig. 3.4: Composition of waste generated by Higher income group in Kanpur

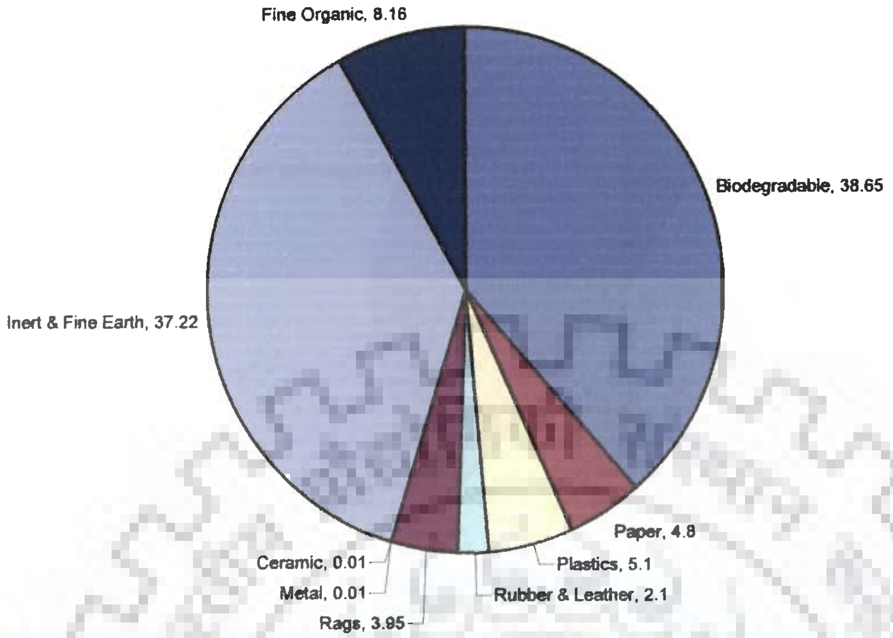


Fig. 3.5: Composition of waste generated by Middle income group in Kanpur

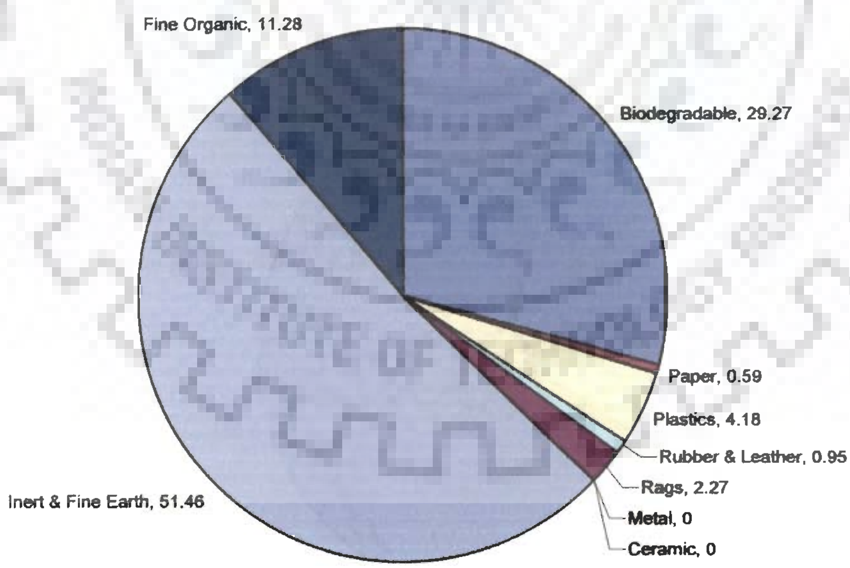


Fig. 3.6: Composition of waste generated by Lower income group in Kanpur

3.3.3 WASTE DENSITY

Waste density is an important parameter for proper designing of a solid waste management system. It has been observed that the average density of municipal wastes in the city is 873 kg/m^3 (between 652 - 98 kg/m^3), based on the ten samples collected from various generation points (Kanpur Municipal Corporation, 2001). This average density is very high compared to that in other cities as shown in Table 3.7. The possible reasons of this wide variation in density of wastes is due to the small sample size and secondly due to the higher amount of cow dung, wet waste and inert materials in the rubbish depots at the time of sampling.

Table 3.7: Density of municipal solid waste in some cities in India

S. No.	City	Density (kg/m^3)
1.	Bangalore	390
2.	Baroda	457
3.	Delhi	422
4.	Hyderabad	369
5.	Jaipur	537
6.	Jabalpur	395
7.	Raipur	405

Source: MOUD, 2000

To analyse the chemical composition of wastes in Kanpur city, wastes generated in different sources such as different income-groups, commercial waste, wastes from industries, vegetable markets, collection depots and disposal site has been considered and the results are presented in Table 3.8.

Table 3.8: Chemical Analysis of Kanpur City Refuse

SN	Item	Mixed	Door to Door HIG	Resi HIG	MIG	LIG	Veg. Market	Com market	Indus	Collection depot	Disp
		1	2	3	4	5	6	7	8	9	10
1	Moisture %	40.50	57.50	60.00	50.00	52.70	64.50	36.50	32.80	37.80	36.80
2	pH	3.00	7.47	7.44	7.80	8.50	6.90	7.70	8.20	7.20	6.75
3	Organic matter %	24.89	51.60	53.00	33.50	21.80	70.50	27.80	12.00	21.80	20.10
4	Organic carbon %	13.80	28.66	29.44	18.61	12.11	39.16	15.44	6.66	12.11	11.16
5	Total nitrogen %	0.45	0.80	0.85	0.50	0.39	1.05	0.50	0.18	0.35	0.32
6	Phosphorus %	0.31	0.45	0.50	0.41	0.25	0.65	0.42	0.11	0.28	0.22
7	Potassium %	0.82	0.59	0.60	0.80	0.68	0.45	0.38	0.85	0.90	0.85
8	c/n	30.72	35.82	34.63	37.22	31.05	37.29	30.88	37.03	34.60	34.89

Source: Kanpur Nagar Nigam ,1999

In the study, 10 samples were taken in total, representing different waste generation sources. Three samples were taken from handcarts in high, middle and lower income group areas. One sample was taken from a ward where house-to-house collection took place by an NGO (CDC). The other samples were taken from a commercial area, a vegetable market, an industrial area, a collection depot before loading on a truck and on the disposal site (Kanpur Nagar Nigam, 1999). The table illustrates that there are wide variations in characteristic features of waste samples from various sources. The moisture content varies from 32.8 per cent in industrial waste sample to 60 per cent in High Income Group waste. The pH value varies from 6.75 in disposal site waste sample to 8.5 in Low Income Group waste sample. Even among the various income group people, there are wide variations like, organic content is very low in Low Income Group waste sample (21.8 per cent) as compared to that in High Income Group waste sample (53 per cent). Phosphorous content is high in vegetable market and High Income Group waste samples. C/N ratio is high in vegetable market and Middle Income Group waste samples and lowest in commercial market waste sample as the latter lacks organic waste.

3.4 WASTE QUANTITIES

3.4.1 INTRODUCTION

Data about the waste quantities from various generation points is a prerequisite for proper designing, handling and management of municipal waste. In a developing country like India, there are hardly any major studies attempted about the amount of waste generated by a city. However, few studies have been undertaken by private organizations or research institutions like National Environmental Engineering Research Institute, Nagpur (NEERI). Even in the few studies available, small sample sizes have been taken which makes the reliability of data questionable. Yearly updating of data is also not available in this regard. Besides, hidden wastes like waste separated in houses for direct sale to itinerant waste buyers and middlemen and given to servants or for charity usually remains unaccounted for. Burning of waste and illegal dumping, often in low-lying areas is also a common practice in Indian cities and towns, which makes the precise estimation of waste generation rather difficult.

3.4.2 WASTE GENERATION

In the absence of any detailed survey about waste generation rates in Kanpur city, a number of estimates can be used, as follows:

1. As per the study of National Environmental Engineering Research Institute, 1996, the average rate of municipal solid waste generation is 0.35 kg/capita/day for cities with a population range between 2 and 5 million inhabitants [245]. This figure is also reported by the Supreme Court and Govt. of India in their manuals.
2. According to the World Bank [165] the average per capita per day waste generation in India is 0.46 kg.

3. According to ICDP-Phase I [167], the figures of waste generation vary between 0.5 and 0.6 kg per capita per day (an average of 0.55 kg/capita/day).

Based on the above waste generation rates, the waste generation estimates are presented in Table 3.9:

Table 3.9: Waste generation estimates for Kanpur urban area*

S. No.	Source Agency	Waste generation (kg/cap/day)	Waste generated (tons/day)					
			1991 (20.37 lakh)	2001 (Census 2001)27.72	2006** (31.40)	2007** (32.0)	2011** (35.0)	2015** (40.0)
1.	NEERI	0.35	712.95	970.20	1099	1120	1225	1400
2.	World Bank	0.46	937.02	1275.12	1444.4	1472	1610	1840
3.	ICDP	0.50	1018.5	1386	1570	1600	1750	2000
4.	ICDP	0.55	1120.35	1524.6	1727	1760	1925	2200
5.	ICDP	0.60	1222.2	1663.2	1884	1920	2100	2400

*Kanpur urban area includes Nagar mahapalika (Corporation area), Bithoor and Kanpur Cantonment

**Based on Projected population data

Source: Compiled by the Investigator

Population projections are based on the projections given in the report "Integrated City Development Project for Kanpur Metropolis-2007, Urban Development Project Phase- II", as it is quite close to the census data for 2001.

Considering a floating population of 2 lakhs and their average waste generation to be 0.3 kg/capita/day, 60 tons of waste is generated by the floating population. Taking the average generation rate of 0.55 kg/capita/day, the waste generation by the resident population of Kanpur city as stated in Table 3.9 for the year 2001 is 1524 tons/day. The total waste generation thus comes out to be 1584 tons/day in the year 2001.

3.4.3 Waste Collection

During the study conducted by ICDP-Phase-II (May-June, 2000), the collected waste accounted to 680 tons per day on an average. This includes silt, sludge, construction and debris, and slaughterhouse waste and some fractions of industrial and hospital waste also. Kanpur Nagar Nigam (KNN), however, claims 90 per cent waste collection of 1266 tons per day.

3.4.4 Gap between generation estimates and collection

The average waste collection as reported by the Kanpur Nagar Nigam is 90 per cent. By field study however, it is estimated to be 42.92 per cent. The remaining 57.08 per cent is the gap between generation estimates and collection. A certain portion of the organic waste is eaten by cows, stray dogs and pigs from the waste collection depots and streets. Stray animals eat up to 5 per cent of the waste generated and almost 14 per cent is recovered by the recycling sector [128, 138]. The estimated gap between waste generation and collection in Kanpur city is presented in Table 3.10.

Table 3.10: Estimation for gaps between waste generation and collection in Kanpur

S. No	Activity	Quantity (t/d)	Percentages (%)
1.	Waste generated in Kanpur (including floating population)	1584	100
2.	Waste collected by KNN	681	43
3.	Animal scavenging	79.2	5
4.	Recovery and Reprocessing	221.8	14
5.	Others - Burning - Illegal dumping - Natural degradation - Non collection, etc.	602	38

3.4.5 COMPARISON OF WASTE GENERATION AND COLLECTION WITH OTHER INDIAN CITIES

Comparison of waste generation and collection rate in various Indian cities is a complex and difficult task due to various reasons like, reliability of the data of various cities, variations in the methodology adopted for estimation of waste generations and collection rate, lack of detailed study in most cities, small size of the sample wherever any detailed study has been taken, etc. Howsoever, an attempt is made to compare the waste generation and collection rate of few Indian cities and is presented in Table 3.11. The table clearly illustrates that Kanpur city has a poor waste collection rate as compared to cities like Surat, Madras, Bombay, etc.

Table 3.11: Comparison of waste generation and collection in few Indian cities

S. No.	City	Population served(million)	Waste generation	Waste collection		Year
				(tons/day)	% of waste generation	
1.	Bombay	10.2	5,001	3,463	69	1994
2.	Surat	2.3	1008	960	95	1999
3.	Ahmedabad	3.2	1450	Not available	-	1996
4.	Lucknow	2.2	1414	635	45	1996
5.	Madras	4.2	2500	1875	75	2001
6.	Delhi	9.8	5000	3000	60	2001
7.	Calcutta	13.2	6800	4964	73	2001
8.	Tripura	0.4	223	158	68	2005
9.	Bangalore	5	3613	1451	40	1999
10.	Kanpur(as estimated)	2.7	1584	681	43	2001

Source: Compiled by the Investigator

3.5. PRIMARY COLLECTION

3.5.1 ORGANIZATION OF PRIMARY COLLECTION

Primary collection of wastes comes under the purview of the Health Department of Kanpur Nagar Nigam (KNN). The city is divided into six zones for primary waste collection; each zone headed by a Zonal Health Officer. At present, there are only four Zonal Health Officers, the remaining 2 zones being looked after by a Health Officer and the Senior Health Officer. A Chief Sanitary Inspector is assigned to each of the six zones, reporting directly to the Health Officer. Each Chief Sanitary Inspector presides over sanitary inspectors, who in turn are reported to by the Safai Naiks. The Safai Naiks are assigned to a number of wards. The sweepers are assigned to beats and report to the Safai Naiks. The structure of the Health department is shown in Fig. 3.7. The existing workforce of the Health department (in 2005) is presented in Table 3.12. The table explains that against the sanctioned post of 6100, there are only 4280 people working in the department, inclusive of the temporary sweepers, and the total gap in the workforce is thus 2631.

Table 3.12: Workforce of the Health Department

	Position	Sanctioned Post	Working	Vacant Post
1.	Zonal Health Officer	6	4	2
2.	Chief Sanitary Inspector	12	5	7
3.	Sanitary Inspector	42	18	24
4.	Safai Naik	184	113	71
5.	Sweeper	5,856	3329	2527
6.	Temporary sweepers	-	811	-
	Total workforce	6100	4280	2631

Source: Kanpur Nagar Nigam

The Public Health Manual states the number of sweepers to be 65 per 10,000 inhabitants. However, the number of sweepers in Kanpur city per 10,000 inhabitants in the year 2005 is 15 only.

A certain distribution of workforce is followed at zonal level for better management of services in a city. In Kanpur also, different number of sweepers have been assigned to various zones and is presented in Table 3.13 and Table 3.14. The tables illustrate zone wise population, the recommended number of sweepers and handcarts and the available number of sweepers and handcarts. Table 3.13 clearly shows that there is shortage of sweepers in all the zones except for Zone 1 while there is shortage of handcarts in all zones except for Zone 2. There is a considerable representation of female sweepers with a ratio of male and female sweepers as 1.2:1.

Table 3.13: Zonal distribution of sweepers for street sweeping and primary collection in Kanpur city

S. No.	Zone No	No. of Wards	Population	Sweepers			Recommended no. of workers	Required no. of workers in Zone	No. of temporary sweepers
				Male	Female	Total			
1	1	15	2,95,867	495	415	910	830	+80	80
2	2	18	5,84,024	236	130	366	1618	-1252	184
3	3	18	3,25,395	431	324	755	908	-153	81
4	4	16	3,02,374	227	313	540	834	-294	77
5	5	25	6,26,858	471	332	803	1733	-930	25
6	6	18	3,97,785	217	160	377	1099	-722	147
Total	6	110	25,32,303	2077	1674	3751	7022	-3271	795

Source: Kanpur Nagar Nigam Report, 2005

Table 3.14: Zonal distribution of handcarts available and required in Kanpur city

S. No.	Zone No.	No. of Wards	No. of new hand carts	Handcarts required	Surplus/Deficit of handcarts
1	1	15	159	288	-129
2	2	18	102	87	+15
3	3	18	155	212	-57
4	4	16	126	143	-17
5	5	25	149	270	-121
6	6	18	94	110	-16
Total	6	110	785	1110	-325

Source: Kanpur Nagar Nigam Report, 2005

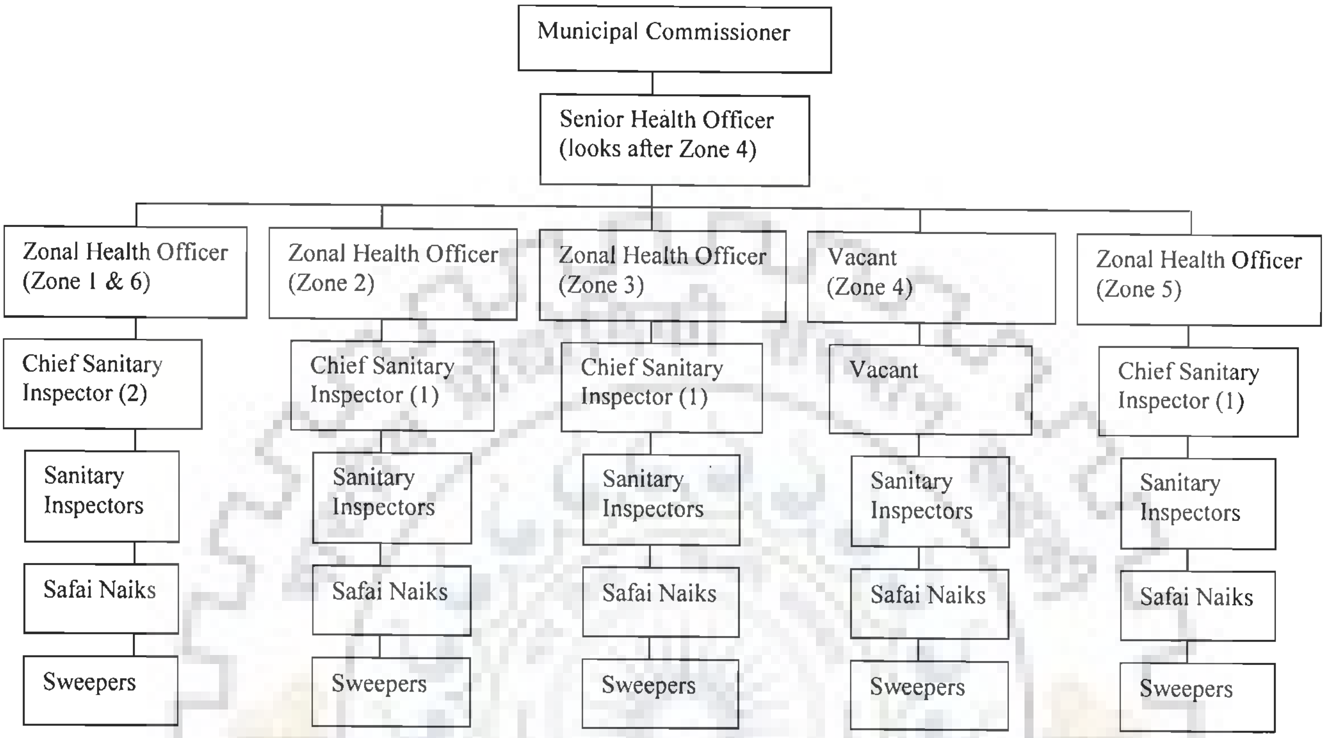


Fig. 3.7: Structure of the Health Department (primary waste collection) of Kanpur Nagar Nigam

3.5.2 WASTE COLLECTION POINTS

Three different types of waste storage facilities are used in Kanpur city. They are (i) Rubbish depots, (ii) Open depots and (iii) Containers.

(i) Rubbish Depot: It is an enclosed storage area for wastes with concrete floor and surrounding walls, with two entrances at the front or side.

(ii) Open depot: It is an open space without any built boundaries and is treated as an official storage point.

(iii) Containers: Four different types of containers with varying capacities are used for waste storage. Open type containers with smaller capacity of 0.75 m^3 and 1.0 m^3 are open at the top. Containers of capacity 6.5 m^3 and 8.5 m^3 are closed and have filling windows.

All the above types of waste storage facilities used in Kanpur city is shown in the following figures, Fig 3.8, 3.9, 3.10, 3.11 and 3.12.

During the study, it has been observed that the generated wastes are not fully reaching these depots. Infact, wastes heaps are often seen lying all around these depots rather than inside the depots as seen in Fig. 3.13 and Fig 3.14. Small and bigger heaps of garbage along road sides and vacant plots is a common sight in Kanpur.

Fig. 3.8: Cement and Concrete Rubbish Depot **Fig. 3.9: Open Depot**

Fig. 3.10 : 8.5 m^3 iron container

Fig. 3.11: 6.5 m^3 iron container

Fig. 3.12: 1 and 0.75 m^3 iron containers

Fig. 3.13: Wastes lying around the rubbish depot

Fig. 3.14: Wastes lying all around the container

As per the Municipal administration, there are 1275 waste collection points provided in the urban limits of the city (Kanpur Nagar Nigam, 2001), but research study reveals that there are 748 collection points available in the city, which is only 58 per cent of the quoted figure in the official report of Kanpur Nagar Nigam. The various types of collection points available in the city are presented in Table 3.15. The table illustrates that there is difference in the figures stated by the Municipal Corporation and field studies undertaken by ICDP. This highlights the existing loopholes in database generated by the Nagar Nigam.

Table 3.15: Number of Collection points in Kanpur

S. No.	Collection point	KNN	ICDP-II
1.	Rubbish Depot	120	101
2.	Open Depot	150	169
3.	Container ($0.75 m^3$)	820	125
4.	Container ($1 m^3$)	0	11
5.	Container ($6.5 m^3$)	120	299
6.	Container ($8.5 m^3$)	65	43
	Total	1275	748

KNN-Kanpur Nagar Nigam; ICDP-Institutional and Community Development Project

Wastes from wastewater treatment plant, slaughterhouse and silt are not dumped in these collection points. They are taken separately by the open trucks.

3.5.3 Operation procedure

3.5.3.1 Primary collection system

Primary collection basically involves sweeping of the streets, cleaning the drains of the assigned area and bringing the waste to a depot (rubbish depot or open depot), from where it is lifted by the vehicle fleet of Kanpur Nagar Nigam. Door-to-door collection facility is available only in few pockets of the city, using Centre for Development Communication (CDC) model[1].

[1] CDC model owns its origin to Jaipur city and is a 'near-zero waste disposal' model. In this model, there is waste segregation at source and door-to-door collection. Recyclables are sold while biodegradable are composted.

CDC model has been paid 4.80 lakhs from Nagar Nigam for door to door collection garbage in Ratanlal nagar and surrounding areas for 10,000 population and this model will sustain for 30 years. The door-to-door waste collection is shown in Fig. 3.15 and Fig. 3.16.

<u>CDC Model</u>

- They collect garbage from the doorstep of each house and charge nominal Rs. 25-30 per month.
- They provide two plastic containers, one for kitchen waste and one for recyclable waste.
- They bring kitchen garbage to site provided by KNN for vermi-composting and the recyclable waste to be sent for further operation. Composting is not being practiced currently.
- They charge Rs. 480,000/- only once for 30 years for 2000 houses/10,000 population.
- The model is successful partially as composting is yet to start.

Fig. 3.15: Door-to-door collection using tricycle

Fig. 3.16: Door-to-door collection using Tricycle

In the areas given below, door to door collection are being done through NGOs at no profit no loss basis.

1. Swaroop Nagar Sales Tax Road
2. Swaroop Nagar Mohan Medical Store lane

3. Swaroop Nagar Choona Manurang Road
4. Lakhanpur
5. R.S. Puram Colony
6. Friends Colony
7. Chandra Vihar colony

The sweepers are required to start their work at their assigned beats at 7.30 a.m. The Safai Naik supervises the work of sweepers and marks their attendance at 11 a.m. He decides to which beat the sweepers will go in the second half. The Sanitary Inspector supervises the work of Safai Naik and other works like, inspection of deaths, birth registration and taking food samples. The Chief Sanitary Inspectors supervises the work of sanitary Inspectors, while the Zonal Health Officer has the overall responsibility of the particular zone(s) assigned to him. He is also responsible for controlling epidemic outbreaks and disease prevention.

The assigned working hours for sweepers is 8 hours. However, field studies found that they hardly work for more than 3 hours a day. Sweepers often, contract out their job to somebody else against lesser payment and they work somewhere else.

3.5.3.2 Equipments and tools

For street sweeping, brooms, spades, shovels and metal plates are conventionally provided as shown in Fig 3.17. The equipments supplied are however, insufficient and often in shortage. The street waste is collected with the help of broom and metal plate or paper board. The swept waste is collected in handcarts of capacity $0.18 m^3$ with a carrying capacity of 100 kg. The number of handcarts is also insufficient. As a result, sweepers often leave the waste in small heaps on the streets or burn the waste, so that volume of waste to be carried to the collection points reduces. Burning of waste in the closed containers is also observed at many collection points during the study.

Fig. 3.17: Equipments used by the sweepers

Mixing of municipal waste with the hazardous bio-medical waste is rampant in the city. Besides, the presence of plastics and hazardous waste makes the burning a major health hazard. The wards lying on the outskirts have very irregular collection facility. Field study conducted by the Investigator shows that in few wards, there is hardly any primary collection and waste is collected from the collection points once in a month or not even that.

3.5.3.3 Private primary collection services

A number of colonies employ private sweepers who are involved only in house to house collection of wastes. In some colonies, the private sweepers work alongside the municipal sweepers. Payment to municipal sweepers by individual households for primary collection is a common practice observed during the study conducted by the Investigator.

3.5.3.4 Waste recycling and scavenging

Recycling at household level is a frugal practice in India. Materials like magazines, newspaper, bottles, cans, glass, metals, etc., are stored and sold to the itinerant waste buyers, who pay for the materials by weight. These Itinerant Waste Buyers in turn sell to the small-scale waste traders who in turn supply the material to big traders and wholesalers. Field study shows the presence of small-scale waste traders spread all over the city, especially along the highways.

There are no estimates as to the number of people involved in waste recycling sector in Kanpur city. Studies undertaken in cities of similar size put the estimate that some 10 per cent of the wastes is recycled. This amounts to 220 tons per day. The network of the various actors involved in informal waste recycling and scavenging as observed in Kanpur is shown in Fig. 3.18. It clearly shows that the generated waste reaches back to the consumers for consumption through various channels.

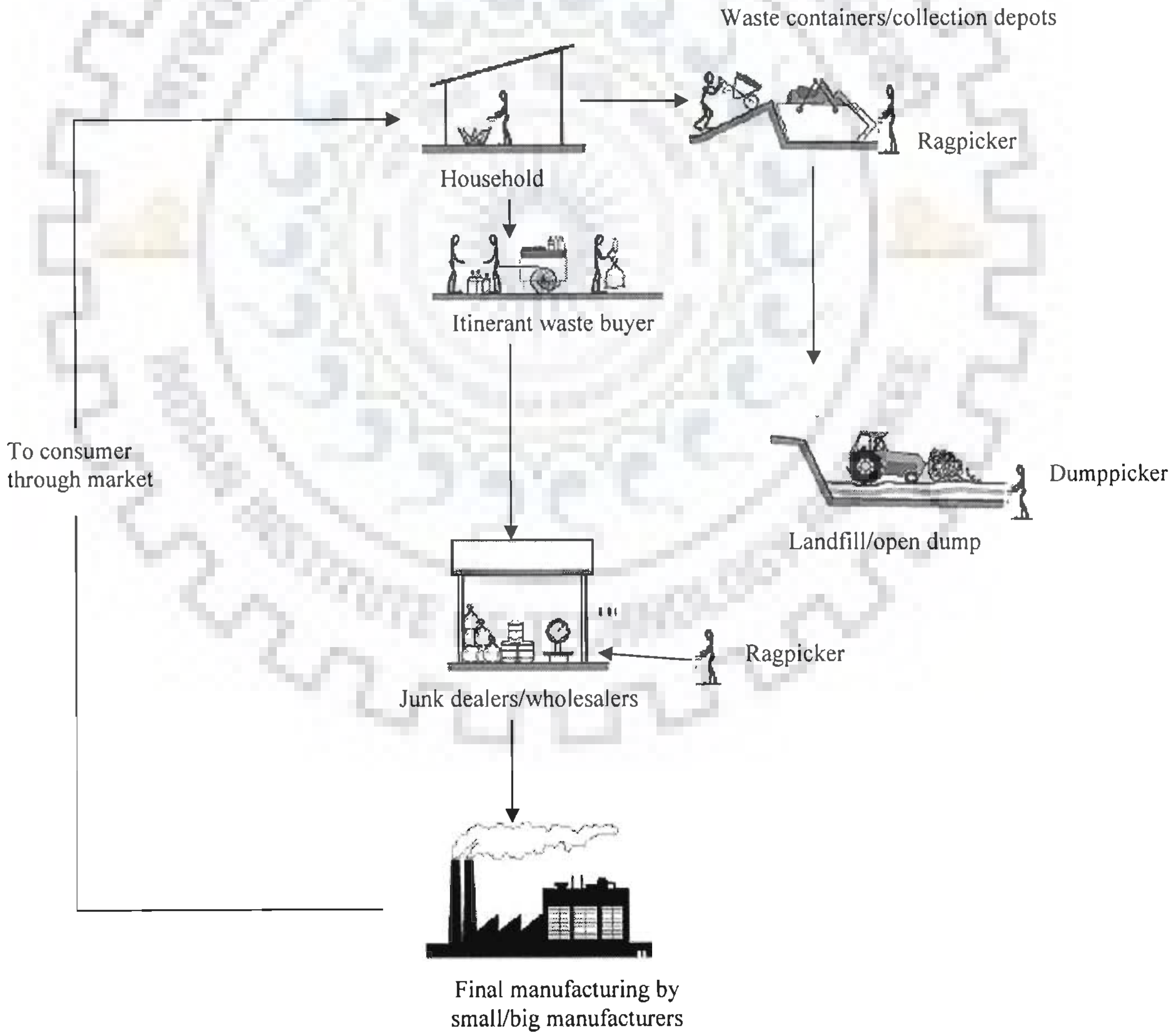


Fig. 3.18: A simple diagram showing flow of recyclables say, bottles, cans, plastics, paper, etc. from Households (one of the waste producers) to the manufacturers and back to the consumer

3.6 SECONDARY COLLECTION

3.6.1 ORGANIZATION OF CITY CLEANSING DEPARTMENT

The City Cleansing department of the Municipal Corporation looks after the task of secondary collection and disposal of wastes. There is no co-ordination between the City Cleansing department and the Health department, which looks after the primary collection. The department is headed by the Director City Cleansing. The workforce of the department is shown in Table 3.16. The table shows that there are 252 vacant posts against the sanctioned post of 595.

Table 3.16: Workforce of the City Cleansing Department

	Position	Sanctioned post	Working Position			Vacant posts
			Bhagwat ghat+Jajmau	Fazalganj+Panki	Total	
1.	Director City Cleansing	1			1	0
2.	Assistant DCC	1			1	0
3.	Depot in-charge	4	1	2	3	1
4.	Drivers	100	40	27	67	33
5.	Fillers	407	129	114	243	164
6.	Beldar (labourers)	71	14	5	19	52
7.	Watchman	5	4	0	4	1
8.	Safainaik	4	1	3	4	0
9.	Rubbish-depot sweeper	2	0	2	2	0
	Total workforce	595	189	153	344	252

Source: Kanpur Nagar Nigam

3.6.1.1 Rubbish Depot

There are four rubbish depots in the city and are situated at Panki, Fazalganj, Bhagwatdas ghat and Jajmau.

3.6.2 VEHICLE FLEET

Various types of vehicles are used for secondary collection and disposal of wastes in Kanpur city. Container-carriers (also called dumper-placers) are used to carry middle and big-size containers (collection depots) while refuse collectors (skip loaders) are used to empty waste from small containers (0.75 and 1 m^3) while bulldozers and dozers are used at the dumpsites. A detailed overview of the available vehicles at each depot, used for secondary collection and disposal of wastes is presented in Table 3.17. Various types of vehicles used for collection and disposal are shown in Fig. 3.19-Fig. 3.29.

Table 3.17: Vehicle fleet owned by KNN at various depots

S. No.	Type of vehicle	Bhagwat ghat	Fazalganj	Jajmau	Panki	*Total*
	Open trucks					
1.	Ashok Leyland	13	10	1	9	*33*
2.	Mazda Tipper	-	4	-	1	*5*
3.	Tata Truck	17	3	3	4	*27*
	Container vehicles					
4.	DP big	2	1	1	1	*5*
5.	DP small	1	9	-	7	*17*
6.	RC big	-	-	-	3	*3*
7.	RC small	-	3	1	2	*6*
	Loaders					
8.	JCB	2	1	-	1	*4*
9.	Loader	9	5	1	2	*17*
	Other					
10.	Bobcat	-	1	-	-	*1*
11.	Fassi	-	1	-	-	*3*
12.	Tractor	6	4	-	3	*13*
	Landfill vehicles					
13.	Bulldozer	1	0	0	0	*1*
14.	Dozer	1	0	0	0	*1*
	Total	*52*	*42*	*7*	*33*	*134*

Source: Kanpur Nagar Nigam

Notes about vehicles:

- Ashok Leyland and Tata trucks have sideboards but no backdoors while the Mazda tipper has sideboards and backdoors;
- Dumper placers are carrier vehicles for big(8.5 m^3) and middle size(6.5 m^3) containers;
- Refuse collectors are skip loaders used to empty the small (0.75 m^3 and 1 m^3) containers;
- Loaders are used to remove wastes from the rubbish depots and open depots and loading them into open trucks;
- JCB are also loaders which can load, doze, grade, dig and landfill. JCB and loaders differ in shovel capacity;
- Fassi is used to clean drains;
- Bobcat is a multi-purpose machine, mostly used for loading;
- Tractors and trucks are used to manually collect wastes;
- Bulldozer and dozer are used to level the waste at dumpsites.

Fig. 3.19: Loader

Fig. 3.20: JCB

Fig. 3.21: Tipper

Fig. 3.22: Tractor

Fig. 3.23: Dumper Placer (big size)

Fig. 3.24: Dumper Placer (small)

Fig. 3.25: DCM and Bob Cot Loader

Fig. 3.26: Tipper

Fig. 3.27: Dozer

Fig. 3.28: Bulldozer (chain drive)

Fig. 3.29: RC Big (refuse collector)

Out of the listed 134 vehicles, the number of collection vehicles is 109. There are only 67 drivers for the whole fleet of vehicles. Utilization rate of vehicles is a direct indicator of the collection efficiency of vehicles and has a strong implication on the overall cleanliness in a city. The utilization rate of collection vehicles and their average breakdown is presented in Table 3.18.

Table 3.18: Average utilization rate of collection vehicles

S. No.	Vehicle type	Average utilization (%)	Average breakdown (%)	Average unaccounted for (%)
1.	Ashok Leyland	53	15	32
2.	Mazda tipper	65	13	22
3.	Tata truck	52	11	37
4.	DP big	57	1	42
5.	DP small	46	5	49
6.	RC big	14	78	8
7.	RC small	26	40	34
8.	Tractor	35	9	56

Source: ICDP (Phase 2), 2001

The table clearly illustrates that average utilization rate for Mazda tippers is maximum at 65 per cent, while Refuse Collectors (big) have the minimum utilization rate. The Dumper placers do not face the problem of breakdown; rather their low utilization is due to unaccounted for reasons like, leave of driver, alternative use, vehicles out of action but not recorded, etc. The average utilization rate of all collection vehicles in Kanpur thus comes out to be 48 per cent, which is very less.

3.6.3 OPERATION PROCEDURE

3.6.3.1 Working days and working time

Collection has to take place seven days a week all year round. There are only two official holidays, the day after Holi and the day after Diwali. The working hours for collection are 8 am to 6 pm. There are no data with the municipality as to the average working time per vehicle. However, the result of the survey done during the ICDP-Phase 2 gives the average working time per vehicle and are presented in Table 3.19.

Table 3.19: Average working time per vehicle

S. No.	Vehicle Type	Average working time(hrs)
1.	Ashok Leyland	3:41
2.	Mazda Tipper	5:48
3.	Tata truck	3:33
4.	DP big	3:12
5.	DP small	2:43
6.	RC big	2:09
7.	RC small	2:25
8.	Tractor	0:51

Source: ICDP (Phase 2), 2001

3.6.3.2 Collection and transportation

Three types of collection system are identified for rubbish and open depots, containers and poor accessibility depots. They are:

1. In this system, 'Batches' are assigned to empty rubbish and open depots. A batch comprises of a loader and 4 to 5 trucks. Each batch is assigned a specific number of depots in an area. The loader empties the depots waste into trucks, which take the waste to dumpsites/landfills. The depots are emptied on a daily basis or once in two days or three days or a week. *All trucks are supposed to make three full-load trips to the dumpsite in a day.*

2. Containers are emptied by dumper-placer and refuse collectors. A dumper-placer replaces full or overloaded containers with an empty one. *Dumper placers and refuse collectors make three full-load trips to the dumpsite on an average.*

3. In areas of poor accessibility, tractors are used for collection of wastes. Depots in such areas are manually emptied by 3-5 helpers (*beldars*) and loaded on tractors, which take the waste to dumpsites. *A tractor group makes only one trip a day, on an average.*

In all the above collection systems, there are no detailed predefined collection routes. The average load per trip by various types of vehicles, as prescribed is presented in Table 3.20.

Table 3.20: Average load per trip

S. No.	Vehicle type	Prescribed load (kg/trip)
1.	Ashok Leyland	6,000
2.	Mazda truck	4,000
3.	Tata truck	6,000
4.	DP big	4,000
5.	DP small	2,000
6.	RC big	6,000
7.	RC small	3,000
8.	Tractor	1,500

Source: ICDP (Phase 2), 2001

Besides the above collection, three waste streams are collected separately, *viz.,* Construction and debris waste, Slaughterhouse waste and waste from treatment plants. On contract basis with UP Jal Nigam, the dried sludge is lifted and transported from the waste water treatment plants to the dumpsite at Rooma. Two open trucks collect waste from the slaughterhouses. The silt left after the cleaning of drains is also picked by the same fleet. During this period, a number of collection vehicle fleet has to be diverted from their regular tasks.

3.6.4 FUEL CONSUMPTION

All the collection vehicles being used by Kanpur Nagar Nigam consume diesel as fuel. The expenditure on fuel constitutes 8 per cent of the total expenditure on Solid Waste Management, which is a substantial portion and therefore, needs detailed analysis. The standard allocation of fuel of vehicles used for collection and disposal of municipal wastes is presented in Table 3.21. It is interesting to note that the allocation of diesel is not based on any actual usage data; rather all the vehicles get a fixed amount of diesel. The vehicles servicing the slaughterhouses get an extra fuel of 5 liters. Extra quantity of fuel is provided for any additional trip of the vehicle.

Table 3.21: Allocation of diesel

S. No.	Type of vehicle	Diesel allocation per vehicle (litres)	*Total No. of vehicles*
	Open trucks		
1.	Ashok Leyland	35	*33*
2.	Mazda Tipper	35	*5*
3.	Tata Truck	35	*27*
	Container vehicles		
4.	DP big	35	*5*
5.	DP small	25	*17*
6.	RC big	30	*3*
7.	RC small	30	*6*
	Loaders		
8.	JCB	45	*4*
9.	Loader	40	*17*
	Other		
10.	Bobcat	30	*1*
11.	Fassi	50	*3*
12.	Tractor	20	*13*
	Landfill vehicles		
13.	Bulldozer	135	*1*
14.	Dozer	100	*1*
	Total	*645*	*134*

Source: Compiled by the Investigator based on Kanpur Municipal Corporation Report and ICDP (Phase 2), 2001

Average amount of diesel used per day (as per ICDP, Phase 2 report) =2387 litres

Average amount of diesel used for the collection of 1 ton of waste = 3.4 litres

Average amount of diesel allotted per day = 3824 litres

As per the City Cleansing Department, on an average, 114,730 litres of diesel was allocated per month (3824 litres per day) between the year 1998 and 2000. The data on fuel used in this regard is presented in Fig 3.30.

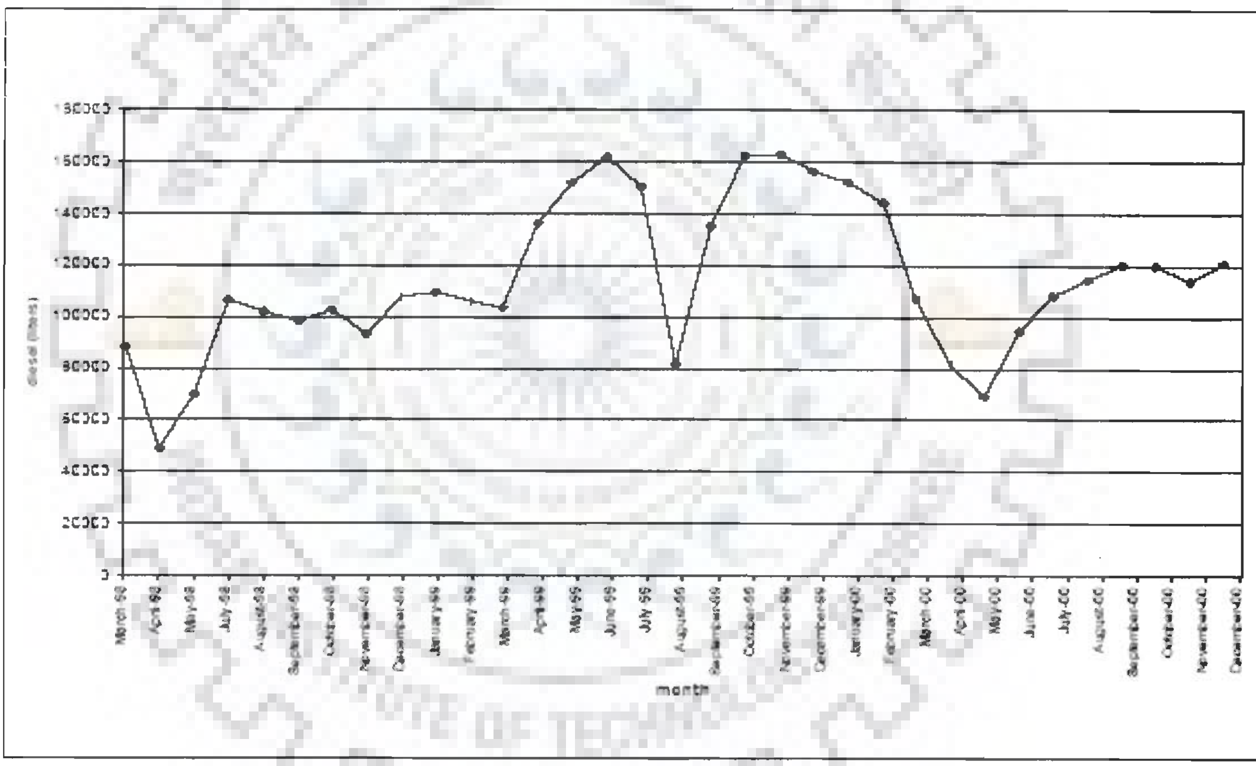


Fig. 3.30: Diesel consumption April 1998-December 2000

The diesel consumption per ton waste collected per vehicle type is presented in Table 3.22. The diesel consumption per ton of waste of the container vehicles is high compared to that consumed by the open trucks.

Table 3.22: Diesel consumption per ton waste collected per vehicle type

S. No.	Vehicle type	Diesel consumption (litres/ton waste collected)	Diesel consumption (average litres/day)		Over allocation	
		Existing	Existing	As given by NEERI*	Litres/day/vehicle	Litres/day
	Open trucks					
1.	Ashok Leyland	2.8	36.4	26.5	9.94	326
2.	Mazda Tipper	2.0	21.7	43.8	0	0
3.	Tata Truck	3.0	40.7	27.4	13.3	359.1
	Container vehicles					
4.	DP big	5.7	32.6	17.2	15.4	77
5.	DP small	6.3	21.1	16.0	5.1	86.7
6.	RC big	6.7	30.5	10.0	20.5	61.5
7.	RC small	6.3	24.2	11.2	13.0	78
	Other					
8.	Tractor	6.4	15.2	5.4	9.8	127.4
	Total					1115.7
	Total(litres per month)					*33471*

Source: City Cleansing Department Report, Kanpur Nagar Nigam

The table clearly illustrates that there is an estimated over allocation of 33,471 litres (this excludes the allocation of diesel for loaders, JCB, dozers, bull-dozers, etc. due to lack of adequate data). This amounts to an extra cost of Rs 952249.95 per month (9.5 lakh) or Rs 11426999.4 (114.2 lakh) annually at the prevalent rate of diesel (Rs 28.45 per litre).

At the existing increased[1] cost of Rs. 30.45, the cost for over allocation of diesel comes out to be Rs 1019191.95 (10.2 lakh) per month.

* National Environmental Engineering Research Institute, Nagpur, India

3.7 ENGINEERING DEPARTMENT

3.7.1 ORGANIZATION OF THE ENGINEERING DEPARTMENT

The Workshop or the Engineering department looks after the repair and maintenance of the vehicle fleet. There are two vehicle workshops at Fazalganj and Chunniganj for maintenance of vehicles used for secondary collection. Fazalganj workshop looks after vehicle depots at Fazalganj and Panki while Chunniganj workshop looks after the vehicle depot at Bhagwatdas ghat and Jajmau. Both the workshops also have fuel-filling stations. Fazalganj's diesel pump was closed in year 2000 for want of some minor repair. Chunniganj workshop has both diesel and petrol pump but was discontinued functioning in the year 1994 for want of repairs. Each workshop is headed by a foreman. The staff of the department is presented in Table 3.23 and in total, 85 people are employed in this department. The Government of India increased the cost of diesel and petrol in tune with flaring international prices on September 6, 2005

Table 3.23: Staff of Engineering Department

S. No.	Post	Number
1.	Assistant Engineer	1
2.	Foremen	3
3.	Mechanics	4
4.	Fitters	23
5.	Carpenter	1
6.	Hammer men	6
7.	Black Smith	0
8.	Cleaners	38
9.	Sweeper	3
10.	Watchman	3
11.	Peon	3
	Total	*85*

Source: Kanpur Nagar Nigam, 2005

[1] The Govt. of India increased the cost of diesel and petrol in tune with flaring international prices on September 6, 2005

3.7.2 Repair and Maintenance

The workshops are in poor shape. The department does not have its own finances, which often results in delays in repairs. Lack of experts is observed due to absence of any fresh appointments. Major repairs are contracted out to private contractors and only minor repairs are dealt with in the workshops. Servicing of vehicles is not based on kilometers traveled; rather it is infrequently done on a three-month basis. Repair takes long time depending on the clearance of funds for spare parts by the Municipal Commissioner (MNA). Drivers therefore, tend to repair minor defects of their vehicles, often spending from their own pockets to avoid their vehicles staying in workshop for long duration.

Filling is done at Jajmau filling-station and Satnam pump at Panki. The vehicles have to travel great distances for getting their vehicles filled, which results in undue wastage of fuel.

3.8 DISPOSAL OF WASTE

There is no sanitary landfill in Kanpur city. The city does not have even controlled dumps. Waste is simply dumped at the designated sites (with or without compaction) where no soil cover is used, no visual or environmental barriers and no provision for leachate checking is there.

The following dumpsites are available for the disposal of municipal wastes at:

i) Panki (16-20 acres): The site is full beyond its capacity at present and hence been closed. No post site-closure measures have so far been taken.

ii) Krishna nagar (40-50 acre): It is the property of Ministry of Defense but was used for waste disposal for a number of years. It has been closed since 2001. Appropriate post-closure treatment is absent.

iii) Bingawan: Currently, the municipal waste is being dumped at Bingawan. The site is purely an open dump, adjacent to the agricultural fields at Bingawan. There is no use of soil cover or any other preventive measures to curtail the possible environmental pollution (Fig 3.31).

iv) Rooma (for chromium sludge): For the disposal of chromium sludge from the waste treatment plants at Jajmau, there is a 12.4 hectare site at Rooma with no infrastructure whatsoever to handle hazardous and toxic wastes (Fig 3.32).

v) Bhauti (Biomedical waste): There is a site at Bhauti for disposal of the waste coming out from the incinerator for treatment of bio-medical waste.

Besides the above official dump sites, the city is full of unofficial dump sites (Fig.3.33 to Fig 3.36). Waste is often openly burned in containers, on road sides, small dumps, etc., by the people and also by the municipal sweepers. The potential environmental risks associated with the existing dumping sites are listed in Table 3.24.

Fig. 3.31: Official Dumpsites at Bingawan

Fig. 3.32: Official dumpsite at Rooma (seen from the waste treatment plant)

Fig.3.33: Unofficial dump in a busy commercial area, Kalyanpur

Fig. 3.34: Unofficial dump at Naubasta

Fig. 3.35: Unofficial dump at Govindnagar

Fig. 3.36: Unofficial dump at a construction site, Aryanagar

Table 3.24: Potential environmental risks associated with the various dumpsites in Kanpur

S.No.	*Hazard*	*Pathway*	*Receptor*	*Risk*
1.	Leachate	Hydrogeological	Aquifers(ground water) Potable water supply Rivers Ganga and Pandu Crops and associated flora and fauna	Surface and ground water pollution Loss of supply Public health risk Contamination of crops Loss of flora and fauna
2.	Gas migration	Soil Air via waste	Buildings nearby People Air	Explosion Injury, death, illness, asphyxiation Global warming and ozone depletion
3.	Infectious waste and harmful chemicals, metals, etc.	Direct contact Purchase of recovered materials Food crops and vegetables grown in the adjacent land	People Animals Flora and fauna	Illness, death, wounding, etc.
4.	Odour	Air	People	Illness Public nuisance Loss in real estate value of nearby property
5.	Vermin	Waste	People	Illness, death
6.	Dust	Air	People	Illness

3.9 TREATMENT

A compost plant with a capacity of 200 tons of compost per day was set up in 1979 but the plant closed after half year of operation due to high presence of inert materials in the waste and lack of technical and management skills.

3.10 PRIVATIZATION OF SOLID WASTE MANAGEMENT IN KANPUR

Privatization in full fledged form in the field of Solid Waste Management is not successful in Kanpur city. It exists but only on small-scale like contracting of vehicle repair, etc. Contracting of transportation of wastes was tried from 1988 to 1991 but the attempt was not useful. In the contract, the firm was supposed to use the Kanpur Nagar Nigam fleet and its personnel against a fixed fee of Rs 55 per ton of waste transported. The construction and demolition waste is also lifted by private contractors and the *malba* used for leveling/filling of ground and small water bodies.

Door-to-door collection based on CDC model in few selected colonies involves some Non-Government Organizations (NGOs) on no-profit no-loss basis. Besides, people also employ private sweepers to daily collect waste from their residences and throw at collection depots.

3.11 FINANCES OF SOLID WASTE MANAGEMENT

The expenditure on solid waste management comes under the 'Sanitation' head in the financial overview (Annual budget reports) of Kanpur Municipal Corporation (KNN). There is no separate mention of the solid waste. The expenditure incurred for solid waste management in the city is analyzed based on the available data and presented in Table 3.24 and Fig 3.37. Table 3.25 and Fig 3.37 give an overview of the expenditure on Sanitation from 1990 onwards. The expenditure on Sanitation as part of the total budget shows an increasing trend till 1997 when it became 51 per cent of the total municipal budget and then gradually decreased to 28.5 per cent of the total budget in the financial year 2005-06.

Table 3.25: Expenditure on Sanitation by Kanpur Nagar Nigam (KNN)

S.No.	Year	Expenditure on SWM In INR(Indian Rupees)	% of total expenditure
1.	1990-91	158,056,973	32.4
2.	1991-92	154,102,482	31.2
3.	1992-93	174,160,542	37.7
4.	1993-94	188,779,521	37.4
5.	1994-95	192,625,582	41.1
6.	1995-96	210,465,307	42.1
7.	1996-97	242,055,621	51.0
8.	1997-98	280,131,088	42.4
9.	1998-99	330,620,296	45.4
10.	1999-00	364,820,000	38.0
11.	2000-01	Not available	-
12	2001-02	Not available	-
13.	2002-03	388,366,913	38.5
14.	2003-04	422,207,165	34.1
15.	2004-05	450,600,000	29.7
16.	2005-06	462,100,000	28.5

Note: Data under Sanitation includes expenditure on SWM, toilets construction and their maintenance, salary to people working on sewage farm, etc.

Source: Various Annual Budget Reports of Kanpur Nagar Nigam

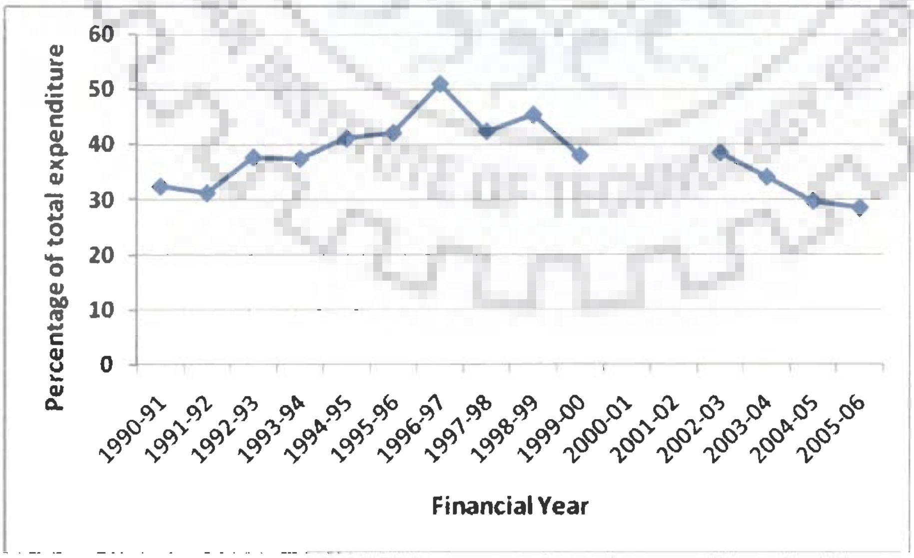


Fig. 3.37: Expenditure on SWM as part of total expenditure by Kanpur Nagar Nigam

As mentioned earlier, the municipal budget reports do not mention solid waste separately, rather the various budget proposals, income and expenditure incurred is mentioned under the head Sanitation. The expenditure for various financial years (2002-2006) as given in various municipal budget reports is presented in Table 3.26 for better understanding.

Table 3.26: Division of Expenditure under various heads of Sanitation (in Indian Rupees)

S. No.	Name of various heads under Sanitation	Expenditure			
		(2002-03)	(2003-04)	(2004-05)	(2005-06) *proposed
1.	Salary-Sewage farm	629,660	541,622	1,100,000	1,100,000
2.	Salary-Cleansing department and Health department	308,397,090	329,727,768	320,000,000	320,000,000
3.	Salary to workers on Contract	8,993,612	9,030,374	10,000,000	20,000,000
4.	Salary-Engineering department(Workshops)	11,396,626	12,955,533	12,500,000	12,500,000
5.	Equipment and emergency expenditure	16,497,018	16,730,459	15,000,000	15,000,000
6.	New vehicles/Bobcot/Dumper/hand carts, etc	0	0	5,000,000	5,000,000
7.	Cattle catching vehicles	0	0	0	1,500,000
8.	Storage	810,266	1,902,593	3,000,000	3,000,000
9.	Diesel/petrol	40,750,028	50,275,050	80,000,000	80,000,000
10.	Construction of toilets/urinals	576,422	694,224	1,500,000	1,500,000
11.	Maintenance/repair of toilets	316,412	349,542	1,500,000	1,500,000
12.	Interest on loan	0	0	1,000,000	1,000,000
	Total	*388,366,913*	*422,207,165*	*450,600,000*	*462,100,000*

Source: Various Municipal budget reports, Kanpur Nagar Nigam

The table demonstrates that there are wide variations in the expenditure if analyzed under different heads. The expenditure on Sewage farm just doubled in the financial year 2004-05. Salaries for cleansing and health departments constitute the maximum part of the expenditure incurred under Sanitation. It was highest in the financial year 2003-04 and then decreased in the following years. The reason is probably the gradual retirement of workforce and non-appointment of new Safai-karamcharis (sweepers). Spending on the construction of new toilets/urinals and maintenance/repair of the existing ones increased tremendously in the financial year 2004-05.

A detailed analysis of breakdown of the detailed expenditure under various heads of solid waste management will shed a better light on the expenditure incurred and eventually help in managing the finances in a better way. An attempt has therefore, been made to calculate a sample breakdown of the detailed expenditure done under various headings of solid waste management for the financial year 1999-2000, based on secondary data reports and discussions with the Kanpur Nagar Nigam authorities, and is presented in Table 3.27.

Table 3.27: Sample breakdown of the expenditure on SWM by KNN

S. No.	Budget Item	Existing Number	Payment@ (monthly in INR)	Expenditures (monthly in INR)	Expenditures (annual in INR)
A.	**Primary collection (Health Department)**				
1.	Zonal Health Officers[1]	4	-	-	-
2.	Chief Sanitary Inspectors	5	12,788	63,942	767,300
3.	Sanitary Inspectors	18	11,724	211,032	2,532,384
4.	Safai Naiks	113	5,890	665,622	7,987,464
5.	Sweepers (permanent+temporary)	4260	5,188	23,196,047	278,352,560
	Subtotal (Indian Rupees)			*24,136,642*	*289,639,708*
	Subtotal (in lakhs)			*241.3*	*2,896.4*

[1] The salary of the Zonal Health Officer falls under the Medical Department

Table 3.27 (Continued)

S. No.	Budget Item	Existing Number	Payment@ (monthly in INR)	Expenditures (monthly in INR)	Expenditures (annual in INR)
B.	**Secondary Collection (City Cleansing department)**				
1.	Director City Cleansing	1	19,673	19,673	236,076
2.	Assistant DCC	1	8,757	8,757	105,084
3.	Depot in charge	3	5,890	17,670	212,040
4.	Drivers	67	4,769	319,523	3,834,276
5.	Fillers	243	3,843	933,849	11,206,188
6.	Beldar (labourers)	19	5,393	102,467	1,229,604
7.	Watchman	4	5,163	20,652	247,824
8.	Safainaik	4	6,062	24,248	290,976
9.	Rubbish-depot sweeper	2	5,188	10,376	124,512
	Subtotal	344		1,457,215	17,486,580
	Subtotal (in lakhs)			*14.6*	*1,74.9*
C.	**Engineering department**				
1.	Assistant Engineer	1	12,000	12,000	144,000
2.	Foremen	3	8,333	24,999	299,988
3.	Mechanics	4	5,500	22,000	264,000
4.	Fitters	23			
5.	Carpenter	1			
6.	Hammer men	6		*Together*	*Together*
7.	Black Smith	0		351,047	4,212,564
8.	Cleaners	38			
9.	Sweeper	3			
10.	Watchman	3			
11.	Peon	3			
	Subtotal	*85*		*410,047*	*4920564*
	Subtotal (in lakhs)			*4.1*	*49.2*
D.	**Tools & Equipment for primary collection**			700,000	8,400,000
	Subtotal(in lakhs)			*7.0*	*84.0*
E.	**Tools & Equipment for secondary collection**			1,501,255	18,015,065
	Subtotal(in lakhs)			*15.0*	*180.1*
F.	**Fuel and Oil**			1,771,790	21,261,481
	Subtotal(in lakhs)			*17.7*	*212.6*
G.	**Maintenance and Repairs**				
	Materials and labour contracted out			258,333	3,100,000
	Contracted out repairs			166,667	2,000,000
	Subtotal			*425,000*	*5,100,000*
	Subtotal (in lakhs)			*4.2*	*51*
	A+B+C+D+E+F+G			303.9	3648.2

Source: Compiled by the Investigator based on reports of Kanpur Nagar Nigam

The table shows that the average monthly expenditure on solid waste management comes out to be Rs 304 lakhs and the annual expenditure as Rs 3648 lakhs. The health department constitutes the major work force employed and thereby, the maximum expenditure is incurred in the department. The Engineering section is the most deprived department. A considerable amount is also spent on fuel and oil and on the purchase and maintenance of tools and equipments.

The average monthly waste collection as claimed by the Kanpur Nagar Nigam is 37988 tons per month. Thus, the average cost per collected ton is Rs. 800. The average monthly waste collection was however, found to be much lower during the ICDP study in 1999 at 21,090 tons (ICDP, 2001). This makes the average cost per collected ton as Rs. 1441. This is comparable to the expenditures in metros like Bombay and Delhi, where it is Rs. 917 and Rs. 879 respectively. The expenditure on solid waste management can also be expressed in terms of cost per capita per year. It comes out to be Rs 137 for the financial year 1999-2000, while it is Rs 114 for Bombay. The per capita expenditure is lower in Bombay but comparatively, it is a cleaner city with better collection facilities.

The percentage breakup of expenditure on various heads of solid waste management, based on the earlier calculations done in Table 3.27, is also presented through pie-chart (Fig 3.38). The figure clearly shows that the salaries of the Health department take the biggest part of the total expenditure on Solid Waste Management. The salaries for primary collection, secondary collection and workshop alone constitute 86 per cent of the total expenditure on Solid Waste Management. Expenditure on fuel and oil and vehicles and equipment purchase consume 6 and 7 per cent respectively.

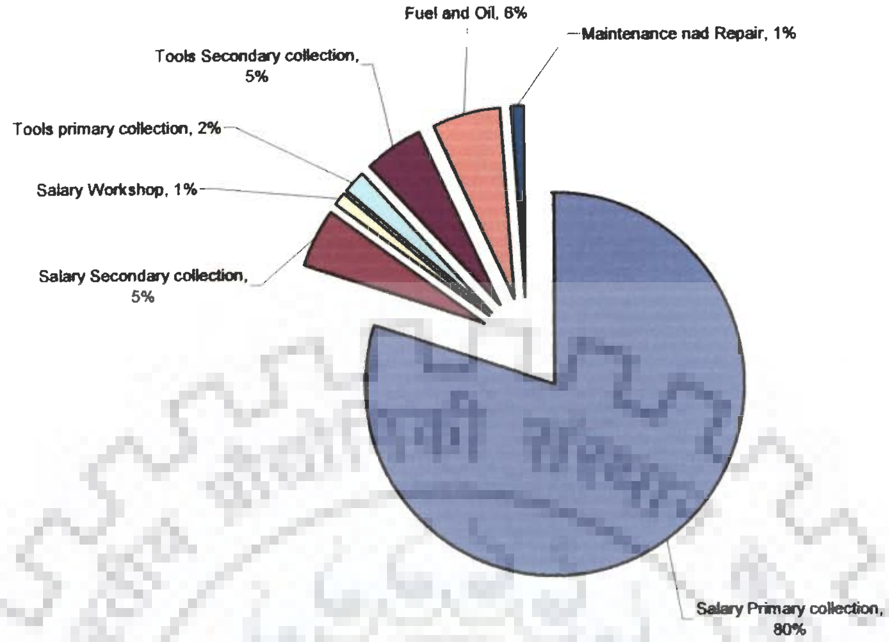


Fig. 3.38: Division of expenditure on Solid Waste Management (1999-2000)

The expenditure on the purchase of vehicles and equipment for the last few years is presented in Table 3.28. There was an increased spending between 1996 and 2000 due to additional sources like Institutional and Community Development Project (ICDP) and the Government of India. The average expenditure on this segment is 177 lakhs per annum.

Table 3.28: Expenditure on purchase of new vehicles and equipments

S. No.	Financial year	(Rs in lakhs)
1.	1996-97	333.11
2.	1997-98	532.98
3.	1998-99	304.52
4.	1999-2000	264.07
5.	2002-03	164.97
6.	2003-04	167.30
7.	2005-06(proposed)	200.00

Source: Various annual reports of Kanpur Nagar Nigam

The trend of change in expenditure on the purchase of new vehicles and equipments is shown in Fig. 3.39. The figure clearly shows a decreasing trend in the expenditure on the purchase of new vehicles and equipments.

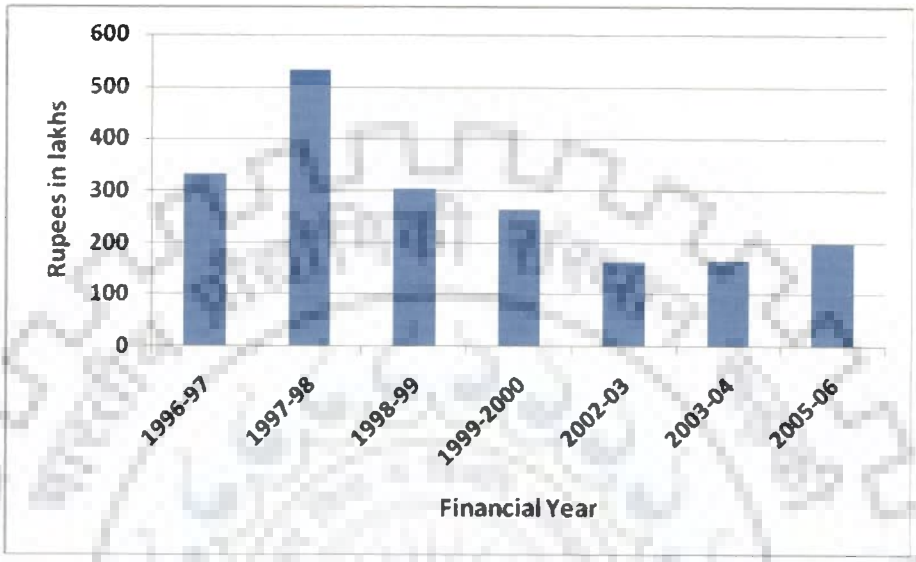


Fig. 3.39: Expenditure on vehicles and equipment for Solid Waste Management in Kanpur

3.12 ANALYSIS BASED ON FIELD OBSERVATIONS

3.12.1 Waste Generation

The data about the most waste generating areas and along roads is not available to the authorities. The current lifting capacity is much less as compared to the waste generated per day. The redressal system does not exist; it is just by a system on demand by the community.

3.12.2 Primary Storage

There is no source-separation of wastes at various generation points like households, institutions, commercial establishments, markets and not even hospitals. Primary storage is done in plastic bags, containers, etc.

3.12.3 PRIMARY COLLECTION

1. The bins are mostly in a dilapidated state so people just throw waste around the bins. People's apathy on their role is visible in the very fact that most people have a tendency to throw waste just outside their house. Collection points are not conveniently located.
2. The surroundings of depots and containers are very dirty as heaps of garbage is seen lying all around the containers and depots (Fig. 3.40, 3.41, 3.42 and 3.43).
3. The walls and floors of the rubbish depots are mostly damaged or broken, which makes the lifting of waste by loader difficult. Besides, the depots become inaccessible during monsoons.
4. The condition of open depots in the city is very poor. It gives a very dirty look even immediately after the lifting of wastes.
5. The Dumper-placer containers are not emptied regularly. Burning of wastes by the municipal sweepers in the containers is a common practice. The dumper-placer containers are mostly in dilapidated state.
6. The RC skip-containers are also in dilapidated state which leads to littering of waste all around.
7. Bins of different types are unnecessarily been provided on a stretch of various roads, which basically accounts to additional cost of diesel, manpower, equipment etc.

Fig.3.40: Waste spread in and around an open depot

Fig.3.41:Waste spill over to main road from a rubbish Depot

Fig.3.42:Waste lying around container

Fig. 3.43:Pitiable condition of an open depot along highway

8. The prescribed working hours for the municipal sweepers is 8 hours but due to inadequate supervision, an average sweeper works only for 4 hours. Malpractices in the form of contracting out of jobs by sweepers are also observed in the city.
9. The equipments given to the sweepers are inadequate. Shovels and spades are hardly available. The handcarts are usually in poor shape due to lack of maintenance. They are also difficult for women sweepers to handle due to the poor design and small capacity.
10. Rag-pickers who collect recyclables from the secondary storage containers and depots often result in spreading of waste outside the waste collection points leading to further littering.

3.12.4 SECONDARY COLLECTION AND TRANSPORTATION

1. The vehicle utilisation rate of the vehicle fleet is very low, resulting in low collection of wastes. The average utilisation rate of vehicles is just 48 per cent though experts believe that even with an average fall-out rate of 20 per cent, an optimal utilisation rate of 80 per cent can be achieved.
2. Lack of supervision is observed even in secondary collection due to which there is an unpredictable number of drivers on leave.
3. Loaders often breakdown resulting in hampering of the work.
4. Poor maintenance results in frequent breakdown of vehicles. Workshops lack sufficient budget and hence are not able to do timely repair of the vehicles.
5. Deployment of vehicles and collection routes to be adopted at each depot is not carefully planned.
6. There is shortage of drivers employed.
7. Only day shifts is practiced in Kanpur city, which often results in road blockages and longer time for waste collection in busy and congested areas.
8. Waste transportation in open trucks result in lot of littering.
9. Route planning is never prepared and is currently done as and when need arises.
10. Fuel allocation to the vehicles is on a daily basis on a fixed basis. This often results in mal practices by the drivers who sell the diesel for extra income. Fuel allocation is not rational and results in high expenditure on fuel costs.
11. The citizens often complain that solid waste is never lifted from its place, it is observed that the bins are full and the waste is lying for days without being lifted to the landfill site.

12. Collection of waste as claimed by Kanpur Nagar Nigam is 1266 tons per day. Field studies however, done by ICDP in 1999-2000 show that it is only 680 tons per day on an average. Field observations done by the author also support the latter as heaps of uncollected garbage is found all over the city.

13. The average waste collected by the collection crew under existing conditions and the utilization rate of each vehicle type is presented in Table 3.29.

Table 3.29: Estimated Waste collection by the collection crew

S. No.	Vehicle type	No. of vehicles	Average load per trip (kg/trip)	Prescribed load per trip (kg/trip)	Utilization rate (%) of vehicles
1.	Ashok Leyland	33	6085	6000	53
2.	Mazda tipper	5	3649	4000	65
3.	Tata truck	27	6045	6000	52
4.	DP big	5	2172	4000	57
5.	DP small	17	1336	2000	46
6.	RC big	3	2889	6000	14
7.	RC small	6	2034	3000	26
8.	Tractor	13	2106	1500	35

Source: Compiled by the Investigator based on secondary data

3.12.5 DISPOSAL

Dumping in low-lying areas is a common practice in the city (Fig. 3.44). Even authorities like Kanpur Development Authority (KDA) favour it. Municipal waste is often dumped on the orders of Kanpur Development Authority and Kanpur Nagar Nigam (KNN) for levelling of low-lying areas. The new bus-stand at Jhakarkatti is also built on waste-levelled site. This is not recommended as when the biodegradable part of the wastes decomposes, the volume reduces by 60 per cent threatening the safety of the structure. Besides, the percolation of leachate also poses water contamination.

Fig. 3.44: Municipal waste dumped in a low-lying residential area of Jajmau for levelling purpose

3.13 PRIORITISATION MATRIX FOR SWM IN KANPUR

A scoring-index has been used to develop a matrix to identify the main problems related to waste management in Kanpur city, based on field observations, primary survey and secondary data. An attempt has also been made to study the various socio-economic/ecological impacts of the various existing waste management practices in the study area. The scoring matrix is presented in Table 3.30.

The matrix clearly illustrates that there is a serious impact on public health (a score of 35), followed by urgency of the problem and irreversibility of the damage done. The overall total score of 191 indicates the severity of the problem.

Table 3.30: Prioritisation matrix for waste management in Kanpur

	Problems	Socio-economic/ecological impacts							
		Impact on public health	Loss of biodiversity	Impact on vulnerable groups	Productivity loss	Impact on critical ecosystem	Irreversibility /reversibility	Urgency of the problem	Total
1	Illegal disposal of MSW, HZ, BMW	5	3	3	5	3	5	5	29
2	Mixing of BMW with MSW	5	1	5	5	3	3	5	27
3	Improper mgt & handling of wastes	5	3	3	3	3	5	5	27
4	Absence of engineered disposal sites for haz. waste	5	5	3	3	5	5	3	29
5	Unorganised sec generating haz waste	5	3	5	3	3	5	5	29
6	Improper mgt of sharp wastes	5	1	5	3	1	5	5	25
7	Illegal recycling of biomedical wastes	5	1	5		1	5	5	
8	Total	35	17	29	25	21	31	33	191

Scale: 1=low, 3=medium, 5=high; MSW-Municipal Solid Waste; HZ-Hazardous waste; BMW-Biomedical waste

Source: Prepared by the Investigator

3.14 ALLIANCES/PARTNERSHIPS IN SOLID WASTE MANAGEMENT IN KANPUR CITY

Various alliances exist and function in the field of waste recycling sector in the study area of Kanpur. These existing alliances have been studied in detail and are presented in the following section.

a) Public-Community

The city of Kanpur does not have active partnerships in solid waste management between the Local authorities and NGOs contrary to other metropolitan cities like Bangalore, Chennai, Delhi, etc. However, the authority has attempted to try door-to-door collection in Ratanlalnagar area and seven colonies, comprising a population of 10,000 based on CDC model[1].

b) Private-private

- Waste pickers, itinerant waste buyers-dealers
- Dealers-wholesalers

Private-private partnership flourishes in the city in the field of solid waste management. Monetary profit is the main incentive, although indirectly they contribute significantly to the environment (sustainability goals). There is a chain of relations between various actors of this informal segment. Waste pickers and dump pickers sell their collection to the dealers or small traders. Itinerant buyers also sell their collections to them. The small traders and dealers in turn, sell the proceeds to wholesalers. The wholesalers thereafter send the collections to the recycling factories in the city and nearby places.

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[1] CDC model ows its origin to Jaipur city and is a 'near-zero waste disposal' model. In this model, there is waste segregation at source and door-to-door collection. Recyclables are sold while biodegradable are composted.

Table 3.31 presents an analysis of the various alliances in Kanpur city. These alliances have been studied for co-ordination, financial viability, ability to achieve the goal of cleaner environment and legitimacy status. The table clearly illustrates that only private-private partnership is strong in Kanpur. However, there is no partnership attempted between the local authorities and the informal (private) sector. The alliance between Local Authority and NGO is in experimental stage in Kanpur.

Table 3.31: Status of alliances in Kanpur city

S. No.	Alliances	Co-ordination	Financial viability	Clean urban environment	Legitimacy
1.	LA-private enterprises(tried earlier)	?	+	-	+
2.	LA-waste-pickers	-	-	-	-
3.	LA-traders	-	-	-	-
4.	LA-recycling units	-	-	-	-
5.	LA-NGO/CBOs	+	+	+	+
6.	NGO/CBOs-waste pickers	+	?	+	+
7.	Waste-pickers-traders	+	+	To some extent	-
8.	Traders-Recycling enterprises	+	+	To some extent	+

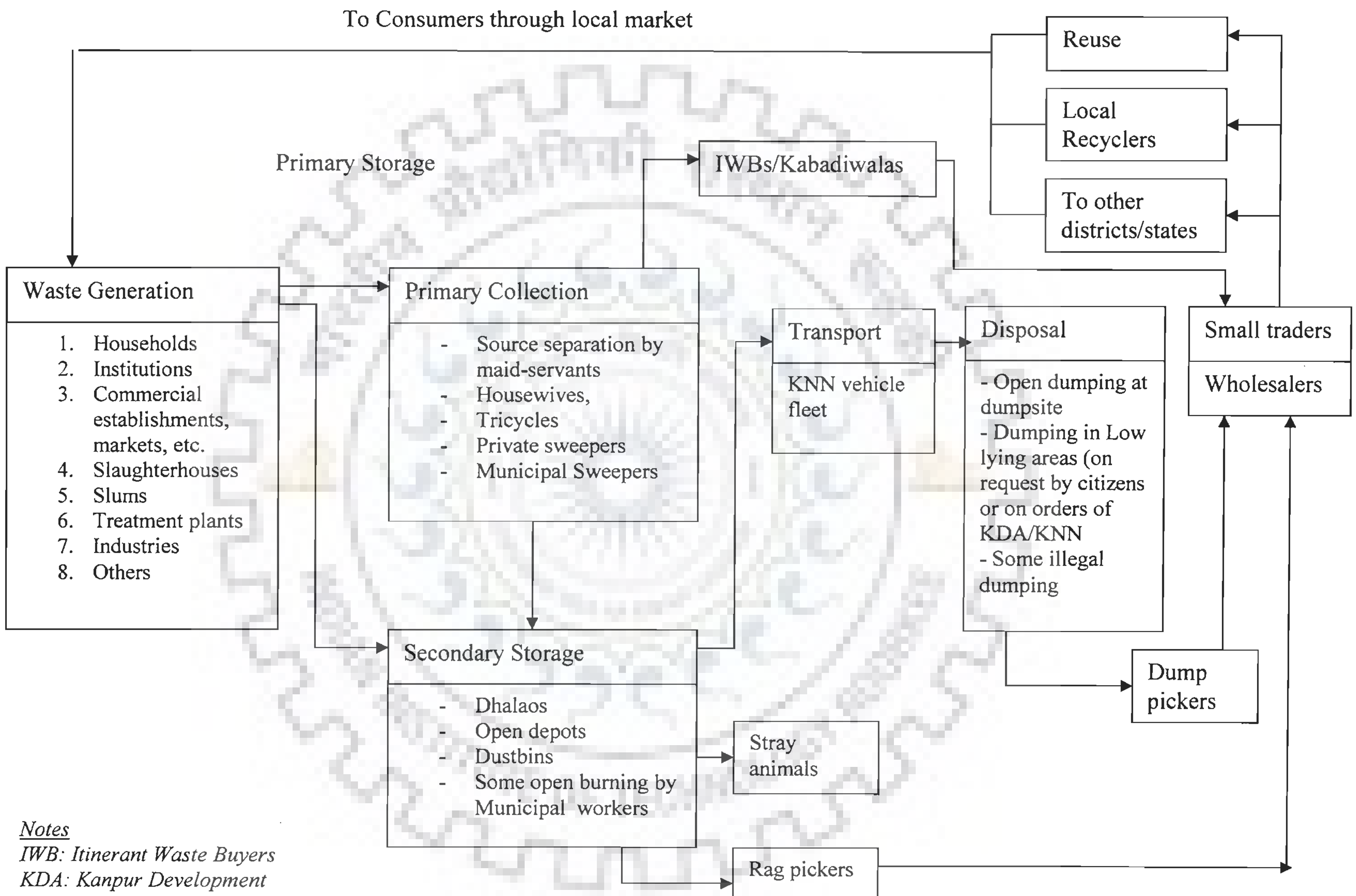
LA- Local Authority (Kanpur Municipal Corporation)
NGO: Non-government organization, CBO: Community Building Organization
+ : Existing/existed; - : not existing , ? : status not known
Source: Prepared by the Investigator

3.15 SUMMARY

Based on the above investigation pertaining to the municipal solid waste management in Kanpur city, the overall solid waste management can be presented in Fig. 3.45. Further, the cause-effect relationship of the various problems in the existing Solid waste management system is summarised in Fig. 3.46.

3.16 CONCLUSIONS

In this Chapter, the Investigator has attempted to have an in-depth knowledge about various elements of the municipal solid waste management existing in the study area. She has covered aspects like organogram of the public agency dealing with municipal waste management, waste generation, characteristics of generated waste, details of the primary and secondary waste collection procedure, various types and number of collection points, various kinds of vehicles used for primary and secondary collection, details about treatment facilities (if any), disposal at legal and illegal open dumps, recycling activity, etc. A prioritization matrix has also been prepared to understand the existing ecological and socio-economic impacts of the current waste management practices in the city. The various types of alliances working in the field of any or all aspects of solid waste management have also been studied by the Investigator. A detailed study of the various socio-economic, infrastructure and environmental aspects of the households and the informal sector, based on the primary survey, is presented in the following Chapter 4.



Notes
IWB: Itinerant Waste Buyers
KDA: Kanpur Development Authority
KNN: Kanpur Nagar Nigam

Fig. 3.45: Solid Waste Management in Kanpur city

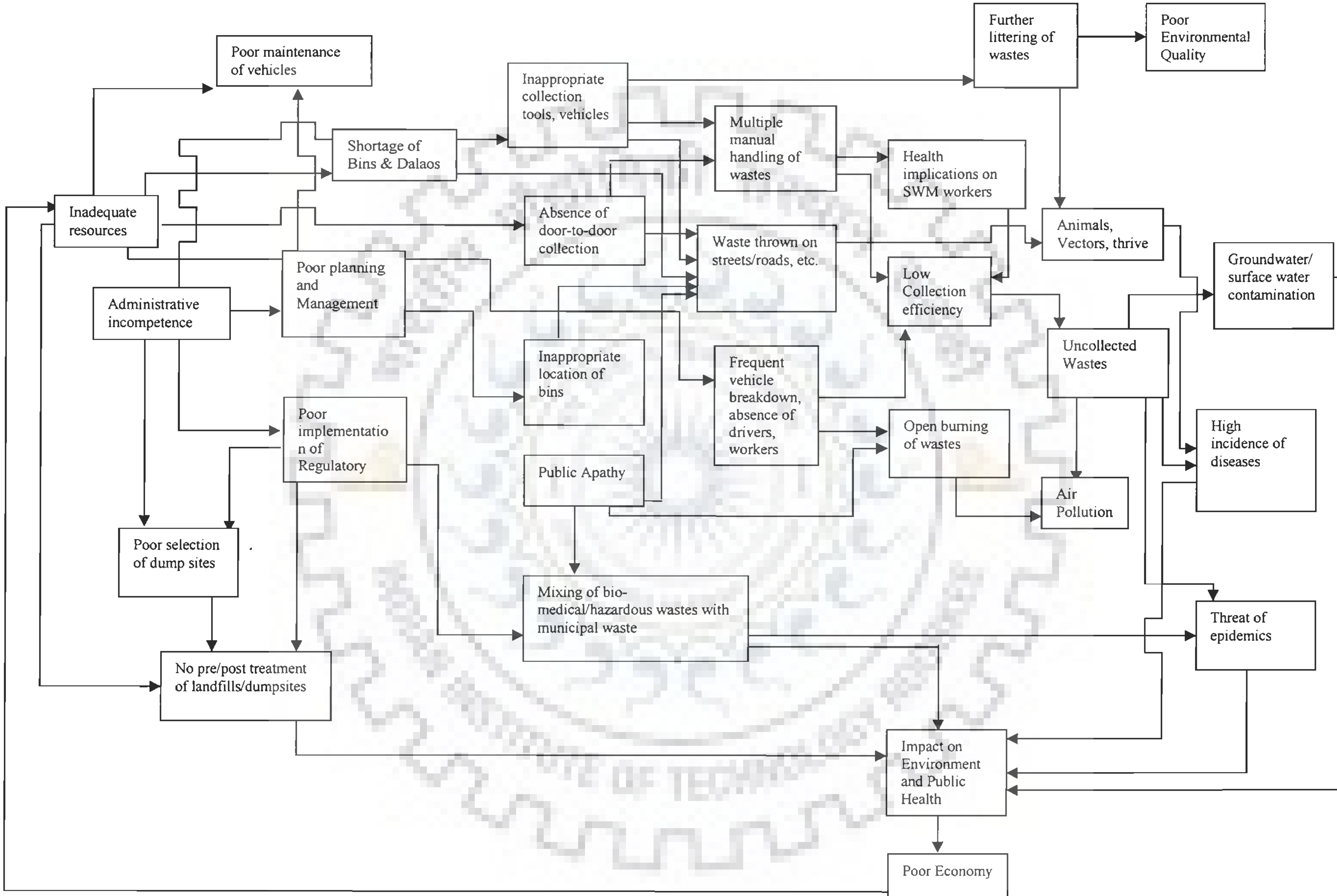


Fig. 3.46: Cause-Effect Relationship of Existing Solid Waste Management in Kanpur City

Chapter 4

DYNAMIC FUNCTIONS OF THE STUDY AREA

4.0 INTRODUCTION

It is essential to understand the physical, socio-economic and environmental conditions and infrastructure of the system at the grassroots level for proper understanding of the functions of a system. Survey research methods have been employed to achieve this. Some of the major variables to conduct the investigation are like, household size, income, religion, expenditure on various commodities, means of transportation, education, primary and secondary occupation, housing condition, water supply, sewerage, drainage, solid waste management related issues, health problems, willingness to pay user charges for better services, etc.

Pre-tested schedules have been used to conduct the grassroots level investigation, and a survey of 300 households is done. Data collection was followed by crosschecking and subsequent correction of discrepancies and transference of collected data into code sheets. For statistical analysis, Excel and SPSS software packages were used. Household income has been chosen as the dependant variable and the others as independent variables for analysis, and the results are presented in the subsequent section. The methodology employed to conduct the survey is presented in Chapter 1.

4.1 SOCIO-ECONOMIC, ENVIRONMENTAL AND INFRASTRUCTURE CONDITIONS OF THE STUDY AREA

4.1.1 INCOME

Income is one of the most important parameters that decide the functions of a dynamic system like city. It decides the standard of living, purchasing power, consumption pattern, infrastructure, capital formation, savings, trade and commerce, etc., of the residents. The total 300 households selected for the present investigation have been grouped under six major categories for better understanding of the dynamics of resident population. These classified income groups are people having annual income less than Rs 50000, Rs 50000-100000, Rs 100000-150000, Rs 150000-200000, Rs 200000-250000 and those having annual income greater than Rs 250000 respectively, and is presented in Table 4.1 and Fig. 4.1.

The table illustrates that the number of respondents show a decreasing trend along with increase in income from the Second group onwards. The income group with annual income of Rs 50000-100000 form about half of the surveyed households, i.e., 46.33 per cent, followed by the next income group (Rs 100000-150000) occupying the second place with more than one-fourth of the respondents, i.e., 28 per cent. This indicates that middle class forms the bulk of the sample population and truly reflects the dominance of lower and higher middle income group people in the structure of a typical Indian city. It is observed that two-third respondents are confined within the income group Rs 50000-100000 and Rs 100000-150000. The number of households confined in the lowest income group is just about one-tenth of the total households, i.e., 11.67 per cent. The other three income groups Rs 150000-200000, Rs 200000-250000, and greater than 250000 comprise 9, 2.67 and 2.33 per cent respectively.

Table 4.1: Income-wise distribution of surveyed households

S. No.	Income-group (Rs in 000)	No. of HHS	Per cent
1	<50	35	11.67
2	50-100	139	46.33
3	100-150	84	28.00
4	150-200	27	9.00
5	200-250	8	2.67
6	>250	7	2.33
	Total	300	100.00

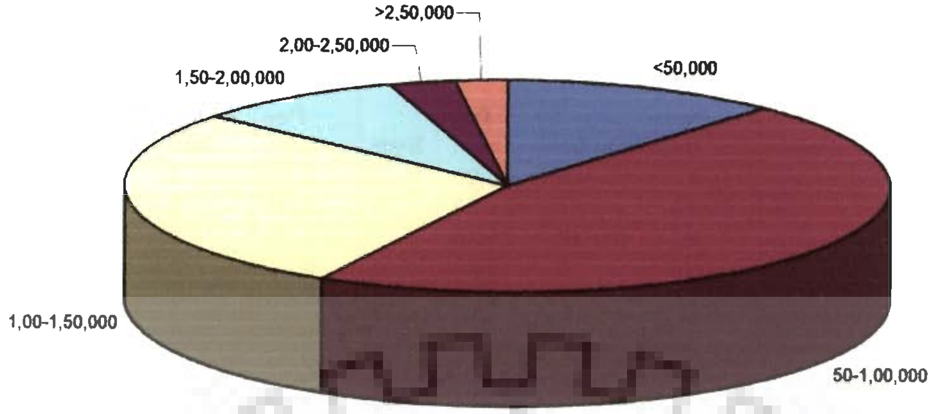


Fig. 4.1: Income wise distribution of households

Note: People living in slums have been excluded from the present investigation due to time and resource constraints as explained in the limitations in Chapter1.

4.1.2 RELIGION

Religion is an integral part of Indian society. The major religions followed in the country is Hinduism, followed by Islam, Christianity, Sikhism, Buddhism, Jainism, etc., living on and off in a harmonious relationship. It has been observed that people of minority groups tend to club together, phenomena observed in Indian cities and towns of all sizes. Certain social habits like food habits, clothing, cultural traits, hygiene, etc., are a reflection of the ideological religious thinking of the people. Keeping this in view, an attempt was therefore made to study the religious pattern of the people of the study area, and is presented in Table 4.2 and Fig 4.2.

The table elucidates that of the observed 300 households, 86.33 per cent belong to Hindu religion, signifying that it is a Hindu dominated city, followed by 10.67 per cent Muslims, 2.33 per cent Sikhs and 0.67 per cent Christians.

Table 4.2: Income-group and religion

S. No.	Income-group (Rs in 000)	Hindu	Per cent	Muslim	Per cent	Sikh	Per cent	Christian	Per cent	Total no. of HHs
1	<50	27	10.42	8	25.00	0	0.00	0	0.00	35
2	50-100	130	50.19	7	21.88	0	0.00	2	100.00	139
3	100-150	67	25.87	10	31.25	7	100.00	0	0.00	84
4	150-200	22	8.49	5	15.63	0	0.00	0	0.00	27
5	200-250	6	2.32	2	6.25	0	0.00	0	0.00	8
6	>250	7	2.70	0	0.00	0	0.00	0	0.00	7
	Total	259	100.00	32	100.00	7	100.00	2	100.00	300
	Per cent	86.33		10.67		2.33		0.67		100

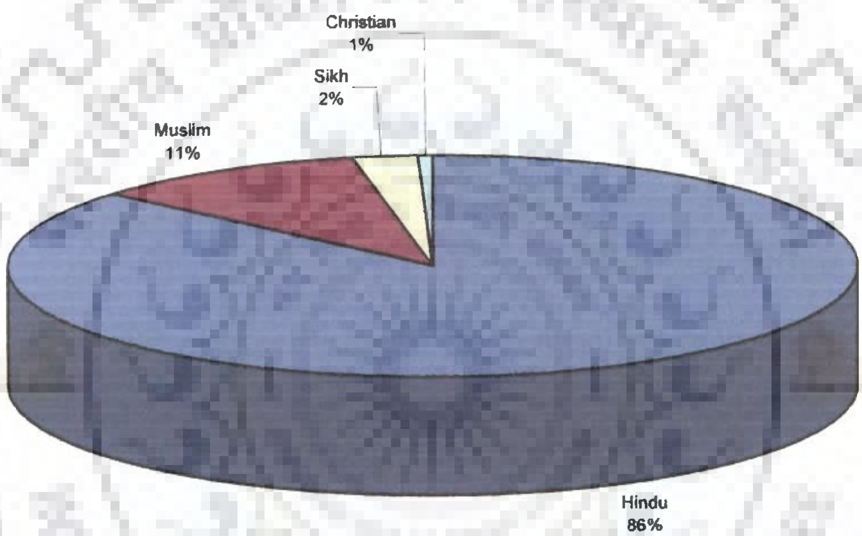


Fig. 4.2: Religion-wise distribution of surveyed households

An observation pilot study of the city indicates that areas like Meston road, Jajmau, Bakarmandi, Chamanganj, etc., are dominated by Muslims, pockets of Govindnagar, Harjindernagar, etc., by Sikhs, while other areas have mixed religious group. Kanpur is a communally sensitive place and even small clashes often turn into riots as evident from the recent history of the city.

The Investigator has observed during the survey that the areas dominated by Muslims like Bakarmandi have poor to very poor sanitary conditions. The lanes and by-lanes often stink with heaps of uncollected garbage lying outside and near residences. Similar is the case for the new wards and areas lying in peripheral areas of the city.

4.1.3 POPULATION

Population is a key parameter of both urban and rural systems. Indian cities are soon becoming the pull-factors, drawing population from nearby villages and towns. One of the important population parameters is the household size. Household size and the relative income of the family is the determining force for the family's prosperity, well-being and social status. Owing to the importance of household size, distribution of males and females among various income-groups, an attempt has been made by the Investigator to include the same in survey investigations. The results are presented in Table 4.3 and Fig 4.3.

Table 4.3: Population distribution

S. No.	Income-group (Rs in 000)	No. of males	Per cent	No. of females	Per cent	Total no.	Per cent	Average HH size
1	<50	75	9.95	71	9.78	146	9.86	4.2
2	50-100	330	43.77	316	43.53	646	43.65	4.65
3	100-150	217	28.78	208	28.65	425	28.72	5.06
4	150-200	66	8.75	67	9.23	133	8.99	4.93
5	200-250	20	2.65	20	2.75	40	2.70	5
6	>250	46	6.10	44	6.06	90	6.08	12.86
	Total	754	100.00	726	100.00	1480	100.00	6.12

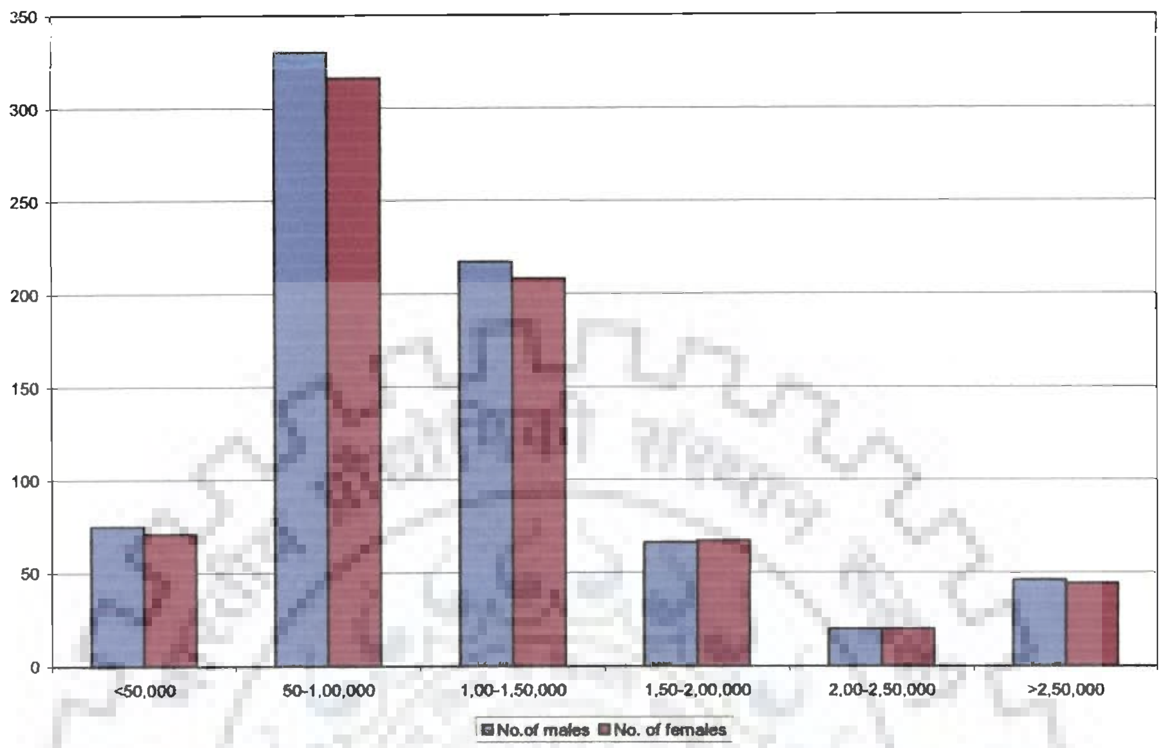


Fig. 4.3: Distribution of males/females in various income-groups

The table and figure clearly shows that there is almost an equal distribution of males and females in all the income-groups among the surveyed households. The distribution is more equal in the higher income-groups. More than two-third of the surveyed persons belong to the second and third income-groups i.e., 72 per cent of the persons fall under the income-groups Rs 50000-100000 and Rs 100000-150000. The table further illustrates that there are 1480 people in all the 300 surveyed families, with an average family size of 6. The sixth income group (greater than Rs 250000) shows a very high family size because of the presence of joint families in this group for the surveyed households. Excluding this income-group, the average household size is coming as 4.8. An interesting observation as illustrated in the table is that the average family size increases gradually as the income increases. It is 4.2 for the lowest income group and increases to 5 for the fifth income-group. This is in contradiction to the general notion that lower income-groups have larger family size. It seems that even the lower income group of the city is aware of the various population control measures and willingly participate in the process.

4.1.4 Literacy and Education

Literacy rate of a society is certainly a direct indicator of the socio-economic development and well being of its people. It is one of the basic needs of the society and decides its human development index. Besides, literates are believed to have more environmental consciousness and have the ability to adapt and practice methods leading to sustainable development and better waste management practices. Having this in mind, this parameter was studied for both males and females during the sample survey and is presented in Table 4.4 and 4.5 and in Fig. 4.4.

Table 4.4: Education level among males

S. No.	Income-group (Rs in 000)	No education	Up to 8th	Matric	Graduation	PG	Professional	Total HHs
1	<50	2	5	13	12	3	0	35
2	50-100	0	0	24	90	19	6	139
3	100-150	0	0	4	43	31	6	84
4	150-200	0	0	4	10	10	3	27
5	200-250	0	0	0	3	2	3	8
6	>250	0	0	0	2	3	2	7
	Total	2	5	45	160	68	20	300
	Percent	0.67	1.67	15.00	53.33	22.67	6.67	100.00

Table 4.5: Education level among females

S. No.	Income-group (Rs in 000)	No education	Upto 8th	Matric	Graduation	PG	Professional	Total HHs
1	<50	2	8	12	13	0	0	35
2	50-100	0	5	53	55	23	3	139
3	100-150	0	0	23	27	34	0	84
4	150-200	0	0	8	8	10	1	27
5	200-250	0	0	0	3	3	2	8
6	>250	0	0	1	1	4	1	7
	Total	2	13	97	107	74	7	300
	Per cent	0.67	4.33	32.33	35.67	24.67	2.33	100.00

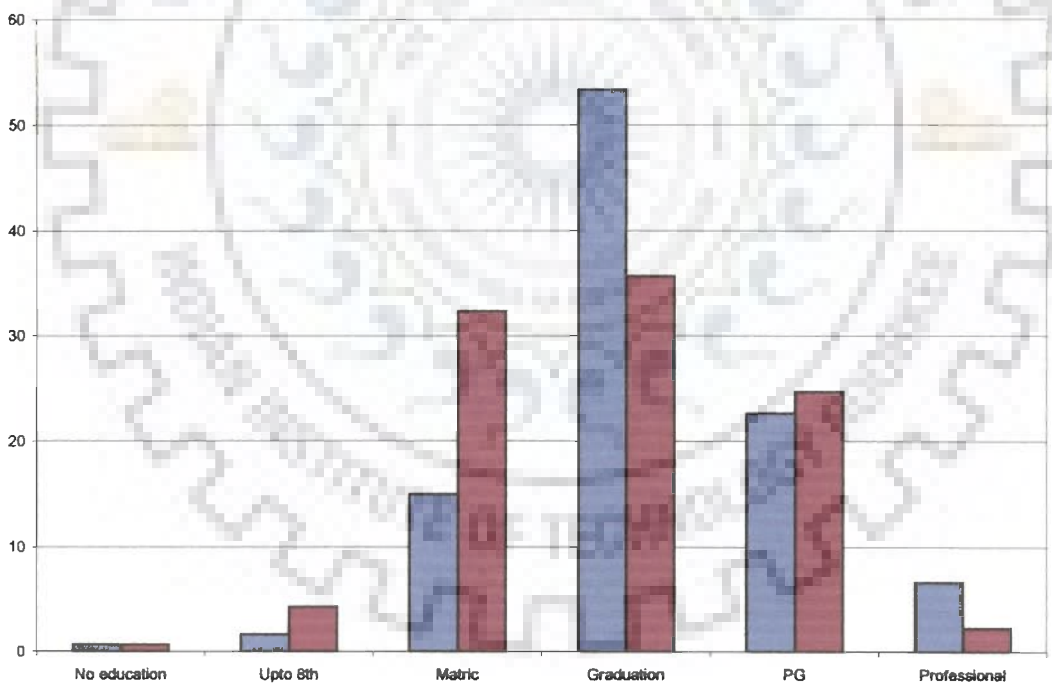


Fig. 4.4: Education level among males and females (as percentage)

The tables illustrate that almost half of the total households, i.e., 53.3 per cent have males with maximum education level of Graduation while that of females is only 35.7 per cent. In case of higher education, one-fourth of the total households have females studied up to post graduation level, i.e., 24.7 per cent while that of males is slightly lower at 22.7 per cent. Among the lowest income group people, only 2 households had overall literacy level of zero. Higher income groups show better education level both among males and females.

4.1.5 EMPLOYMENT

Cities are considered to be engines of economic growth and attract people from far away places by the sheer presence of better employment opportunities. The city of Kanpur has a stronghold in both secondary and tertiary sectors of economy but it is showing more strength in tertiary sector recently due to the poor status of infrastructure, in general. The employment status is a direct indicator of the quality of life and an indirect indicator of the type and quantity of waste generated. It has therefore, been studied by the Investigator. The employed persons confined in various income-groups have been carefully studied and presented in Table 4.6 and Fig. 4.5.

Table 4.6: Employment status

S. No.	Income-group (Rs in 000)	Total no. of persons	No. of employed members	Percentage of total employed	Percentage employed of income group
1	<50	146	39	9.61	26.71
2	50-100	646	165	40.64	25.54
3	100-150	425	123	30.30	28.94
4	150-200	133	39	9.61	29.32
5	200-250	40	16	3.94	40.00
6	>250	90	24	5.91	26.67
	Total	1480	406	100.00	27.43

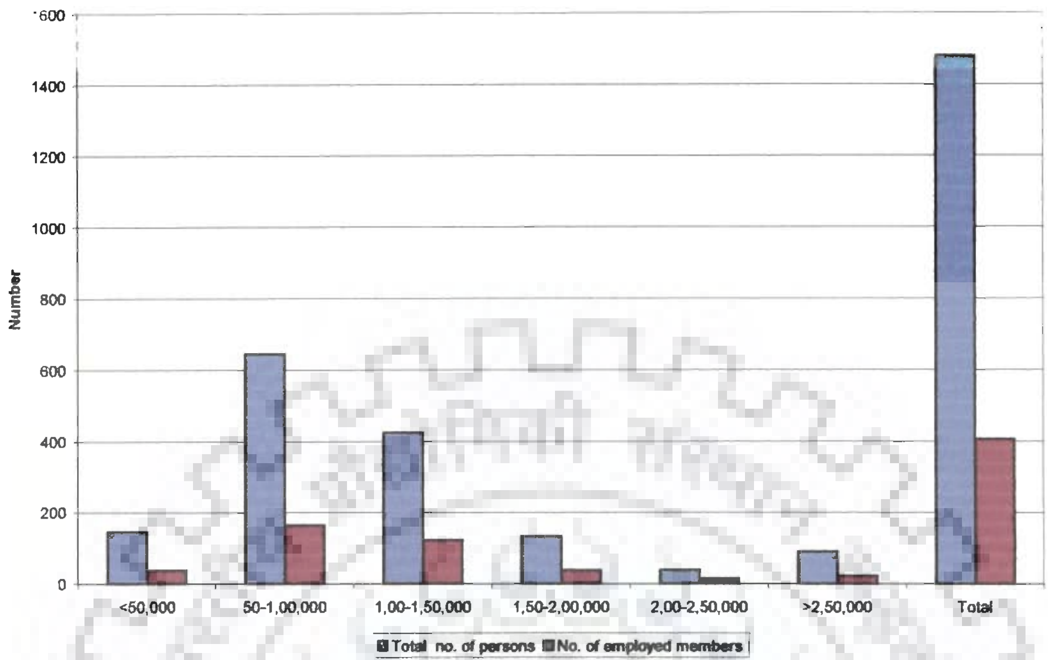


Fig. 4.5: Employment status

The table illustrates that of the total surveyed population, less than one-third are employed, i.e., 27.43 per cent is employed; the rest being dependent population which is high. It is further observed that two-fifth of the people belonging to the higher income group of Rs 200000-250000 annual income are employed, i.e., 40 per cent. In the other income-groups, the percentage employment varies between 26 and 29 per cent. It is also observed that almost one-third of the total employed population belong to the lower income–groups (Rs 50000-100000 and Rs 100000-150000 annual income).

A further analysis of the people engaged in various occupations (primary and secondary) throws light on the employment pattern among various income groups and is presented in Table 4.7 and 4.8 respectively. Table 4.7 clearly illustrates that in case of primary occupation, three-fifth of the total population, i.e., 60.67 per cent of the total surveyed households are employed in government job, 17 per cent in own business and 8.33 per cent in private service. Table 4.8 clearly illustrates that in case of secondary occupation only one-fifth, i.e., 19 per cent of the households are engaged in some kind of secondary occupation of which 4.67 per cent are engaged in private service, 3.33 per cent in agriculture, 2.33 per cent in government jobs and 7.33 per cent in others.

Table 4.7: Employment pattern for primary occupation among various income-groups

S. No.	Income-group (Rs in 000)	Agriculture	Per cent	Own business	Per cent	Private service	Per cent	Govt. job	Per cent	Others	Per cent	Total
1	<50	2	*50*	2	*3.92*	6	*24*	20	*10.99*	5	*13.16*	35
2	50-100	2	*50*	21	*41.18*	9	*36*	97	*53.30*	10	*26.32*	139
3	100-150	0	*0*	18	*35.29*	6	*24*	53	*29.12*	7	*18.42*	84
4	150-200	0	*0*	7	*13.73*	3	*12*	9	*4.95*	8	*21.05*	27
5	200-250	0	*0*	2	*3.92*	1	*4*	1	*0.55*	4	*10.53*	8
6	>250	0	*0*	1	*1.96*	0	*0*	2	*1.10*	4	*10.53*	7
	Total	4	*100*	51	*100*	25	*100*	182	*100*	38	*100*	300
	Per cent	*1.33*		*17.00*		*8.33*		*60.67*		*12.67*		*100.00*

Table 4.8: Employment pattern for Secondary occupation among various income-groups

S. No.	Income-group (Rs in 000)	Agriculture	Per cent	Own business	Per cent	Private service	Per cent	Govt job	Per cent	Others	Per cent	None	Per cent
1	<50	0	0	0	0	0	0	0	0	0	0	35	14.40
2	50-100	5	50	1	25	7	50	1	14.29	11	50	114	46.91
3	100-150	2	20	2	50	6	42.86	3	42.86	9	40.91	62	25.51
4	150-200	2	20	1	25	1	7.14	1	14.29	1	4.55	21	8.64
5	200-250	0	0	0	0	0	0	2	28.57	0	0.00	6	2.47
6	>250	1	10	0	0	0	0	0	0	1	4.55	5	2.06
	Total	10	100	4	100	14	100	7	100	22	100	243	100.00
	Per cent	3.33		1.33		4.67		2.33		7.33		81.00	

4.1.6 Transportation

A strong efficient public transport system is the lifeline of any urban system. It is a major parameter having cause-effect relationships with various sub-systems like housing, place of work, etc. Increase in personalized vehicles results in the need for greater space for roads; in the absence of which congestion, traffic jams and higher air pollution is observed. It also disrupts the transportation of the collected waste due to want of clear space on roads. The study area has a poor public transport network in general. Inter-city buses, auto rickshaws, highly polluting Vikram (6-seater) constitute the fast moving public transport system of the city, while the slow-moving rickshaws are prominent source for covering short distances. In the absence of an efficient public transport, people mostly use their own personal vehicles for mobility. Besides, in Indian psychology, ownership of vehicles is a matter of prestige and social status as it reflects the purchasing power and economic well-being of the people. Having this knowledge in mind, an attempt has therefore been made to analyse vehicle ownership pattern and the mode of transportation used by the households surveyed and the results are presented in Table 4.9 and Table 4.10 and Fig. 4.6.

Table 4.9: Mode of transportation among various income-groups

S. No.	Income-group (Rs in 000)	Bus	Per cent	Tempo	Per cent	Own vehicle	Per cent	On foot	Per cent	Combi nation	Per cent	Total
1	<50	0	0.00	11	36.67	23	8.78	1	33.33	0	0.00	35
2	50-100	1	100.00	16	53.33	121	46.18	0	0.00	1	25.00	139
3	100-150	0	0.00	0	0.00	80	30.53	2	66.67	2	50.00	84
4	150-200	0	0.00	2	6.67	24	9.16	0	0.00	1	25.00	27
5	200-250	0	0.00	0	0.00	8	3.05	0	0.00	0	0.00	8
6	>250	0	0.00	1	3.33	6	2.29	0	0.00	0	0.00	7
	Total	1	100.00	30	100.00	262	100.00	3	100.00	4	100.00	300
	Per cent	0.33		10.00		87.33		1.00		1.33		100.00

The table clearly illustrates that a majority of people use personalised vehicles amounting to 87.33 per cent (more than four-fifth of the surveyed households) followed by 10 per cent people using tempo (6-seaters) for mobility and only 1.33 per cent using a combination of bus, tempo and own vehicle as per the need. A very low percentage of people are found to be using buses, indicating the poor state of the service. The analysis of vehicle wise usage indicates that almost half of the users using tempo for transportation belong to the second income-group (Rs 50000-100000) i.e., 53.33 per cent, followed by the lowest income-group people (36.67 per cent). Among the users of personalised vehicles also, the second income group leads with almost half of the people with own vehicles belonging to this income-group of Rs 50000-100000. It is also observed that among the people using combination of these modes of transport, 50 per cent belong to the income-group Rs 100000-150000.

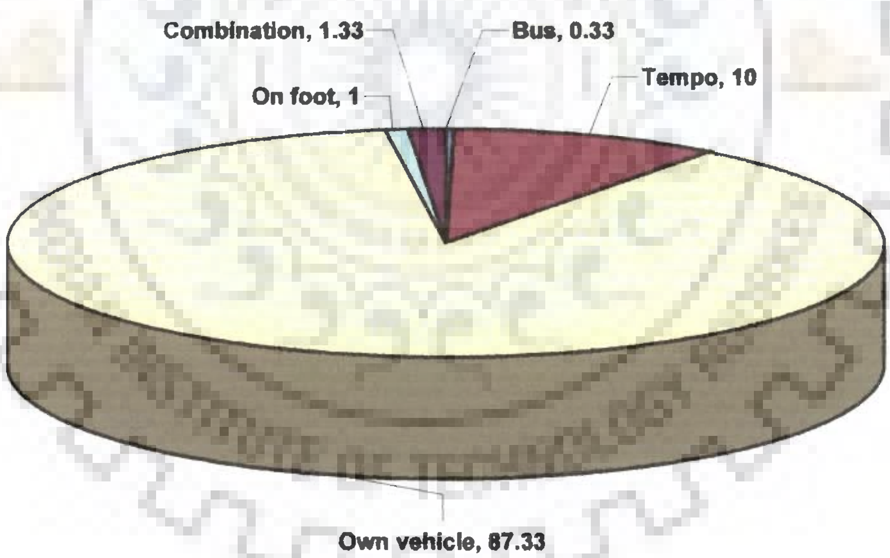


Fig. 4.6: Mode of transportation (as percentage)

As far as ownership of vehicles is concerned, almost two-third of the personalised vehicles including bicycles belong to the lower income-groups, i.e., Rs 50000-100000 and Rs 100000-150000 (Table 4.10). The table further illustrates that almost two-fifth of the total personalised vehicles belong to the second income-group, i.e., 41.24 per cent, followed by the third income-group. The third-income group (Rs 100000-150000) has maximum number of cars (43.84 per cent) while second income-group (Rs 50000-100000) has maximum number of two-wheelers and bicycles (38.46 per cent and 52.42 per cent respectively).

Table 4.10: Ownership of vehicles

S. No.	Income-group (Rs in 000)	No. of cars	Per cent	No. of 2-wheeler	Per cent	No. of bicycle	Per cent	Total	Per cent
1	<50	0	0.00	14	4.90	38	14.13	52	8.28
2	50-100	8	10.96	110	38.46	141	52.42	259	41.24
3	100-150	32	43.84	106	37.06	53	19.70	191	30.41
4	150-200	15	20.55	28	9.79	16	5.95	59	9.39
5	200-250	6	8.22	15	5.24	4	1.49	25	3.98
6	>250	12	16.44	13	4.55	17	6.32	42	6.69
	Total	73	100.00	286	100.00	269	100.00	628	100.00

Public transport service is the backbone for an efficient city. The level of satisfaction with the public transport service has therefore been studied by the investigator and presented in Table 4.11 and Fig. 4.7. An attempt is also made to study the distance of residence from the place of work to have an idea of the average distances travelled by the surveyed households for daily work. Besides, it often reflects the availability of employment opportunities, population density, etc., and the results are presented in Table 4.12.

Table 4.11: Public Transport Service

S. No.	Income-group (Rs in 000)	Good	Per cent	Average	Per cent	Poor	Per cent	Total
1	<50	9	14.1	21	10.77	5	12.20	35
2	50-100	34	53.13	87	44.62	18	43.90	139
3	100-150	14	21.88	60	30.77	10	24.39	84
4	150-200	5	7.81	17	8.72	5	12.20	27
5	200-250	0	0.00	6	3.08	2	4.88	8
6	>250	2	3.13	4	2.05	1	2.44	7
	Total	64	100.00	195	100.00	41	100.00	300
	Per cent	21.33		65.00		13.67		100.00

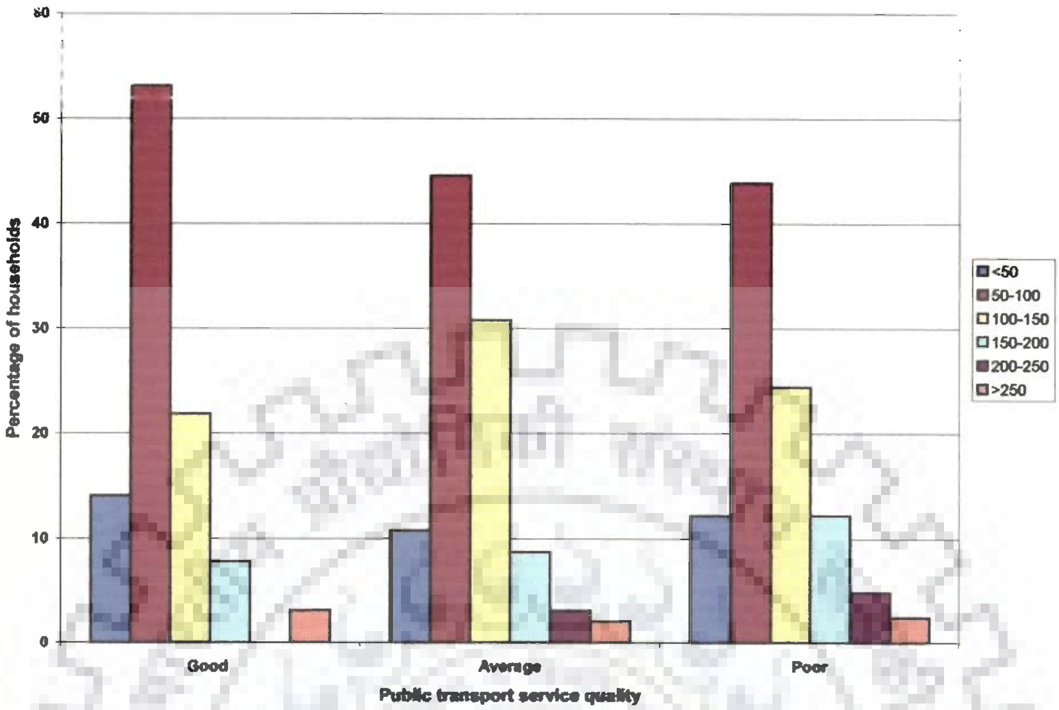


Fig. 4.7: Public transport service quality

The table illustrates that 21.33 per cent of the respondents say that the public transport service in the city is good, 65 per cent say it is average while 13.67 per cent say it is in a dismal state and needs improvement. Among the respondents who opinioned that the public transport services are good, almost half belong to the income group of Rs 50000-100000 i.e., 53.13 per cent. Similarly, 44.62 per cent of the respondents saying that the public transport service is average also belong to this group while another 43.90 per cent of the respondents saying the service is poor belong to the income group Rs 50000-100000. Table 4.12 further elucidates that the more than half of the respondents have their work places located within 4 km distance (56.34 per cent) while 11.33 per cent of the households have their work places up to 6 km away from home. Another 22.66 per cent of the households have their work places between 6 and 10 km away from home while 9.67 per cent have their work places more than 10 km away.

It is also observed that people whose work place is greater than 10 km usually work in Government or quasi-government organisations and industries.

Table 4.12: Distance from place of work (in km)

S. No.	Income-group (Rs in 000)	<2	2-4	4-6	6-8	8-10	>10	Total HHs
1	<50	15	5	9	3	2	1	35
2	50-100	35	47	18	12	13	14	139
3	100-150	25	17	5	13	14	10	84
4	150-200	10	7	1	3	4	2	27
5	200-250	3	0	0	3	0	2	8
6	>250	1	4	1	0	1	0	7
	Total	89	80	34	34	34	29	300
	Per cent	29.67	26.67	11.33	11.33	11.33	9.67	100.00

The type and condition of roads is an important indicator of the level of infrastructure development of an urban system and has direct and indirect impacts on the functioning of the system. Therefore, the type of roads were also studied during the survey, analysed and presented in Table 4.13 and 4.14. Table 4.13 illustrates that more than four-fifth of the surveyed households have kutcha (brick/mud laden) roads and/or bylanes in their vicinity, i.e., 82 per cent while only 18 per cent have pucca roads. Among the respondents with kutcha roads in their residence vicinity, almost three-fourth belong to the income groups Rs 50000-100000 and Rs 100000-150000. At some places, the inner lanes are mud-covered and the condition becomes very poor during downpours especially in the suburban and peripheral wards.

Table 4.13: Type of road/bylanes

S. No.	Income-group (Rs in 000)	Kutcha	Per cent	Pucca	Per cent	Total
1	<50	26	10.57	9	16.67	35
2	50-100	106	43.09	33	61.11	139
3	100-150	77	31.30	7	12.96	84
4	150-200	24	9.76	3	5.56	27
5	200-250	7	2.85	1	1.85	8
6	>250	6	2.44	1	1.85	7
	Total	246	100.00	54	100.00	300
	Per cent	82.00		18.00		100.00

Table 4.14: Maintenance of roads

S. No.	Income-group (Rs in 000)	Well maintained	Per cent	Poorly maintained	Per cent	No maintenance	Per cent	Total
1	<50	7	5.26	22	15.94	6	20.69	35
2	50-100	65	48.87	61	44.20	13	44.83	139
3	100-150	40	30.08	35	25.36	9	31.03	84
4	150-200	10	7.52	16	11.59	1	3.45	27
5	200-250	6	4.51	2	1.45	0	0.00	8
6	>250	5	3.76	2	1.45	0	0.00	7
	Total	133	100.00	138	100.00	29	100.00	300
	Per cent	44.33		46.00		9.67		100.00

With regard to maintenance of roads in the vicinity of their residence, Table 4.14 elucidates that 44.33 per cent respondents say that the roads in their vicinity are well-maintained, 46 per cent say that the roads are poorly maintained while 9.67 per cent of the respondents report no maintenance of roads. Thus, more than half of the respondents report poor to no maintenance of the roads in their residence vicinity.

4.1.7 Distance to Social Infrastructure

The distribution of various social infrastructure facilities are a precursor to effective and smooth functioning of a city and help in raising the human development index. Access to such facilities is usually good for higher-income group people and gradually decreases on moving down the income ladder. The observed city, however, has more or less equitable distribution of shopping facilities, education and health-care facilities. The qualitative distribution however, varies. It is also observed that the higher-income group people tend to go to places which provide better services or are more posh and chic, irrespective of the distance from their residence. Recreation facilities are not well distributed. In fact, the city lacks in open spaces, parks and playgrounds, etc.

The shopping habits of the people has been carefully studied, analysed and presented in Table 4.15. The table illustrates that for shopping purpose, almost one-third of the people of all income-groups surveyed usually have adequate facilities near their homes (up to 4 km), i.e., 74 per cent. It is observed that 11.33 per cent of the respondents go up to 6 km away from residence for shopping while 6.33 per cent go up to 8 km for shopping; only 1.33 per cent of the respondents go more than 10 km away for shopping.

Table 4.15: Place of shopping (distance in km)

S. No.	Income-group (Rs in 000)	<2	Per cent	2-4	Per cent	4-6	Per cent	6-8	Per cent	8-10	Per cent	>10	Per cent	Total
1	<50	18	51.43	10	28.57	5	14.29	1	2.86	1	2.86	0	0.00	35
2	50-100	62	44.60	52	37.41	12	8.63	3	2.16	8	5.76	2	1.44	139
3	100-150	28	33.33	22	26.19	9	10.71	14	16.67	10	11.90	1	1.19	84
4	150-200	10	37.04	7	25.93	7	25.93	1	3.70	1	3.70	1	3.70	27
5	200-250	3	37.50	4	50.00	0	0.00	0	0.00	1	12.50	0	0.00	8
6	>250	4	57.14	2	28.57	1	14.29	0	0.00	0	0.00	0	0.00	7
	Total	125	41.67	97	32.33	34	11.33	19	6.33	21	7.00	4	1.33	300
	Per cent	41.67		32.33		11.33		6.33		7.00		1.33		100.00

The frequency of visits for entertainment has also been studied and presented in Table 4.16. Visits for entertainment include visits to parks, playgrounds, restaurant, picnic, water parks, cinema, etc. It shows that the frequency of visits increases as one moves up the economic ladder as presented in Table 4.16. The table shows that one-third of the total surveyed households do not go for any entertainment in a month, i.e., 33.33 per cent while 42.33 per cent go once in a month, 15 per cent go twice, 5 per cent thrice and only 1 per cent go more than 5 times in a month for entertainment. This shows that entertainment visits are not much important to the people in general.

Table 4.16: Frequency of entertainment (in a month)

S. No.	Income-group (Rs in 000)	0	1	2	3	4	5	>5	Total
1	<50	24	7	4	0	0	0	0	35
2	50-100	57	64	11	4	3	0	0	139
3	100-150	11	40	23	5	4	0	1	84
4	150-200	5	13	3	4	0	0	2	27
5	200-250	3	1	1	2	0	1	0	8
6	>250	0	2	3	0	2	0	0	7
	Total	100	127	45	15	9	1	3	300
	Per cent	33.33	42.33	15.00	5.00	3.00	0.33	1.00	100.00

4.1.8 HOUSING

Housing is one of the key parameters which decide the human development index and is one of the basic necessities of life. Owing a house in urban centres is very difficult due to the scarcity of land. Housing directly affects the health of the citizens. A well ventilated, serviced, structurally safe and aesthetically pleasing house is every man's delight. Similar to other metropolitan cities of the country, the study area suffers from housing shortage. An attempt has therefore, been made to study the housing characteristics of the surveyed households and presented in Table 4.17 and Fig. 4.8.

Table 4.17: Type of Dwelling-unit

S. No.	Income-group (Rs in 000)	Detached	Per cent	Semi-detached	Per cent	Apartment	Per cent	Row	Per cent	Total	Per cent
1	<50	7	20.00	5	14.29	0	0.00	23	65.71	35	100.0
2	50-100	31	22.30	32	23.02	11	7.91	65	46.76	139	100.0
3	100-150	35	41.67	18	21.43	4	4.76	27	32.14	84	100.0
4	150-200	12	44.44	5	18.52	2	7.41	8	29.63	27	100.0
5	200-250	3	37.50	0	0.00	1	12.50	4	50.00	8	100.0
6	>250	3	42.86	2	28.57	0	0.00	2	28.57	7	100.0
	Total	91	30.33	62	20.67	18	6.00	129	43.00	300	100.00

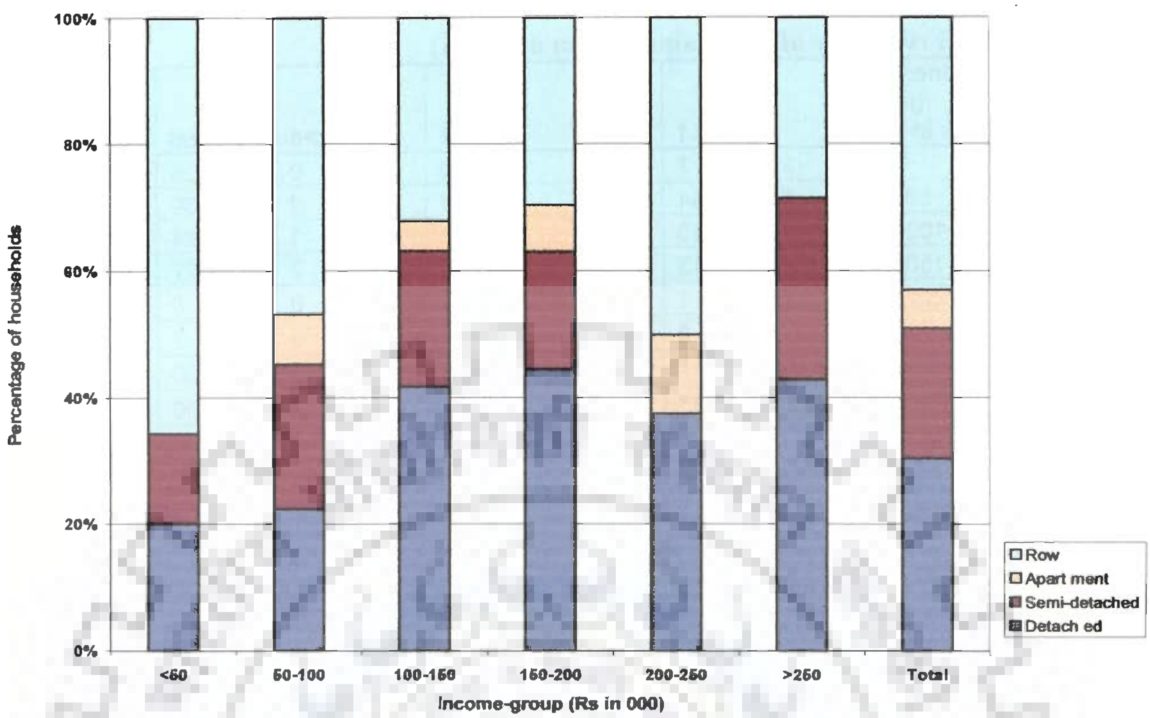


Fig. 4.8: Type of dwelling unit

The table illustrates that almost two-fifth of the respondents (43 per cent) live in row houses which is the most popular of all the categories; followed by detached houses which is 30.33 per cent while another one-fifth of the surveyed households live in semi-detached houses (20.67 per cent). In the first and second income group, maximum number of people lives in row houses (65.71 per cent and 46.76 per cent respectively). In the third, fourth and sixth income-groups, maximum number of surveyed households were found to live in detached houses (41.67 per cent, 44.44 per cent and 42.86 per cent respectively) while in the fifth income-group most people were found to live in row houses (50 per cent).

It is also important to study the age of dwelling unit and the liveability conditions. An attempt has therefore, been made to study these factors and is presented in Table 4.18 and 4.19.

Table 4.18: Age of house in years

S. No.	Income-group (Rs in 000)	<10	Per cent	10-25	Per cent	25-40	Per cent	>40	Per cent	Total	Per cent
1	<50	10	28.57	14	40.00	6	17.14	5	14.29	35	100.0
2	50-100	49	35.25	47	33.81	26	18.71	17	12.23	139	100.0
3	100-150	17	20.24	38	45.24	13	15.48	16	19.05	84	100.0
4	150-200	7	25.93	12	44.44	2	7.41	6	22.22	27	100.0
5	200-250	2	25.00	2	25.00	1	12.50	3	37.50	8	100.0
6	>250	1	14.29	4	57.14	0	0.00	2	28.57	7	100.0
	Total	86		117		48		49		300	
	Per cent	28.67		39.00		16.00		16.33		100.00	

Table 4.19: Liveability condition of houses

S. No.	Income-group (Rs in 000)	Good	Per cent	liveable	Per cent	dilapidated	Per cent	Total	Per cent
1	<50	12	34.29	21	60.00	2	5.71	35	12
2	50-100	54	38.85	85	61.15	0	0.00	139	54
3	100-150	58	69.05	26	30.95	0	0.00	84	58
4	150-200	22	81.48	5	18.52	0	0.00	27	22
5	200-250	5	62.50	3	37.50	0	0.00	8	5
6	>250	5	71.43	2	28.57	0	0.00	7	5
	Total	156		142		2		300	156
	Per cent	52.00		47.33		0.67		100	52.00

Table 4.18 illustrates that almost two-fifth of the surveyed dwelling units are of the age 10 to 25 years (i.e., 39 per cent) and should be in sound condition given this age. This is followed by 28.67 per cent of the total dwelling less than 10 years in age, 16.33 per cent as very old (greater than 40 years) and another 16 per cent as old (25 to 40 years old). Among the highest income-groups it is observed that a considerable percentage of dwelling units is coming under the greater than 40 years age. This is due to the reason that these houses are mostly ancestral and in quite good condition owing to frequent maintenance. Table 4.19 further illustrates that 52 per cent of the surveyed houses are in good condition, 47.33 per cent in liveable condition while 0.67 per cent of the houses are in dilapidated condition and these belong to people from the lowest income-group.

An attempt has also been made to study the number of rooms in the dwelling units of the surveyed households and is presented in Table 4.20.

Table 4.20: Number of rooms in dwelling units for various income-groups

S. No.	Income-group (Rs in 000)	1-3	Per cent	4-6	Per cent	7-9	Per cent	>9	Per cent	Total	Per cent
1	<50	34	97.14	1	2.86	0	0.00	0	0.00	35	100.0
2	50-100	93	66.91	43	30.94	3	2.16	0	0.00	139	100.0
3	100-150	27	32.14	48	57.14	7	8.33	2	2.38	84	100.0
4	150-200	8	29.63	15	55.56	4	14.81	0	0.00	27	100.0
5	200-250	1	12.50	3	37.50	3	37.50	1	12.50	8	100.0
6	>250	0	0.00	0	0.00	5	71.43	2	28.57	7	100.0
	Total	163	54.33	110	36.67	22	7.33	5	1.67	300	100.0

The table illustrates that the highest income-groups have bigger houses with 7 to 9 number of rooms in their houses. While in case of the first and second income-groups (less than Rs 50000 and Rs 50000-100000), 97.14 per cent and 66.91 per cent of the households live in houses having 1 to 3 rooms respectively. In the third and fourth income-groups (Rs 100000-150000 and Rs 150000-200000), there is a slight increase in the number of rooms; 57.14 per cent and 55.56 per cent live in houses with 4 to 6 rooms respectively. On looking at the overall percentage variation with regard to number of rooms in dwelling units, there is a gradual decreasing order, i.e., more than half of the houses have 1 to 3 rooms (54.33 per cent), more than one-third have 4 to 6 rooms (36.67 per cent), 7.33 per cent have 7 to 9 rooms and only 1.67 per cent have more than 9 rooms.

An attempt has also been made to access the tenure status of the surveyed households since the tenure status has a direct impact on the quality of dwelling. The tenure status of surveyed houses is presented in Table 4.21 and Fig. 4.9. The table illustrates that more than two-third of the surveyed houses are owner-occupied, i.e., 69 per cent; while 18.33 per cent are rented and rest 12.67 per cent are owned by some government organization. It is, thus, observed that the owner-occupied houses are considerable in number and suggest that people prefer to live in self-owned houses. The ownership status increases with increase in income as observed in the table where, the highest income group people (Rs 200000-250000 and greater than Rs 250000) completely own the houses.

Table 4.21: Tenure status of houses

S. No.	Income-group (Rs in 000)	Rented	Per cent	Owned	Per cent	Other	Per cent	Total	Per cent
1	<50	10	28.57	21	60.00	4	11.43	35	100.0
2	50-100	29	20.86	85	61.15	25	17.99	139	100.0
3	100-150	11	13.10	65	77.38	8	9.52	84	100.0
4	150-200	5	18.52	21	77.78	1	3.70	27	100.0
5	200-250	0	0.00	8	100.00	0	0.00	8	100.0
6	>250	0	0.00	7	100.00	0	0.00	7	100.0
	Total	55		207		38		300	
	Per cent	18.33		69.00		12.67		100.00	

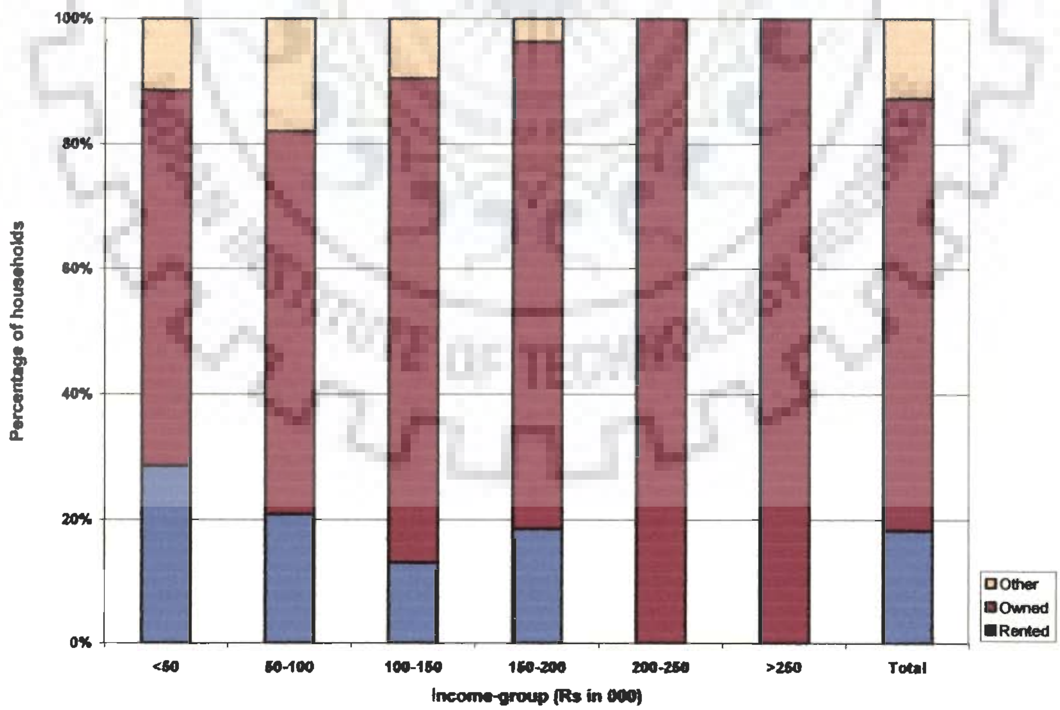


Fig. 4.9: Tenure status of houses

The housing finance system plays an important role in the ownership of houses and has therefore been studied by the Investigator and the results are presented in Table 4.22. The table clearly illustrates that almost half of the total surveyed houses are self-financed (45.33 per cent), 16.33 per cent houses are ancestral and only 7 per cent are financed by the bank. Another 31.33 per cent of the houses fall under the others category, which means houses belonging to governmental organisations like Cantonment, Hindustan Aeronautical Limited (HAL), etc. This shows that financing by banks have still not taken the pace as expected in the city.

Table 4.22: Financing of houses

S. No.	Income-group (Rs in 000)	Bank	Per cent	Self	Per cent	Ancestral	Per cent	Other	Per cent	Total	Per cent
1	<50	1	2.86	14	40.00	7	20.00	13	37.14	35	100.0
2	50-100	6	4.32	68	48.92	10	7.19	55	39.57	139	100.0
3	100-150	6	7.14	39	46.43	19	22.62	20	23.81	84	100.0
4	150-200	6	22.22	9	33.33	7	25.93	5	18.52	27	100.0
5	200-250	1	12.50	3	37.50	3	37.50	1	12.50	8	100.0
6	>250	1	14.29	3	42.86	3	42.86	0	0.00	7	100.0
	Total	21	7.00	136	45.33	49	16.33	94	31.33	300	100.0

4.1.9 Power Supply

Electricity is one of the basic necessities of modern lifestyle. It is directly related to an urban system's growth. It is well known that a city stops functioning due to power failure. Instances of public unrest and agitation on account of frequent power cuts are common in Indian cities. The study area also faces such problems and instances of public hue and cry are prevalent especially during the summers. Services like housing, water supply, transport, telecommunications, industries, etc., are all directly or indirectly inter-related with the power sector. Regular power supply of desired quality according to the need of a city is one of the indicators of the quality of life. Keeping this knowledge in mind, an attempt has therefore been made to analyse the electricity supply, type of tariff, consumption pattern, etc., in the surveyed households and presented in Table 4.23 and 4.24.

Table 4.23: Type of Tariff in various income-groups

S. No.	Income-group (Rs in 000)	Monthly	Per cent	Flat	Per cent	Both	Per cent	None	Per cent	Total	Per cent
1	<50	29	82.86	3	8.57	0	0.00	3	8.57	35	100.0
2	50-100	127	91.37	7	5.04	0	0.00	5	3.60	139	100.0
3	100-150	82	97.62	2	2.38	0	0.00	0	0.00	84	100.0
4	150-200	24	88.89	0	0.00	3	11.11	0	0.00	27	100.0
5	200-250	8	100.00	0	0.00	0	0.00	0	0.00	8	100.0
6	>250	7	100.00	0	0.00	0	0.00	0	0.00	7	100.0
	Total	277	92.33	12	4.00	3	1.00	8	2.67	300	100.0

The table illustrates that 92.33 per cent of the households have a monthly mode of payment, based on meter readings; 4 per cent have a flat payment while 1 per cent have to pay both meter-based and flat payments. On detailed investigation, it was found that these houses (who pay both meter-based and flat payments) are given connection of different phases by various private (illegal) service providers. These providers charge a flat rate while the government takes meter-based payment. It was also observed that 2.67 per cent of the houses have illegal connection (also defined as thefts) and/or have free supply from Kanpur Electricity Supply Authority as they work in them.

Table 4.24: Average bill per month (in Indian Rupees)

S. No.	Income-group (Rs in 000)	<200	Per cent	200-400	Per cent	400-600	Per cent	>600	Per cent	Total	Per cent
1	<50	15	42.86	20	57.14	0	0.00	0	0.00	35	100.0
2	50-100	21	15.11	102	73.38	14	10.07	2	1.44	139	100.0
3	100-150	1	1.19	37	44.05	37	44.05	9	10.71	84	100.0
4	150-200	0	0.00	8	29.63	12	44.44	7	25.93	27	100.0
5	200-250	0	0.00	2	25.00	3	37.50	3	37.50	8	100.0
6	>250	0	0.00	0	0.00	1	14.29	6	85.71	7	100.0
	Total	37	12.33	169	56.33	67	22.33	27	9.00	300	100.0

Table 4.24 illustrates that more than half of the surveyed households pay on an average Rs 200 to 400 as electricity bill (56.33 per cent), 22.33 per cent pay Rs 400 to 600 per month, 12.33 per cent pay less than Rs 200 while 9 per cent pay greater than Rs 600 per month as electricity bill. On further analysis, it is observed that the highest income group people consume maximum electricity as 85.71 per cent people of this group pay greater than Rs 600 per month as electricity bill. Whereas the first income group consume lesser electricity as 42.86 per cent people of this group pay less than Rs 200 as electricity bill.

A regular supply of power is essential for the smooth functioning of electricity dependent modern cities. However, Kanpur city is crippled by frequent power cuts. Therefore, the average power cut in summers and winters was also studied in the survey and is presented in Table 4.25 and 4.26 and Fig. 4.10 and 4.11.

Table 4.25: Average daily power cut in summers (hours)

S. No.	Income-group (Rs in 000)	<5	5-10	10-15	>15	Total
1	<50	2	2	15	16	35
2	50-100	18	15	60	46	139
3	100-150	5	7	40	32	84
4	150-200	1	0	15	11	27
5	200-250	0	0	5	3	8
6	>250	0	1	4	2	7
	Total	26	25	139	110	300
	Per cent	8.67	8.33	46.33	36.67	100.00

Table 4.26: Average daily power cut in winters (hours)

S. No.	Income-group (Rs in 000)	<5	5-10	10-15	>15	Total
1	<50	3	30	1	1	35
2	50-100	26	107	5	1	139
3	100-150	11	68	5	0	84
4	150-200	2	25	0	0	27
5	200-250	0	8	0	0	8
6	>250	1	6	0	0	7
	Total	43	244	11	2	300
	Per cent	14.33	81.33	3.67	0.67	100.00

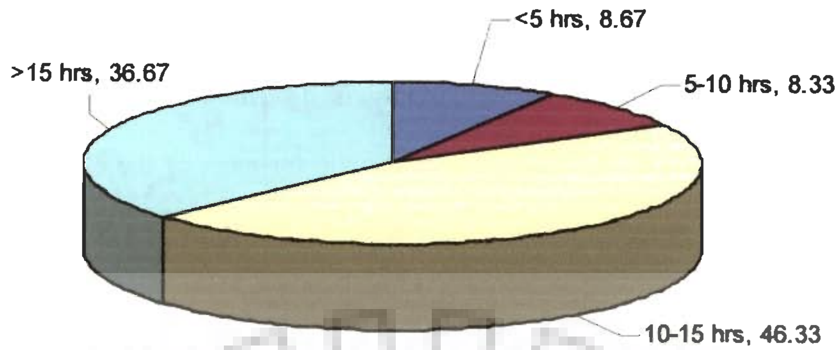


Fig. 4.10: Duration of power cut in summers

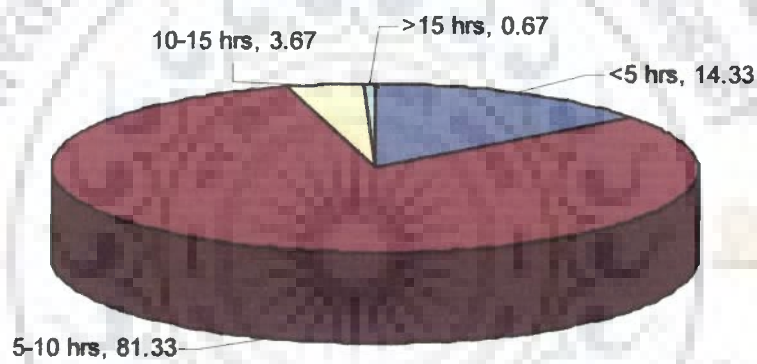


Fig. 4.11: Duration of power cut in winters

Table 4.25 illustrates that during summers almost half of the residents do not have electricity for 10 to 15 hours per day on an average (46.33 per cent) while more than one-third respondents do not have power supply for more than 15 hours per day i.e., 36.67 per cent. Table 4.26 further illustrates that during winters also, more than four-fifths of the surveyed households do not have power in their houses for 5 to 10 hours daily on an average i.e, 81.33 per cent, while 3.67 per cent report power cut for 10 to 15 hours and another 0.67 per cent report power cut for more than 15 hours daily on an average. This shows a sorry state of power supply in the study area both during summers and winters.

Besides the regular power supply, good quality is also anticipated for better functioning of equipments and plants. Quality of power supply is determined by the level of voltage fluctuations. More fluctuation in voltage is problematic for most of the electrical appliances and gadgets. Hence, this aspect was also analysed during the study and is presented in Table 4.27.

Table 4.27: Voltage fluctuation

S. No.	Income-group (Rs in 000)	More	Per cent	less	Per cent	Total	Per cent
1	<50	19	54.29	16	45.71	35	100.0
2	50-100	52	37.41	87	62.59	139	100.0
3	100-150	34	40.48	50	59.52	84	100.0
4	150-200	18	66.67	9	33.33	27	100.0
5	200-250	5	62.50	3	37.50	8	100.0
6	>250	1	14.29	6	85.71	7	100.0
	Total	129	43.00	171	57.00	300	100.0

The table illustrates that more than two-fifth households face high voltage fluctuation problem, i.e., 43 per cent. There is no distinguished pattern if the voltage fluctuation problem is analysed income-wise as the sample households are scattered in various parts of the city. The problem is in fact area wise/location centric.

4.1.10 Water Supply

Adequate supply of clean water is essential for the survival of any city. In fact, water crisis has become one of the major issues faced by all major cities of the world. The study area of Kanpur is however, blessed by a perennial source of surface water in the form of river Ganga. However, like all big cities, the inadequate management of various urban activities has resulted in excessive pollution of the river and also the underground aquifers which supplement the surface water supply. The public supply system constitutes water provided by the Municipal Corporation after some treatment. Having this knowledge in mind, the

Investigator has attempted to look at the problem both from quantitative and qualitative perspective and the results presented in Table 4.28, 4.29 and 4.30 and Fig. 4.12.

Table 4.28: Water Supply System

S. No.	Income-group (Rs in 000)	Municipal supply	Per cent	Own source	Per cent	Both	Per cent	Total	Per cent
1	<50	19	54.29	15	42.86	1	2.86	35	100.0
2	50-100	61	43.88	61	43.88	17	12.23	139	100.0
3	100-150	24	28.57	47	55.95	13	15.48	84	100.0
4	150-200	3	11.11	19	70.37	5	18.52	27	100.0
5	200-250	2	25.00	6	75.00	0	0.00	8	100.0
6	>250	0	0.00	3	42.86	4	57.14	7	100.0
	Total	109		151		40		300	
	Per cent	36.33	0.00	50.33	0.00	13.33	0.00	100.00	

The table illustrates that more than one-third of the surveyed households get water supply from the Municipal Corporation (36.33 per cent), half of the surveyed households have their own sources of water in the form of jet pumps and borewells (50.33 per cent) while 13.33 per cent of the surveyed households use both the sources of water supply. Income-group wise analysis further shows that more than half of the higher income group people (greater than Rs 250000) have both sources of water supply, i.e., 57.14 per cent. The higher ownership of own sources of water shows that the municipal supply is erratic, owing to which people tend to depend on their own sources taking the advantage of the fact that the study area is blessed with aquifers at shallow depth.

Table 4.29: Time of public water supply (hours per day)

S. No.	Income-group (Rs in 000)	<1	Per cent	1-2	Per cent	>2	Per cent	Total	Per cent
1	<50	19	54.29	15	42.86	1	2.86	35	100.0
2	50-100	61	43.88	61	43.88	17	12.23	139	100.0
3	100-150	24	28.57	47	55.95	13	15.48	84	100.0
4	150-200	3	11.11	19	70.37	5	18.52	27	100.0
5	200-250	2	25.00	6	75.00	0	0.00	8	100.0
6	>250	0	0.00	3	42.86	4	57.14	7	100.0
	Total	109	36.33	151	50.33	40	13.33	300	100.0

Table 4.29 illustrates that more than one-third of the total surveyed households get public water supply of less than 1 hour per day, which is grossly inadequate; while almost half of the surveyed households get water supply up to 2 hours per day. Only 13.33 per cent of the surveyed people get public water supply greater than 2 hours per day. Therefore, people who can afford have installed in their houses jet pumps or hand pumps to overcome the problem.

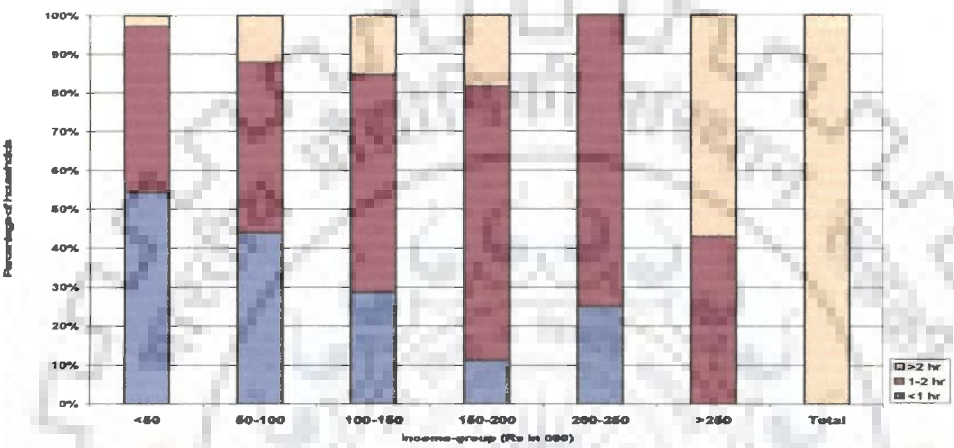


Fig. 4.12: Time of water supply in various income-group households

The area is blessed with two sources of surface water, viz., river Ganga and river Pandu. Hence, the water table is also higher. Table 4.30 consolidates this by stating that almost half of the surveyed households (47.33 per cent) have 100 to 150 feet deep borewells while only 4.67 per cent households have borewells deeper than 150 feet. Another 35 per cent people do not have their own source of water supply and depend on the municipal supply solely.

Table 4.30: Depth of borewell (in feet)

S. No.	Income-group (Rs in 000)	Not present	Per cent	<100'	Per cent	100-150'	Per cent	>150'	Per cent	Total	Per cent
1	<50	18	51.43	9	25.71	6	17.14	2	5.71	35	100.0
2	50-100	59	42.45	20	14.39	56	40.29	4	2.88	139	100.0
3	100-150	23	27.38	8	9.52	48	57.14	5	5.95	84	100.0
4	150-200	3	11.11	2	7.41	20	74.07	2	7.41	27	100.0
5	200-250	2	25.00	0	0.00	6	75.00	0	0.00	8	100.0
6	>250	0	0.00	0	0.00	6	85.71	1	14.29	7	100.0
	Total	105	35.00	39	13.00	142	47.33	14	4.57	300	100.0

Water invariably suffers from contamination problems due to various reasons in most of the country's urban centres. The quality of water has wide impact on the health and well being of people. An attempt has, therefore, been made to also study the qualitative aspects of water and the results are presented in Table 4.31, 4.32, 4.33 and 4.34 and Fig. 4.13 respectively.

Table 4.31: Quality of water

S. No.	Income-group (Rs in 000)	Good	Per cent	Average	Per cent	Poor	Per cent	Total	Per cent
1	<50	10	28.57	20	57.14	5	14.29	35	100.0
2	50-100	49	35.25	82	58.99	8	5.76	139	100.0
3	100-150	26	30.95	56	66.67	2	2.38	84	100.0
4	150-200	6	22.22	15	55.56	6	22.22	27	100.0
5	200-250	0	0.00	8	100.00	0	0.00	8	100.0
6	>250	3	42.86	4	57.14	0	0.00	7	100.0
	Total	94	31.33	185	61.67	21	7.00	300	100.0

Table 4.32: Colour related problem in water

S. No.	Income-group (Rs in 000)	Yes	Per cent	No	Per cent	Total	Per cent
1	<50	5	14.29	30	85.71	35	100.0
2	50-100	22	15.83	117	84.17	139	100.0
3	100-150	8	9.52	76	90.48	84	100.0
4	150-200	7	25.93	20	74.07	27	100.0
5	200-250	0	0.00	8	100.00	8	100.0
6	>250	1	14.29	6	85.71	7	100.0
	Total	43		257		300	0.0
	Per cent	14.33		85.67		100.00	

Table 4.31 illustrates that almost one-third of the surveyed people say that the water is of good quality (31.33 per cent), three-fifth of the people find it average (61.67 per cent) while 7 per cent find the water of poor quality. As far as presence of colour in water is concerned, Table 4.32 shows that more than four-fifth of the respondents do not report colour related water problem, i.e., 85.67 per cent while 14.33 per cent have some colour related problems. These households were found to be located near tanneries and/or other industries.

Table 4.33: Presence of particles in water

S. No.	Income-group (Rs in 000)	Yes	Per cent	No	Per cent	Total	Per cent
1	<50	24	68.57	11	31.43	35	100.0
2	50-100	90	64.75	49	35.25	139	100.0
3	100-150	57	67.86	27	32.14	84	100.0
4	150-200	26	96.30	1	3.70	27	100.0
5	200-250	6	75.00	2	25.00	8	100.0
6	>250	4	57.14	3	42.86	7	100.0
	Total	207		93		300	0.0
	Per cent	69.00		31.00		100.00	

Table 4.34: Presence of odour in water

S. No.	Income-group (Rs in 000)	Yes	Per cent	No	Per cent	Total	Per cent
1	<50	9	25.71	26	74.29	35	100.0
2	50-100	37	26.62	102	73.38	139	100.0
3	100-150	14	16.67	70	83.33	84	100.0
4	150-200	8	29.63	19	70.37	27	100.0
5	200-250	3	37.50	5	62.50	8	100.0
6	>250	1	14.29	6	85.71	7	100.0
	Total	72	24.00	228	76.00	300	100.0

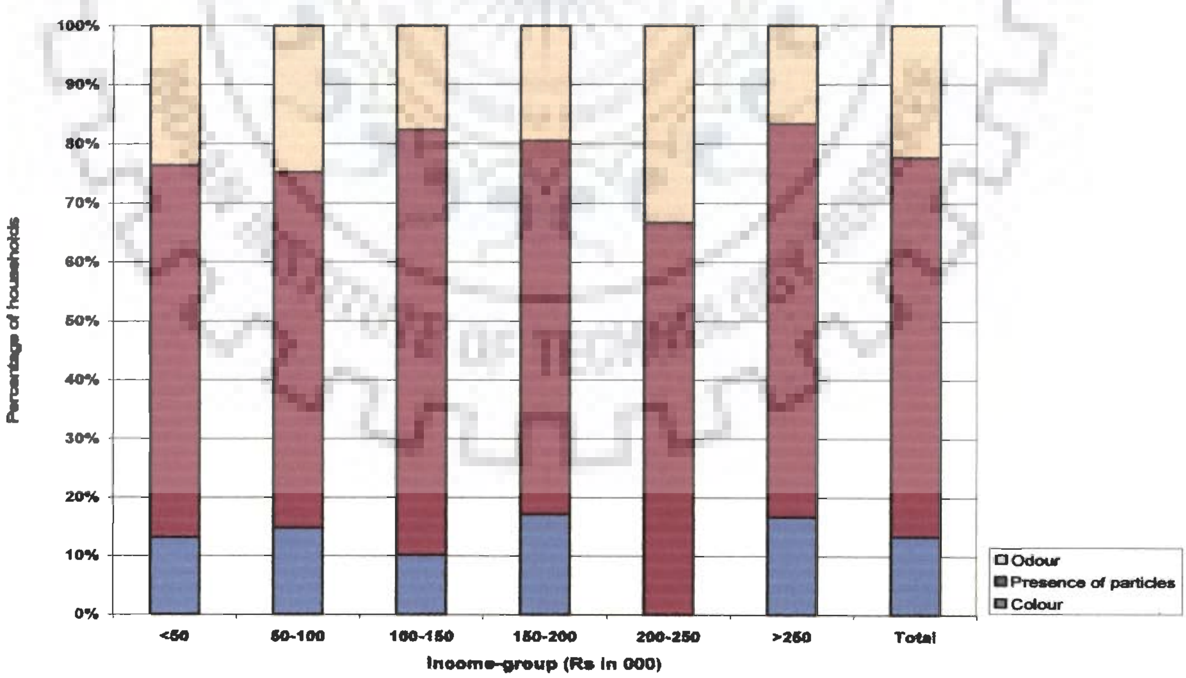


Fig. 4.13: Water related problems in various income-group households

As far as presence of particles in water is concerned, Table 4.33 illustrates that almost three-fourth of the surveyed households report this problem which is a matter of concern, i.e, 69 per cent. This problem is found to exist among all income-groups irrespective of their place of living. With regard to presence of odour in water, Table 4.34 very well shows that this problem is also present in some places as it is reported to be there by almost one-third of the respondents. The problems of odour and presence of particles do not follow any income disparity as depicted by the above tables.

4.1.11 Sanitation, Sewerage and Drainage

A clean city with efficient sewerage and drainage network is a prerequisite for the well-being of its citizens and smooth functioning of the city. Most of the Indian cities are plagued by sewerage problems and are often flooded during heavy downpours due to the non-working of drainage system. Having this knowledge, an attempt has been made by the Investigator to study these parameters at household level survey and the results presented in Table 4.35, 4.36, 4.37 and 4.38 respectively.

Table 4.35: Sanitation

S. No.	Income-group (Rs in 000)	Septic tank	Per cent	Sewer	Per cent	Soak pit	Per cent	Total	Per cent
1	<50	13	37.14	8	22.86	14	40.00	35	100.0
2	50-100	44	31.65	16	11.51	79	56.83	139	100.0
3	100-150	22	26.19	6	7.14	56	66.67	84	100.0
4	150-200	6	22.22	3	11.11	18	66.67	27	100.0
5	200-250	1	12.50	0	0.00	7	87.50	8	100.0
6	>250	1	14.29	0	0.00	6	85.71	7	100.0
	Total	87	29.00	33	11.00	180	60.00	300	100.0

The table illustrates that three-fifth of the surveyed households have soak pits (60 per cent), almost one-third respondents use septic tanks (29 per cent) and only 11 per cent of the surveyed households are connected to the sewer line. It shows that the sewer network has not yet penetrated all the nooks and corners of the city. Income-wise analysis of the type of sanitation facility shows that the higher-income groups (Rs 200000-250000 and greater than Rs 250000) houses are not connected at all with the sewer line. This may be due to the smaller sample size of the families accounted for from the higher income-group. In all the income-groups, soak-pits or septic tanks are found to be more popular.

Table 4.36: Type of Drainage

S. No.	Income-group (Rs in 000)	Open drains	Per cent	Covered drains	Per cent	No drainage	Per cent	Total	Per cent
1	<50	21	60.00	12	34.29	2	5.71	35	100.0
2	50-100	57	41.01	71	51.08	11	7.91	139	100.0
3	100-150	35	41.67	45	53.57	4	4.76	84	100.0
4	150-200	21	77.78	6	22.22	0	0.00	27	100.0
5	200-250	5	62.50	3	37.50	0	0.00	8	100.0
6	>250	5	71.43	2	28.57	0	0.00	7	100.0
	Total	144	48.00	139	46.33	17	5.67	300	100.0

The table illustrates that almost half of the surveyed households have open drains for storm water drainage (48 per cent), 46.33 per cent have covered drains while 5.67 per cent do not have any type of drainage. Households with no drainage belong to low-income and middle-income group (less than Rs 50000, Rs 50000-100000 and Rs 100000-150000). This shows that the drainage system is in poor state in the study area.

Table 4.37: Overflow of drains during rainy season

S. No.	Income-group (Rs in 000)	Yes	Per cent	No	Per cent	Total	Per cent
1	<50	26	74.29	9	25.71	35	100.0
2	50-100	86	61.87	53	38.13	139	100.0
3	100-150	54	64.29	30	35.71	84	100.0
4	150-200	24	88.89	3	11.11	27	100.0
5	200-250	5	62.50	3	37.50	8	100.0
6	>250	5	71.43	2	28.57	7	100.0
	Total	200	66.67	100	33.33	300	100.0

Table 4.37 illustrates that more than three-fifth of the people have overflowing drains during rainy season, i.e., 66.67 per cent. It is mostly due to frequent blockage by the presence of plastics and other wastes in the open drains. All income-group people face more or less the problems of overflow of drains. Amongst the problems due to inadequate drainage, one-fifth of the respondents face the problem of overflow of drains, 7.33 per cent report clogging of drains, 11.33 per cent report bad odour from drains and almost two-fifth of the surveyed households report all the problems of clogging of drains, overflow and bad odour, i.e., 43 per cent as illustrated in Table 4.38 and Fig. 4.14.

Table 4.38: Problems faced due to inadequate drainage

S. No.	Income-group (Rs in 000)	Clogging of drains	Per cent	Over flow	Per cent	Bad odour	Per cent	All	Per cent	None	Per cent	Total	Per cent
1	<50	4	11.43	4	11.43	3	8.57	17	48.57	7	20.00	35	100.0
2	50-100	15	10.79	27	19.42	19	13.67	54	38.85	24	17.27	139	100.0
3	100-150	2	2.38	16	19.05	9	10.71	36	42.86	21	25.00	84	100.0
4	150-200	1	3.70	6	22.22	3	11.11	16	59.26	1	3.70	27	100.0
5	200-250	0	0.00	2	25.00	0	0.00	4	50.00	2	25.00	8	100.0
6	>250	0	0.00	3	42.86	0	0.00	2	28.57	2	28.57	7	100.0
	Total	22	7.33	58	19.33	34	11.33	129	43.00	57	19.00	300	100.0

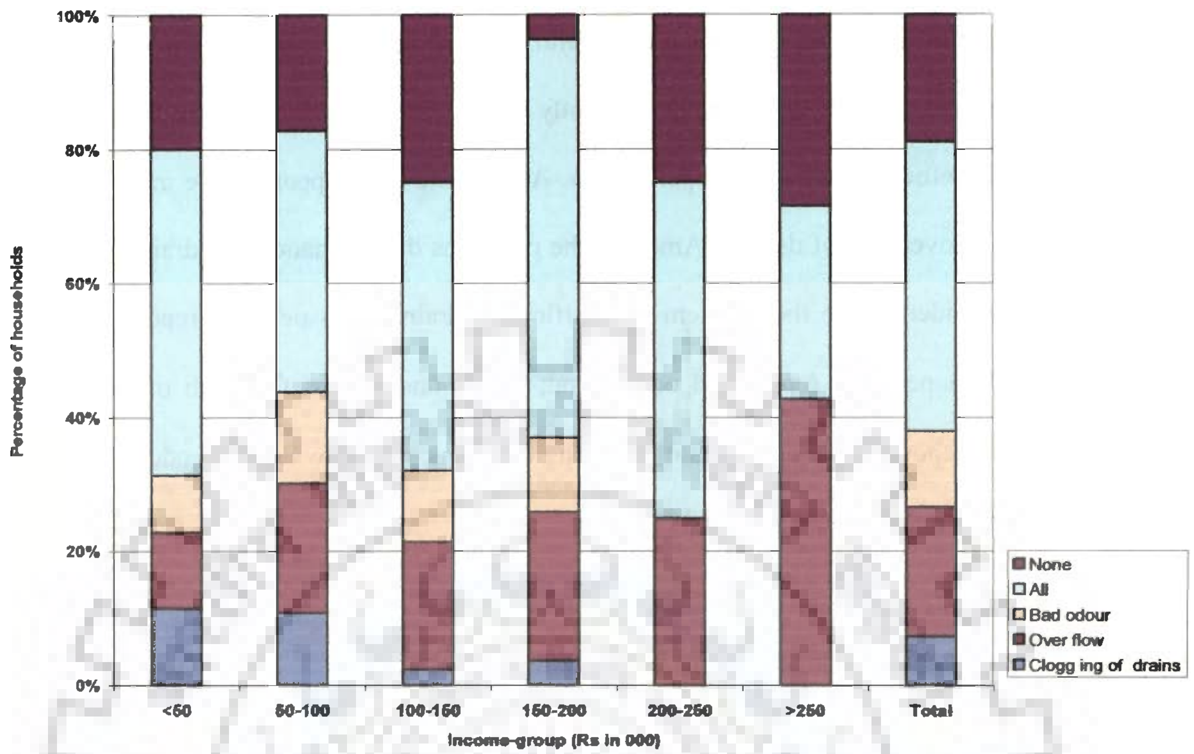


Fig. 4.14: Problems faced due to inadequate drainage

4.1.12 SOLID WASTE MANAGEMENT

Management of the daily waste generated in a city is one of the biggest infrastructural challenges faced by all the cities. Clean cities in India are difficult to find. Kanpur city has a notorious reputation of one of the dirtiest cities of North India. Having this knowledge in mind, the Investigator has attempted to study the solid waste generation aspects and presented in Table 4.39 and Fig. 4.15.

Table 4.39: Average solid waste produced per day (in grams)

S. No.	Income-group (Rs in 000)	<200	Per cent	200-400	Per cent	400-600	Per cent	600-800	Per cent	>800	Per cent		Per cent
1	<50	19	54.29	13	37.14	3	8.57	0	0.00	0	0.00	35	100.0
2	50-100	40	28.78	65	46.76	24	17.27	9	6.47	1	0.72	139	100.0
3	100-150	10	11.90	37	44.05	24	28.57	10	11.90	3	3.57	84	100.0
4	150-200	2	7.41	14	51.85	8	29.63	3	11.11	0	0.00	27	100.0
5	200-250	2	25.00	3	37.50	2	25.00	1	12.50	0	0.00	8	100.0
6	>250	0	0.00	0	0.00	1	14.29	2	28.57	4	57.14	7	100.0
	Total	73	24.33	132	44.00	62	20.67	25	8.33	8	2.67	300	100.0

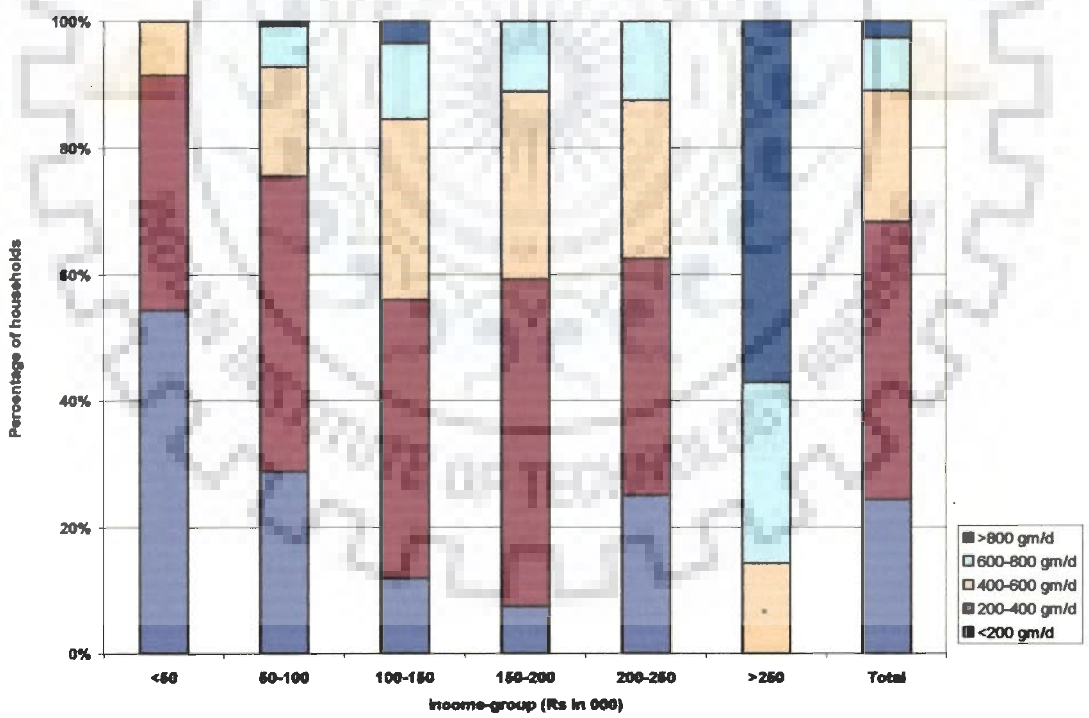


Fig. 4.15: Average solid waste generated by various income-group households

The table elucidates that on an average, almost two-fifth of the surveyed households generate 200 to 400 grams of solid waste daily (44 per cent), one-fifth respondents generate less than 200 grams of solid waste daily (24.33 per cent) and only 11 per cent of the households generate greater than 600 grams of waste per day. Income-group wise analysis of the solid waste generation reveals that the lowest income-group generate lesser waste per day (54.29 per cent produce less than 200 gram of waste) while in the highest income group (greater than Rs 250000) 57.14 per cent generate more than 800 gram of waste. This is also due to the presence of joint family in this income-group. In other income-groups the average solid waste produced shows an increasing trend gradually.

A study of the existing practices of the method of primary collection of waste generated and type of waste disposal is an important aspect for design of solid waste management system. Hence, an attempt has been made to study these aspects and the results presented in Table 4.40. The table illustrates that 85.33 per cent of the surveyed people store the waste in dustbins/PVC bag while 12.67 per cent burn it and 1.33 per cent directly throw it away along streets/roads or vacant adjacent plots. The method of primary collection/storage of waste is irrespective of the income-group.

Table 4.40: Method of Primary waste collection at house

S. No.	Income-group (Rs in 000)	Dust bin/PVC bag	Per cent	Throwing out	Per cent	Burning	Per cent	Throwing and burning	Per cent	Total	Per cent
1	<50	27	77.14	0	0.00	8	22.86	0	0.00	35	100
2	50-100	118	84.89	1	0.72	19	13.67	1	0.72	139	100
3	100-150	79	94.05	1	1.19	4	4.76	0	0.00	84	100
4	150-200	18	66.67	1	3.70	7	25.93	1	3.70	27	100
5	200-250	7	87.50	1	12.50	0	0.00	0	0.00	8	100
6	>250	7	100.00	0	0.00	0	0.00	0	0.00	7	100
	Total	256	85.33	4	1.33	38	12.67	2	0.67	300	100

Disposal of generated wastes at household level is one of the elements of solid waste management which needs to be studied. There are possibilities of burning it at local level or composting it in backyard or simply throwing on the street in the absence of door-to-door collection. The type of waste disposal as practiced by the people of Kanpur city is presented in Table 4.41. The table illustrates that more than half of the people dispose the waste generated in and around municipal dustbins (55 per cent), one-third throw directly on street as per their convenience (33.33 per cent), only 2 per cent of the respondents try to compost the organic part of the waste and 5.33 per cent of the respondents burn it.

Table 4.41: Type of Waste Disposal

S. No.	Income-group (Rs in 000)	Thrown on street	Per cent	Munici-pal dustbin	Per cent	Composting	Per cent	open burning	Per cent	any other	Per cent
1	<50	16	45.71	13	37.14	0	0.00	3	8.57	3	8.57
2	50-100	55	39.57	70	50.36	4	2.88	5	3.60	5	3.60
3	100-150	17	20.24	58	69.05	1	1.19	6	7.14	2	2.38
4	150-200	10	37.04	12	44.44	1	3.70	1	3.70	3	11.11
5	200-250	1	12.50	6	75.00	0	0.00	1	12.50	0	0.00
6	>250	1	14.29	6	85.71	0	0.00	0	0.00	0	0.00
	Total	100	33.33	165	55.00	6	2.00	16	5.33	13	4.33

The frequency of municipal collection of waste is an important parameter from cleanliness point of view. It has, therefore, been studied by the Investigator and the results presented in Table 4.42 and Fig. 4.16. The table illustrates that one-fifth of the people, i.e., 20.33 per cent say that waste is collected daily from their areas, 16.67 per cent report collection on alternate days, 31 per cent find the municipal waste collection service once a week, while 16.33 per cent never have any waste collection by the municipality and waste is collected only after repeated complaints. This problem is more in areas dominated by lower-income group people.

Table 4.42: Frequency of municipal collection of waste from the area

S. No.	Income-group (Rs in 000)	Daily	Alternate days	Every 3 days	Every 4 days	weekly	every 15 days	every 30 days	never/only on complaints	Total
1	<50	8	6	2	0	6	0	2	11	35
2	50-100	12	26	12	3	53	3	3	27	139
3	100-150	21	15	13	1	26	1	3	4	84
4	150-200	11	3	3	0	3	0	1	6	27
5	200-250	4	0	0	0	3	0	0	1	8
6	>250	5	0	0	0	2	0	0	0	7
	Total	61	50	30	4	93	4	9	49	300
	Per cent	20.33	16.67	10.00	1.33	31.00	1.33	3.00	16.33	100.00

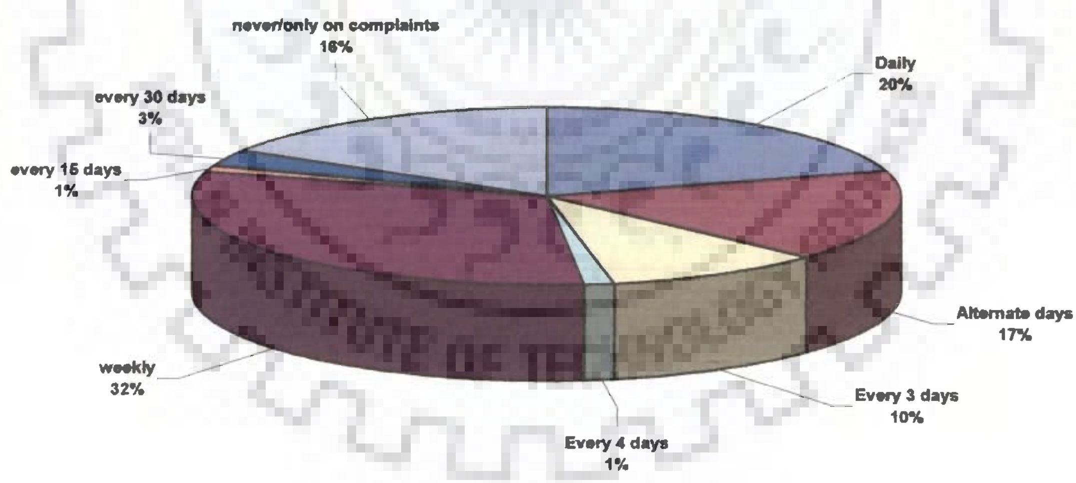


Fig. 4.16: Frequency of waste collection by the Corporation

Plastics have become an inevitable part of municipal wastes. It has penetrated every nook and corner of the current life style. There is an increasing use of plastics in our day to day life. Its disposal is however, problematic and if not managed properly lead to clogging of drains and water bodies and environmental stress. The average number of plastics in daily waste at household level has therefore, been studied by the Investigator and the results are presented in Table 4.43. The table illustrates that on moving up the economic ladder, the average number of plastics present in daily waste increase. It is due to the change in lifestyle also. The consumption of junk food and eatables/drinks increase as the economic level increases and is reflected in the Table 4.43.

Table 4.43: Average number of plastics present in daily waste

S. No.	Income-group (Rs in 000)	1-2	Per cent	3-4	Per cent	5-6	Per cent	>6	Per cent	Total	Per cent
1	<50	27	77.14	3	8.57	5	14.29	0	0.00	35	100.0
2	50-100	74	53.24	45	32.37	18	12.95	2	1.44	139	100.0
3	100-150	33	39.29	42	50.00	7	8.33	2	2.38	84	100.0
4	150-200	5	18.52	19	70.37	2	7.41	1	3.70	27	100.0
5	200-250	4	50.00	3	37.50	1	12.50	0	0.00	8	100.0
6	>250	1	14.29	1	14.29	3	42.86	2	28.57	7	100.0
	Total	144	48.00	113	37.67	36	12.00	7	2.33	300	100.0

Collection of wastes is one of the essential elements of an integrated solid waste management. It has therefore, been studied by the Investigator and the results presented in Table 4.44 and Fig. 4.17. The table illustrates that only one-fourth of the respondents opinioned that waste is regularly collected from their areas (24.67 per cent), 50 per cent say that it is irregularly collected, 3.33 per cent opinioned that it is only collected on complaints while 22 per cent say that it is not collected even on complaints.

Table 4.44: Waste collection system in the area

S. No.	Income-group (Rs in 000)	regularly collected	Per cent	collected but not regular	Per cent	collected but on complaints	Per cent	not collected	Per cent	Total	Per cent
1	<50	8	22.86	14	40.00	1	2.86	12	34.29	35	100
2	50-100	25	17.99	72	51.80	4	2.88	38	27.34	139	100
3	100-150	25	29.76	47	55.95	3	3.57	9	10.71	84	100
4	150-200	9	33.33	10	37.04	2	7.41	6	22.22	27	100
5	200-250	3	37.50	4	50.00	0	0.00	1	12.50	8	100
6	>250	4	57.14	3	42.86	0	0.00	0	0.00	7	100
	Total	74	24.67	150	50.00	10	3.33	66	22.00	300	100

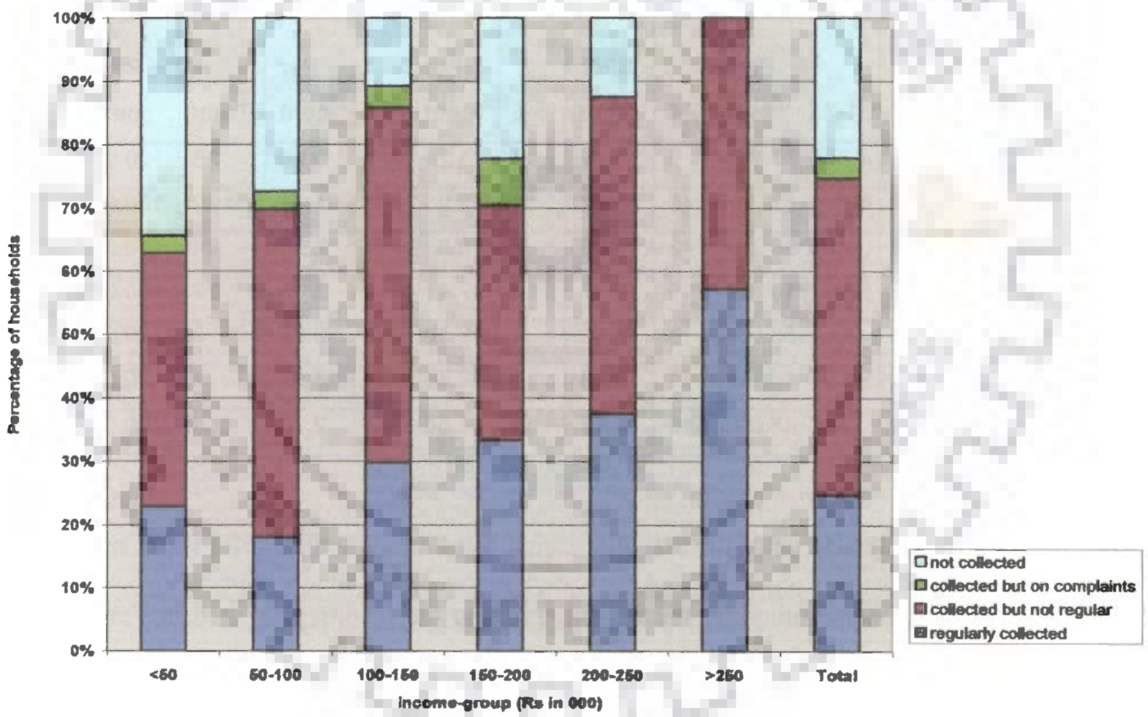


Fig. 4.17: Waste collection system in various income-groups

Indian cities, in general, follow secondary collection system wherein the residents and generators of waste are supposed to bring the wastes generated to the nearest communal bin provided from where the Corporation collect the wastes for further treatment/disposal. It has however, been observed that communal bins are provided randomly and are not necessarily sufficient to cater to the surrounding population. The presence of community-bin system in the surveyed residents' area has therefore, been studied and the results presented in Table 4.45.

Table 4.45: Community bin system

S. No.	Income-group (Rs in 000)	Yes	Per cent	No	Per cent	Total	Per cent
1	<50	9	25.71	26	74.29	35	100.0
2	50-100	58	41.73	81	58.27	139	100.0
3	100-150	38	45.24	46	54.76	84	100.0
4	150-200	13	48.15	14	51.85	27	100.0
5	200-250	5	62.50	3	37.50	8	100.0
6	>250	4	57.14	3	42.86	7	100.0
	Total	127	42.33	173	57.67	300	100.0

The table elucidates that almost three-fifth of the respondents do not have any community-bins in their area, i.e, 57.67 per cent, which shows the dismal state of waste management in the study area. Income-group wise analysis shows that on moving down the economic ladder, the percentage of people not having community bins in their area increases as evident from the table.

An attempt has also been made to study the satisfaction level of the respondent households with regard to the waste collection service as provided by the Municipal Corporation and the results presented in Table 4.46 and Fig. 4.18. The table illustrates that 78.67 per cent of the surveyed households are not satisfied with the collection service provided by the government. This holds true for all the income-groups as evident from the table. The dissatisfaction level increases with income.

Table 4.46: Satisfaction with the solid waste collection service of Municipal Corporation

S. No.	Income-group (Rs in 000)	Yes	Per cent	No	Per cent	Total	Per cent
1	<50	9	25.71	26	74.29	35	100
2	50-100	33	23.74	106	76.26	139	100
3	100-150	17	20.24	67	79.76	84	100
4	150-200	3	11.11	24	88.89	27	100
5	200-250	1	12.50	7	87.50	8	100
6	>250	1	14.29	6	85.71	7	100
	Total	64	21.33	236	78.67	300	100

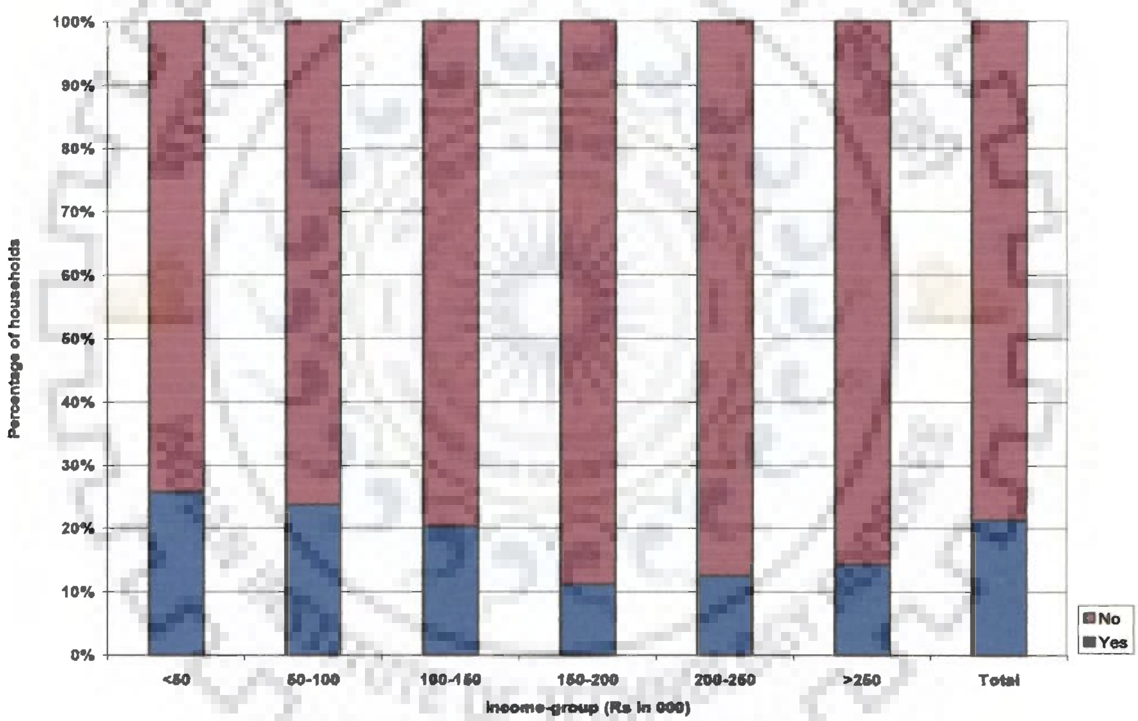


Fig. 4.18: Percentage of households satisfied with the waste collection service

An attempt has also been made to study the willingness of the people to pay some user fees if better solid waste management services are provided by the Corporation and the results presented in Table 4.47. The willingness of people to hand over the solid waste management services, partially or fully to private sector, has also been studied and the results are presented in Table 4.48 and Fig. 4.19.

Table 4.47: Willingness to pay if better (Solid Waste Management) services are provided

S. No.	Income-group (Rs in 000)	Yes	Per cent	No	Per cent	Total	Per cent
1	<50	25	71.43	10	28.57	35	100.0
2	50-100	118	84.89	21	15.11	139	100.0
3	100-150	75	89.29	9	10.71	84	100.0
4	150-200	25	92.59	2	7.41	27	100.0
5	200-250	8	100.00	0	0.00	8	100.0
6	>250	7	100.00	0	0.00	7	100.0
	Total	258	86.00	42	14.00	300	100.0

Table 4.47 clearly shows that more than four-fifth of the surveyed households are willing to pay if better waste collection and management services are provided to them (86 per cent). The higher income groups totally agree to pay if better waste management services are provided whereas in the lowest income-group 71.43 per cent people show their willingness to pay extra charges for such services.

Table 4.48: Willingness to hand over waste collection to private sector

S. No.	Income-group (Rs in 000)	Yes	Per cent	No	Per cent	Total	Per cent
1	<50	22	62.86	13	37.14	35	100.0
2	50-100	110	79.14	29	20.86	139	100.0
3	100-150	69	82.14	15	17.86	84	100.0
4	150-200	26	96.30	1	3.70	27	100.0
5	200-250	8	100.00	0	0.00	8	100.0
6	>250	7	100.00	0	0.00	7	100.0
	Total	242	80.67	58	19.33	300	100.0

Table 4.48 illustrates that more than four-fifth of the respondents is willing to hand over secondary waste collection service to private sector as they find the private sector to be more competent. Cent per cent people of the highest income-groups want the service to be done by the private sector, whereas the trend decreases gradually on moving down the economic ladder

with only 62.86 per cent people of the lowest income-group willing to hand over the service to private sector.

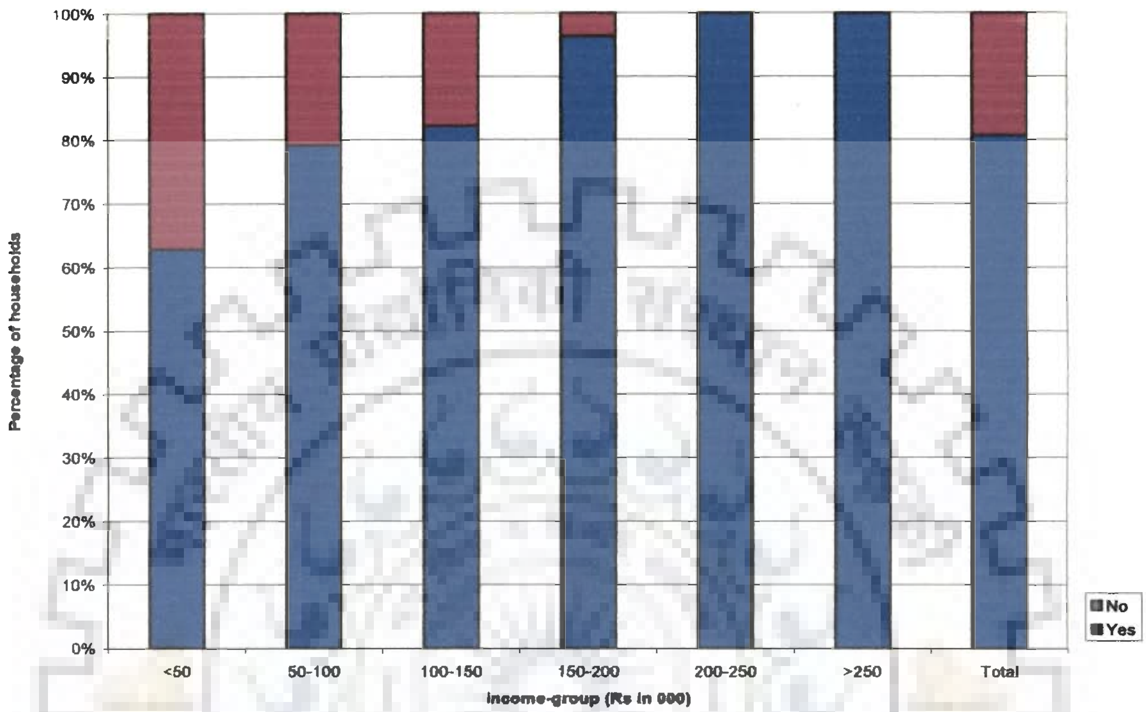


Fig. 4.19: Percentage of households showing willingness to hand over waste collection to private sector

Consumers have the power to bring about a change in the quality of services provided to them. For this, the consumers need to be alert, attentive and aware of their rights as well as duties. With this knowledge, an attempt has been made by the Investigator to study whether the city's residents lodge complaints and in what ways to solve the waste management related problems in their areas. Table 4.49 and Fig. 4.20 present the method of lodging complaints.

Table 4.49: Method of lodging complaints

S. No.	Income-group (Rs in 000)	A	Per cent	B	Per cent	C	Per cent	D	Per cent	Total	Per cent
1	<50	1	2.86	6	17.14	2	5.71	26	74.29	35	100.0
2	50-100	10	7.19	32	23.02	28	20.14	69	49.64	139	100.0
3	100-150	5	5.95	6	7.14	27	32.14	46	54.76	84	100.0
4	150-200	0	0.00	4	14.81	10	37.04	13	48.15	27	100.0
5	200-250	0	0.00	0	0.00	6	75.00	2	25.00	8	100.0
6	>250	1	14.29	1	14.29	4	57.14	1	14.29	7	100.0
	Total	17	5.67	49	16.33	77	25.67	157	52.33	300	100.0

A: Using ones' personal contacts B: go personally to the concerned office

C: complain telephonically D: wait & watch

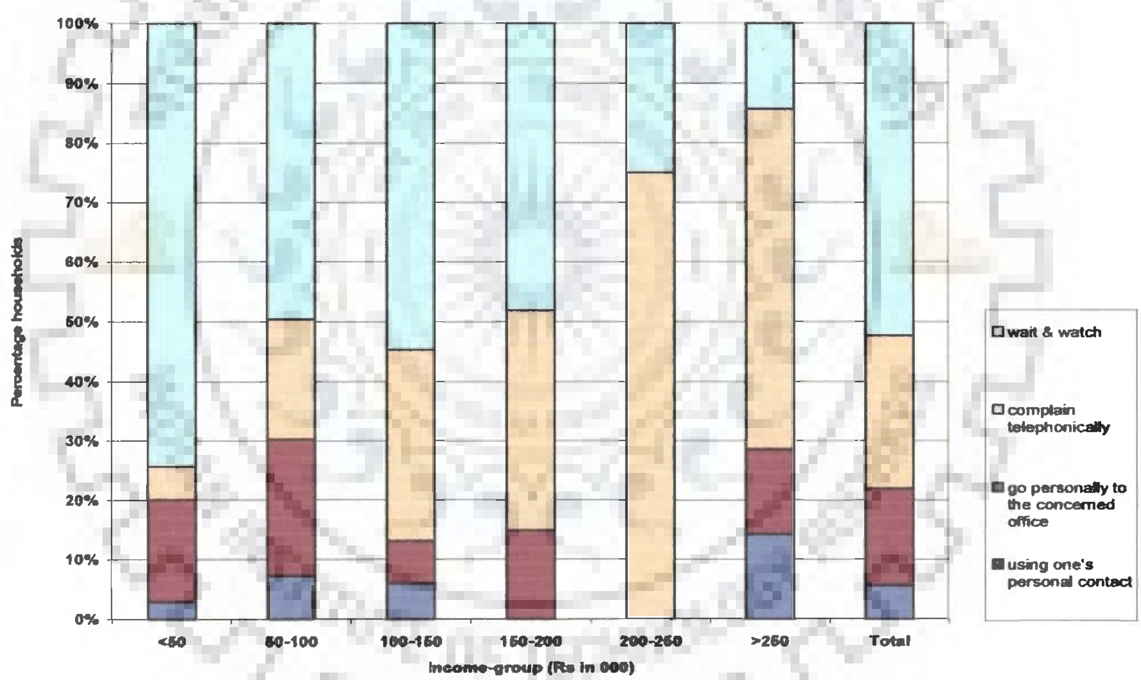


Fig. 4.20: Method of lodging complaints for solid waste management related problems

Table 4.49 illustrates that more than half of the respondents are silent spectators and do not attempt to get the waste cleared from their vicinity in case of lapse on part of the government. Among the lowest income-group, this trend is more common as they are more engrossed in other pressing problems of survival. A considerable 25.67 per cent of the respondents complain telephonically while 16.33 per cent personally go to the concerned office.

4.1.13 ENVIRONMENT

A city's' health is reflected by the overall environmental quality. Environmental quality is measured by the quality of water, air and land. A healthy environment makes the people healthier and they have better economic output, whereas polluted environment affects the health and general well-being of the people with health implications and economic loss.

Water, the elixir of life, is increasingly becoming a scarce resource in Indian cities. It is one of the basic infrastructural requirements. Availability of safe drinking water is hampered due to the water sources getting polluted by various human activities. Kanpur city has advantageous location of being situated on the banks of the holy river Ganga. However, the water quality, both surface and underground, has deteriorated with time. An attempt has therefore, been made to study the water quality in the respective areas as perceived by the consumers (surveyed households) and the results presented in Table 4.50 and Fig. 4.21.

Table 4.50: Water Quality

S. No.	Income-group (Rs in 000)	Good	Per cent	Moderate	Per cent	Poor	Per cent	Very poor	Per cent	Total	Per cent
1	<50	11	31.43	18	51.43	5	14.29	1	2.86	35	100.0
2	50-100	42	30.22	81	58.27	12	8.63	4	2.88	139	100.0
3	100-150	22	26.19	52	61.90	10	11.90	0	0.00	84	100.0
4	150-200	3	11.11	14	51.85	7	25.93	3	11.11	27	100.0
5	200-250	0	0.00	6	75.00	2	25.00	0	0.00	8	100.0
6	>250	1	14.29	4	57.14	2	28.57	0	0.00	7	100.0
	Total	79	26.33	175	58.33	38	12.67	8	2.67	300	100.0

The table illustrates that just above one-fourth of the surveyed households find the water quality provided to them as good, i.e., 26.33 per cent, while 15.34 per cent find it poor and very poor. Water quality related problems are faced by almost all income-groups of households.

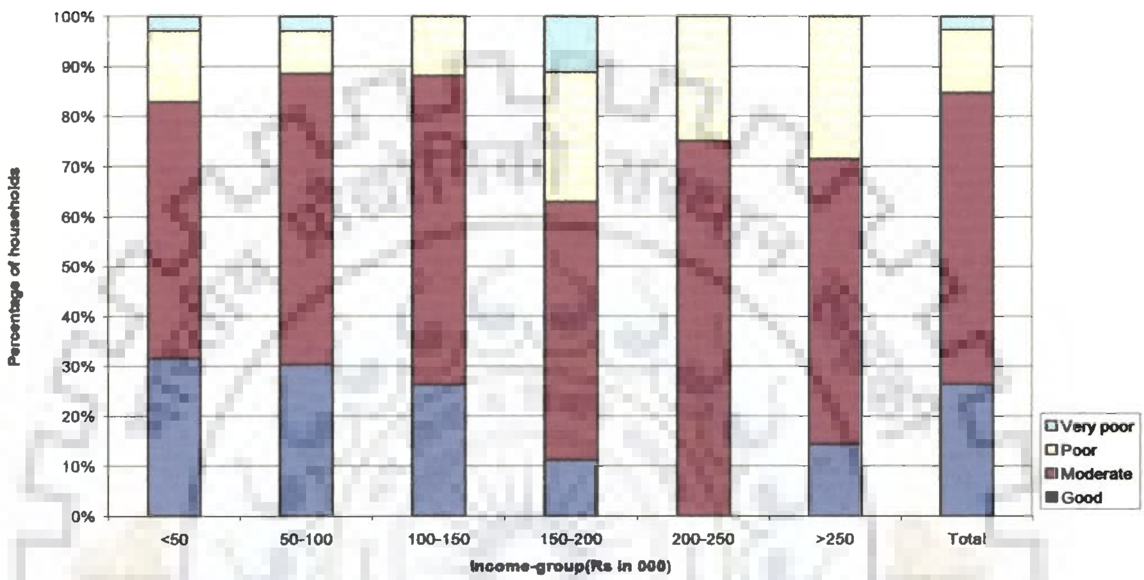


Fig. 4.21: Water quality in various income-group households

The study area of Kanpur has a poor reputation of one of the dirtiest cities of India. The quality of land has also been studied and the results are presented in Table 4.51 and Fig. 4.22. The table clearly elucidates that only one-fifth of the surveyed household find the quality of land as good (21 per cent), 55.67 per cent find it of moderate quality, 21 per cent find it poor while 2.33 per cent find it very poor. Higher income-groups people relatively find the quality of land in their areas better because of their better paying capacities.

Table 4.51: Land Quality

S. No.	Income-group (Rs in 000)	Good	Per cent	Moderate	Per cent	Poor	Per cent	Very poor	Per cent	Total	Per cent
1	<50	9	25.71	15	42.86	9	25.71	2	5.71	35	100.0
2	50-100	32	23.02	79	56.83	27	19.42	1	0.72	139	100.0
3	100-150	17	20.24	50	59.52	13	15.48	4	4.76	84	100.0
4	150-200	2	7.41	14	51.85	11	40.74	0	0.00	27	100.0
5	200-250	1	12.50	6	75.00	1	12.50	0	0.00	8	100.0
6	>250	2	28.57	3	42.86	2	28.57	0	0.00	7	100.0
	Total	63	21.00	167	55.67	63	21.00	7	2.33	300	100.0

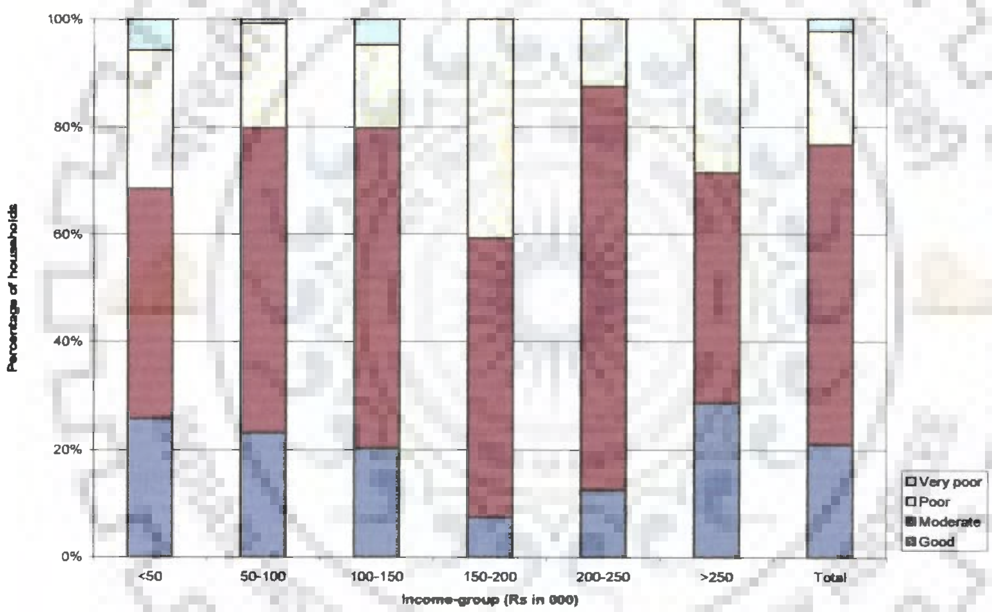


Fig. 4.22: Land quality in various income-group households

Air quality can have serious health implications. The study area is a ticking time-bomb for tuberculosis and other broncho-respiratory diseases. The air, in general, has high suspended particulate matter. An attempt has therefore, been made to study the quality of air as perceived by the residents in their respective areas and the results presented in Table 4.52 and Fig. 4.23.

Table 4.52: Air Quality

S. No.	Income-group (Rs in 000)	Good	Per cent	Moderate	Per cent	Poor	Per cent	Very poor	Per cent	Total	Per cent
1	<50	9	25.71	17	48.57	8	22.86	1	2.86	35	100
2	50-100	33	23.74	69	49.64	32	23.02	5	3.60	139	100
3	100-150	19	22.62	33	39.29	30	35.71	2	2.38	84	100
4	150-200	5	18.52	8	29.63	12	44.44	2	7.41	27	100
5	200-250	0	0.00	3	37.50	5	62.50	0	0.00	8	100
6	>250	2	28.57	4	57.14	1	14.29	0	0.00	7	100
	Total	68	22.67	134	44.67	88	29.33	10	3.33	300	100

The table clearly illustrates that 29.33 per cent of respondents find air quality as poor, 3.33 per cent as very poor, 44.67 per cent find the air quality moderate while only 22.67 per cent find the air quality as good. Higher income-groups people are more dissatisfied with air quality due to their increased awareness of health hazards of breathing polluted air. Air in residential areas near tanneries like Jajmau, J.K. colony, etc., is especially poor with a pungent smell always hanging in the area.

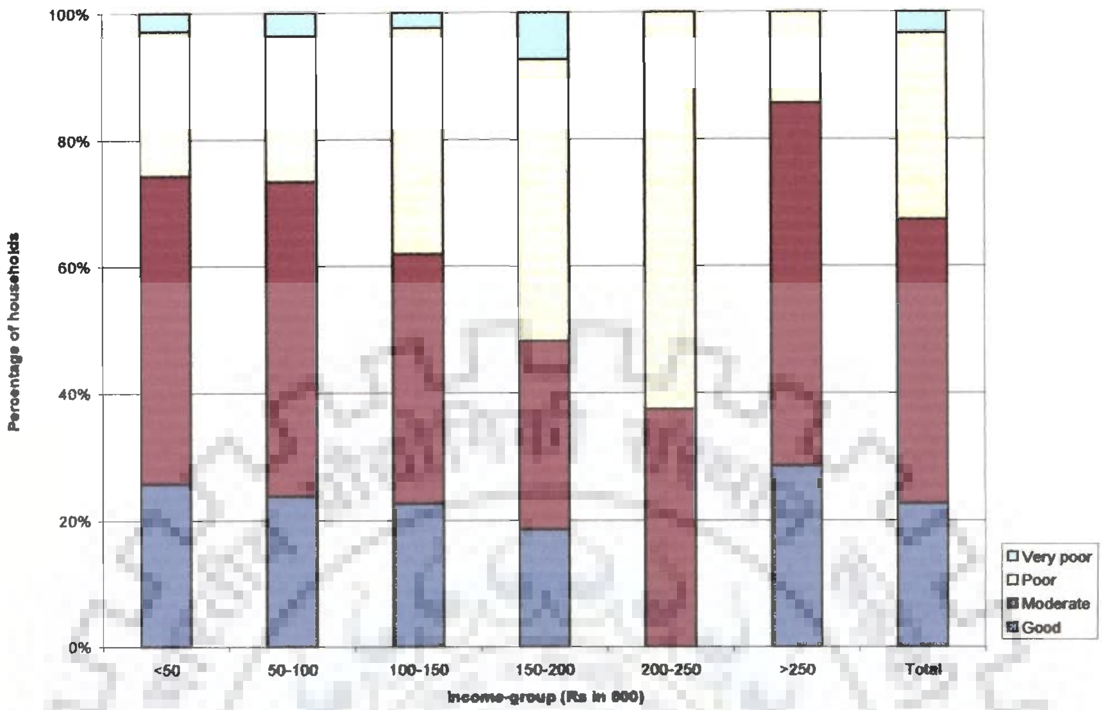


Fig. 4.23: Air quality in various income-group households

Indian cities, besides having polluted air also have high levels of noise pollution. The problem is more in cities and areas with more heavy-industries. The Investigator has, therefore, attempted to qualitatively study the level of noise in various areas and the results presented in Table 4.53 and Fig. 4.24.

Table 4.53: Noise Pollution

S. No.	Income-group (Rs in 000)	Very high	Per cent	High	Per cent	Moderate	Per cent	Low	Per cent	Total	Per cent
1	<50	0	0.00	7	20.00	16	45.71	12	34.29	35	100.0
2	50-100	11	7.91	25	17.99	72	51.80	31	22.30	139	100.0
3	100-150	3	3.57	22	26.19	36	42.86	23	27.38	84	100.0
4	150-200	4	14.81	4	14.81	10	37.04	9	33.33	27	100.0
5	200-250	1	12.50	2	25.00	3	37.50	2	25.00	8	100.0
6	>250	0	0.00	4	57.14	1	14.29	2	28.57	7	100.0
	Total	19	6.33	64	21.33	138	46.00	79	26.33	300	100.0

The table illustrates that more than one-fourth of the respondents find the noise pollution as high and very high (27.66 per cent) while 26.33 per cent find it low. Among the respondents reporting very high noise level, 14.8 per cent belong to the income-group Rs 150000-200000. It is further observed that 57.14 per cent of the highest-income group (greater than Rs 250000) people find high noise level in their areas while, on an average, 15 to 26 per cent of the rest of the income-group people find high noise levels in their areas and more than half of the respondents belonging to the second income group experience moderate noise pollution.

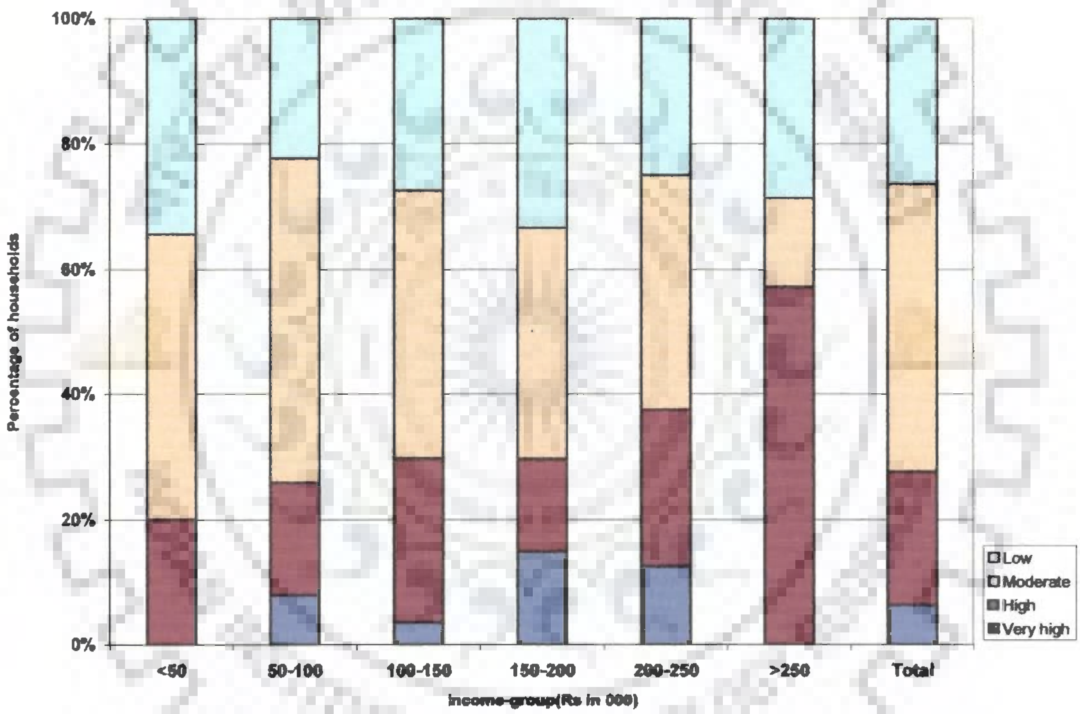


Fig. 4.24: Noise quality in various income-group households

In view of the degrading environmental quality, an attempt has been made by the Investigator to take peoples opinion of their willingness to pay increased taxes/user-charges if better water supply is provided and sewerage and sanitation conditions are improved and the results presented in Table 4.34 and Fig. 4.25.

Table 4.54 :Willingness to pay more tax for improved water supply, sewerage and sanitation

S. No.	Income-group (Rs in 000)	Yes	Per cent	No	Per cent	Total	Per cent
1	<50	20	57.1	15	42.9	35	100.0
2	50-100	104	74.8	35	25.2	139	100.0
3	100-150	66	78.6	18	21.4	84	100.0
4	150-200	24	88.9	3	11.1	27	100.0
5	200-250	7	87.5	1	12.5	8	100.0
6	>250	5	71.4	2	28.6	7	100.0
	Total	226	75.3	74	24.7	300	100.0

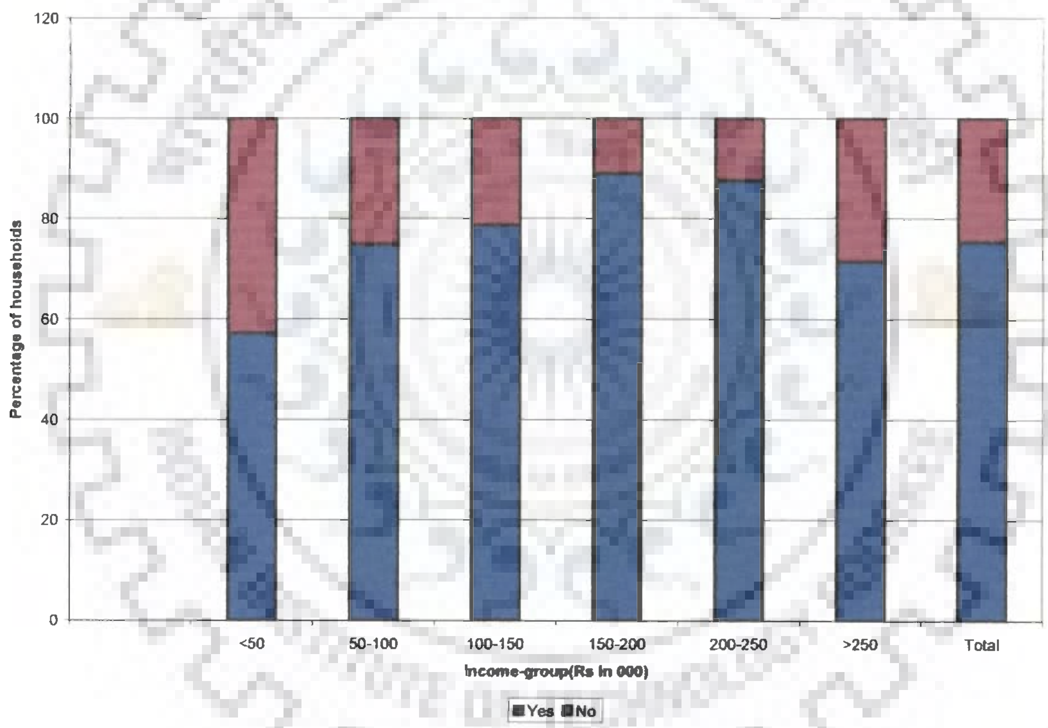


Fig. 4.25: Percentage of households showing willingness to pay more tax for improved water supply, sewerage and sanitation

The table illustrates that a whopping 75.3 percent of the respondents (three fourth) are ready to pay more tax provided they get an improved water supply, cleaner roads and cleaner drains and sewers. The income group wise analysis of willingness to pay further reveals that only the lowest income group (annual income less than Rs. 50,000) shows a lesser percentage of 57.1 while rest of the income groups show greater willingness to pay more taxes for better services.

4.1.14 HEALTH

Health is one of the essential criteria reflecting the quality of life and well being of the people in a city. It has been observed in the study area that for minor ailments, people of all income-groups tend to go to nearby facilities whereas for ailments like Tuberculosis, heart disease, bronco-respiratory infections, etc., people of higher income group go to far away places for having better facilities irrespective of the distances from their residence. However, lower income-groups whose affordability is poor tend to go to government hospitals where treatment expenditure is much lower. In the present investigation, an attempt has therefore, been made to study the incidence of major diseases like, Tuberculosis, malaria, typhoid, respiratory diseases, hepatitis, etc., place of treatment and the average amount of money spent on treatment and presented in the subsequent Tables.

a) Tuberculosis : Tuberculosis is an infectious disease caused by a bacteria and the study area has a high percentage of population suffering from this disease. The number of surveyed people suffering from this, the place of medical aid and the expenditure incurred is presented in Table 4.55, 4.56 and 4.57 and Fig. 4.26 respectively.

Table 4.55: Number of persons having TB

S. No.	Income-group (Rs in 000)	No.	Per cent	Total no.	Per cent
1	<50	2	1.37	146	100
2	50-100	2	0.31	646	100
3	100-150	3	0.71	425	100
4	150-200	0	0.00	133	100
5	200-250	0	0.00	40	100
6	>250	1	1.11	90	100
	Total	8	0.54	1480	100

Table 4.56: Place for medical-aid (TB)

S. No.	Income-group (Rs in 000)	Clinic	Per cent	Hospital	Per cent	Total	Per cent
1	<50	1	50.00	1	50.00	2	100
2	50-100	2	100.00	0	0.00	2	100
3	100-150	2	66.67	1	33.33	3	100
4	150-200	0	0.00	0	0.00	0	0
5	200-250	0	0.00	0	0.00	0	0
6	>250	1	100.00	0	0.00	1	100
	Total	6	75.00	2	25.00	8	100

Table 4.57: Annual Expenditure on treatment of TB (in Indian Rupees)

S. No.	Income-group (Rs in 000)	<1000	Per cent	>3000	Per cent	Total	Per cent
1	<50	1	50.00	1	50.00	2	100
2	50-100	0	0.00	2	100.00	2	100
3	100-150	1	33.33	2	66.67	3	100
4	150-200	0	0.00	0	0.00	0	0
5	200-250	0	0.00	0	0.00	0	0
6	>250	0	0.00	1	100.00	1	100
	Total	2	25.00	6	75.00	8	100

Table 4.55 illustrates that 0.54 per cent of the total people investigated were suffering from Tuberculosis and undergoing treatment. Incidence of tuberculosis was found to be more in lower income-groups. Of these people, 75 per cent were found to be getting treatment at private clinic and only 25 per cent from government hospitals as illustrated in Table 4.56. As far as the annual expenditure by these people on treatment of tuberculosis is concerned, one-fourth of the respondents (25 per cent) spend less than Rs 1000 while the remaining three-fourth respondents spend more than Rs 3000 per annum (Table 4.57).

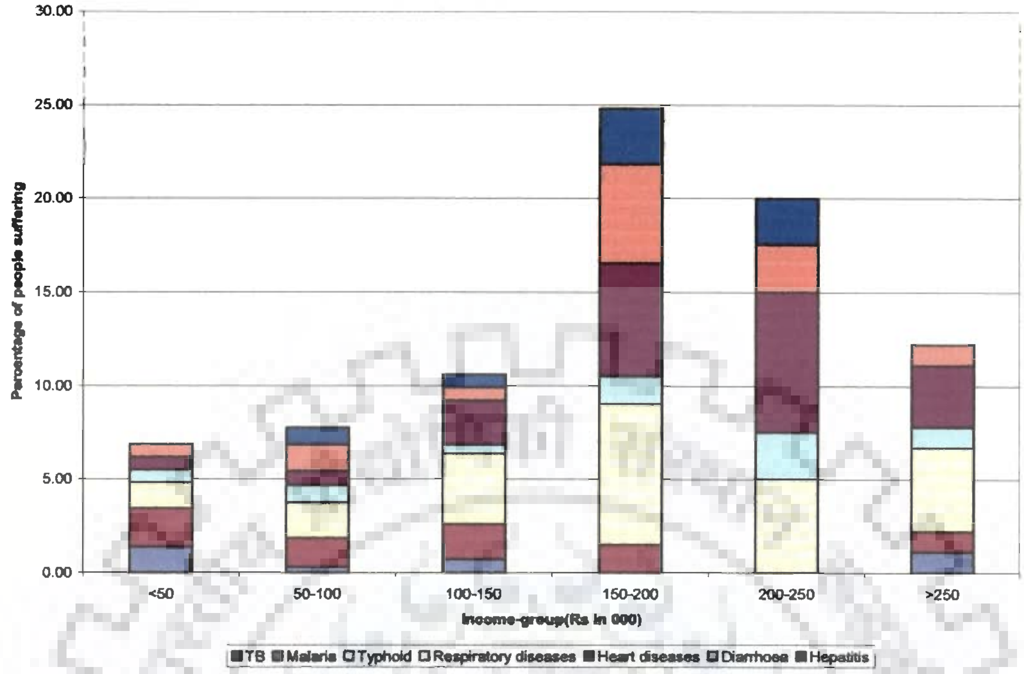


Fig. 4.26: Percentage of people suffering from Tuberculosis, Malaria, Typhoid, Respiratory diseases, Heart diseases, Diarrhoea and Hepatitis

b) Malaria

The city has high rate of malaria cases during summers and was therefore investigated in the survey. The results of the findings pertaining to incidence of malaria, place of treatment and expenditure incurred are presented in Table 4.58, 4.59 and 4.60 and Fig. 4.26. Table 4.58 illustrates that 1.62 per cent of the respondents had malaria. The incidence rate is higher in lower income group people.

Table 4.58: Number of persons having Malaria

S. No.	Income-group (Rs in 000)	No.	Per cent	Total no.	Per cent
1	<50	3	2.05	146	100
2	50-100	10	1.55	646	100
3	100-150	8	1.88	425	100
4	150-200	2	1.50	133	100
5	200-250	0	0.00	40	100
6	>250	1	1.11	90	100
	Total	24	1.62	1480	100

Table 4.59: Place for medical-aid (Malaria)

S. No.	Income-group (Rs in 000)	Clinic	Per cent	Hospital	Per cent	Total	Per cent
1	<50	1	33.33	2	66.67	3	100.0
2	50-100	6	60.00	4	40.00	10	100.0
3	100-150	5	62.50	3	37.50	8	100.0
4	150-200	2	100.00	0	0.00	2	100.0
5	200-250	0	0.00	0	0.00	0	0.0
6	>250	1	100.00	0	0.00	1	100.0
	Total	15	62.50	9	37.50	24	100.0

Table 4.59 further illustrates that of the deceased, three-fifth respondents, i.e., 62.5 per cent, go to private clinics for treatment and the rest 37.5 per cent go to government hospitals. The lower-income group people go to government hospitals on account of smaller medical expenditure incurred there.

Table 4.60: Annual Expenditure on treatment of Malaria (in Indian Rupees)

S. No.	Income-group (Rs in 000)	<200	Per cent	200-400	Per cent	400-600	Per cent	600-800	Per cent	800-1000	Per cent	Total	Per cent
1	<50	2	66.67	1	33.33	0	0.00	0	0	0	0.00	3	100.0
2	50-100	3	30.00	6	60.00	1	10.00	0	0	0	0.00	10	100.0
3	100-150	3	37.50	2	25.00	2	25.00	0	0	1	12.50	8	100.0
4	150-200	0	0.00	2	100.00	0	0.00	0	0	0	0.00	2	100.0
5	200-250	0	0.00	0	0.00	0	0.00	0	0	0	0.00	0	0.0
6	>250	0	0.00	0	0.00	0	0.00	0	0	1	100.00	1	100.0
	Total	8	33.33	11	45.83	3	12.50	0	0	2	8.33	24	100.0

It is observed that with regard to annual expenditure on treatment of malaria, Table 4.60 clearly elucidates that almost one-tenth (33.33 per cent) of the deceased spent less than Rs 200 annually on treatment, 45.83 per cent spend between Rs 200 and 400, while only 8.33 per cent spend between Rs 800 and Rs 1000 annually on treatment.

c) Typhoid

Occurrence of typhoid is also observed in the residents and the results presented in Table 4.61, 4.62 and 4.63 and Fig. 4.26 respectively. Table 4.61 clearly illustrates that 3.11 per cent of the surveyed people had suffered from typhoid in the year of investigation. As far as place of treatment is concerned, 89.13 per cent people were found to avail of the services offered by private clinics (Table 4.62). Expenditure on treatment as presented in Table 4.63 shows that 23.91 per cent spend less than Rs 200, 28.26 per cent between Rs 400 and Rs 600 and 23.91 per cent spend between Rs. 800 and Rs 1000 on treatment of typhoid.

Table 4.61: Number of persons having Typhoid

S. No.	Income-group (Rs in 000)	No.	Per cent	Total no.	Per cent
1	<50	2	1.37	146	100
2	50-100	12	1.86	646	100
3	100-150	16	3.76	425	100
4	150-200	10	7.52	133	100
5	200-250	2	5.00	40	100
6	>250	4	4.44	90	100
	Total	46	3.11	1480	100

Table 4.62: Place for medical-aid (Typhoid)

S. No.	Income-group (Rs in 000)	Clinic	Per cent	Hospital	Per cent	Total
1	<50	2	100.00	0	0.00	2
2	50-100	7	58.33	5	41.67	12
3	100-150	16	100.00	0	0.00	16
4	150-200	10	100.00	0	0.00	10
5	200-250	2	100.00	0	0.00	2
6	>250	4	100.00	0	0.00	4
	Total	41	89.13	5	10.87	46

Table 4.63: Annual Expenditure on treatment of Typhoid (in Indian Rupees)

S. No.	Income-group (Rs in 000)	<200	Per cent	200-400	Per cent	400-600	Per cent	600-800	Per cent	800-1000	Per cent	Total	Per cent
1	<50	2	100.00	0	0.00	0	0.00	0	0.00	0	0.00	2	100
2	50-100	7	58.33	4	33.33	1	8.33	0	0.00	0	0.00	12	100
3	100-150	2	12.50	1	6.25	7	43.75	1	6.25	5	31.25	16	100
4	150-200	0	0.00	4	40.00	2	20.00	1	10.00	3	30.00	10	100
5	200-250	0	0.00	0	0.00	2	100.00	0	0.00	0	0.00	2	100
6	>250	0	0.00	0	0.00	1	25.00	0	0.00	3	75.00	4	100
	Total	11	23.91	9	19.57	13	28.26	2	4.35	11	23.91	46	100

d) <u>Respiratory diseases</u>

The Investigator has also attempted to study the incidence of respiratory diseases among the surveyed households and the results are presented in Table 4.64, 4.65 and 4.66 and Fig. 4.26 respectively. Of the total surveyed people, 0.88 per cent was found to be suffering from some sort of respiratory problems. This was observed to be irrespective of the income-group level. In fact, Table 4.64 clearly illustrates that more percentage of people in higher-income groups have broncho-respiratory infections.

Table 4.64: Number of persons having Respiratory diseases

S. No.	Income-group (Rs in 000)	No.	Per cent	Total no.	Per cent
1	<50	1	0.68	146	100
2	50-100	6	0.93	646	100
3	100-150	2	0.47	425	100
4	150-200	2	1.50	133	100
5	200-250	1	2.50	40	100
6	>250	1	1.11	90	100
	Total	13	0.88	1480	100

Table 4.65: Place for medical-aid (Respiratory diseases)

S. No.	Income-group (Rs in 000)	Clinic	Per cent	Hospital	Per cent	Total	Per cent
1	<50	0	0.00	1	100.00	1	100
2	50-100	3	50.00	3	50.00	6	100
3	100-150	0	0.00	2	100.00	2	100
4	150-200	1	50.00	1	50.00	2	100
5	200-250	1	100.00	0	0.00	1	100
6	>250	1	100.00	0	0.00	1	100
	Total	6	46.15	7	53.85	13	100

It has been observed that almost equal percentage of people was found to be going to private clinics and government hospitals for treatment purpose as presented in Table 4.65. Annual expenses of more than half of the respondents (i.e., 53.85 percent) people ranged up to Rs 400 for treatment while 38.46 per cent spend between Rs 800 and Rs 1000 for treatment as presented in Table 4.66.

Table 4.66: Annual Expenditure on treatment of Respiratory diseases (in Indian Rupees)

S. No.	Income-group (Rs in 000)	<200	Per cent	200-400	Per cent	400-600	Per cent	600-800	Per cent	800-1000	Per cent	Total	Per cent
1	<50	1	100.00	0	0.00	0	0.00	0	0.00	0	0.00	1	100
2	50-100	2	33.33	3	50.00	1	16.67	0	0.00	0	0.00	6	100
3	100-150	0	0.00	0	0.00	0	0.00	0	0.00	2	100.00	2	100
4	150-200	0	0.00	1	50.00	0	0.00	0	0.00	1	50.00	2	100
5	200-250	0	0.00	0	0.00	0	0.00	0	0.00	1	100.00	1	100
6	>250	0	0.00	0	0.00	0	0.00	0	0.00	1	100.00	1	100
	Total	3	23.08	4	30.77	1	7.69	0	0.00	5	38.46	13	100

e) Heart diseases

Heart diseases are observed more in urban system due to the stressful life style and poor environmental quality and were therefore, studied during the household survey. The results of the analysis are presented in Table 4.67, 4.68 and 4.69 and Fig. 4.26 respectively. The primary survey reveals that 2.03 per cent of the surveyed people are suffering from heart related problems (Table 4.67). The percentage of people suffering from heart ailments increases with increase in income. For medical aid, two-fifth (40 per cent) of the suffering people go to private clinics while three-fifth (60 per cent) go to government hospitals (Table 4.68). This is contrary to the trend observed for other ailments. The reasons being government hospitals have good heart specialists and the expenditure incurred is comparatively lower. Annual expenditure incurred on treatment for heart ailments by 40 per cent of the people is more than Rs 10,000 as illustrated in Table 4.69.

Table 4.67: Number of persons having Heart diseases

S. No.	Income-group (Rs in 000)	No.	Per cent	Total no.	Per cent
1	<50	1	0.68	146	100
2	50-100	5	0.77	646	100
3	100-150	10	2.35	425	100
4	150-200	8	6.02	133	100
5	200-250	3	7.50	40	100
6	>250	3	3.33	90	100
	Total	30	2.03	1480	100

Table 4.68: Place for medical-aid (Heart diseases)

S. No.	Income-group (Rs in 000)	Clinic	Per cent	Hospital	Per cent	Total	Per cent
1	<50	1	100.00	0	0.00	1	100
2	50-100	2	40.00	3	60.00	5	100
3	100-150	4	40.00	6	60.00	10	100
4	150-200	4	50.00	4	50.00	8	100
5	200-250	1	33.33	2	66.67	3	100
6	>250	0	0.00	3	100.00	3	100
	Total	12	40.00	18	60.00	30	100

Table 4.69: Annual Expenditure on treatment of Heart diseases (in '000 Indian Rupees)

S. No.	Income-group (Rs in 000)	<2	Per cent	2-4	Per cent	4-6	Per cent	6-8	Per cent	8-10	Per cent	> 10	Per cent	Total	Per cent
1	<50	0	0.00	1	100.00	0	0.00	0	0.00	0	0.00	0	0.00	1	100
2	50-100	5	100.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	5	100
3	100-150	0	0.00	3	30.00	2	20.00	1	10.00	1	10.00	3	30.00	10	100
4	150-200	0	0.00	2	25.00	2	25.00	0	0.00	0	0.00	4	50.00	8	100
5	200-250	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	3	100.00	3	100
6	>250	0	0.00	0	0.00	0	0.00	0	0.00	1	33.33	2	66.67	3	100
	Total	5	16.67	6	20.00	4	13.33	1	3.33	2	6.67	12	40.00	30	100

f) Diarrhoea

Diarrhoea is a very common problem observed in urban system due to various reasons. The Investigator has attempted to study the number of persons suffering from this particular disease, place of medical-aid and expenditure incurred and the results are presented in Table 4.70, 4.71 and 4.72 and Fig. 4.26 respectively. Table 4.71 clearly elucidates that 1.49 per cent of the total surveyed population suffered from diarrhoea in the year of investigation, of which 68.18 per cent went to private clinics for treatment and the rest to government hospitals (Table 4.72). The annual expenditure incurred on treatment was less than Rs 200 for 45.45 per cent people while 27.27 per cent people spend between Rs 400 and 600.

Table 4.70: Number of persons having Diarrhoea

S. No.	Income-group (Rs in 000)	No.	Per cent	Total no.	Per cent
1	<50	1	0.68	146	100
2	50-100	9	1.39	646	100
3	100-150	3	0.71	425	100
4	150-200	7	5.26	133	100
5	200-250	1	2.50	40	100
6	>250	1	1.11	90	100
	Total	22	1.49	1480	100

Table 4.71: Place for medical-aid (Diarrhoea diseases)

S. No.	Income-group (Rs in 000)	Clinic	Per cent	Hospital	Per cent	Total	Per cent
1	<50	0	0.00	1	100.00	1	100
2	50-100	5	55.56	4	44.44	9	100
3	100-150	2	66.67	1	33.33	3	100
4	150-200	6	85.71	1	14.29	7	100
5	200-250	1	100.00	0	0.00	1	100
6	>250	1	100.00	0	0.00	1	100
	Total	15	68.18	7	31.82	22	100

Table 4.72: Annual Expenditure on treatment of Diarrhoea (in Indian Rupees)

S. No.	Income-group (Rs in 000)	<200	Per cent	200-400	Per cent	400-600	Per cent	600-800	Per cent	800-1000	Per cent	Total	Per cent
1	<50	1	100.00	0	0.00	0	0.00	0	0.00	0	0.00	1	100
2	50-100	6	66.67	1	11.11	1	11.11	1	11.11	0	0.00	9	100
3	100-150	1	33.33	0	0.00	1	33.33	0	0.00	1	33.33	3	100
4	150-200	2	28.57	0	0.00	4	57.14	0	0.00	1	14.29	7	100
5	200-250	0	0.00	1	100.00	0	0.00	0	0.00	0	0.00	1	100
6	>250	0	0.00	0	0.00	0	0.00	1	100.00	0	0.00	1	100
	Total	10	45.45	2	9.09	6	27.27	2	9.09	2	9.09	22	100

g) Hepatitis

Cases of Jaundice or Hepatitis A have been found to occur prominently among the residents of the study area and have therefore been studied. Vaccination for hepatitis has still not become very popular. The results are presented in Table 4.73, 4.74 and 4.75 and Fig. 4.26 respectively. It has been observed that 0.95 per cent of the people were found to be suffering/suffered from hepatitis in the year of investigation (Table 4.73). For the treatment, 78.57 per cent of the respondents go to private clinics while 21.43 per cent go to government hospitals (Table 4.74). In the survey, more people from higher income-groups were found to be suffering from jaundice. Hence, the higher percentage of people going to private clinics is observed. Annual expenditure for treatment ranges between less than Rs 200 and greater than Rs. 800 as observed in Table 4.75.

Table 4.73: Number of persons having Hepatitis

S. No.	Income-group (Rs in 000)	No.	Per cent	Total no.	Per cent
1	<50	0	0.00	146	100
2	50-100	6	0.93	646	100
3	100-150	3	0.71	425	100
4	150-200	4	3.01	133	100
5	200-250	1	2.50	40	100
6	>250	0	0.00	90	100
	Total	14	0.95	1480	100

Table 4.74: Place for medical-aid (Hepatitis)

S. No.	Income-group (Rs in 000)	Clinic	Per cent	Hospital	Per cent	Total	Per cent
1	<50	0	0.00	0	0.00	0	0
2	50-100	4	66.67	2	33.33	6	100
3	100-150	3	100.00	0	0.00	3	100
4	150-200	3	75.00	1	25.00	4	100
5	200-250	1	100.00	0	0.00	1	100
6	>250	0	0.00	0	0.00	0	0
	Total	11	78.57	3	21.43	14	100

Table 4.75: Annual Expenditure on treatment of Hepatitis (in Indian Rupees)

S. No.	Income-group (Rs in 000)	<200	Per cent	200-400	Per cent	400-600	Per cent	600-800	Per cent	>800	Per cent	Total	Per cent
1	<50	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0
2	50-100	1	16.67	3	50.00	1	16.67	1	16.67	0	0.00	6	100
3	100-150	1	33.33	0	0.00	0	0.00	0	0.00	2	66.67	3	100
4	150-200	0	0.00	3	75.00	0	0.00	0	0.00	1	25.00	4	100
5	200-250	0	0.00	0	0.00	1	100.00	0	0.00	0	0.00	1	100
6	>250	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0
	Total	2	14.29	6	42.86	2	14.29	1	7.14	3	21.43	14	100

4.1.15 INFRASTRUCTURE RELATED PROBLEMS

An attempt has also been made by the Investigator to get the people's view with regard to the infrastructure related problems. They were asked to rate the problems starting from the greatest to the lowest as 1 to 10 in that order for power supply, water supply, solid waste management, sewerage/drainage, air pollution, noise pollution and roads/transportation related problems. The problems perceived by the people in various income-groups vary. Therefore, the rank wise analysis of infrastructure related problems has been done income-group wise and is presented in the following section.

4.1.15.1 Annual income less than Rs 50,000

The rank wise rating as given by the lowest income-group with annual income less than Rs 50,000 for infrastructure related problems is presented in Table 4.76. The table clearly shows that 91.40 per cent of the surveyed people of this income-group find power supply to be the biggest problem. The second biggest infrastructure related problems was observed to be water supply and roads/transportation related (25.71 per cent). Sewerage/drainage related problems were voted as the fourth largest problem by 34.29 per cent of the people whereas solid waste management was found to be the fifth largest problem. This is followed by the poor quality of air and noise pollution related problems respectively.

4.1.15.2 Annual income Rs. 50,000-1,00,000

The rank wise rating as given by the income-group with annual income Rs. 50,000-1,00,000 for infrastructure related problems is presented in Table 4.77. The table clearly shows that 84.89 per cent of the surveyed people of this income-group find power supply to be the biggest problem. The second biggest infrastructure related problems was observed to be solid waste management related (28.06 per cent). Sewerage/drainage related problems was voted as the third largest problem by 30.22 per cent of the people whereas roads/transportation related problems was found to be the fourth largest problem. This is followed by the poor quality of air and water supply and noise pollution related problems respectively.

Table 4.76: Rank wise problem in Annual Income group < Rs 50,000

S. No.	Rank	Electricity	Water supply	SWM	Sewerage /drainage	Air pollution	Noise pollution	Roads/transportation related
1	0	1	1	1	1	1	1	1
2	1	32	1	1	0	0	0	0
3	2	2	9	5	5	4	0	9
4	3	0	5	6	11	6	3	3
5	4	0	4	8	12	1	2	7
6	5	0	2	12	5	5	4	6
7	6	0	4	1	1	12	12	4
8	7	0	9	1	0	6	13	5
	Total	35	35	35	35	35	35	35
	max	32	9	12	12	12	13	9
	Per cent	91.40	25.71	34.29	34.29	34.29	37.14	25.71

Table 4.77: Rank wise problem in Annual Income group Rs 50,000-1,00,000

S. No.	Rank	Electricity	Water supply	SWM	Sewerage /drainage	Air pollution	Noise pollution	Roads/transportation related
1	0	4	4	4	4	4	4	0
2	1	118	1	6	4	3	0	3
3	2	3	16	39	31	18	5	25
4	3	6	21	27	42	7	11	21
5	4	0	25	32	21	17	14	25
6	5	0	22	19	18	30	27	20
7	6	4	18	9	16	38	29	21
8	7	4	32	3	3	22	49	20
	Total	139	139	139	139	139	139	135
	max	118	32	39	42	38	49	25
	Per cent	84.89	23.02	28.06	30.22	27.34	35.25	18.52

4.1.15.3 Annual income Rs. 1,00,000-1,50,000

The rank wise rating as given by the income-group with annual income Rs. 1,00,000-1,50,000 for infrastructure related problems is presented in Table 4.78. The table clearly shows that 92.86 per cent of the surveyed people of this income-group find power supply to be the biggest problem. The second biggest infrastructure related problems was observed to be solid waste management and sewerage/drainage related. It is observed that 21 per cent of the people vote roads/transportation related problems as the fifth largest problem followed by quality of air. Further, 21 per cent of the people ranked water supply as the seventh largest problem along with noise pollution.

Table 4.78: Rank wise problem in Annual Income group Rs 1,00,000-1,50,000

S. No.	Rank	Electricity	Water supply	SWM	Sewerage /drainage	Air pollution	Noise pollution	Roads/transportation related
1	0	0	0	0	0	0	0	0
2	1	78	1	2	1	1	1	0
3	2	1	13	25	20	7	7	12
4	3	2	8	21	19	9	6	19
5	4	0	16	21	19	13	10	5
6	5	0	13	7	15	16	12	21
7	6	1	12	8	9	27	17	10
8	7	2	21	0	1	11	31	17
	Total	84	84	84	84	84	84	84
	max	78	21	25	20	27	31	21
	Per cent	92.86	25.00	29.76	23.81	32.14	36.90	25.00

4.1.15.4 Annual income Rs. 1,50,000-2,00,000

The rank wise rating as given by the income-group with annual income Rs. 1,50,000-2,00,000 for infrastructure related problems is presented in Table 4.79. The table clearly shows that 100 per cent of the surveyed people of this income-group find power supply to be the biggest problem. The second biggest infrastructure related problems was observed to be water supply, both quantity and quality wise. This is followed by sewerage/drainage related problems. Almost one-third of the people ((33.33 per cent) voted solid waste management as the fourth largest problem followed by air pollution. Noise pollution and roads/transportation related problems were ranked as the seventh largest problem.

Table 4.79: Rank wise problem in Annual Income group Rs 1,50,000-2,00,000

S. No.	Rank	Electricity	Water supply	SWM	Sewerage /drainage	Air pollution	Noise pollution	Roads/transportation related
1	0	0	0	0	0	0	0	0
2	1	27	0	0	0	0	0	0
3	2	0	9	8	3	1	0	6
4	3	0	3	5	13	2	0	4
5	4	0	1	9	8	1	3	5
6	5	0	5	5	2	7	5	3
7	6	0	8	0	0	9	7	3
8	7	0	1	0	1	7	12	6
	Total	27	27	27	27	27	27	27
	max	27	9	9	13	9	12	6
	Per cent	100.00	33.33	33.33	48.15	33.33	44.44	22.22

4.1.15.5 Annual income Rs. 2,00,000-2,50,000

The rank wise rating as given by the income-group with annual income Rs. 2,00,000-2,50,000 for infrastructure related problems is presented in Table 4.80. The table clearly shows that 100 per cent of the surveyed people of this income-group find power supply to be the biggest problem. The second biggest infrastructure related problems was observed to be solid waste management followed by sewerage/drainage related problems. It is observed that 50 per cent of the people of this income group voted air pollution as the fifth largest problem followed by noise pollution and roads/transportation related problems respectively.

Table 4.80: Rank wise problem in Annual Income group Rs 2,00,000-2,50,000

S. No.	Rank	Electricity	Water supply	SWM	Sewerage /drainage	Air pollution	Noise pollution	Roads/transportation related
1	0	0	0	0	0	0	0	0
2	1	8	0	0	0	0	0	0
3	2	0	1	4	2	0	1	0
4	3	0	1	0	6	0	0	1
5	4	0	1	3	0	1	1	2
6	5	0	1	1	0	4	1	1
7	6	0	2	0	0	2	4	0
8	7	0	2	0	0	1	1	4
	Total	8	8	8	8	8	8	8
	max	8	2	4	6	4	4	4
	Per cent	100.00	25.00	50.00	75.00	50.00	50.00	50.00

4.1.15.6 Annual income greater than Rs. 2,50,000

The rank wise rating as given by the income-group with annual income greater than Rs. 2,50,000 for infrastructure related problems is presented in Table 4.81. The table clearly shows that 100 per cent of the surveyed people of this income-group find power supply to be the biggest problem. The second biggest infrastructure related problems was observed to be sewerage/drainage and air pollution, while 42.86 per cent of the people voted solid waste management as the third largest problem followed by water supply related problems. Roads/transportation related problems were ranked as the sixth largest problem followed by noise pollution.

Table 4.81: Rank wise problem in Annual Income group greater than Rs 2,50,000

S. No.	Rank	Electricity	Water supply	SWM	Sewerage/ drainage	Air pollution	Noise pollution	Roads/transportation related
1	0	0	0	0	0	0	0	0
2	1	7	0	0	0	0	0	0
3	2	0	0	2	3	2	0	0
4	3	0	1	3	2	0	1	0
5	4	0	2	1	1	1	0	2
6	5	0	2	1	0	1	2	1
7	6	0	0	0	1	2	1	3
8	7	0	2	0	0	1	3	1
	Total	7	7	7	7	7	7	7
	max	7	2	3	3	2	3	3
	Per cent	100.00	28.57	42.86	42.86	28.57	42.86	42.86

4.1.16 EXPENDITURE

Modern urban society is a consumer society and loves to spend as per their paying capacity. The major segments where expenditure is considerable are food, clothes, education, health, recreation, transportation, electricity, cooking gas, utilities, newspaper/magazine/internet, telephone, housing, etc. The expenditure pattern is mostly in accordance with the income earned. It also reflects the well-being of a city and can be compared to the economic status of other cities. Having this knowledge in mind, the Investigator has attempted to study the expenditure pattern of various income-groups and the results are discussed as under:

4.1.16.1 Expenditure on food

Food is one of the prime necessities of life. A major part of ones' income is spent on meeting this requirement. The expenditure pattern of the surveyed households is presented in Table 4.82.

Table 4.82: Monthly Expenditure on food (in Indian Rupees)

S. No.	Income-group (Rs in '000)	<1000	1000-2000	2000-3000	3000-4000	4000-5000	5000-6000	6000-7000	7000-8000	>8000	Total
1	<50	4	31	0	0	0	0	0	0	0	35
		11.43	*88.57*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
2	50-100	2	17	60	46	14	0	0	0	0	139
		1.44	*12.23*	*43.17*	*33.09*	*10.07*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
3	100-150	0	0	10	36	21	12	4	1	0	84
		0.00	*0.00*	*11.90*	*42.85*	*25.00*	*14.29*	*4.76*	*1.19*	*0.00*	*100.00*
4	150-200	0	0	2	2	9	5	7	2	0	27
		0.00	*0.00*	*7.41*	*7.41*	*33.33*	*18.52*	*25.92*	*7.41*	*0.00*	*100.00*
5	200-250	0	0	0	0	2	1	3	0	2	8
		0.00	*0.00*	*0.00*	*0.00*	*25.00*	*12.50*	*37.50*	*0.00*	*25.00*	*100.00*
6	>250	0	0	0	0	0	0	1	1	5	7
		0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*14.29*	*14.29*	*71.42*	*100.00*
	Total	6	48	72	84	46	18	15	4	7	300
		2.00	*16.00*	*24.00*	*28.00*	*15.34*	*6.00*	*5.00*	*1.33*	*2.33*	*100.00*

Values in italics are percentage

The table clearly illustrates that more than half of the households spend between Rs 2000 and 4000 on food per month (52 per cent), 15.34 per cent spend up to Rs 5000 per month while 2.33 per cent spend greater than Rs 8000 per month on food. The average expenditure, maximum and minimum expenditure on food by different income-groups is also presented in Table 4.83 and Fig. 4.27.

Table 4.83: Average , maximum and minimum monthly Expenditure on food (in INR)

S. No.	Income-group (Rs in 000)	Monthly expenditure on Food			Monthly expenditure on clothes		
		Average	Maximum	Minimum	Average	Maximum	Minimum
1	<50	1374.29	2000	500	241.43	600	0
2	50-100	2572.62	4500	600	448.02	1000	75
3	100-150	3857.14	7000	2000	659.88	2000	100
4	150-200	4851.85	7000	2000	966.67	3000	200
5	200-250	5937.50	8000	4000	1150	1500	1000
6	>250	7928.57	10000	6000	2600	5000	1000

The table illustrates that the average expenditure on food gradually increases from Rs 1,374 to Rs 7,929 per month as the income increases from less than Rs 50,000 annually to greater than Rs. 250,000 annually. The minimum expenditure on food was found to be Rs 500 while the maximum as Rs 10,000 per month. This is indicative of the great income-disparities in Indian society.

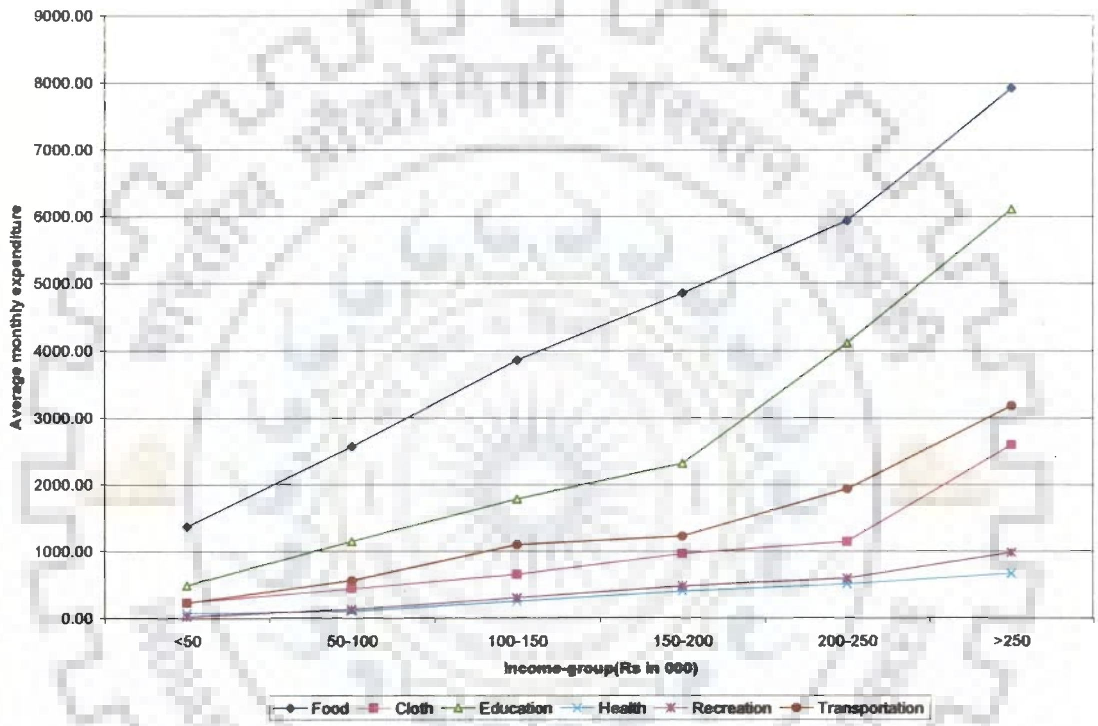


Fig. 4.27: Average monthly expenditure on food, cloth, education, health, recreation and transportation

4.1.16.2 Expenditure on Clothes

Clothing is also one of the basic necessities of life. The study area itself has a number of garment manufacturing industries. The expenditure pattern of the spending on clothes by the surveyed households is presented in Table 4.84.

Table 4.84: Monthly Expenditure on Clothes (in Indian Rupees)

S. No.	Income-group (Rs in '000)	<500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	3500-4000	>4000	Total
1	<50	29	6	0	0	0	0	0	0	0	35
		82.86	*17.14*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
2	50-100	60	66	13	0	0	0	0	0	0	139
		43.17	*47.48*	*9.35*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
3	100-150	21	35	27	0	1	0	0	0	0	84
		25.00	*41.67*	*32.14*	*0.00*	*1.19*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
4	150-200	4	7	12	2	1	0	1	0	0	27
		14.81	*25.93*	*44.44*	*7.41*	*3.70*	*0.00*	*3.70*	*0.00*	*0.00*	*100.00*
5	200-250	0	0	6	2	0	0	0	0	0	8
		0.00	*0.00*	*75.00*	*25.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
6	>250	0	0	2	1	1	1	0	0	2	7
		0.00	*0.00*	*28.57*	*14.29*	*14.29*	*14.29*	*0.00*	*0.00*	*28.57*	*100.00*
	Total	114	114	60	5	3	1	1	0	2	300
		38.00	*38.00*	*20.00*	*1.67*	*1.00*	*0.33*	*0.33*	*0.00*	*0.67*	*100.00*

Values in italics are percentage

The table illustrates that 76 per cent of the household spend up to Rs 1000 per month on an average. The lower and middle-income group buy clothes mainly on occasions like festivals, marriage celebrations, etc. The spending increases gradually with increase in income. The average expenditure, maximum and minimum expenditure on clothes by different income-groups is also presented in Table 4.83 and Fig. 4.27. It shows that the average expenditure per month on clothes increases gradually from Rs 241 to Rs 2600 as the income increases from less than Rs 50,000 annually to greater than Rs. 250,000 annually.

4.1.16.3 Expenditure on Education

Cities have long been the centres for education. Urban India increasingly realises the importance of education and its important role for attaining a secure employment. Having this knowledge, the expenditure on education by the surveyed households was studied by the Investigator and the results are presented in Table 4.85.

Table 4.85: Monthly Expenditure on Education (in Indian Rupees)

S. No.	Income-group (Rs in '000)	<500	500-1500	1500-2500	2500-3500	3500-4500	4500-5500	5500-6500	>6500	Total
1	<50	13	21	1	0	0	0	0	0	35
		37.14	*60.00*	*2.86*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
2	50-100	14	77	42	6	0	0	0	0	139
		10.07	*55.40*	*30.22*	*4.32*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
3	100-150	11	19	26	22	4	2	0	0	84
		13.10	*22.62*	*30.95*	*26.19*	*4.76*	*2.38*	*0.00*	*0.00*	*100.00*
4	150-200	1	7	6	7	3	2	1	0	27
		3.70	*25.93*	*22.22*	*25.93*	*11.11*	*7.41*	*3.70*	*0.00*	*100.00*
5	200-250	0	1	0	3	2	0	0	2	8
		0.00	*12.50*	*0.00*	*37.50*	*25.00*	*0.00*	*0.00*	*25.00*	*100.00*
6	>250	0	0	0	2	0	0	1	4	7
		0.00	*0.00*	*0.00*	*28.57*	*0.00*	*0.00*	*14.29*	*57.14*	*100.00*
	Total	39	125	75	40	9	4	2	6	300
		13.00	*41.67*	*25.00*	*13.33*	*3.00*	*1.33*	*0.67*	*2.00*	*100.00*

Values in italics are percentage

The table illustrates that 41.7 per cent of the households spend between Rs 500 and 1000 per month on education, 25 per cent spend between Rs 1500 and 2500 while 2 per cent spend more than Rs 6500 per month on education. The spending increases with increase in income. The average expenditure, maximum and minimum expenditure on education by different income-groups is also presented in Table 4.86. It shows that the average expenditure per month on education increases gradually from Rs 495 to Rs 6112 as the income increases from less than Rs 50,000 annually to greater than Rs 250,000 annually.

Table 4.86 : Average , maximum and minimum monthly Expenditure on education and health

S. No.	Income-group	Monthly expenditure on education			Monthly expenditure on health		
		Average	Maximum	Minimum	Average	Maximum	Minimum
1	<50,000	495.00	1500	0	81.86	1000	0
2	50-1,00,000	1155.18	3000	0	109.75	1000	0
3	1,00-1,50,000	1790.24	5000	0	259.05	2500	0
4	1,50-2,00,000	2323.33	5500	0	405.56	1500	50
5	2,00-2,50,000	4112.50	8000	1000	512.50	1000	0
6	>2,50,000	6112.14	8510	2775	671.43	2000	150

4.1.16.4 Expenditure on Health

Health services are invariably better in urban centres all over the world. It results in better health profile for certain set of diseases while for others the cities often become hotbed for spread of contagious diseases as well, like AIDS, broncho-respiratory tract infections, etc. The monthly expenditure on health throws some light on the health of people in general. It has therefore, been investigated by the Author and the results are presented in Table 4.87.

Table 4.87: Monthly Expenditure on Health (in Indian Rupees)

S. No.	Income-group (Rs in '000)	<100	100-500	500-1000	1000-1500	1500-2000	>2000	Total
1	<50	28	5	1	1	0	0	35
		80.00	*14.29*	*2.86*	*2.86*	*0.00*	*0.00*	*100.00*
2	50-100	69	64	4	2	0	0	139
		49.64	*46.04*	*2.88*	*1.44*	*0.00*	*0.00*	*100.00*
3	100-150	19	56	3	4	0	2	84
		22.62	*66.67*	*3.57*	*4.76*	*0.00*	*2.38*	*100.00*
4	150-200	1	18	4	2	2	0	27
		3.70	*66.67*	*14.81*	*7.41*	*7.41*	*0.00*	*100.00*
5	200-250	1	3	2	2	0	0	8
		12.50	*37.50*	*25.00*	*25.00*	*0.00*	*0.00*	*100.00*
6	>250	0	2	4	0	0	1	7
		0.00	*28.57*	*57.14*	*0.00*	*0.00*	*14.29*	*100.00*
	Total	118	148	18	11	2	3	300
		39.33	*49.33*	*6.00*	*3.67*	*0.67*	*1.00*	*100.00*

Values in italics are percentage

The table illustrates that 88.66 per cent of the surveyed household spend up to Rs 500 per month on an average on health. The spending increases with increase in income. The average expenditure, maximum and minimum expenditure on health by different income-groups is also presented in Table 4.86 and Fig. 4.27. It shows that the average expenditure per month on health increases gradually from Rs 81 to Rs 671 as the income increases from less than Rs 50,000 annually to greater than Rs 250,000 annually. The lower-income groups mostly go to government hospitals where the treatment is free or nominal while the higher-income groups prefer the services of private doctors, nursing homes and hospitals.

4.1.16.5 Expenditure on Recreation

Entertainment is an important part of life to keep vigour in life and to get out of the boredom of routine life. In urban lifestyle, the major means of recreation include visits to parks, restaurants, movie, theatre, water parks, play, etc. It also includes social visits to friends and relatives but has not been considered in the survey. It is indicative of the role of entertainment as perceived by the people and society of a given area. The Investigator has therefore, attempted to study the expenditure on recreation by all income-groups investigated during the survey and the results presented in Table 4.88.

The table illustrates that more than two-fifth of the total surveyed population spend up to Rs 500 per month on recreational visits (i.e., 43 per cent), 18 per cent spend up to Rs 1000 per month, 2.33 per cent spend up to Rs 1500 per month while only 1 per cent of the households spend greater than Rs 2000 per month on recreational visits. The average expenditure, maximum and minimum expenditure on recreation by different income-groups is also presented in Table 4.89 and Fig. 4.27. It shows that the average expenditure per month on recreation increases gradually from Rs 34 to Rs 986 as the income increases from less than Rs 50,000 annually to greater than Rs 250,000 annually. The maximum expenditure on recreation in the fifth income-group is found to be lower than that in the fourth income group. This is indicative of the lifestyle of the people. It was observed that few of the surveyed households even in the higher income-group do not like spending money on activities like, theatre, cinema, restaurants, disco, etc.

Table 4.88: Monthly Expenditure on Recreation (in Indian Rupees)

S. No.	Income-group (Rs in '000)	<100	100-500	500-1000	1000-1500	1500-2000	>2000	Total
1	<50	26	9	0	0	0	0	35
		74.29	*25.71*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
2	50-100	62	63	14	0	0	0	139
		44.60	*45.32*	*10.07*	*0.00*	*0.00*	*0.00*	*100.00*
3	100-150	12	46	26	0	0	0	84
		14.29	*54.76*	*30.95*	*0.00*	*0.00*	*0.00*	*100.00*
4	150-200	6	8	9	2	0	2	27
		22.22	*29.63*	*33.33*	*7.41*	*0.00*	*7.41*	*100.00*
5	200-250	1	2	3	2	0	0	8
		12.50	*25.00*	*37.50*	*25.00*	*0.00*	*0.00*	*100.00*
6	>250	0	1	2	3	0	1	7
		0.00	*14.29*	*28.57*	*42.86*	*0.00*	*14.29*	*100.00*
	Total	107	129	54	7	0	3	300
		35.67	*43.00*	*18.00*	*2.33*	*0.00*	*1.00*	*100.00*

Values in italics are percentage

Table 4.89: Average, maximum and minimum monthly expenditure on recreation and transportation

S. No.	Income-group	Monthly expenditure on recreation			Monthly expenditure on Transportation		
		Average	Maximum	Minimum	Average	Maximum	Minimum
1	<50,000	33.71	150	0	238.86	650	0
2	50-1,00,000	139.75	700	0	567.27	1800	50
3	1,00-1,50,000	310.71	800	0	1104.17	3000	250
4	1,50-2,00,000	483.33	2000	0	1229.63	3000	200
5	2,00-2,50,000	600.00	1200	0	1937.50	3500	800
6	>2,50,000	985.71	2000	400	3185.71	5000	1800

4.1.16.6 Expenditure on Transportation

Transportation is the life line of any system. An efficient city is often characterised by a good road network and a parallel public transportation system. Most of the Indian cities lack a strong public transport system. A lot of money is therefore spent on commuting for various purposes using personalised vehicles. An attempt has therefore, been made to study the expenditure on transportation by different income-groups during the survey, and the results are presented in Table 4.90. The table illustrates that about two-fifth (38 per cent) of the surveyed households spend Rs 500 to 1000 on transportation per month, just above one-tenth (10.33 per cent) spend between Rs 1500 to 3000 per month, while 4 per cent spend more than Rs 3000 on transportation.

The average monthly expenditure on transportation also shows a gradual increase with increase in income and is presented in Table 4.89 and Fig. 4.27. The table illustrates that the average expenditure increases from Rs 239 per month for the lowest income-group to Rs 3186 per month for the highest income group.

Table 4.90: Monthly Expenditure on Transportation (in Indian Rupees)

S. No.	Income-group (Rs in '000)	<100	100-500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	3000-3500	>3500	Total
1	<50	8	22	5	0	0	0	0	0	0	35
		22.86	*62.86*	*14.29*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.0*
2	50-100	3	50	70	12	4	0	0	0	0	139
		2.16	*35.97*	*50.36*	*8.63*	*2.88*	*0.00*	*0.00*	*0.00*	*0.00*	*100.0*
3	100-150	0	7	28	29	0	12	5	2	1	84
		0.00	*8.33*	*33.33*	*34.52*	*0.00*	*14.29*	*5.95*	*2.38*	*1.19*	*100.0*
4	150-200	0	2	10	8	1	1	3	2	0	27
		0.00	*7.41*	*37.04*	*29.63*	*3.70*	*3.70*	*11.11*	*7.41*	*0.00*	*100.0*
5	200-250	0	0	1	2	0	3	0	0	2	8
		0.00	*0.00*	*12.50*	*25.00*	*0.00*	*37.50*	*0.00*	*0.00*	*25.00*	*100.0*
6	>250	0	0	0	0	1	0	1	3	2	7
		0.00	*0.00*	*0.00*	*0.00*	*14.29*	*0.00*	*14.29*	*42.86*	*28.57*	*100.0*
	Total	11	81	114	51	6	16	9	7	5	300
		3.67	*27.00*	*38.00*	*17.00*	*2.00*	*5.33*	*3.00*	*2.33*	*1.67*	*100.0*

Values in italics are percentage

4.1.16.7 Expenditure on Electricity

A country's economic status is often defined by the per capita power consumption. Higher the per capita power consumption greater is the development and economic status of the place. The monthly expenditure on electricity is an indirect indicator of the well-being of the people. An attempt has therefore, been made by the Investigator to study the expenditure on electricity of the surveyed households and is presented in Table 4.91. The table clearly illustrates that 76.67 per cent pay between Rs 100 to 500 per month on electricity, 14.33 per cent spend Rs

500 to Rs1000 per month while only 0.67 per cent of the people spend up to Rs 2000 per month on electricity. The average, maximum and minimum expenditure on electricity is also analysed and presented in Table 4.92 and Fig. 4.27. The average monthly expenditure shows a gradual increase from Rs 180 for the first income-group to Rs 1014 for the last income-group. The minimum expenditure of Rs 0 in the first income-group is due to the electricity drawn by theft by few of the surveyed households. In the second and third-income groups, employees of Kanpur Electricity Supply Authority (KESA) get free power supply due to which the minimum expenditure for these income-groups is Rs 0.

Table 4.91: Monthly Expenditure on Electricity (in Indian Rupees)

S. No.	Income-group (Rs in '000)	<100	100-500	500-1000	1000-1500	1500-2000	Total
1	<50	5	30	0	0	0	0
		14.29	*85.71*	*0.00*	*0.00*	*0.00*	*0.00*
2	50-100	14	120	5	0	0	0
		10.07	*86.33*	*3.60*	*0.00*	*0.00*	*0.00*
3	100-150	1	61	22	0	0	0
		1.19	*72.62*	*26.19*	*0.00*	*0.00*	*0.00*
4	150-200	0	16	8	2	1	0
		0.00	*59.26*	*29.63*	*7.41*	*3.70*	*0.00*
5	200-250	0	3	4	1	0	0
		0.00	*37.50*	*50.00*	*12.50*	*0.00*	*0.00*
6	>250	0	0	4	2	1	0
		0.00	*0.00*	*57.14*	*28.57*	*14.29*	*0.00*
	Total	20	230	43	5	2	0
		6.67	*76.67*	*14.33*	*1.67*	*0.67*	*0.00*

Values in italics are percentage

Table 4.92: Average, maximum and minimum monthly expenditure on electricity

S. No.	Income-group	Monthly expenditure on Electricity		
		Average	Maximum	Minimum
1	<50,000	180.00	300	0
2	50-1,00,000	254.96	600	0
3	1,00-1,50,000	400.24	900	0
4	1,50-2,00,000	533.33	1500	250
5	2,00-2,50,000	593.75	1200	200
6	>2,50,000	1014.29	1500	500

4.1.16.8 Expenditure on Cooking Gas

The major source of energy for cooking purposes in Indian cities and towns is LPG/cooking gas. The lowest income-group people living in slums and squatters or the people engaged in informal sector like tea-stalls, etc., use wood or charcoal for cooking purpose. This segment has not been included in the sample as discussed in Chapter 1.

LPG has long been subsidised by the government to help the common man. Its recent increase in price met a lot of hue and cry in the public. The expenditure on cooking gas is undoubtedly an indicator of the economic well-being, paying capacity and the cultural habits of the people. This aspect has therefore, been analysed and presented in Table 4.93.

Table 4.93: Monthly Expenditure on Cooking gas (in Indian Rupees)

S. No.	Income-group (Rs in '000)	<100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	>800	Total
1	<50	1	3	15	16	0	0	0	0	0	35
		2.86	*8.57*	*42.86*	*45.71*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
2	50-100	0	5	35	93	4	1	1	0	0	139
		0.00	*3.60*	*25.18*	*66.91*	*2.88*	*0.72*	*0.72*	*0.00*	*0.00*	*100.00*
3	100-150	0	1	4	57	15	0	7	0	0	84
		0.00	*1.19*	*4.76*	*67.86*	*17.86*	*0.00*	*8.33*	*0.00*	*0.00*	*100.00*
4	150-200	0	0	1	18	4	3	1	0	0	27
		0.00	*0.00*	*3.70*	*66.67*	*14.81*	*11.11*	*3.70*	*0.00*	*0.00*	*100.00*
5	200-250	0	2	0	0	3	2	0	0	1	8
		0.00	*25.00*	*0.00*	*0.00*	*37.50*	*25.00*	*0.00*	*0.00*	*12.50*	*100.00*
6	>250	0	0	0	0	0	0	5	1	1	7
		0.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*71.43*	*14.29*	*14.29*	*100.00*
	Total	1	11	55	184	26	6	14	1	2	300
		0.33	*3.67*	*18.33*	*61.33*	*8.67*	*2.00*	*4.67*	*0.33*	*0.67*	*100.00*

Values in italics are percentage

The table clearly illustrates that more than three-fifth (61.33 per cent) of the people spend Rs 300 to 400 per month on cooking gas, 18.33 per cent spend Rs 200 to 300, 8.67 per cent spend Rs 400 to 500 while 7.67 per cent spend more than Rs 500 per month on cooking gas. On analysing the income-group wise expenditure pattern, it is observed that the expenditure increases as the income increases. In the first income-group, 88.57 per cent of the people spend between Rs 200 and 400 per month on cooking gas, whereas in the sixth income-group 71.43 per cent of the people spend Rs 600 to 700 per month and 14.29 per cent spend more than Rs 800 on cooking gas.

The average, maximum and minimum expenditure observed in each income-group on cooking gas is presented in Table 4.94 and Fig. 4.27. The average monthly expenditure shows a subtle increase as the income increases. The average expenditure on cooking gas is same for the third and fourth income-group. The last income group however, shows a high expenditure due to the presence of joint families in this segment of the surveyed households.

Table 4.94: Average, maximum and minimum monthly expenditure on cooking gas and kerosene

S. No.	Income-group (Rs in '000)	Monthly expenditure on cooking Gas			Monthly expenditure on kerosene		
		Average	Maximum	Minimum	Average	Maximum	Minimum
1	<50	249.91	310	50	30	200	0
2	50-100	290.19	600	150	17.84	200	0
3	100-150	347.43	600	150	9.89	200	0
4	150-200	348.15	600	200	11.11	150	0
5	200-250	431.25	800	150	0.00	0	0
6	>250	664.29	900	600	0.00	0	0

4.1.16.9 Expenditure on Kerosene

Kerosene is one of the sources of energy and is not widely used these days in urban centres except for by the lower segments of people where it is extensively used. This energy source is also subsidized to help the common man. In the study area, this source is used for lighting during extreme power cuts and some cooking in emergency situations when cooking gas is not available. The expenditure pattern for kerosene has been studied by the Investigator and the results are presented in Table 4.95.

Table 4.95: Monthly Expenditure on Kerosene (in Indian Rupees)

S. No.	Income-group (Rs in '000)	0	<50	50-100	100-150	150-200	>200	Total
1	<50	18	6	8	2	0	1	35
		51.43	*17.14*	*22.86*	*5.71*	*0.00*	*2.86*	*100.00*
2	50-100	106	7	12	12	0	2	139
		76.26	*5.04*	*8.63*	*8.63*	*0.00*	*1.44*	*100.00*
3	100-150	74	1	4	4	0	1	84
		88.10	*1.19*	*4.76*	*4.76*	*0.00*	*1.19*	*100.00*
4	150-200	24	0	1	1	1	0	27
		88.89	*0.00*	*3.70*	*3.70*	*3.70*	*0.00*	*100.00*
5	200-250	8	0	0	0	0	0	8
		100.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
6	>250	7	0	0	0	0	0	7
		100.00	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
	Total	237	14	25	19	1	4	300
		79.00	*4.67*	*8.33*	*6.33*	*0.33*	*1.33*	*100.00*

Values in italics are percentage

The table illustrates that the major user of kerosene amongst the surveyed households belong to the first income-category, i.e. annual income less than Rs 50,000. Almost half of the households (i.e., 48.57 per cent) of this group use kerosene, of which 22.86 per cent spend between Rs 50 and 100 per month on purchasing kerosene. In the second income-group, only 23.74 per cent use kerosene to some extent followed by 11.90 and 11.10 per cent users in the subsequent third and fourth income-groups respectively. The last two groups do not use kerosene at all. The overall analysis shows that more than three-fourth (79 per cent) of the surveyed households do not use kerosene at all. On an average, less than one-tenth of the households (8.33 per cent) spend between Rs 50 and 100 per month on kerosene while 6.33 per cent spend Rs 100 to 150 per month.

The average, maximum and minimum expenditure observed in each income-group on kerosene is presented in Table 4.94 and Fig. 4.27. The average monthly expenditure is maximum for the lowest income group and the higher income groups do not use kerosene.

4.1.16.10 Expenditure on Telephone/mobile, Utilities and Newspaper/internet

The urban society is primarily a consumer society. The wide spread use of telephones, mobiles and newspaper/internet is a hallmark of today's Indian urban centres and Kanpur city is no exception. Besides, it is also observed that the urban society spends a lot on utilities and newspaper/internet, etc. It has therefore, been studied by the Investigator and the findings presented in Table 4.96, 4.97 and 4.98 respectively. Table 4.96 illustrates that almost half of the surveyed households, i.e., 50 per cent, spend less than Rs 500 on telecommunications, while one-fourth (25 per cent) households spend between Rs 500 and 1000 on this. It has also been observed that the monthly expenditure on telephone/mobile is higher among the higher income group people.

Table 4.96: Monthly Expenditure on Telephone/mobile (in Indian Rupees)

S. No.	Income-group (Rs in '000)	0	<500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	>3000	Total
1	<50	19	15	1	0	0	0	0	0	35
		54.29	*42.86*	*2.86*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
2	50-100	13	101	21	4	0	0	0	0	139
		9.35	*72.66*	*15.11*	*2.88*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
3	100-150	1	28	38	16	0	1	0	0	84
		1.19	*33.33*	*45.24*	*19.05*	*0.00*	*1.19*	*0.00*	*0.00*	*100.00*
4	150-200	0	5	13	2	4	3	0	0	27
		0.00	*18.52*	*48.15*	*7.41*	*14.81*	*11.11*	*0.00*	*0.00*	*100.00*
5	200-250	0	1	2	2	3	0	0	0	8
		0.00	*12.50*	*25.00*	*25.00*	*37.50*	*0.00*	*0.00*	*0.00*	*100.00*
6	>250	0	0	0	2	1	3	1	0	7
		0.00	*0.00*	*0.00*	*28.57*	*14.29*	*42.86*	*14.29*	*0.00*	*100.00*
	Total	33	150	75	26	8	7	1	0	300
		11.00	*50.00*	*25.00*	*8.67*	*2.67*	*2.33*	*0.33*	*0.00*	*100.00*

Values in italics are percentage

Table 4.97: Monthly Expenditure on Utilities (in Indian Rupees)

S. No.	Income-group (Rs in '000)	<100	100-200	200-300	300-400	400-500	500-600	600-700	700-800	>800	Total
1	<50	13	18	2	2	0	0	0	0	0	35
		37.14	*51.43*	*5.71*	*5.71*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
2	50-100	20	59	39	10	4	7	0	0	0	139
		14.39	*42.45*	*28.06*	*7.19*	*2.88*	*5.04*	*0.00*	*0.00*	*0.00*	*100.00*
3	100-150	0	21	29	19	5	8	2	0	0	84
		0.00	*25.00*	*34.52*	*22.62*	*5.95*	*9.52*	*2.38*	*0.00*	*0.00*	*100.00*
4	150-200	0	8	6	5	3	3	0	0	2	27
		0.00	*29.63*	*22.22*	*18.52*	*11.11*	*11.11*	*0.00*	*0.00*	*7.41*	*100.00*
5	200-250	0	2	1	4	0	0	0	0	1	8
		0.00	*25.00*	*12.50*	*50.00*	*0.00*	*0.00*	*0.00*	*0.00*	*12.50*	*100.00*
6	>250	0	0	2	1	1	0	1	1	1	7
		0.00	*0.00*	*28.57*	*14.29*	*14.29*	*0.00*	*14.29*	*14.29*	*14.29*	*100.00*
	Total	33	108	79	41	13	18	3	1	4	300
		11.00	*36.00*	*26.33*	*13.67*	*4.33*	*6.00*	*1.00*	*0.33*	*1.33*	*100.00*

Values in italics are percentage

Table 4.97 clearly shows that more than one-third of the surveyed households spend between Rs 100 and 200 per month on utilities, i.e., 36 per cent, while 26.33 per cent spend up to Rs 300. Six per cent of the people are observed to spend between Rs 500 and 600 per month while only 1.33 per cent spend greater than Rs 800. The expenditure on utilities increases with income-group as seen in the table.

Table 4.98 clearly shows that more than three-fifth of the surveyed households spend up to Rs 100 per month on newspaper/magazine and internet facilities, i.e., 63 per cent while only 0.67 per cent households spend more than Rs 250 per month on these facilities.

Table 4.98: Monthly Expenditure on Newspaper/magazine/internet (in Indian Rupees)

S. No.	Income-group (Rs in '000)	0	<50	50-100	100-150	150-200	200-250	>250	Total
1	<50	22	0	13	0	0	0	0	35
		62.86	*0.00*	*37.14*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
2	50-100	18	3	100	15	1	2	0	139
		12.95	*2.16*	*71.94*	*10.79*	*0.72*	*1.44*	*0.00*	*100.00*
3	100-150	1	0	58	16	6	2	1	84
		1.19	*0.00*	*69.05*	*19.05*	*7.14*	*2.38*	*1.19*	*100.00*
4	150-200	0	0	15	9	3	0	0	27
		0.00	*0.00*	*55.56*	*33.33*	*11.11*	*0.00*	*0.00*	*100.00*
5	200-250	0	0	3	4	0	0	1	8
		0.00	*0.00*	*37.50*	*50.00*	*0.00*	*0.00*	*12.50*	*100.00*
6	>250	0	0	0	4	2	1	0	7
		0.00	*0.00*	*0.00*	*57.14*	*28.57*	*14.29*	*0.00*	*100.00*
	Total	41	3	189	48	12	5	2	300
		13.67	*1.00*	*63.00*	*16.00*	*4.00*	*1.67*	*0.67*	*100.00*

Values in italics are percentage

4.1.16.11 Expenditure on Petrol and Diesel

In the absence of a strong public transport system, the use of personalized vehicles is an essential necessity in the study area. The monthly expenditure on petrol and diesel has therefore, been studied and the results are presented in Table 4.99 and 4.100 respectively. Table 4.99 illustrates that more than half of the surveyed households spend up to Rs 1000 per month on petrol alone, i.e., 56.33 per cent, 19 per cent do not spend any money on petrol which means they do not have any personal motorised vehicles and they mostly belong to the lower income-groups. A considerable 10.34 per cent of the households spend more than Rs 1500 per month on petrol alone. Higher income-groups spend more money on petrol due to greater ownership of motorised vehicles by them. In the case of diesel consumption, Table 4.100 illustrates that only 6 per cent of the surveyed households spend less than Rs 500 whereas 93.33 per cent do not spend any money on diesel. This shows that the ownership of diesel-run vehicles is less in the study area.

Table 4.99: Monthly Expenditure on Petrol (in Indian Rupees)

S. No.	Income-group (Rs in '000)	0	<500	500-1000	1000-1500	1500-2000	2000-2500	2500-3000	>3000	Total
1	<50	23	8	4	0	0	0	0	0	35
		65.71	*22.86*	*11.43*	*0.00*	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
2	50-100	31	55	41	10	2	0	0	0	139
		22.30	*39.57*	*29.50*	*7.19*	*1.44*	*0.00*	*0.00*	*0.00*	*100.00*
3	100-150	1	13	35	22	8	3	1	1	84
		1.19	*15.48*	*41.67*	*26.19*	*9.52*	*3.57*	*1.19*	*1.19*	*100.00*
4	150-200	2	3	9	8	1	3	0	1	27
		7.41	*11.11*	*33.33*	*29.63*	*3.70*	*11.11*	*0.00*	*3.70*	*100.00*
5	200-250	0	0	1	2	2	2	0	1	8
		0.00	*0.00*	*12.50*	*25.00*	*25.00*	*25.00*	*0.00*	*12.50*	*100.00*
6	>250	0	0	0	1	1	1	2	2	7
		0.00	*0.00*	*0.00*	*14.29*	*14.29*	*14.29*	*28.57*	*28.57*	*100.00*
	Total	57	79	90	43	14	9	3	5	300
		19.00	*26.33*	*30.00*	*14.33*	*4.67*	*3.00*	*1.00*	*1.67*	*100.00*

Values in italics are percentage

Table 4.100: Monthly Expenditure on Diesel (in Indian Rupees)

S. No.	Income-group (Rs in '000)	0	<500	500-1000	1000-1500	>1500	Total
1	<50	35	0	0	0	0	35
		100.00	*0.00*	*0.00*	*0.00*	*0.00*	*100.00*
2	50-100	136	3	0	0	0	139
		97.84	*2.16*	*0.00*	*0.00*	*0.00*	*100.00*
3	100-150	80	4	0	0	0	84
		95.24	*4.76*	*0.00*	*0.00*	*0.00*	*100.00*
4	150-200	20	6	0	0	1	27
		74.07	*22.22*	*0.00*	*0.00*	*3.70*	*100.00*
5	200-250	5	2	1	0	0	8
		62.50	*25.00*	*12.50*	*0.00*	*0.00*	*100.00*
6	>250	4	3	0	0	0	7
		57.14	*42.86*	*0.00*	*0.00*	*0.00*	*100.00*
	Total	280	18	1	0	1	300
		93.33	*6.00*	*0.33*	*0.00*	*0.33*	*100.00*

Values in italics are percentage

The quantity of petrol used per week by the respondents is a clear indicator of aspects like preferential use of personalised vehicles, income-level, distances travelled, etc. Having this knowledge, the weekly consumption of petrol by the respondents has been surveyed and the results presented in Table 4.101.

Table 4.101: Quantity of petrol used per week (in litres)

S. No.	Income-group (Rs in '000)	<5	Per cent	5-10	Per cent	10-15	Per cent	15-20	Per cent	Total	Per cent
1	<50	35	100.00	0	0.00	0	0.00	0	0.00	35	100.00
2	50-100	114	82.01	24	17.27	1	0.72	0	0.00	139	100.00
3	100-150	35	41.67	37	44.05	9	10.71	3	3.57	84	100.00
4	150-200	9	33.33	12	44.44	1	3.70	5	18.52	27	100.00
5	200-250	3	37.50	1	12.50	1	12.50	3	37.50	8	100.00
6	>250	0	0.00	0	0.00	1	14.29	6	85.71	7	100.00
	Total	196	65.33	74	24.67	13	4.33	17	5.67	300	100.00

The table illustrates that more than three-fifth of the total surveyed households use less than 5 litres of petrol (i.e., 65.33 per cent), 24.67 per cent consume 5 to 10 litres of petrol per week while 5.67 per cent consume more than 15 litres of petrol per week on an average. On analysing the consumption pattern along various income-groups, a distinct pattern is observed that the consumption quantity of petrol increases as the income increases. It is due to higher ownership of personalised vehicles by the higher-income group people which is essential for a public-transport weak city like Kanpur.

A comparative line graph of the average expenditure by the various income-group households on various energy carriers like, kerosene, LPG, electricity, petrol and diesel is presented in Fig. 4.28. The figure clearly shows that the slope of expenditure on each energy carrier with varying degree increases with increase in income except for kerosene. Kerosene is a subsidised energy carrier and mainly used by the lower-income group people, primarily for cooking purpose and for lighting during power cuts.

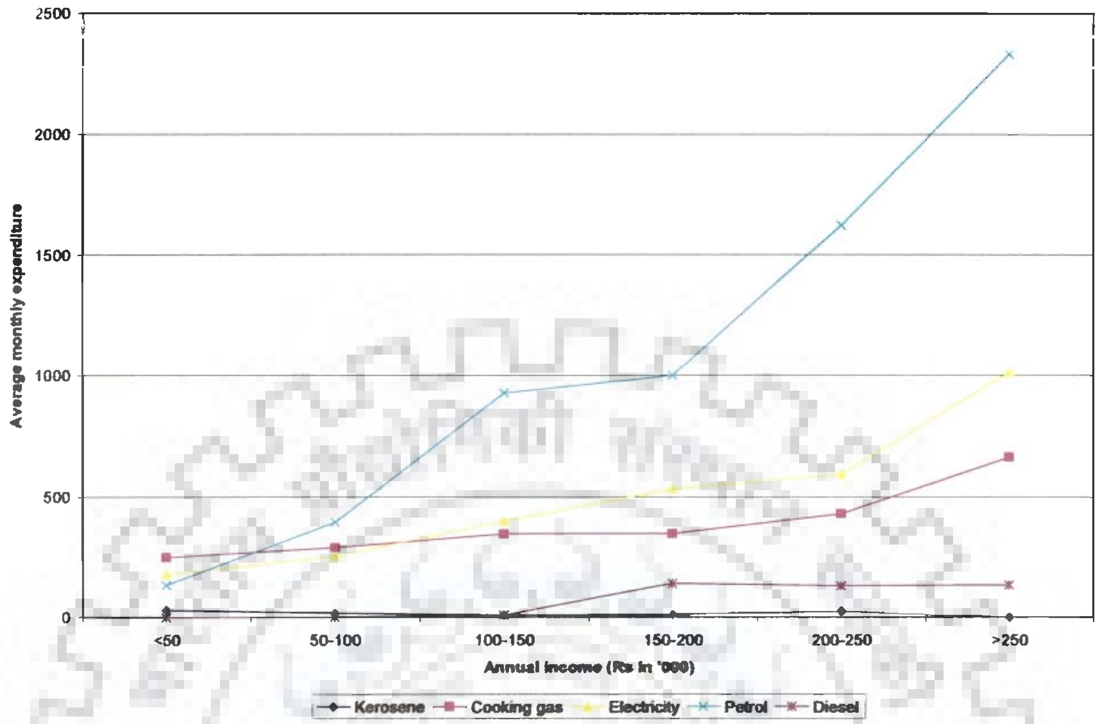


Fig. 4.28: Average expenditure on various energy-carriers by various income-groups

4.1.17 WASTE SEPARATION AND STORAGE

As widely recognized, the separation of waste components like newspaper, magazines, bottles, etc., at the source of generation (including households) is one of the most effective ways to achieve the recovery and reuse of materials. In Indian cities, people do tend to separate only those waste types which could fetch some monetary rewards. An attempt has therefore, been made to find this waste separation and storage tendencies among the respondents of the study area and the findings are presented in Table 4.102. The table clearly illustrates that more than three-fourth of the surveyed households separate only high quality recyclables like newspaper, magazine, bottles, etc., to be later resold to the Itinerant Waste Buyers; only 10.67 per cent of the people separate both high quality and low quality recyclables while 12.33 per cent of the respondents make no attempts to separate the generated waste.

Table 4.102: Waste separation in surveyed households

S. No.	Item	No. of Households	Percentage
1.	Only high quality recyclables (newspapers, magazines, bottles, etc.)	231	77.00
2.	Both high quality and low quality recyclables(wet and dry)	32	10.67
3.	No separation attempted (Mixed waste)	37	12.33
	Total	300	100.00

4.2 SOCIO-ECONOMIC CONDITIONS OF THE INFORMAL SECTOR

The private-private alliances seem to be strong in Kanpur in spite of any support by the Local Authorities as discussed in Chapter 3. It is important to study the socio-economic conditions of this sector, with special focus on the conditions of waste-pickers and dump-pickers as these are the most economically backward of all. The salient features of this sector as observed in the study area are presented as under:

4.2.1 TYPES OF WASTE PICKERS

There are four different kinds of waste pickers identified in the study area. They are classified as follows:

- Waste pickers who carry a sack on their back and collect whatever has any resale value. These street waste pickers pick up waste from streets, drains, municipal bins and open dumps.
- Dump-pickers who collect waste from landfills/dumpsites and have their dwelling places adjacent to the dumps.

- Waste pickers who carry a huge sack across a bicycle/rickshaw They are often termed as *Kabariwala* or Itinerant Waste buyers. They collect only specific items like glass bottles, plastic, magazines, newspaper, metals, etc., and sell them separately. In Kanpur, a section of the Itinerant waste buyers called *Jogies* directly resell the items in a market (Parade ground) after little/no modifications.
- Waste pickers who work for waste dealers. These waste pickers are committed to sell their daily collection to the waste dealers who employ them. They also help the dealers by sorting the waste.

For most of the waste pickers, it is their only source of livelihood. However, it is also observed that some do it as an additional support to the family's income.

4.2.2 LIFE-STYLE OF WASTE PICKERS

The waste-pickers, dump-pickers and itinerant waste buyers usually live on subsistence level and have just enough to support their food requirements on a day-to-day basis. During lean seasons and health problems, they get financial help only from small-scale traders and dealers as they are outcasted from the formal segment. Even the ordinary moneylenders hesitate to give them loans.

4.2.2.1 Education

The waste-pickers and itinerant buyers live in very poor conditions and are found to be illiterate during the survey. Even the children have no education as they are also engaged in helping their parents for waste picking/sorting right from the childhood.

4.2.2.2 Gender-bias

Dump-pickers are found to be mostly women while waste-pickers in Kanpur were found to be all males (Fig 4.29). Women face more harassment from the society, police and local authorities and hence, prefer to pick wastes form the dump-sites.

Fig. 4.29: Women comprise majority of dump-pickers (Kanpur dump site at Bingawan)

4.2.2.3 Child labour

In Kanpur, children of all age-group (5 to 16 years) were found to be engaged in waste-picking (Fig 4.30). The children engaged in waste-picking were however, only males while female children were found to be engaged in dump-picking.

Fig. 4.30: Children engaged in waste-picking in Kanpur

4.2.2.4 Place of residence

I. **WASTE-PICKERS**

In Kanpur, they were found to be living in slums near Railway line and Kalyanpur. The hutments are made from polythene, mud, tin, etc (Fig 4.31).

II. **DUMP-PICKERS**

In Kanpur, these dump-pickers lived a secluded life in mud-made hutments next to the dump-site at Bingawan and Panki (Fig 4.32).

III. **JOGIES**

These people live in Parade ground and Jogiana. The hutments are mostly tin-sheds and made from composite materials usually retrieved from wastes.

IV. **TRADERS/DEALERS**

An interesting feature found during the field survey in Kanpur was that the small-scale traders and dealers were found to be spread almost all over the city with principal agglomerations in Juhi, Lucknow-Kanpur byepass (State-highway), Kalyanpur, Jajmau, Harjindernagar, etc. The houses are *pucca* houses, but most do not have tenure ownership and live on municipal land along the highways.

V. **WHOLESALERS**

They are concentrated in areas like Kalyanpur and Afim ki kothi. They are well-to-do people and have good houses.

Fig. 4.31: Dwellings of ragpickers and *Jogis*(IWB)

Fig. 4.32: Dump pickers huts right next to a Landfill

4.2.2.5 Social profile

Waste-pickers and dump-pickers were found to be mostly Hindus. Among the wholesalers and traders, Muslims do figure out in a larger number. The respondent waste-pickers and dump-pickers were found to be mostly migrants from nearby and far off villages and few from Bihar.

4.2.2.6 Common health hazards

The working and living conditions of the waste-pickers and dump-pickers make them susceptible to many types of diseases and health hazards, as presented in Table 4.103.

Table 4.103: Common ailments among the waste and dump-pickers

S.No.	Infection type	Average Frequency in a year/person
1.	Viral infections	14
2.	Broncho-respiratory infections	Throughout the year
3.	Skin problems	common
4.	Cuts and wounds	Throughout
5.	Stomach disorders	48-50

The table illustrates that the prominent ailments among the pickers are viral infections, broncho-respiratory infections, skin problems and stomach disorders besides regular cuts and wounds encountered during waste picking.

4.2.2.7 Family size

An attempt was also made during survey to study the family size of the people engaged in informal waste recycling sector and the results are presented in Table 4.104.

Table 4.104: Average family size in informal waste recycling sector

S.No.	Group	Average family size
1	Waste pickers	7
2	Itinerant waste buyers (Kabaris)	6
3	Jogies	6
4	Retailers	6
5	Wholesalers	5

The table clearly illustrates that the average size of family is larger in the lowest segment i.e., waste-pickers which further aggravates their problems. The average family size for itinerant waste buyers, jogies and retailers was found to be six, which is also large while that in wholesalers the average family size was observed to be five.

4.2.3 THE RECYCLABLE STREAM

The waste-pickers and dump-pickers pick the recyclables and anything which has some resale value. Once picked-up, the waste enters into a hierarchy of traders and dealers as under:

a) Small dealers/traders : Small dealers buy all kinds of recyclables like plastics, paper, glass, metals, etc. from the waste-pickers and do some primary sorting before selling to the medium dealers/traders and wholesalers. They sell once in 15 days or one month depending on the quantity of materials and the storage space available with them (Fig. 4.33, 4.34, 4.35).

b) Medium dealers/traders: Medium dealers have larger storage space and usually specialize in one or more materials. Their number is less (Fig. 4.36).

c) Wholesalers: Wholesalers are materials specialist. They have large godowns for storage of materials and send truck loads of materials to the manufacturing enterprises in and out of the city. They also employ 10-12 sorters for sorting and loading the waste.

Fig. 4.33: Small waste trader

Fig. 4.34: Small waste trader

Fig. 4.35: Small waste trader

Fig. 4.36: Middle-scale waste traders

4.2.4 Income generation and quantity of waste collected

A random sample survey of 40 waste pickers was carried out in Kanpur city by the Investigator to find out the waste composition collected by them and the contribution made by various types of waste in income. The results are shown in the adjoining pie-charts (Fig 4.37

and 4.38). The figures clearly depict that polythene/carry bags (thicker ones) and metals are found to bring more income compared to other wastes.

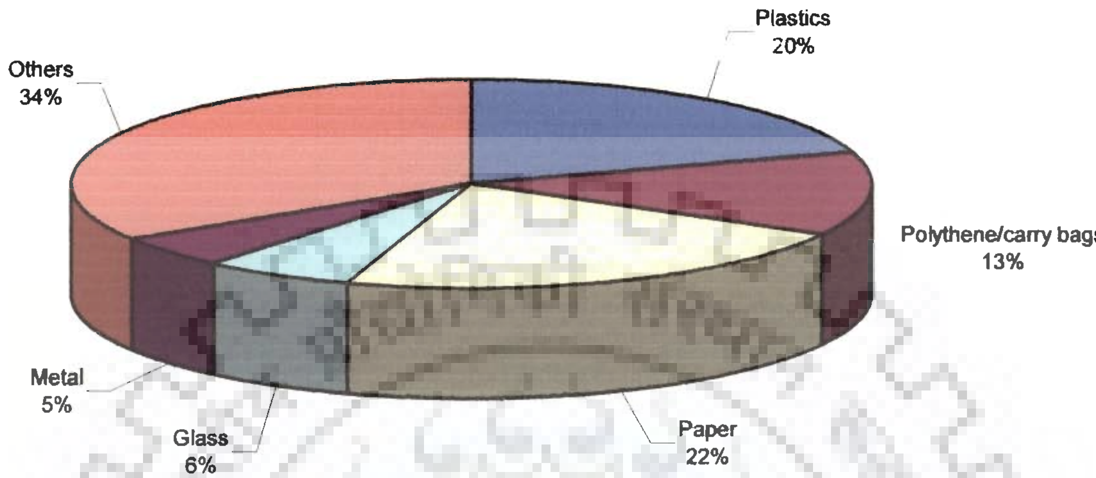


Fig. 4.37: Composition of quantity of waste collected by Waste pickers

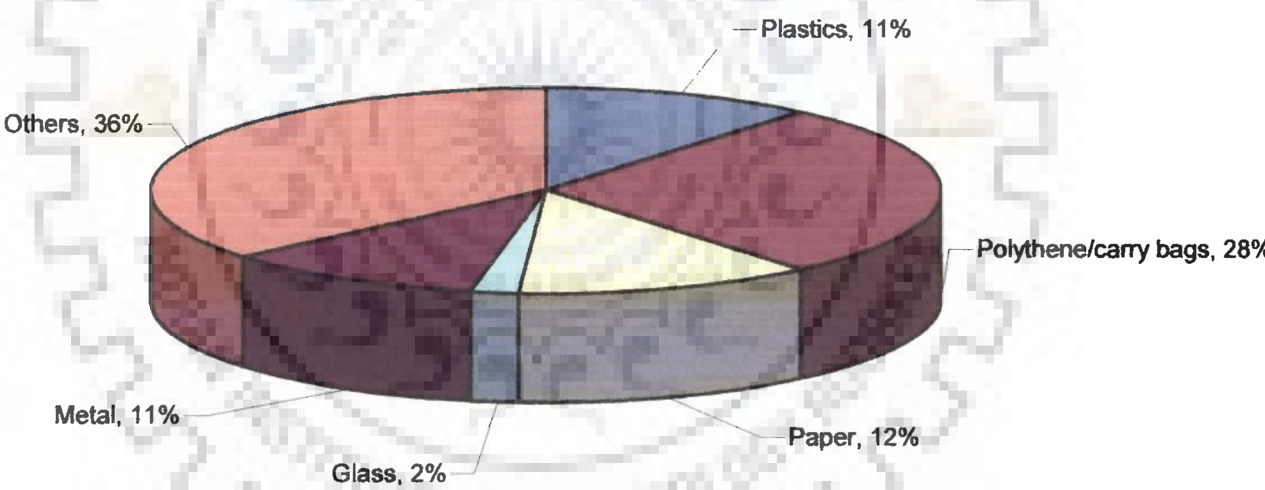


Fig. 4.38: Income generated from various types of waste

There is a wide variation in the income of various actors of this informal waste sector and is presented in Table 4.105 and Fig. 4.39. The table shows the income variation between Rs 1,527 for waste-pickers and Rs 10,700 per month for wholesalers.

Table 4.105: Average monthly income among various segments

S.No.	Group	Monthly income (Rs)
1	Waste pickers	1527
2	Itinerant waste buyers (Kabaris)	2046
3	Jogies	3780
4	Retailers/traders/dealers	4067
5	Bone collectors/merchant	6037
6	Wholesalers	10700

This clearly shows that the wholesalers and retailers/bone collectors enjoy a good amount of monthly income, whereas the waste pickers and Itinerant waste buyers live on subsistence level. The waste pickers have an average daily income of Rs 50.9. This is similar to findings by Beukering, et. al., 1996 in Mumbai and Agarwal, et al., 2005 in Delhi. Their daily income, in fact, at times jumps down during lean seasons like monsoons, extreme winter and summers. Their already deplorable condition becomes worse during such lean seasons.

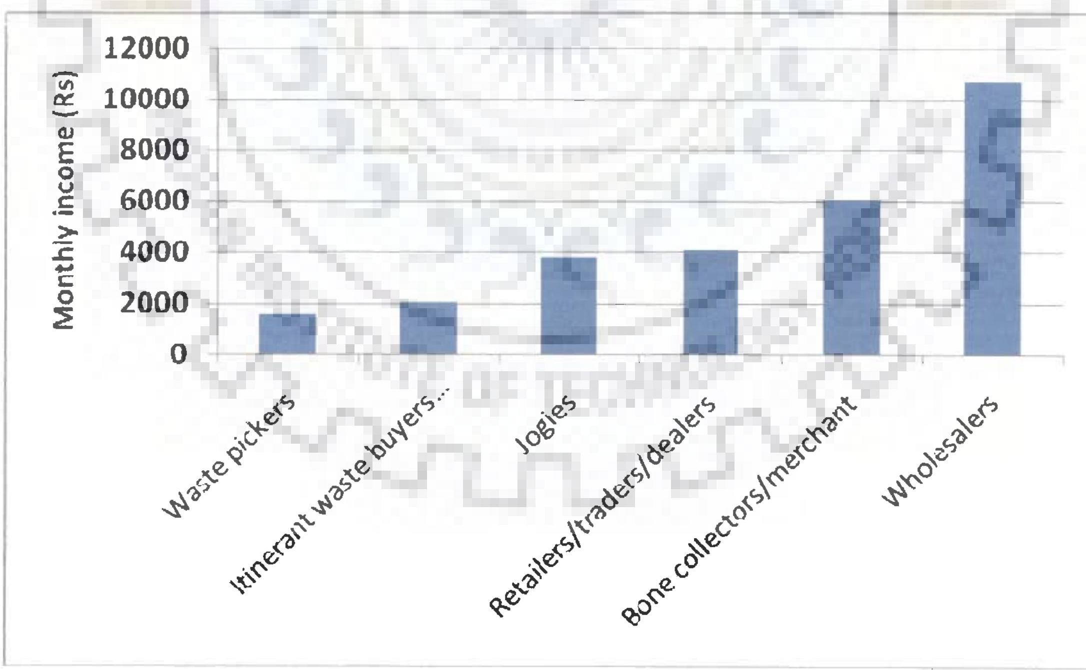


Fig. 4.39: Comparison of income of various actors of the Informal Sector

There are no data available for the collected quantity of waste by various actors of the recycling sector. Field studies done in Kanpur by the researchers reveal that the average collection by a waste-picker is 38.35 kg per day while that for retailers/traders (small and medium) is about 377.5 kg per day as presented in Table 4.106 and Fig. 4.40.

Table 4.106: Average collection of waste in Kanpur

S. No.	Average collection	Kg/day
1.	Waste picker	38.25
2.	Itinerant waste-buyers	89.00
3.	Retailers/traders	377.50
4.	Wholesalers (paper)	2150
5.	Wholesalers (scrap)	3767
6.	Wholesalers (plastic)	529

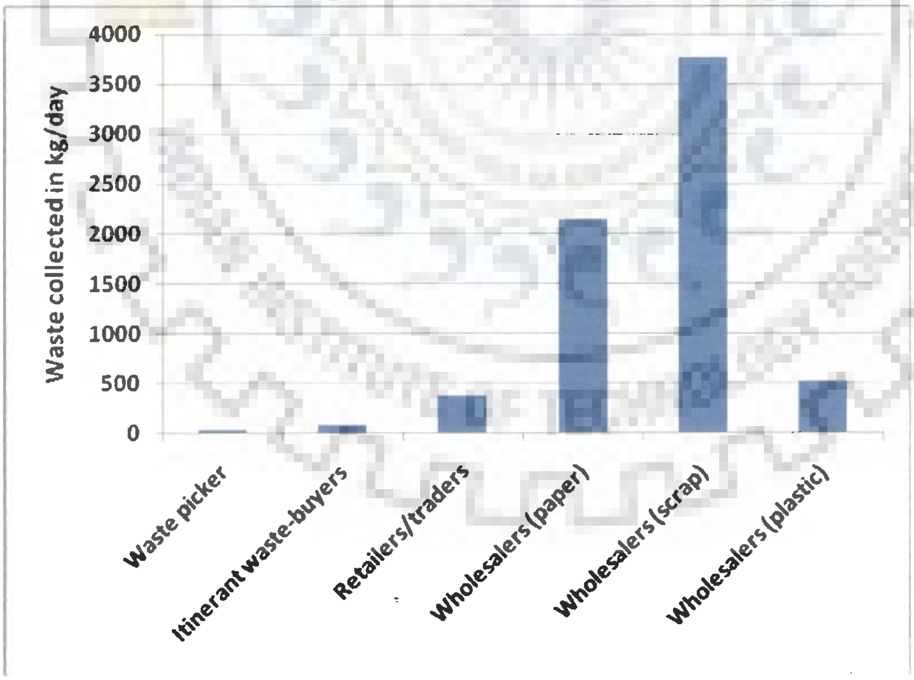


Fig. 4.40: Average collection of waste by various actors of the Informal Sector

The sale price differentials of various materials show the socio-economic condition of various sectors of informal waste recycling sector. The study conducted by the investigators in Kanpur city shows a wide range of price differentials and is presented in Table 4.107 and Fig. 4.41.

Table 4.107: Sale price differentials among various materials, Kanpur (Rs./kg)

S.No.	Type	Waste paper	Plastic (Hard)	Polypack	Newspaper	Glass	Iron
1	Waste pickers	1.00	2.50	1.50	1.00	0.75	4.00
2	Itinerant waste buyers/kabadis	3.50	5.00	5.25	5.00	1.50	5.50
3	Retailers	4.00	6.00	8.50	5.75	2.00	6.00

The table depicts the wide variation in the selling price of various materials (retrieved form wastes) among various segments of the recycling sector. The waste pickers are clearly the ones who make least profit.

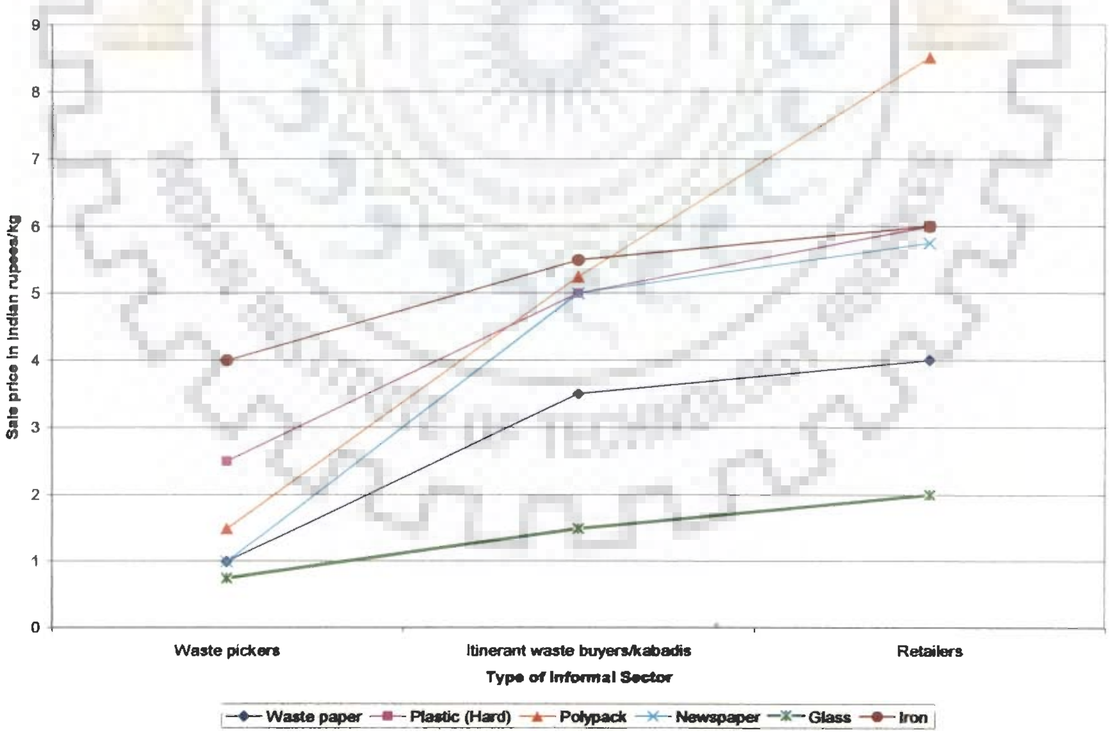


Fig. 4.41: Sale price differentials among various materials for various actors of the Informal Sector

4.3 CONCLUSIONS

In this Chapter, the socio-economic, environmental and infrastructure conditions of the study area is studied based on the primary survey conducted. Further, an attempt has also been made to closely examine the socio-economic conditions of the informal sector working in solid waste management. The findings would eventually help in deciding the control parameters for model formulation, appropriate policy making and for evolving strategic action plan for municipal solid waste management in the study area, as discussed in the subsequent Chapters.

Chapter 5

APPLICATION OF THEORIES AND MODELS

5.0 INTRODUCTION

In this present investigation, the Investigator has done thorough investigation at the grassroots level to understand the functions of the system. A system is decided and controlled by a large number of parameters. These parameters are termed as control parameters. In this chapter, the control parameters that decide the functions of the study area (system) are identified by employing field studies, correlation method, discussion with experts and secondary sources of data.

Multiple regression models have been attempted based on the available data. Further, Systems theory is employed, and appropriate System Dynamics models are developed and validated for accuracy. Plausible scenarios are thereafter developed and tested in the validated System Dynamics model under various alternative conditions to understand the functions of the system. It is observed that waste management of a city comprises of two separate sectors- formal and informal, each rendering partial or complete management of six elements of municipal solid waste management system. Thus, a number of sub-systems exist in the integrated municipal waste management system. An attempt is, therefore, made to develop an integrated model consisting of various subsystems based on the controlling parameters that decide the function of each sub-system to evolve a set of policy guidelines for optimal management of municipal solid waste in the study area (system).

5.1 CORRELATION COEFFICIENT METHOD

Correlation analysis helps in analysing the covariation of two or more variables. It refers to the techniques used in measuring the closeness of the relationship between the variables. The measure of correlation is known as correlation coefficient and it summarizes the direction and degree of correlation. Having this knowledge, the Investigator has therefore, attempted to use Correlation coefficient method to analyze the parameters of the various subsystems that highly influence the system. The household data collected for this investigation are utilized for the said purpose and correlation coefficients between the dependent variable and the independent variables have been established. Annual income of the households is considered as the dependent variable (y) and all other parameters are considered as independent variables (x_1, x_2, x_3......x_n) for analysis.

Correlation analysis helps in determining the degree of relationship between two or more variables. The results of the correlation analysis between the monthly income and various other variables, based on the results of the primary survey are presented in Table 5.1. The correlated variables have been presented in three categories of very high, high and moderate positive correlation. The table elucidates that none of the parameters show very high correlation; correlation between monthly income and expenditure on food, education, transportation, electricity, telephone and petrol is high and ranges between 0.70 and 0.85, whereas the rest of the parameters show a moderate correlation between 0.50 and 0.70.

Table 5.1: Association between monthly income and other variables

Size of Correlation		Interpretation
Size of correlation : 0.90 to 1.00		Very high positive correlation
1.	None	
Size of correlation : 0.70 to 0.90		High positive correlation
1.	Monthly income and expenditure on food	0.85
2.	Monthly income and expenditure on education	0.71
3.	Monthly income and expenditure on transportation	0.75
4.	Monthly income and expenditure on electricity	0.71
5.	Monthly income and expenditure on telephone/mobile	0.73
6.	Monthly income and expenditure on petrol	0.70
Size of correlation : 0.50 to 0.70		Moderate positive correlation
1.	Monthly income and expenditure on clothes	0.68
2.	Monthly income and expenditure on recreation	0.60
3.	Monthly income and expenditure on cooking	0.63
4.	Monthly income and no. of rooms in house	0.60
5.	Monthly income and quantity of fuel (petrol) used	0.68
6.	Monthly income and consumption of water (Nov-Feb)	0.64
7.	Monthly income and consumption of water (Mar-Jun)	0.62
8.	Monthly income and consumption of water (Jul-Oct)	0.64
9.	Monthly income and cooler	0.61
10.	Monthly income and geyser	0.61
11.	Monthly income and T.V	0.63
12.	Monthly income and pressure cooker	0.67
13.	Monthly income and no. of persons suffering from Typhoid	0.61
14.	Monthly income and no. of persons suffering from Diarrhoea	0.68
15.	Monthly income and washing machine	0.65
16.	Monthly income and no of employed members	0.50
17.	Monthly income and expenditure on utility goods/toiletries	0.51
18.	Monthly income and expenditure on newspaper/magazine/internet	0.54
19.	Monthly income and no. of family members	0.51
20.	Monthly income and no. of cars owned	0.51
21.	Monthly income and use of inverter, generator, etc.	0.51
22.	Monthly income and no. of refrigerators	0.58
23.	Monthly income and stove	0.53
24.	Monthly income and mixer/grinder	0.50
25.	Monthly income and expenditure for treatment(Malaria)	0.51
26.	Monthly income and place of medical aid (Diarrhoea)	0.52

5.1.1 CONTROL PARAMETERS

Attempt has also been made to study the correlation between other variables having an influence on solid waste generation. Bivariate correlation between quantity of solid waste generated, monthly income, family size, frequency of solid waste collection, number of employed persons and expenditure on food were done and the results are presented in Table 5.2.

Table 5.2: Bivariate correlation between variables having a significant influence on solid waste generation

		monthly income	qty of solid waste	family size	frequency of SW collection	employed persons	exp food
monthly income	Pearson Correlation	1	.424**	.507**	-.240**	.496**	.853**
	Sig. (2-tailed)	.	.000	.000	.000	.000	.000
	N	300	300	300	300	300	300
qty of solid waste	Pearson Correlation	.424**	1	.529**	-.140*	.308**	.452**
	Sig. (2-tailed)	.000	.	.000	.015	.000	.000
	N	300	300	300	300	300	300
family size	Pearson Correlation	.507**	.529**	1	-.081	.605**	.505**
	Sig. (2-tailed)	.000	.000	.	.160	.000	.000
	N	300	300	300	300	300	300
frequency of SW collection	Pearson Correlation	-.240**	-.140*	-.081	1	-.169**	-.301**
	Sig. (2-tailed)	.000	.015	.160	.	.003	.000
	N	300	300	300	300	300	300
employed persons	Pearson Correlation	.496**	.308**	.605**	-.169**	1	.498**
	Sig. (2-tailed)	.000	.000	.000	.003	.	.000
	N	300	300	300	300	300	300
exp food	Pearson Correlation	.853**	.452**	.505**	-.301**	.498**	1
	Sig. (2-tailed)	.000	.000	.000	.000	.000	.
	N	300	300	300	300	300	300

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

5.2 REGRESSION ANALYSIS

5.2.1 MULTIPLE REGRESSION MODEL

Regression analysis is a statistical tool to establish the nature of the relationship between variables and to study the functional relationship between variables and thereby provide a mechanism for prediction or forecasting. It thus helps to estimate the unknown values of one variable from known values of another variable. The variable which is used to predict the variable of interest is termed as the independent variable and the variable which is predicted is known as dependent variable. It is presented by a regression line or regression equation. Based on the above parameters, Multiple regression model has been attempted in this investigation to see the causal relationship between various parameters by using SPSS software. Two regression equations have been evolved-one to establish a relationship between income and related variables that influence the income in the study area, and the other equation to establish a relationship between quantity of solid waste generated and other variables.

5.2.1.1 Multiple Regression Equation for Income

For evaluation, the monthly income has been taken as the dependent variable (y) and the rest of the parameters as independent variables (x_1, x_2, x_3, ...x_n). Four different models have been attempted taking 21, 17, 10 and 8 predictor variables respectively and presented in Appendix IV. A comparison of the four models is presented in Table 5.3. All four models give r^2 value of above 0.9. The four models have then been tested for statistical significance of multiple r and the predictor variables. Model 4 is found to be the appropriate model.

Table 5.3: Comparison of the models

	No. of independent variables	r	r^2	Adjusted r^2
Model 1	21	0.985	0.971	0.969
Model 2	17	0.985	0.971	0.969
Model 3	10	0.984	0.969	0.968
Model 4	8	0.984	0.969	0.968

r^2 = Multiple coefficient of determination; $r = \sqrt{r^2}$ = Multiple Correlation coefficient

DETERMINE WHETHER THE MULTIPLE r IS STATISTICALLY SIGNIFICANT:

Model 1: The critical value is 1.62 for F distribution with 21 and 278 degrees of freedom and assuming α = 0.5, which is greater than the computed value of F, the null hypothesis is rejected and "The probability that r = 0.985 would have occurred by chance, if the null hypothesis were true is less than 0.05." The probability is actually less than 0.0001.

This applies for the rest of three models also.

TESTING THE SIGNIFICANCE OF THE PREDICTOR VARIABLES:

Model 1: Critical value for 278 degrees of freedom, and $\alpha = 0.5 = +\_1.96$; only 8 predictor variables are significant

Model 2: Critical value for 282 degrees of freedom, and $\alpha = 0.5 = +\_1.96$; only 8 variables are significant

Model 3: Critical value for 289 degrees of freedom, and $\alpha = 0.5 = +\_1.96$; only 8 variables are significant

Model 4: Critical value for 291 degrees of freedom, and $\alpha = 0.5 = +\_1.96$; all variables are significant hence the right equation for the model in raw score form is,

$$y = 1.038x_1 + 0.930x_2 + 1.375x_3 + 1.701x_4 + 0.735x_5 + 1.111x_6 + 1.328x_7 + 94.408x_8 + 303.799$$

where y = monthly income

x_1 = expenditure on food

x_2 = expenditure on education

x_3 = expenditure on transportation

x_4 = expenditure on electricity

x_5 = expenditure on petrol

x_6 = expenditure on clothes

x_7 = expenditure on recreation

x_8 = quantity of solid waste generated

The equation for standard score form will be,

$$y = 0.368x_1 + 0.290x_2 + 0.218x_3 + 0.083x_4 + 0.104x_5 + 0.135x_6 + 0.090x_7 + 0.021x_8$$

5.2.1.2 Multiple Regression Equation for quantity of solid waste generated

Attempt has been made in this investigation to study the relation between quantity of solid waste generated at household level and factors like monthly income, family size, expenditure on food, frequency of solid waste collection and number of employed persons. The model summary is presented in Appendix IV.

Regression equation in standard score form is thus,

$$y = 0.043x_1 + 0.455x_2 - 0.108x_3 - 0.042x_4 + 0.227x_5$$

where y = Quantity of solid waste generated at Household level

x_1 = monthly income

x_2 = family size

x_3 = number of employed persons

x_4 = frequency of solid waste collection

x_5 = expenditure on food

The model clearly shows that the multiple coefficient of determination (r^2) is 0.334 while multiple correlation coefficient (r) is 0.578. It shows that 33 per cent of the variation is explained by this regression relation. It is acceptable for the present investigation since the sample size is very small.

The multiple regression models attempted give the relationship between annual household income and most influential variables; and between solid waste generated and the most important variables responsible for waste generation in the system. This has helped in deciding the control parameters that influence the system. It is however, observed that it is not possible to measure a number of indicators (variables) that decide the functions of the system pertaining to municipal solid waste management and total system from these multiple regression models. Therefore, System Dynamics Models have been developed and employed in this investigation to measure the important variables that influence the solid waste management in the system, including the informal sector engaged in partial collection of generated waste and recycling.

5.3 APPLICATION OF THEORY

In this present investigation, the Investigator has employed Systems theory based on systems concept, and System Dynamics models. In this present investigation, the study area is considered as a system. The Investigator observes that solid waste management, which is one of the basic infrastructure requirements of a community, is not treated as an integral component of the system and all its elements are not integrated for a strategic management plan. Stakeholder participation is also absent and is among the many drawbacks of the existing system. Therefore, the Investigator has attempted to establish that waste management should be treated in an integral manner with co-ordination among all its sub-systems for an effective and implementable solution and a healthier city.

Further, attempts have been made to develop System Dynamics Models based on the survey data, historical data and field studies, to understand the influence of the most important controlling parameters of various subsystems while evolving optimal strategies for integrated municipal solid waste management system.

5.3.1 SYSTEMS CONCEPT

The word 'system' has Greek origin and literally means 'to set together'. It is a complex of interrelated parts or sub-systems. A *system* can thus be defined as an organized or connected group or set of objects, principles, or ideas related by some common function or belief [101]. A system functions as a whole with the interaction of several subsystems. All the sub-systems of the system are interconnected, and interdependent on each other, and form a system. If one of the sub-systems of the system is defunct or functions with higher degree (taking lead role during its function) or partly functions, its effects can be visualized in the entire system over a period of time. In some cases, the system may not function at all, while in some cases the system may function, but with a lot of disturbances or smooth functions of the system may be paralyzed.

5.3.1.1 System characteristics

Some of the major features of a system as postulated by Jenkins (1969) are [177]:

- A system is a complex grouping of human beings and machine.
- A system consists of many sub-systems, the amount of sub-systems detail depending on the problem being studied.
- The outputs from a given sub-system provide the inputs to the other sub-system(s). Hence, a sub-system cannot be studied in isolation.
- The system being studied will usually form part of a hierarchy of such-systems. The systems at the top are very important and exert considerable influence on the systems lower down.
- To function, a system must have an objective, but this is influenced by the wider system of which it forms a part. Usually, systems have multiple objectives which are in conflict with one another, so that an overall objective is required which effects a compromise between these conflicting objectives.
- To function at maximum efficiency, a system must be designed in such a way that it is capable of achieving its overall objective in the best possible ways.

Thus, all living systems maintain steady state dynamic equilibria keeping an orderly balance among its sub-systems with respect to its super system and the environment. However, if an element of a system fails to handle a stress, other elements come forward and share this excess stress.

5.3.2 SYSTEMS THEORY

Various forms of systems theories have been proposed over the years. The important ones among them are General Systems theory, Cybernetics, Systems Approach, and System Dynamics approach.

General System theory propounded first by a biologist, Ludwig Von Bertalanffy [39, 40] based on original research of biological organisms (1920s and 1930s), was both supported and criticized by many scientists from various fields [6, 17, 226]. The broad objectives of the theory are to investigate the isomorphy of concepts, laws and models in various fields, and to help in useful transfers from one field to another, to encourage the development of adequate theoretical models in areas which lack them, to eliminate the duplication of theoretical efforts in different fields, and to promote the unity of science through improving communication between specialists [69]. However, this theory has not properly emerged due to lack of methods capable of implementing it [338].

Cybernetics is a theory of communication and control in animals, society, and machines, its main elements being feedback, self-regulation and control, and information transmission. It uses the concept of entropy in communication theory as a measure of disorder, uncertainty or variety of systems [17, 31, 32, 33, 34, 35, 332, 333]. This theory is popular among social scientist; however it remains largely verbal rather than mathematical and dwells upon problems at the conceptual plane only.

The Systems Approach is an out growth of the concepts of General Systems Theory and cybernetics. It suggests a practical philosophy of solving problems in societal systems and is holistic in approach [233]. The characteristics of this theory are [136]:

1. The problem of a system is defined in relation to super-ordinate systems to which it is related by a community of objectives.

2. The objectives of the system must be viewed in relation to these super-ordinate systems or the whole system.
3. Present design must be evaluated in terms of opportunity costs or the extent of divergence of the system from the optimum design.
4. The optimum design cannot usually be found incrementally nearby present adopted forms. It involves planning, evaluation, and implementation of new alternatives, which offer innovative and creative departures from the whole system.
5. System design involves processes of thinking, such as, induction and synthesis, which differ from deductive and reductive methods used in the scientific method of system improvement.
6. Planning is conceived as a process where Planner assumes the role of a leader rather than that of a follower, so that problems are prevented from occurring rather than solved when they occur.
7. It is universally accepted as one of the strongest tool of undertaking a systematic inquiry. However, it does not recommend any specific methodology, which guides the actual employment of approach.

The System Dynamics approach, developed by Forrester, W. J., (1961), amalgamates ideas developed in various System Theories and is a result of cross-fertilization of ideas from traditional management, cybernetics, and computer simulation. It is a theory of structure and behaviour system [118]. It presents a very easy to use, intuitively appealing, and yet mathematically sophisticated methodology for undertaking practical systems enquiry.

It is widely used in industrial systems [116], complex social systems other than industrial systems with problems of controllability [84], such as, urban systems [64, 69, 119, 120, 151, 174, 187, 204, 205, 206, 207, 224, 275], world systems [116, 119], which deal with socio-economic systems and management.

The theory was initially criticized for the limitations such as:

a) Scarce data was used to build models

b) Models were highly aggregated

c) Absence of quantitative validity

d) Practice of trial and error during policy design did not always give the best design

e) Methods of judging parameters sensitivity of models were not fool-proof.

However, after a number of improvements, over the years, System Dynamics has emerged as one of the most powerful methodologies of social systems analysis and design at aggregate level for its ability to address itself to very important long term and short term issues of real system, its ability and simplicity to model complex, non linear relationships, its ability to model soft social and psychological variables, the ease with which the effects of alternative policy options can be tested, and the ease in communicating the model, the results and recommendations [160, 233].

5.3.3 Application of System Dynamics Theory

System Dynamics Theory has been employed to address practically every sort of feedback system. It includes works in Corporate Planning and Policy Design [120, 211], economic behaviour [296], public management and policy [164], biological and medical modelling [152], theory development in the natural and social sciences [102], dynamic decision modelling [294], complex non-linear dynamics [238], software engineering [3], supply chain management [11, 23, 308], tourism system dynamic model [91, 175], business systems [295], ecological systems [142], social-economic systems [119, 120, 220], agricultural systems [276], political decision making systems [244] , and environmental systems [2, 143, 324, 326, 327, 340] , river pollution control [93], population dynamics model [142, 163, 319, 329] , Integrated City Development plans [95, 134, 275] and solid waste management [103, 185, 214, 298, 350] . Within the solid waste management regime, Mashayekhi (1993) explored a dynamic analysis for analyzing the transition in the New York State solid waste system [214]. Sudhir, et. al., (1997) further employed a system dynamics model to capture the dynamic nature of interactions among the various components in the urban solid waste management system [298] ; Karavezyris, et al., (2002) developed a methodology to incorporate qualitative variables such as voluntary recycling participation and regulation impact quantitatively [185]. The model provides a platform for examination of various structural and policy alternatives for sustainable solid waste management. Dyson and Chang (2005) explored a conceptual model for accurate prediction of solid waste generation in an urban setting having a high economic growth potential [103].

In this present investigation, the study area is considered as a System by integrating all the six elements of Integrated Waste Management with various physical, social, economic, environmental, infrastructure and institutional subsystems. The theoretical framework and concepts developed by Sudhir, et. al., (1997) and Patterson, et. al. (2004) is followed to establish the functions of the system [255, 298].

5.3.4 System Dynamic Modelling

System Dynamic modelling holds the potential to help the Urban and Regional Planners and Managers to meet the challenges of decision-making and policy formulation for the development of a system. It represents the key feedback structures in the system. Simulating the model shows the effect of the system structures on policy interventions. It is a problem evaluation approach based on the premise that the structure of a system, that is the way essential components are connected, generates its behaviour [264, 295]. It is well suited to analysis of problems whose behaviour is governed by feed back relationships, have a long-term time horizon [321]. Besides helping in decision-making, system dynamics models also help managers communicate information about the structure of the system and show stakeholders, visually and with a minimum of technical jargon, the consequences of different actions [293].

The process of creating a simulation model helps clarify the resource management problem and makes modeller assumptions about the way the system works explicit. The most important advantage of this model is once the model is built, it can be used to simulate the effect of proposed actions on the problem and the system as a whole. In this regard, Forrester (1987) noted that, this kind of tool is necessary because, while people are good at observing the local structure of the system, they are not good at predicting how the complex and interdependent the system will behave [121].

System Dynamics proceeds through several major steps [114, 264] and these are the same steps followed in any problem solving process. This is also an iterative process and results at any stage can feed back to previous steps. The various steps for developing and employing the System Dynamic models are:

1. Define the problem
2. Describe the system
3. Develop the model
4. Build confidence in the model (Validation)
5. Use the model for policy design and analysis
6. Use the model for public outreach.

The first five steps are used for building a model for decision support within an organization while the sixth step is used for public communication.

5.3.4.1 Define the problem/problem identification

The first step in System Dynamic modeling is to identify the key variables whose behaviour over time defines the problem. To recognize a problem that needs study through modeling is to identify it as the consequence of a system of interactions among large numbers of variables [233]. The interactions of these identified variables generate the dynamics of the system and work on feedback mechanism. In the identification stage, it is important to interpret the problems and the causes thereof from the past behaviour of the system (reference mode). In a social complex system however, it is difficult to build a reference mode and identify a problem. In such situations, the problem is identified through discussions with experts, interviews, questionnaire surveys or Delphi study. It is possible to record multiple perspectives for a problem situation looking at the interactions from different angles [69, 208, 233]. It is possible to identify crucial factors and system boundary with the knowledge of the rich picture of a system. In this present investigation, field observations, discussion with experts and survey methods have been employed to identify the problems of the system and are discussed in detail for each model in subsequent sections of model conceptualization.

5.3.4.2 Describe the system

Describing the system involves identifying the system structure that appears to be generating problematic trend. This involves extracting the essential elements and connections from the real system that produces the anticipated or observed behaviour [293]. Thus, model aggregates and boundary are fixed at this stage [233]. All the factors relevant to the description of the problem phenomena under investigation need to be included at this stage. In an effort to achieve comprehensiveness the modeler sometimes brings a large number of variables within the system boundary but only those variables, which adequately address the problems, should be included in the model. The final representation of key variables and causal links is called dynamic hypothesis and explains the dynamic behaviour of the system.

5.3.4.3 Developing the model

At this stage, a detailed model is developed based on the dynamic hypothesis, by representing through a set of stocks and flow diagrams. Flow diagrams help in presenting the causal mechanism clearly and take into account the physical resources and information linkages at the time of their construction. Further, the variables are presented in different forms to identify them as Stocks or Levels (accumulation), Rates (decisions), Auxiliaries (algebraic subdivision of rates) or Converters and parameters. Model assumptions are also incorporated while developing the model.

5.3.4.4 Build confidence in the model (validation of the model)

Before using the model to identify and test policy options, it must be validated against the observed or anticipated trend. The validity of a model is judged by its usefulness to serve the purpose for which it is designed. Validation in System dynamics is a multi-test process and incorporates both statistical and model-behaviour tests. Validity of a model is critical because the purpose of a system dynamic study is to evaluate alternative structures (strategies, policies) to improve the system's behaviour. Accuracy of the model behaviour is meaningful only if there is sufficient confidence in the structure of the model. Validation needs to be applied at every stage of modelling [118, 204, 205, 206, 207]. Sometimes individual tests, such as, structure oriented behaviour tests [22, 117], extreme condition, behaviour sensitivity and phase relationship tests [22] are used for detection of structural flaws in the model. If the model reproduces the trend and represents the real system as it actually works, then the model leads to accurate behaviour or else the modeller must go back to revise the dynamic hypothesis or model structure.

5.3.4.5 Use the model for policy analysis

The real test of worthiness of a model lies in its ability to reveal the effects of a policy on various sectors of the system. When the model structure is validated, it can be used to test the effects of policy interventions on the problem. It includes studying the model structure to identify policy levers, then simulating the effect of those changes. The effects of policies can be analyzed both quantitatively and qualitatively. In the qualitative approach, the evaluation primarily predicts the effect, which improves or worsens the system behaviour, while in quantitative approach the evaluation is rigorous and uses precise numerical values.

5.3.4.6 Use the model for public out reach

Although involvement of multiple stakeholders during the development of model brings in better results [13, 82, 292, 321]; even when stakeholders are not directly involved in the model development process, a completed model can be effectively used for public outreach. The use of the model not only helps public better understand the basis for management decisions, but also stimulates discussion among group members and can help build the consensus and support resource managers need to implement their decisions.

The schematic diagram developed by Hamilton, et. al., (1969) is presented in Fig. 5.1, showing the steps the model application in the System Dynamic modelling [151].

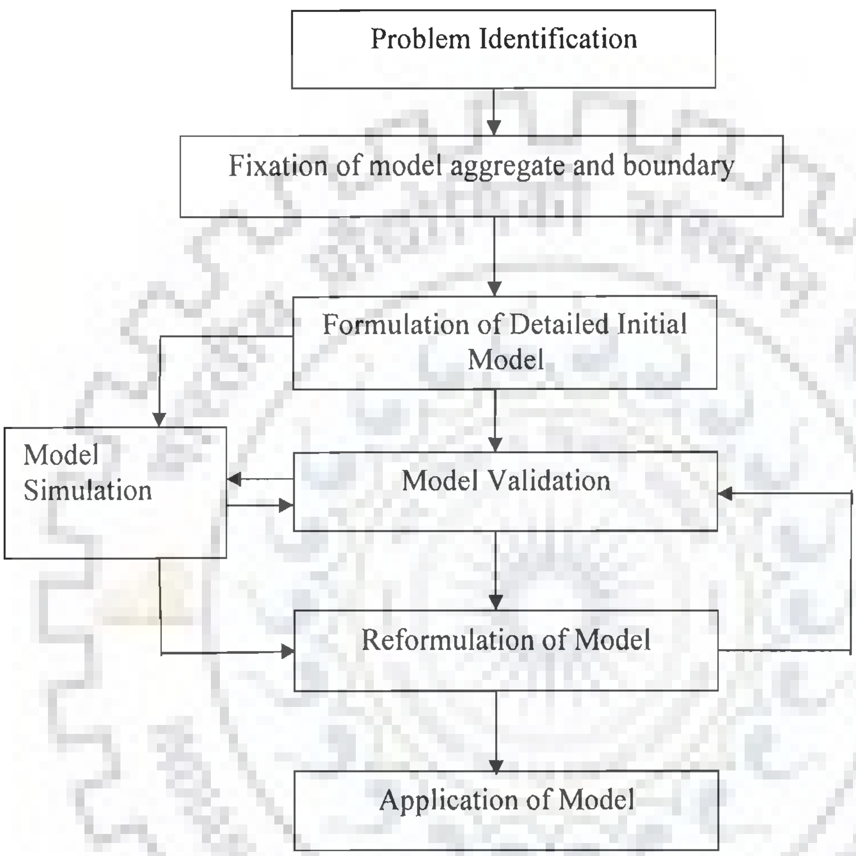
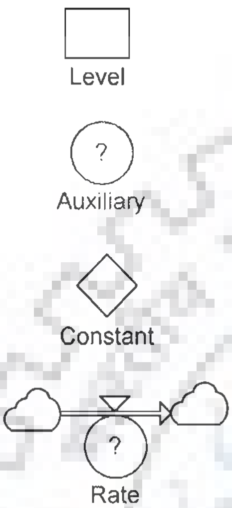


Fig. 5.1: Model development as an iterative process (based on Hamilton, et. al., 1969)

5.3.5 Notations and Equations Adopted in Modelling

The various variables in the System Dynamic models are the level, rate and auxiliary variables.



Level variable (L)

Auxiliary variable (A)

Constant (C)

Rate variable (R)

A level is the accumulation (or integration) of the flows that causes the level to change. Double arrows represent the flows, and the flow is controlled by a flow rate. An auxiliary is used to combine or reformulate information. It has no standard form; it is an algebraic computation of any combination of levels, flow rates, or other auxiliaries. Although auxiliary variables may appear to be accumulations, they have no memory, unlike levels. Constants are, unlike ordinary auxiliaries, constant over the time period of the simulation. A constant is defined by an initial value, and maintains this value throughout the simulation, unless the user changes the value manually.

A level variable depends only on a rate variable; and presented by

$$\mathbf{L\,(t) = f_l\,(R\,(t))}$$

A rate depends on level variables and or auxiliary variables, and on constants, and is presented in any of the forms depending on the various variables and used based on the requirements. The equations are as given below:

$$\mathbf{R\ (t) = f_{r1}\ (L\ (t), C)}$$
$$\mathbf{R\ (t) = f_{r2}\ (A\ (t), C)}$$
$$\mathbf{R\ (t) = f_{r3}\ (L\ (t), A\ (t), C)}$$

An auxiliary variable can be a function of level and or other auxiliary variables and constants and is presented in any of the forms depending on the variables and used based on the requirements. The equations are as given below:

$$\mathbf{A\ (t) = f_{a1}\ (L\ (t), C)}$$
$$\mathbf{A\ (t) = f_{a2}\ (A\ (t), C)}$$
$$\mathbf{A\ (t) = f_{a3}\ (L\ (t), A\ (t), C)}$$

The change in a level's value is determined by integration of the flows going in and out of the level.

The algorithm for numerical solutions by Euler integration of the system dynamic model is presented as:

$$\mathbf{L_i\ (t) = L_i\ (t\text{-}DT) + \Delta L_i\ (t\text{-}DT, t), \text{ for all } i}$$
$$\mathbf{\Delta L_i(t\text{-}DT,t) = DT^*d/dt\ (L_i(t\text{-}DT))}$$

Where, Li (t) = Level values at the end of the time step for all i

t = time period

DT= time step

5.4 INTEGRATED URBAN SYSTEM MODEL

In this investigation, the study area is considered as a system, and it has several subsystems. The various subsystems of the system are physical, social, economic, ecological, environmental, infrastructure and institution. All these sub-systems are interlinked and interdependent to each other and function as a whole dynamically. The dynamic functions of the urban system along with its different subsystems are presented in Fig. 5.2

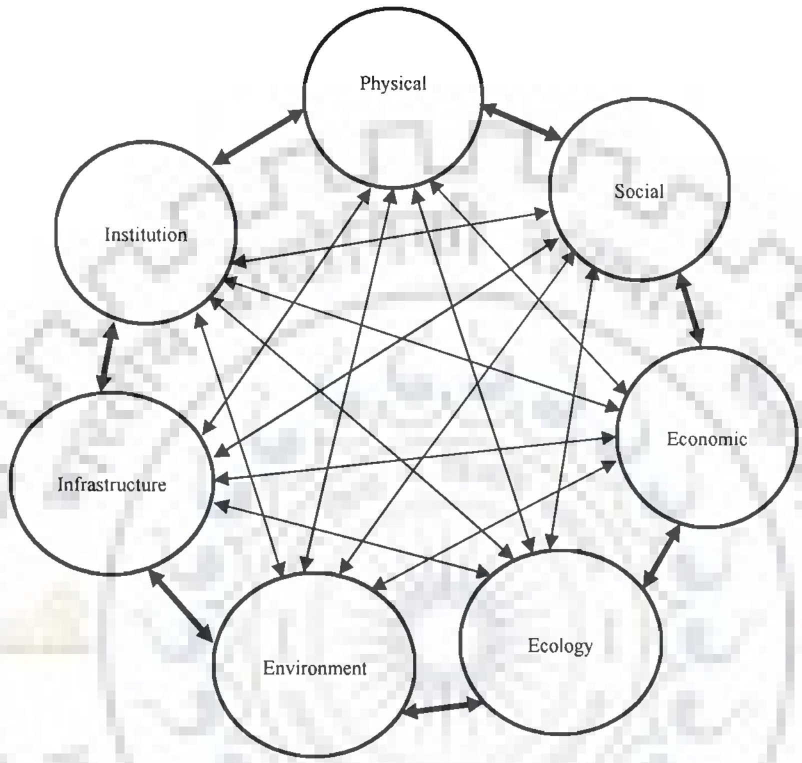


Fig. 5.2: Functions of the urban system along with the sub systems

5.5 CONCEPTUALIZATION OF INTEGRATED SOLID WASTE MANAGEMENT SYSTEM MODEL

Each subsystem as described in the previous section is a system in itself and has several subsystems, which are also interdependent and interlinked. Municipal solid waste management comes under the sub-system Infrastructure and has six basic elements which in turn depend on many factors/controlling parameters (as given in subsequent section). These six elements are interrelated and interdependent on other sub-systems such as, formal sector (government organizations), informal sector (recyclers), environment, public health, land required for land fills, etc. The proposed model thus attempts to capture the activities and interdependencies among various actors directly associated with waste management. The model aims at strengthening the planning process by identifying how the system responds to changes in the environment.

5.5.1 Elements of Municipal Waste Management

There are six elements of MSWM as discussed in Chapter 1. They are a) Generation, onsite handling and storage; b) Collection; c) Transfer and Transport; d) Treatment and Processing; e) Disposal; f) Recycling/Reuse.

All these six elements are influenced by various factors. These factors are discussed element wise as follows:

i) **Generation**: Generation of wastes depends on awareness level, Interventions at Design of products, manufacturing, packaging of products with minimum toxicity and minimum volume also gives desirable results to some extent. Longer useful life of products, charging user fee (on the principles of PAYT pay as you throw) also reduces the waste generation. Life style, cultural habits and per capita expenditure has a direct impact on the quantity and type of waste generation.

ii) **Collection**: It depends on the following:

- Type, number of Collection system, equipment
- Efficiency of manpower and vehicles
- Collection route and length (trip distance)

iii) **Transfer and Transport**: It depends on the following:

- Number of Transfer Stations
- Cost of fuel

- Life of vehicles
- Operation and maintenance costs of vehicles
- Distance of disposal/treatment site, etc.

iv) **Treatment**: It depends on the following:

- Capital costs
- Operation and maintenance costs
- Cost recovery
- Environmental hazards
- Physical and Chemical composition of the residue, etc.

v) **Disposal**: It depends on the following:

- Capital costs
- Operation and maintenance costs
- Cost recovery
- Environmental hazards
- Land requirement
- Land availability, etc.

vi) **Recycling**: It depends on the following:

- presence of recyclables in waste
- Financial viability
- Adoption of Western style Centralised recycling facilities or strengthening of existing informal recycling facilities

Of all the factors considered above, there is a need to consider only those factors, which have a maximum impact on the overall solid waste management.

It is observed that all the six elements are more or less strongly influenced by awareness, investments, and organised sector. So far, only the formal sector is organised and recognised legally. Informal sector also works in an organised way* to a certain extent but the lower level workers of the segment (waste pickers, IWBs, etc.) are not organised.

Assumptions

- The Formal sector comprises of the personnel involved in primary and secondary collection of wastes including street sweeping and disposal at the dump site/landfill. The personnel involved in treatment have been excluded from this as the requirements vary depending on the type of treatment used/proposed.
- It is assumed that actors joining as waste pickers and itinerant waste buyers come from the pool of unemployed segment of the population and live on subsistence level as the sector does not require any investments to begin the work. It also does not have any entry barriers of age, gender and does not require any skills.
- Public-private participation like partnership with Community Building Organizations, Non-government Organizations, private contractors, etc., has not been considered in detail in the model. It has been assumed that when the organised sector increases, it amounts to an increased participation of such partners.
- The model explicitly considers the influence of aspects such as literacy level, environmental education on environmental concern and will result in a reduction in waste generation, increased demand for treatment and safer disposal of generated wastes.

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* The big wholesale traders and recyclers are registered with the Government and hence, form a part of the organized sector

- Environmental concern has been considered cumulative for public and Corporation. Hence, changes in awareness level will influence both.
- Change in area increase for the projected year 2031 has been assumed as proposed in the Revised Master Plan.
- The recyclable material collected by workers in the formal sector (Kanpur Municipal Corporation) has been assumed as negligible.
- Increase in investments is assumed to bring improvements in vehicle maintenance, establishment of new treatment plants, collection efficiency, disposal efficiency and pre-post landfill treatment.
- Part of the increase in investments is assumed to come from application of some user charge/fees for solid waste management services.
- Availability of land for disposal has been considered as a constraint as the city lacks suitable land for disposal if considering the major suitability factors for selection of land for disposal.

5.6 APPLICATION OF THE SYSTEM DYNAMIC MODEL

In this present investigation, the most important controlling parameters, such as, population, principal municipal waste generators, collection, treatment, transportation and disposal of generated/treated waste by municipal workers, collection and recycling by the informal sector, environmental stress are considered for evolving an integrated System Dynamic model for Solid Waste Management. At the outset, all the subsystems are developed separately, and then respective subsystems are amalgamated together to evolve an integrated model for municipal solid waste management in Kanpur city. The detailed methods used for developing the models by subsystem wise are presented as below:

5.6.1 POPULATION

Population is one of the most important parameters, which influence the functions of the system. A System Dynamic model has therefore, been built to calculate the population, by considering the influential variables, such as, Birth Rate, Death Rate, Normal Birth Rate Fraction (NBRF), Normal Death Rate Fraction (NDRF), In-migration Rate (IMR), In-migration fraction (IMF), Out migration Rate (OMR) and Out migration fraction (OMF). In this model, population (P) is considered as a function of birth rate (BR), death rate (DR), in migration rate (IMR) and out migration rate (OMR) that the system experienced in the past years. Population is considered as the level variable, while birth rate, death rate, in migration and out migration rates are taken as rate variables. The model, which is employed for computing the population is presented in a functional flow diagram (Fig 5.3) and the functional relationships among the variables are presented below.

P = f (BR, DR, IMR, OMR)

BR = f (P, NBRF)

DR = f (P, NDRF)

IMR = f (P, IMF)

OMR = f (P, OMF)

The definitions of each variable and mathematical (algebraic) equations are described in the model equations which are presented in Appendix-V.

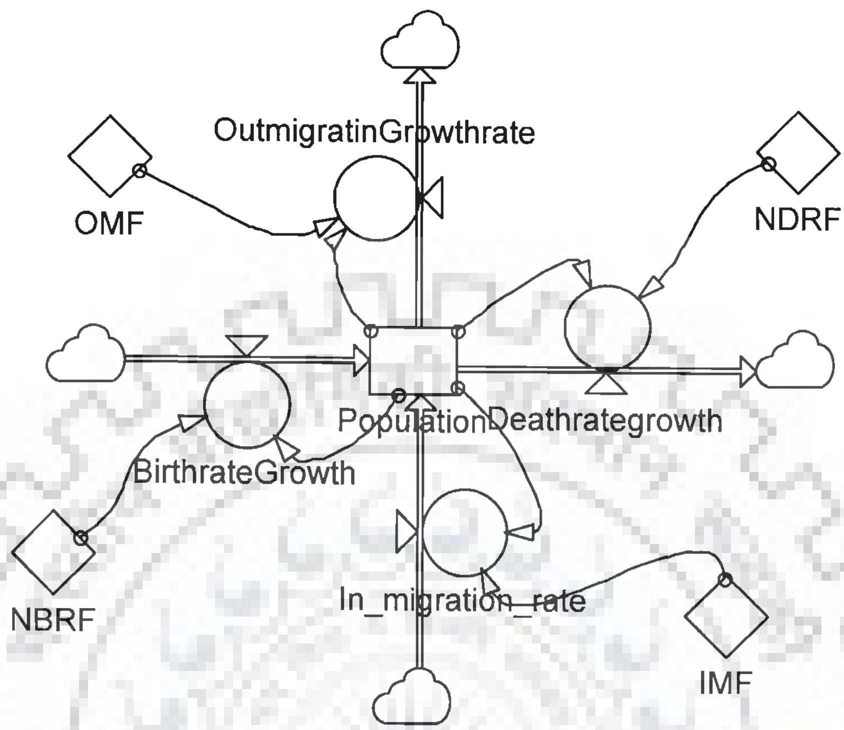

Fig. 5.3: System Dynamics Model for Population

5.6.2 POPULATION DENSITY

Population density is an equally important parameter in an urban system where land is scarce, and with increasing rate of urbanization, it becomes scarcer. A System Dynamic model is developed to calculate the population density, by considering the influential variables, such as, Birth Rate, Death Rate, Normal Birth Rate Fraction (NBRF), Normal Death Rate Fraction (NDRF), In-migration Rate (IMR), In-migration fraction (IMF), Out migration Rate (OMR), Out migration fraction (OMF), and total area of the system. In this model, population (P) is considered as a function of various parameters as discussed in the earlier section. Population density (PD) refers to the number of persons per square kilometer of land area of the system and is a function of population (P) and area (A) of the system while Perceived Density (PERD) is a function of population (P) and perceived area (PA). Perceived area is the projected area of the city based on priorities attached to urban development limits set by the Development Authority from time to time (in Master Plans). Population density and Perceived population density (Perceived_density) are considered as auxiliary variables. The model, which is employed for computing the Population density, is presented in a functional flow diagram (Fig 5.4) and the functional relationships among the variables are presented below.

P= f (BR, DR, IMR, OMR)

PD= f (P, A)

PERD=f (P, PA)

AGR=f (A, AGF)

PAGR=f (A, PAGF)

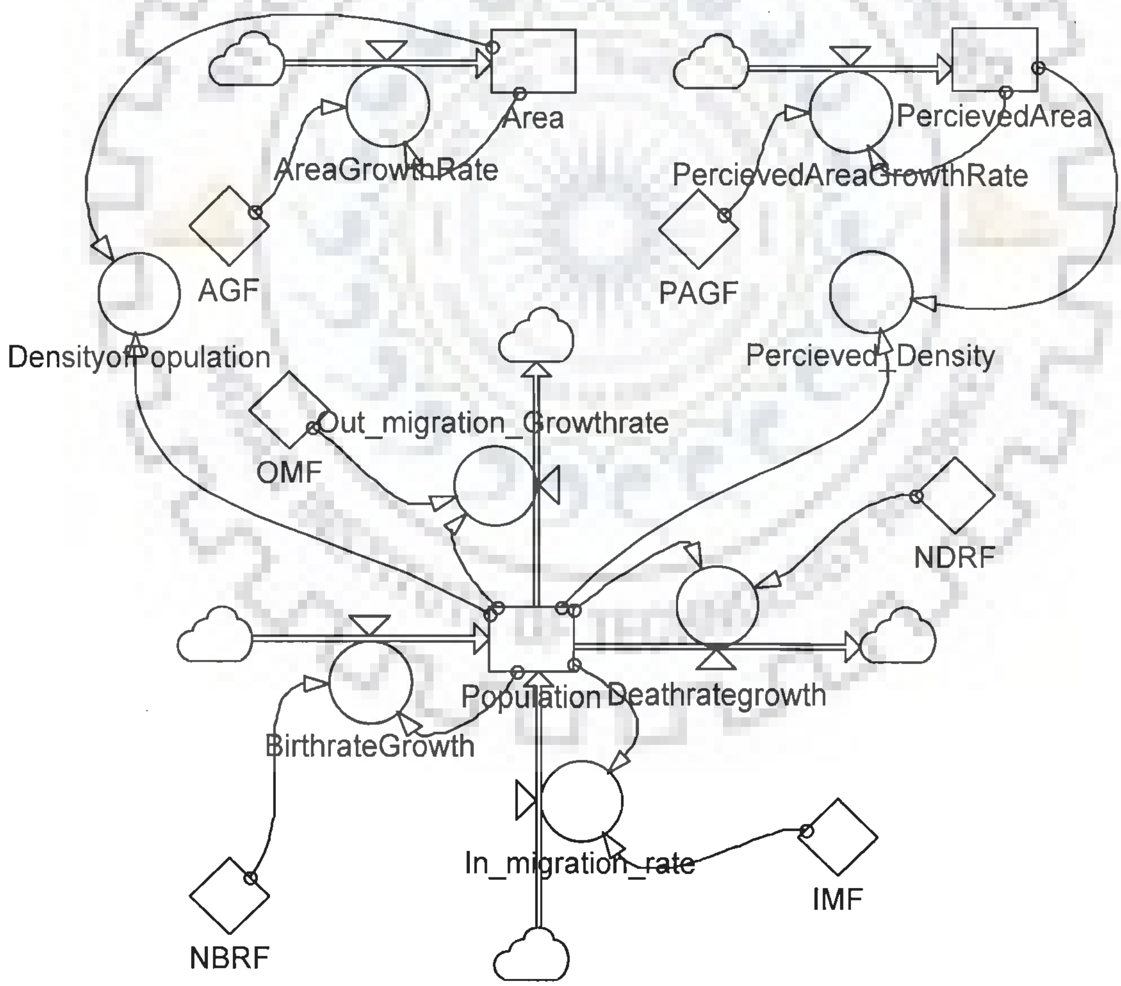

Fig. 5.4: System Dynamics Model for Population Density

The definitions of each variable and mathematical (algebraic) equation are described in the model equations which are presented in Appendix-V.

5.6.3 Waste Generation

Waste generation is the primary functional element of the Solid Waste Management activities. It encompasses activities in which materials are identified as no longer of value and are thrown away for collection/disposal by the waste generator. Under the existing conditions of the study area, the activity is not controllable. However, solid waste managers in developed countries have now started experimenting with measures to reduce generation through various incentives and/or legally. There are various generators of waste as identified in Chapter 3. In this investigation, however, only those principal generators of solid waste have been considered, whose waste become a part of Municipal waste in some way or other. Thus, four System Dynamics sub-models have been developed to calculate the Municipal Waste Generation and the functional diagrams of the said models developed are presented in Fig. 5.5, 5.6, 5.7,and 5.8.

5.6.3.1 Household Waste Generation

Household waste forms a major portion of the Municipal waste. It consists of the organic and inorganic waste generated from residential areas, i.e., single family and multifamily detached dwellings, apartments, row houses, etc. Wastes coming from this sector also constitute a small portion of hazardous waste like paints, varnish, battery, etc.

At the outset, the population is grouped into four different groups, such as, high income group (HIG), middle income group (MIG), low income group (LIG) and economically weaker section (EWS) since the quantity and the type of waste generated is different from one group to other. To have clarity in calculating the quantity of waste generated by different income groups, it is considered by different income group wise while computing the quantity of household waste generated in the system. The model, which is employed for computing the Household waste generation, (hazardous and non-hazardous) is presented in a functional flow diagram (Fig. 5.5). In this System Dynamics model, population and waste generation from HIG (High income groups), MIG (Middle income group), LIG (Low income group) and EWS (Economically weaker section) are taken as level variables; population in each income class, hazardous and non-hazardous waste (recyclables and non-recyclables) as auxiliary variables. The mathematical functions for computing various variables are given below.

HIGPG = f (PCGR)
MIGPG = f (PCGR1)
LIGPG = f (PCGR2)
EWSPG = f (PCGR3)
HIGG = f (HIGPG, HIG)
MIGG = f (MIGPG, MIG)
LIGG = f (LIGG, LIG)
EWSG =f (EWSG, EWS)
THG = f (HIGG, MIGG, LIGG, EWSG)
HIG = f (P, HIGF)
MIG = f (P, MIGF)
LIG = f (P, LIGF)
EWS = f (P, EWSF)

Where,
HIG=Population in High-income group
MIG=Population in Middle-income group
LIG=Population in Low-income group
EWS=Population in Economically-weaker section
HIGG=Solid waste from HIG

MIGG=Solid waste from MIG
LIGG=Solid waste from LIG
EWSG=Solid Waste from EWS
HIGPG=HIG per capita waste generation
MIGPG=MIG per capita waste generation
LIGPG=LIG per capita waste generation
EWSPG=EWS per capita waste generation
PCGR=HIG per capita waste generation rate
PCGR1=MIG per capita waste generation rate
PCGR2=LIG per capita waste generation rate
PCGR3=EWS per capita waste generation rate
THG=Total Household Waste Generation

The definitions of each variable and mathematical (algebraic) equation are described in the model equations which are presented in Appendix-V.

5.6.3.2 Industrial Waste Generation

Only those industrial wastes have been considered in this investigation, which gets commingled with the municipal solid waste. The study area is a prominent centre for leather and leather-based products and there are hundreds of small and big tanneries spread in various parts of the city. Therefore, waste coming from these tanneries has been considered and a system dynamics model for industrial waste generation has been developed.

The model, which is employed for computing the Industrial waste generation (hazardous and non-hazardous) is presented in a functional flow diagram (Fig. 5.6) and the functional relationships among the variables are presented below.

INDU = f (INDR)
PINDUGEN = f (AWF1, INVESTF1)

TOTINDG = f (INDU, PINDUGEN)

HZINDG = f (TOTINDG, IHZF)

NHZINDG = f (TOTINDG, INNHZF)

INDREC = f (NHZINDG, IRSWF)

INDNREC = f (NHZINDG, INRSWF)

where,

TOTINDG=Total quantity of Industrial Waste Generation

INDR=Industrial Units Growth Rate

INDU=Number of Industrial Units

PINDGEN=Per Industrial unit solid waste generation

IHZF=Industrial hazardous waste fraction

INHZF=Industrial non-hazardous waste fraction

HZINDG=Quantity of Industrial Hazardous waste generation

NHZINDG=Quantity of Industrial non-hazardous waste generation

INDREC=Industrial Recyclable solid waste generation

INDNREC=Industrial non-recyclable solid waste generation

AWF1=Awareness Fraction in Industries related to waste management

INVESTF1=Investment Fraction in Industries related to waste minimization

The definitions of each variable and mathematical (algebraic) equation are described in the model equations which are presented in Appendix-V.

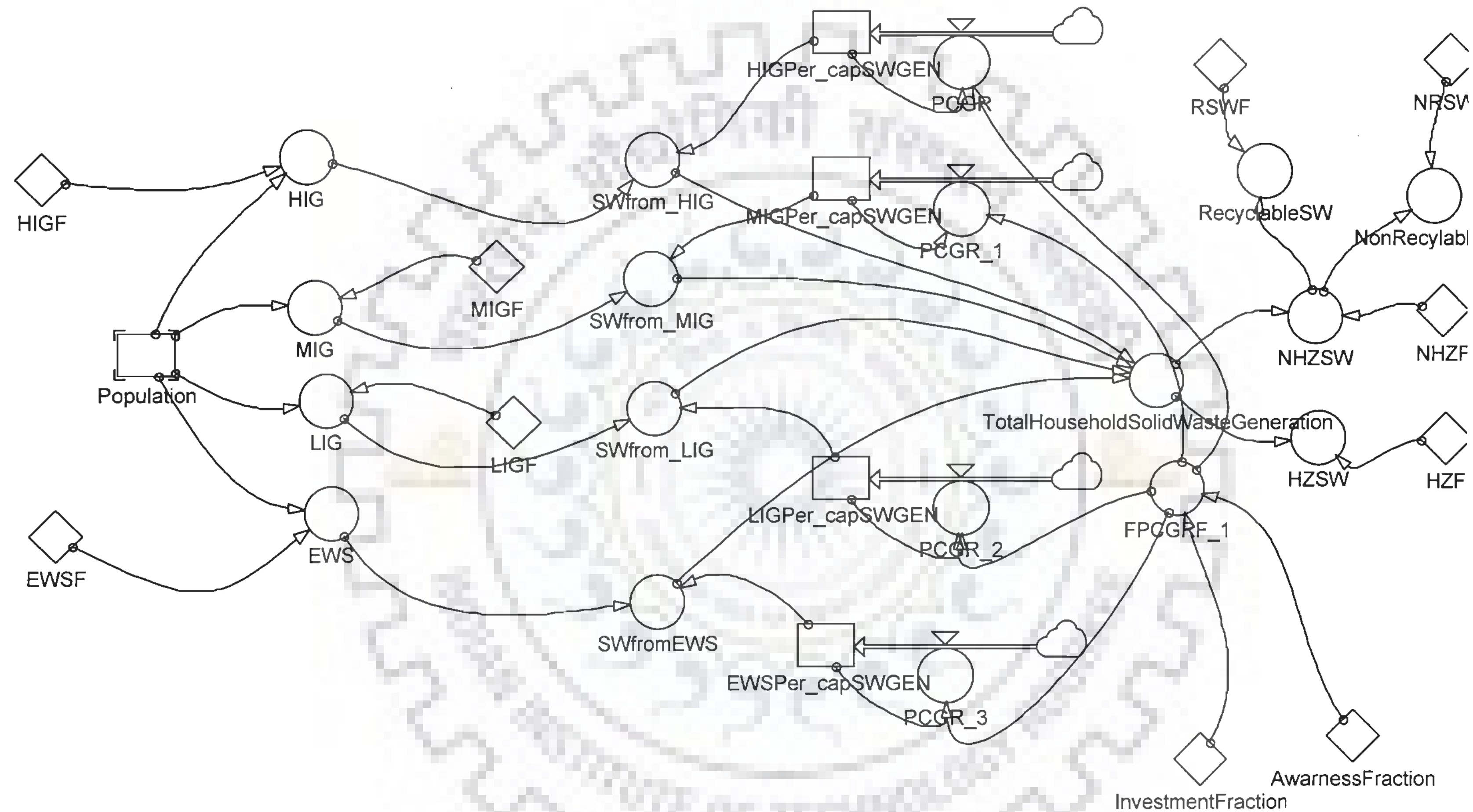

Fig. 5.5: System Dynamics Model for Household Waste Generation

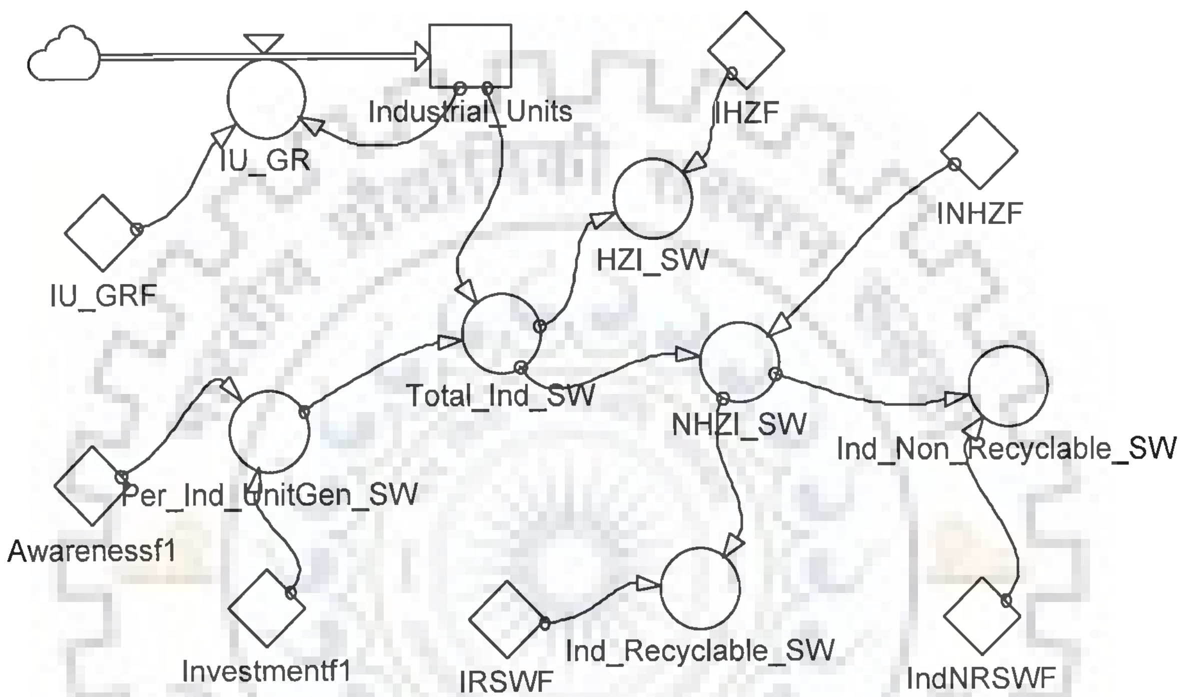

Fig. 5.6: System Dynamics Model for Industrial Waste Generation

5.6.3.3 Commercial and Market Waste Generation

Commercial and market waste forms a big portion of the municipal solid waste. A system dynamics waste generation model for commercial and market activity has therefore, been developed. Markets denote the unorganized fruit markets, vegetable market, flowers market, etc. Hence, waste coming from this segment has been taken in terms of total quantity. Commercial sector is an organized one and is recorded in the Corporation in terms of number of shops. Hence, the waste coming from this segment has been considered in terms of waste generated per commercial unit.

The model, which is employed for computing the Commercial and market waste generation (hazardous and non-hazardous), is presented in a functional flow diagram (Fig. 5.7) and the functional relationships among the variables are presented below.

COMU = f (COMGR)
COMGR = f (COMU, COMRF)
COMG = f (COMU, PERCOM)
MKTGR = f (MKT, MKTGRF)
TOTCOMG=f (COMG, MKT)
HZCOM = f (TOTCOMG, HZCOMF)
NHZCOM=f (TOTCOMG, NHZCOMF)
Where,
COMUGR=Commercial unit growth rate
COMU=number of commercial units
COMRF=Growth rate fraction of Commercial units
MKT=waste from market activity
MKTGR=market growth rate
MKTGRF=Growth rate fraction of market activity waste
COMG=waste generated from commercial units
MKTG=waste generated from market activity
TOTCOMG=Total waste generated from commercial and market activity

PERCOM=Waste generated per commercial unit

HZCOM=Hazardous commercial waste

NHZCOM=Non-hazardous commercial waste

The definitions of each variable and mathematical (algebraic) equation are described in the model equations which are presented in Appendix-V.

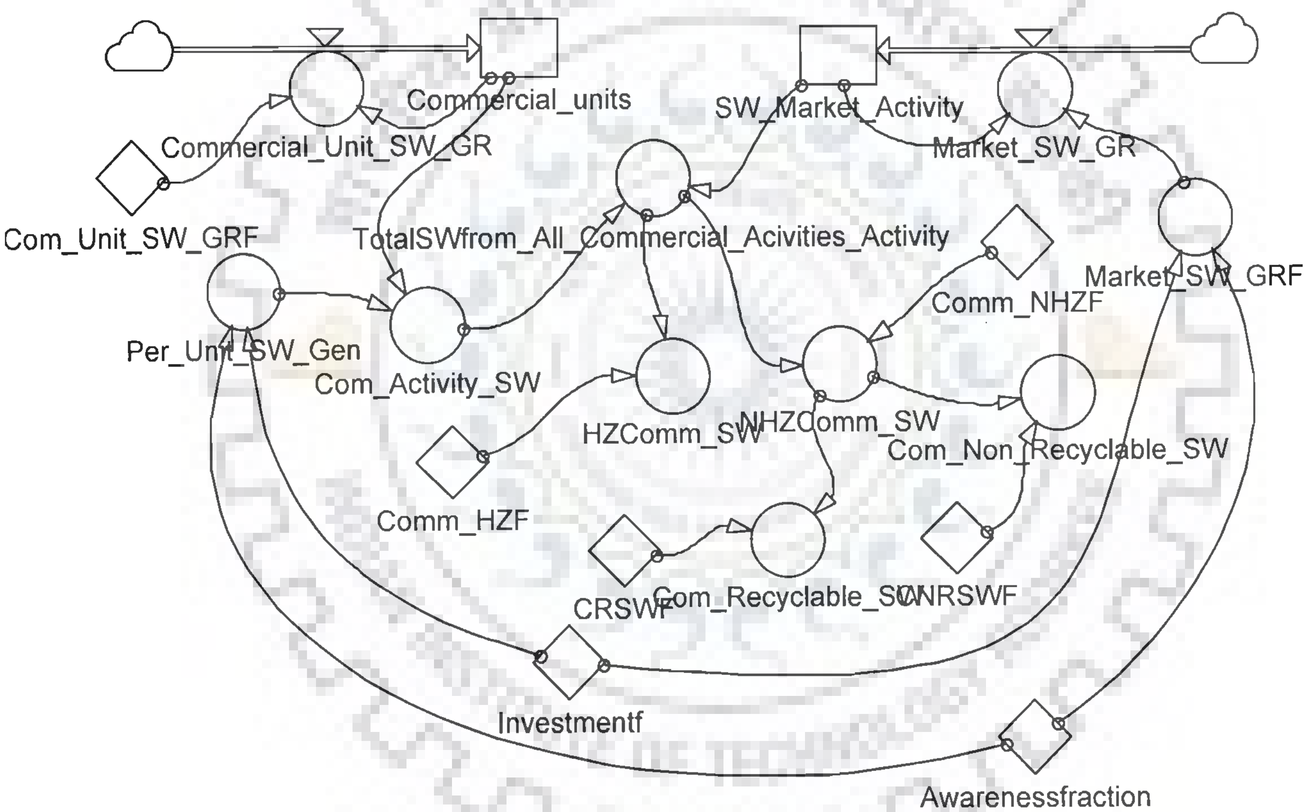

Fig. 5.7: System Dynamics Model for Commercial and Market activity Waste Generation

5.6.3.4 Hospital Waste Generation

It has been observed that a major portion of the hospital waste is dumped in the study area at secondary collection points along with municipal solid waste for further collection and disposal by the municipal workers. Bio-medical waste has therefore, been considered for calculating the total municipal solid waste generation in this present investigation.

The model, which is employed for computing the Hospital waste generation (hazardous and non-hazardous) is presented in a functional flow diagram (Fig. 5.8) and the functional relationships among the variables are presented below.

HOSB = f (HOSBGR)
TOTHOS = f (PERB, HOSB)
NETHOS = f (TOTHOS, ILEGRECF, INCINF)
PERB = f (AWF, INVESF)
HOSNHZ = f (NETHOS, HOSNHZF)
Where,
PERB=Per bed generation of waste
HOSB= Number of Hospital beds
HOSBGR=Hospital bed growth rate
TOTHOS=Total Hospital Waste generation
NETHOS=Net Hospital Waste
ILEGRECF=Illegal Recycling Fraction
INCINF=Incineration Fraction
HOSNHZ=Non-hazardous hospital waste
HOSNHZF=Non-hazardous hospital waste fraction

The definitions of each variable and mathematical (algebraic) equation are described in the model equations which are presented in Appendix-V.

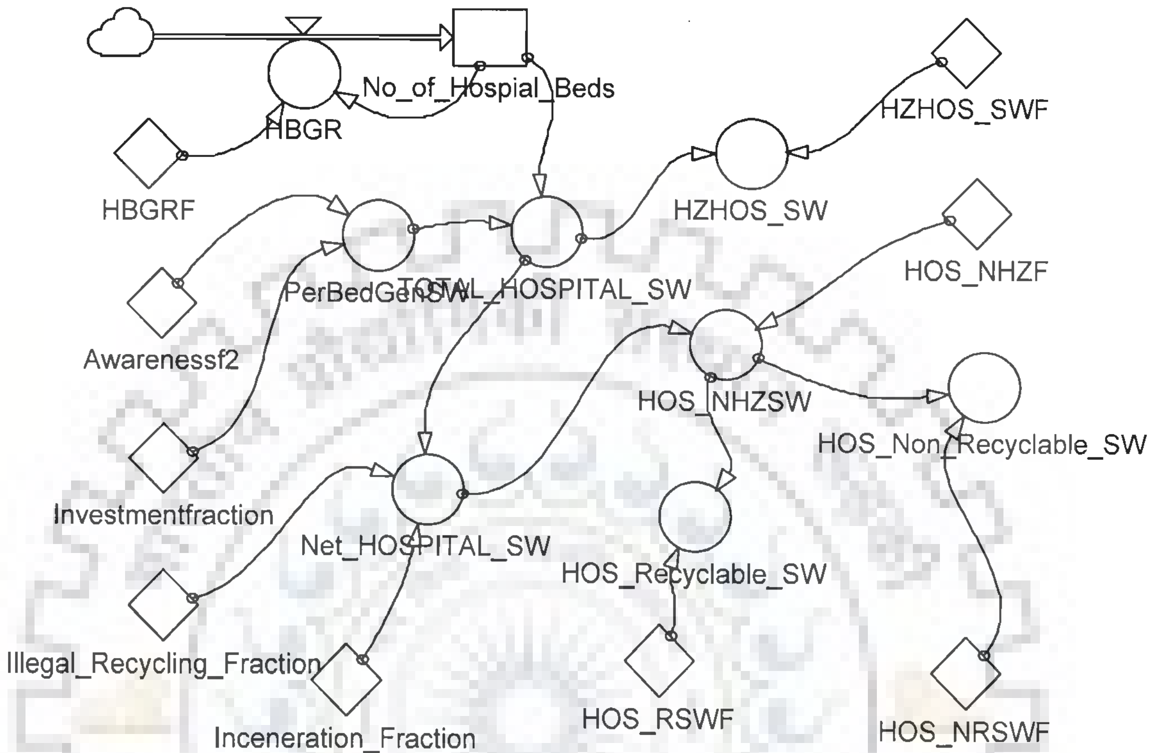

Fig 5.8: System Dynamics Model for Hospital Waste Generation

5.6.4 COLLECTION, TRANSPORTATION, TREATMENT AND DISPOSAL

The generated waste from different sources is dumped at various primary collection points like open depots, containers, etc., or on roadsides for further collection by municipal workers. The collected waste is further transported to the disposal site as so far, there is no treatment done to reduce the volume and/or toxicity of the generated municipal solid waste in the study area.

Collection, transportation and disposal form the essential elements of a solid waste management system. An attempt has, therefore, been made in this investigation to develop a System Dynamics sub-model for collection, transportation and disposal of the generated waste and is presented in Fig. 5.9. The functional relationships among the variables are presented below.

Collection efficiency, treatment efficiency, disposal efficiency have been taken as table functions. The lack of historical data is the main reason for calculating these as table functions. The table functions have been prepared based on discussions with experts and the municipal officers.

TOTGEN = f (THG, TOTINDG, TOTCOMG, TOTHOS)
NETHZCOLL= f(TOTHZ,HZCF,HZILLEGDISCF)
NETNHZCOLL = f(TOTNHZ, NHZCF, NHZILLEGDISCF)
TOTCOLL = f(NETNHZCOLL,NETHZCOLL)
GAPCOLL = f(NETTOTGEN, TOTCOLL)
TOTTRET = f(NHZTRET,HZTRET)
GAPTRET = f(TOTCOLL,TOTTRET)
CMPEFF = f(CEFF,TEFF,DEFF)

where,
TOTGEN= Total generation of municipal solid waste
THG=Total Household waste generation

TOTIND=Total Industrial waste generation

TOTCOMG=Total commercial and market activity waste generation

TOTHOS=Total Hospital waste generation

TOTHZ=Total hazardous waste generation

TOTNHZ=Total non-hazardous waste generation

NHZCF=Non-hazardous collection fraction

HZCF=Hazardous waste collection fraction

HZILLEGDISCF=Illegal disposal of hazardous waste during collection fraction

NHZILLEGDISCF=Illegal disposal of non-hazardous waste during collection fraction

NETNHZCOLL=Net non-hazardous waste collection

NETHZCOLL= Net Hazardous waste collection

TOTCOLL=Total waste collection

GAPCOLL=Gap in waste collection

GAPTRET=Gap in waste treatment

CEFF=Collection efficiency

TEFF=Treatment efficiency

DEFF=Disposal efficiency

CMPEFF=Composite efficiency

The definitions of each variable and mathematical (algebraic) equation are described in the model equations which are presented in Appendix-V.

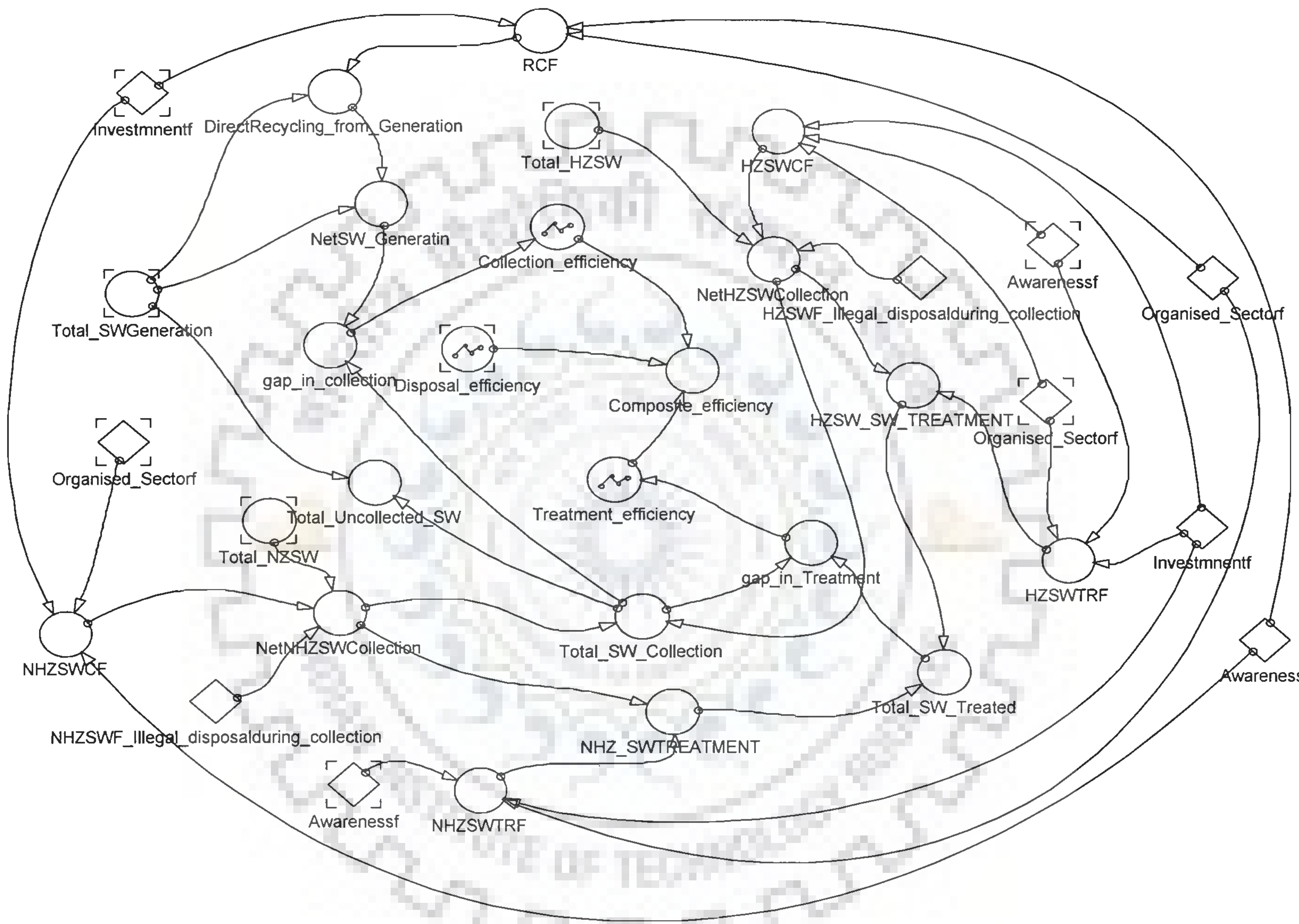

Fig. 5.9: System Dynamics Model for Collection, Treatment and Disposal of Solid Waste

5.6.5 Environmental Stress

One of the goals of a sustainable integrated solid waste management system is to ensure minimal environmental stress on the system due to various activities/elements of waste management. Waste that is not cleared regularly or not treated and disposed of safely can pose public health hazards and indirect threat to the environment. An attempt has therefore been made in this investigation to measure the environmental stress due to the municipal waste management system.

Five types of environmental stress has been measured corresponding to the uncollected and untreated waste, collection of waste, treatment of collected waste, disposal of collected/treated waste and direct recycling of generated waste. These five types of environmental stress have thereafter been expressed as a composite environmental stress (CES). Different weights have been given to the five types of stress based on discussion with experts and related studies. Environmental stress due to uncollected and untreated waste (ES1) has been given a weight of 0.35, environmental stress due to collection of waste (ES2) as 0.10, environmental stress due to treatment of waste (ES3) as 0.20, environmental stress due to disposal of waste(ES4) as 0.25 and that due to recycling of waste (ES5) as 0.10 respectively.

The System Dynamics sub-model for estimating the environmental stress is presented in Fig. 5.10. The functional relationships among the variables are presented below.

ES1 = f (TOTGEN, UNTRT, UNCOL)
ES2 = f (TOTGEN, TOTCOLL)
ES3 = f (TOTGEN, TOTTRT)
ES4 = f (TOTGEN, NETDIS)
ES5 = f (TOTGEN, REC)
CES = f(ES1, ES2, ES3, ES4, ES5)
Where,

TOTGEN=Total generation of municipal solid waste

UNTRT=Untreated waste

UNCOL=Uncollected waste

TOTTRT=Total treated waste

TOTCOLL=Total collected waste

NETDIS=Net disposal of treated/collected waste

REC= Waste going for Direct recycling from generation

The definitions of each variable and mathematical (algebraic) equation are described in the model equations which are presented in Appendix-V.

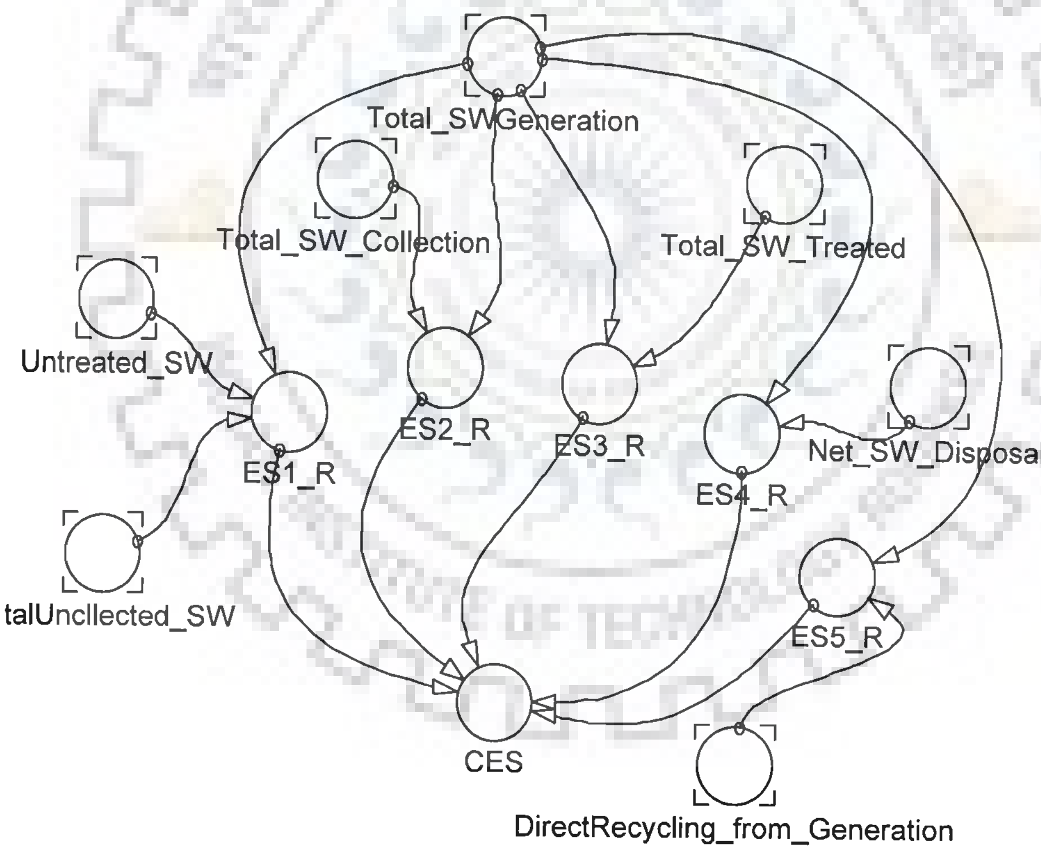

Fig. 5.10: System Dynamics Model for Environmental Stress of the system

5.6.6 EFFICIENCY OF THE SYSTEM

In order to compute the Composite efficiency (CEF) of the integrated waste management system, only formal sector has been considered. It is considered to be a function of three variables, namely, collection efficiency, treatment efficiency and disposal efficiency. Collection efficiency is a table function and related to the auxiliary variable, gap in collection. Gap in collection is a ratio of the difference between total generated waste and total collected waste to the total generated waste. Treatment efficiency is a table function and related to the auxiliary, gap in treatment. Gap in treatment is a ratio of the difference between total waste collected and treated to the total waste collected. Similarly, disposal efficiency is a table function and related to the auxiliary variable, gap in disposal. Gap in disposal is a ratio of the difference between total waste collected and net disposed waste to the total collected waste.

The System Dynamics sub-model for estimating the efficiency of the system in terms of municipal solid waste management is presented in Fig. 5.9. The functional relationships among the variables are presented below.

CEF = f (COLEF,TRTEF,DISEF)
Where,
COLEF = Collection efficiency
TRTEF = Treatment efficiency
DISEF = Disposal efficiency
CEF = Composite efficiency

The definitions of each variable and mathematical (algebraic) equation are described in the model equations which are presented in Appendix-V.

5.6.7 Infrastructure requirement of the formal sector and manpower requirement of informal sector

Estimation of infrastructure, i.e., manpower requirement and vehicles engaged in carrying out the various elements of solid waste management is important. Livelihood of actors in the informal sector is an important requirement for a sustainable integrated solid waste management system. Two types of sectors are primarily involved in solid waste management in the study area. They are: a) formal sector which is primarily the Kanpur Municipal Corporation collecting, transporting and disposing off the waste, and b) informal sector which includes waste pickers, recyclers, small and big traders, wholesalers, etc., involved in recycling and reuse of generated waste.

The System Dynamics sub-model for estimating the infrastructure requirements by formal and informal sector in waste management is presented in Fig. 5.11. The functional relationships among the variables are presented below.

TRPREQ = f (TOTCOLL, AVGCAP)
NVEH = f (TRPREQ, TRPVEH)
LAND = f (NETDIS, LPTON)
TFMANREQ = f (MCOL, MDIS, MTRT)
TINFMANREQ = f (REC, MRECPT)
Where,
AVGCAP = average capacity of collection vehicle
TRPREQ = Number of trips required by collection vehicles
NETDIS = Net disposal of treated/collected waste
LPTON = Land required for disposal per ton of waste
LAND = Land required for disposal
NVEH = Number of vehicles required
TRPVEH =Average number of trips per vehicle

TFMANREQ =Total manpower required in formal sector
TINFMANREQ =Total manpower required in informal sector
MCOL = Manpower required for waste collection
MDIS = Manpower required for waste disposal
MTRT = Manpower required for waste treatment
MRECPT = Manpower required for per ton recycling

The definitions of each variable and mathematical (algebraic) equation are described in the model equations which are presented in Appendix-V.

5.6.8 Integrated Solid Waste Management model

An integrated solid waste management model has been developed by incorporating all the six elements of a waste management system, i.e., waste generation, collection, transportation, treatment, recycling/reuse and disposal, and social and environmental indicators. The systems' efficiency is measured in terms of the composite efficiency which is a function of collection, treatment and disposal efficiency. Total waste generation is considered in terms of total hazardous and non-hazardous waste. Net waste generation, which is the difference between total waste generation and waste going for recycling directly from generation, is considered for collection purpose. It is observed that a part of the collected waste is illegally burned by the municipal workers at the primary/secondary collection points in the study area. This illegal disposal of waste during collection process is also considered in the model. Waste collection and treatment are also considered separately under the hazardous and non-hazardous categories. Non-hazardous waste has further been categorised as recyclables and non-recyclables. This is essential to calculate the policy decisions. The fraction of waste going for collection, treatment and recycling depends on three major factors, namely, organised sector, investment and awareness level. These have therefore, been considered in this integrated solid waste management model.

The mathematical functional relationships among the variables are defined below and presented in the model equation. The integrated system model developed in this present investigation is presented in Fig. 5.12 and the mathematical functions are presented below.

TOTGEN = f(TOTHZ,TOTNHZ)
NETGEN = f(TOTGEN,RECGEN)
TOTCOLL = f(NETNHZCOLL, NETHZCOLL)
GAPCOLL = f(TOTCOLL,NETGEN)
TOTRT = f(NHZTRT,HZTRT)
GAPTRT = f(TOTCOLL,TOTTRT)
RCF = f(ORGF,INVESF,AWF)
HZCF = f(ORGF,INVESF,AWF)
NHZCF = f(ORGF,INVESF,AWF)
HZTRTF = f(ORGF,INVESF,AWF)
NHZTRTF = f(ORGF,INVESF,AWF)

Where,

TOTGEN = Total generation of municipal solid waste
TOTHZ=Total generation of hazardous waste
TOTNHZ= Total generation of non-hazardous waste
RECGEN=Direct recycling from generation
NETGEN=Net generation of solid waste
TOTCOLL=Total collection of solid waste
GAPCOLL=Gap in collection
TOTRT=Total treated waste
GAPTRT=Gap in treatment of waste
RCF=Recycling fraction
HZCF=Hazardous waste collection fraction
NHZCF=Non-hazardous waste collection fraction

HZTRTF=Hazardous treated waste fraction

NHZTRTF=Non-hazardous treated waste fraction

ORGF=Organised sector fraction

INVESF=Investment fraction

AWF=Awareness fraction

The definitions of each variable and mathematical (algebraic) equation are described in the model equations which are presented in Appendix-V.

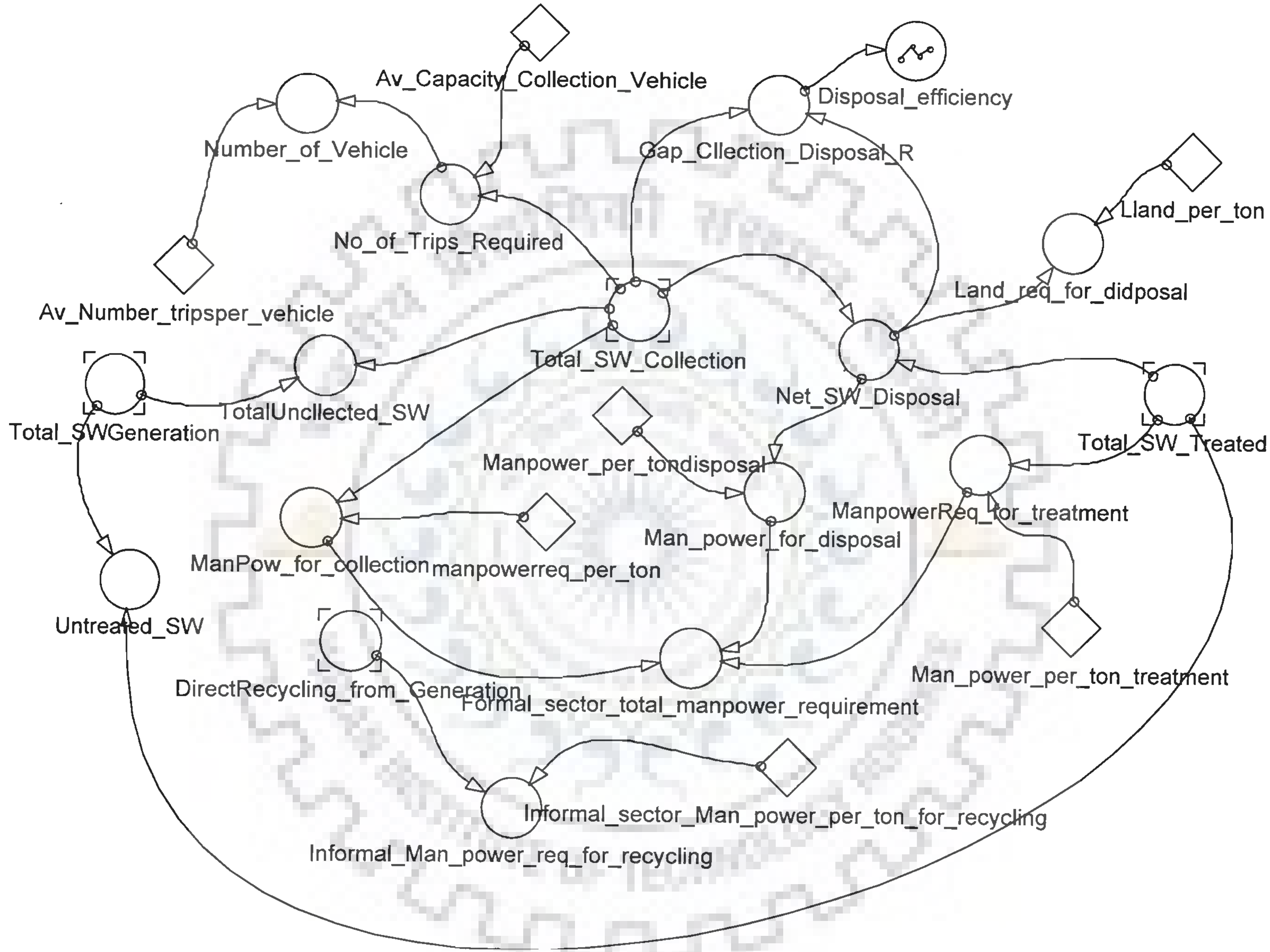

Fig. 5.11: System Dynamics Model for infrastructure requirements by the formal sector and manpower requirement of informal sector

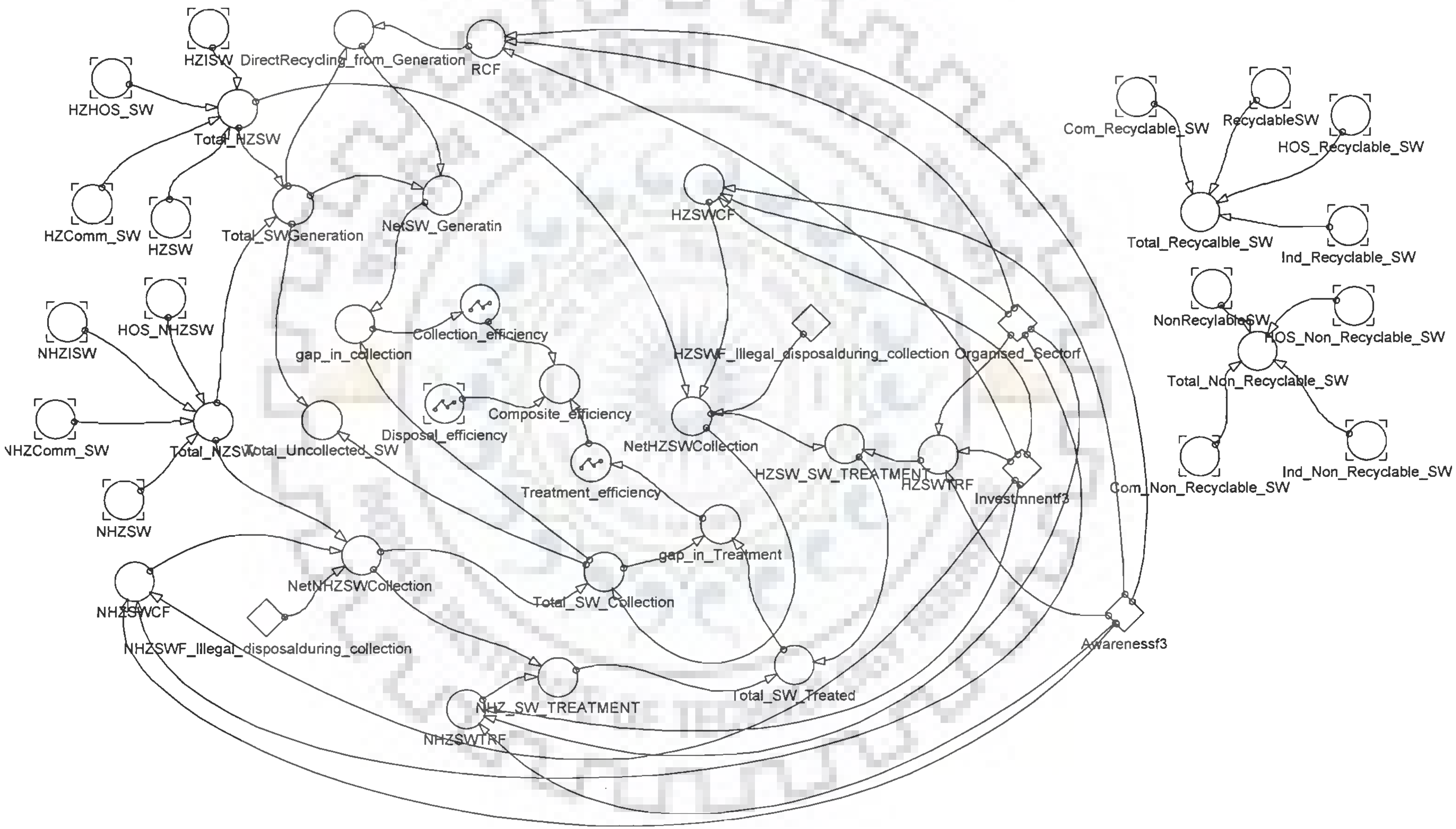

Fig. 5.12: System Dynamics Model for Integrated Solid Waste Management System

5. 7 BASE YEAR MODEL RESULTS (2001)

The System Dynamic models developed in this investigation are employed to understand the functions of the system. In these models, year 2001 is considered as the base year to understand the functions of the system and its various subsystems together. The results of the various variables computed from the models considering year 2001 as the base year are population, area, perceived area, perceived population density, solid waste generation from different income groups, such as, high income group, middle income group, low income group and economically weaker section, solid waste generation from industries, hospital waste generation and commercial and market activity solid waste generation, total employment generation in formal sector, total employment generation from informal sector (recycling activity), total collected waste, treated waste, disposed waste, land requirement for waste disposal, number of vehicles required, number of trips required, efficiency of the system and environmental stress. The results of the base year model are presented in Table 5.4.

Table 5.4 clearly indicates that the population available in the study area is 2,725,207 having a density of 9118 per square kilometre. It is observed from the table that the population belonging to higher income group (HIG), middle income group (MIG), low income group (LIG) and economically weaker section (EWS) are 408781, 545041, 1090082, and 681301 respectively. The solid waste generation from these income-groups are 196.21, 207.12, 207.12, 102.2 tons respectively, thus making the total household solid waste generation as 712.64 tons. The waste coming from commercial activity and market activity in the study area is 500 and 86 tons respectively, thus making the total waste as 586 tons. The hazardous and non-hazardous commercial waste is further calculated as 11.72 and 574.28 tons respectively. Waste coming primarily from leather industries and forming a part of the municipal solid waste is

116.06 tons with hazardous and non-hazardous part as 40.62 tons and 75.44 tons respectively. Among the non-hazardous industrial waste, the recyclables comprise 58.09 tons while non-recyclables as 17.35 tons. As far as bio-medical waste is concerned, the total hospital waste is 6.53 tons with net waste from hospitals as 1.94 tons due to illegal recycling. Of the total generated waste, 597.1 tons is being collected and only a small fraction of 6.4 tons going for treatment (incineration of hospital waste). Direct recycling from the point of generation by the informal sector (*Kabadi* and waste pickers) is coming as 241.41 tons. The net municipal solid waste going for disposal to the dump-sites (landfills) is 590.70 tons.

On computation, the total hazardous and non-hazardous waste is coming as 92.87 and 1327.21 tons respectively. It is observed that the land requirement for disposal is 84.47 sq. m. per day, number of vehicles required by the collection and disposal crew of the formal sector is 15. The employment generation in the formal sector (Municipal Corporation) is 2684 while that in the informal sector (for recycling) is 7001.

Efficiency of the system in terms of solid waste management is also calculated. The collection efficiency is 0.51, treatment efficiency 0.05, disposal efficiency as 0.08 and the composite efficiency as 0.24. It is also observed that the composite environmental stress in the base year is 0.72.

Table 5.4: Base Year Model Results

Sl No.	Parameters	Value
1.	Population	2,725,207
2.	Density of Population	9,118
3.	Area	298.89 sq km
4.	Perceived Area	298.89 sq km
5.	Perceived Density	9,118
6.	Population-HIG	408,781
7.	Population-MIG	545,041
8.	Population-LIG	1,090,083
9.	Population-EWS	681,302

Table 5.4: (Continued)

Sl No.	Parameters	Value
10.	Solid waste generated by HIG	196.21 tons
11.	Solid waste generated by MIG	207.12 tons
12.	Solid waste generated by LIG	207.12 tons
13.	Solid waste generated by EWS	102.20 tons
14.	Total HH solid waste generation	712.64 tons
15.	Solid waste generation from commercial activity	500.00 tons
16.	Solid waste generation from market activity	86.00 tons
17.	Total solid waste from commercial and market activity	586.00 tons
18.	Hazardous commercial waste	11.72 tons
19.	Non-hazardous commercial waste	574.28 tons
20.	Recyclable commercial waste	275.65 tons
21.	Non-recyclable commercial waste	298.63 tons
22.	Industrial Solid waste	116.06 tons
23.	Hazardous industrial waste	40.62 tons
24.	Non-hazardous industrial waste	75.44 tons
25.	Recyclable industrial waste	58.09 tons
26.	Non-recyclable industrial waste	17.35 tons
27.	Total Hospital Solid waste	6.53 tons
28.	Net Hospital solid waste	1.94 tons
29.	Hazardous hospital waste	4.90 tons
30.	Non-hazardous hospital waste	0.48 tons
31.	Recyclable hospital waste	0.24 tons
32.	Non-recyclable hospital waste	0.24 tons
33.	Total hazardous solid waste generated	92.87 tons
34.	Total non-hazardous solid waste generated	1327.21 tons
35.	Total non-recyclable solid waste	641.18 tons
36.	Total recyclable solid waste	686.06 tons
37.	Total solid waste generation	1420.08 tons
38.	Total solid waste collection	597.10 tons
39.	Total uncollected waste	822.98 tons
40.	Total treated solid waste	6.40 tons
41.	Direct recycling from generation	241.41 tons
42.	Net solid waste disposed	590.70 tons
43.	Land required for disposal	84.47 sq km
44.	Number of vehicles	15
45.	Manpower requirement in Formal sector	2684
46.	Manpower requirement in Informal sector	7001
47.	Collection efficiency	0.51
48.	Treatment efficiency	0.05
49.	Disposal efficiency	0.08
50.	Composite efficiency	0.24
51.	Environmental Stress ES1	0.55
52.	Environmental Stress ES2	0.05
53.	Environmental Stress ES3	0.00
54.	Environmental Stress ES4	0.10
55.	Environmental Stress ES5	0.02
56.	Composite Environmental Stress	0.72
57.	Cost of Collection (INR/day)	860424.52
58.	Cost of Treatment (INR/day)	1793.38
59.	Cost of Disposal (INR/day)	5906.97
60.	Total cost (INR/day)	868124.87

5.8 MODEL VALIDATION

The models are employed to compute the outputs from a set of inputs for the year 2001, which is referred as the base year for the model in this investigation and up to the year 2004 for which data for the study area pertaining to a number of variables are available. The model results are closely examined and compared to the data available in the real system and the comparison between model results and the real system data are presented in Fig. 5.13.

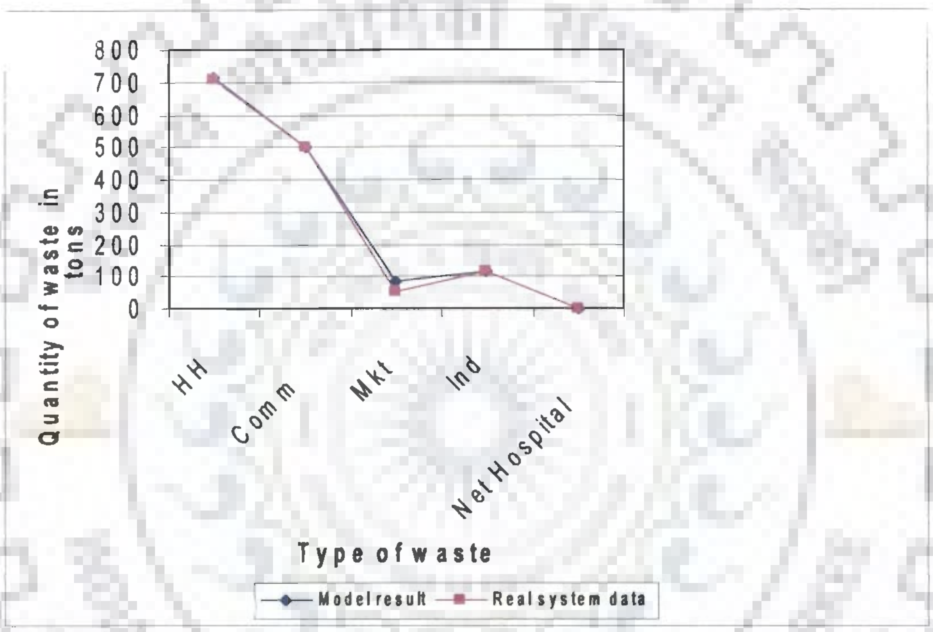

Fig. 5.13: Model results and the Real system data pertaining to waste generation in the base year

5.9 PROJECTIONS

In this present investigation, the various control parameters of different subsystems of the system, which influence the functions of the system largely such as, population, income-group, household waste generation, industrial waste generation, commercial and market waste generation and hospital waste generation, waste collection, treatment, disposal, land requirement for disposal of collected/treated waste, employment generation from waste management related activities in both organized and informal sector, system efficiency and environmental stress have been considered for projecting their value up to 2031 A.D. for strategic planning. Projection was done in the validated integrated base year (year 2001) model by employing Powersim software by considering the time series data available in the system.

5.10 PROJECTED YEAR (2031) MODEL RESULTS

The projected year model results are presented as below:

5.10.1 POPULATION, POPULATION DENSITY, PERCEIVED POPULATION DENSITY

The population, population density, perceived area and perceived population density in the study area are presented in Table 5.5 and Fig. 5.14, 6.15 and 6.16. The results show that the population in the study area would be 6919211 in the year 2031 A.D. The density of the population would be 13430 persons per sq km. The perceived area of the study area as a result of various government policies is expected to be 366.35 sq. km in the year 2031 A.D.; as a result the perceived density would be much higher at 18887 persons per sq km.

Table 5.5: Projected Population, Population Density and perceived population density in study area

S.No.	Year	Population	Density of Population	Area	Perceived Area	Perceived Density
1	2,006	3,183,042	9,726	327.28	309.20	10,294
2	2,011	3,717,793	10,374	358.38	319.87	11,623
3	2,016	4,342,382	11,066	392.42	330.90	13,123
4	2,021	5,071,902	11,803	429.70	342.32	14,816
5	2,026	5,923,982	12,590	470.52	354.13	16,728
6	2,031	6,919,211	13,430	515.22	366.35	18,887

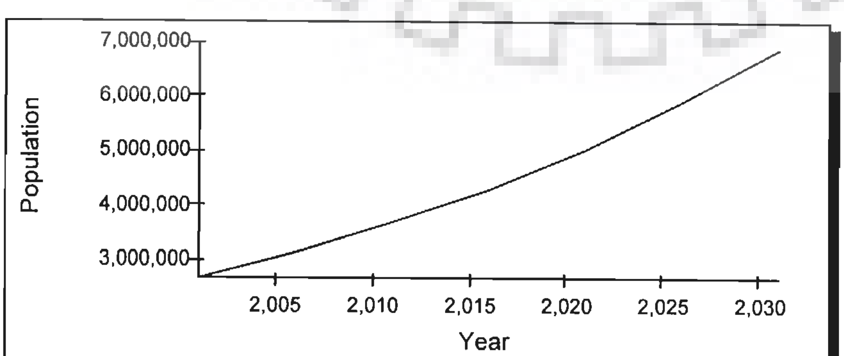

Fig. 5.14: Population in the study area up to 2031 A.D.

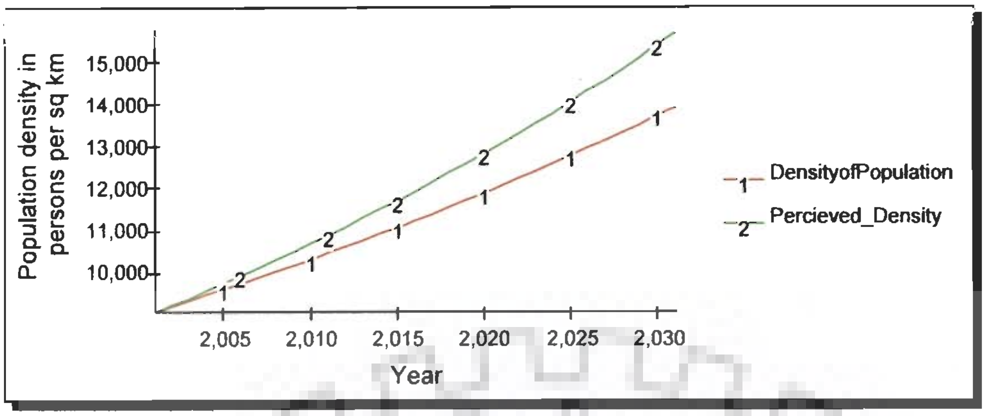

Fig. 5.15: Population density and perceived population density in the study area up to 2031 A.D

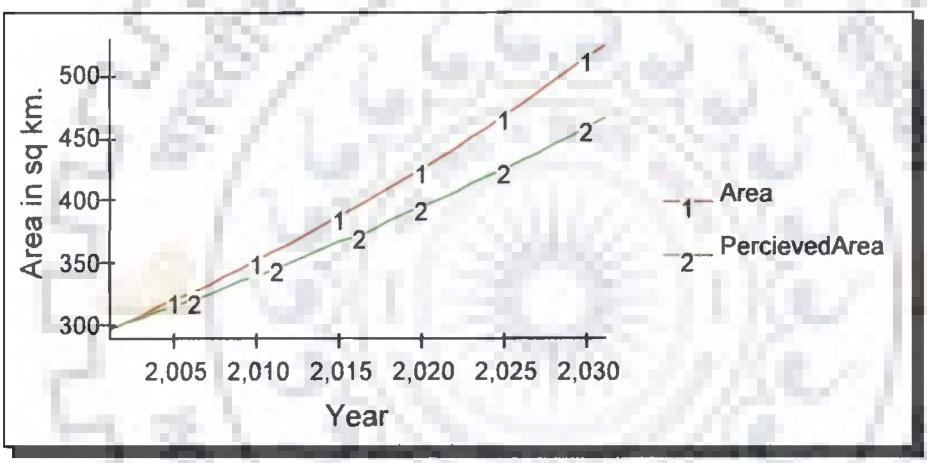

Fig. 5.16: Area and perceived area up to 2031 A.D.

5.10.2 Waste Generation

In this investigation, only four principal generators of solid waste have been considered whose waste becomes a part of Municipal waste in some way or other. They are household waste generation, industrial waste generation, commercial and market activity waste generation and hospital waste generation. Each sub-model is projected up to the year 2031 A.D. and presented in the following sections:

5.10.2.1 Household solid waste generation

The household solid waste generation is based on the waste coming from different income-groups as the per capita waste generation varies with income. The population in each income-group and the waste coming from each income-group has been projected up to the year 2031 A.D. and presented in Table 5.6 and 5.7 and Fig. 5.17.

It is observed that the population in high income group (HIG), middle income group (MIG), low income group (LIG) and economically weak section (EWS) in the year 2031 A.D will become 1037882, 1383842, 277684 and 1729803 respectively. The solid waste generation in each income group in the year 2031 A.D. will be 733.08, 773.81, 773.81 and 381.81 tons respectively, thus making the total household solid waste generation as 2662.52 tons.

Table 5.6: Income-wise population

S. No.	Year	HIG	MIG	LIG	EWS	Population
1	2,006	477,456	636,608	1,273,217	795,760	3,183,042
2	2,011	557,669	743,559	1,487,117	929,448	3,717,793
3	2,016	651,357	868,476	1,736,953	1,085,595	4,342,382
4	2,021	760,785	1,014,380	2,028,761	1,267,976	5,071,902
5	2,026	888,597	1,184,796	2,369,593	1,480,995	5,923,982
6	2,031	1,037,882	1,383,842	2,767,684	1,729,803	6,919,211

Table 5.7: Income-wise household solid waste generation

S.No.	Year	SW from HIG	SW from MIG	SW from LIG	SW from EWS	Total Household Solid Waste Generation
1	2,006	244.42	258.00	258.00	127.30	887.72
2	2,011	304.47	321.38	321.38	158.58	1105.81
3	2,016	379.27	400.34	400.34	197.53	1377.47
4	2,021	472.44	498.69	498.69	246.06	1715.88
5	2,026	588.51	621.20	621.20	306.51	2137.42
6	2,031	733.08	773.81	773.81	381.81	2662.52

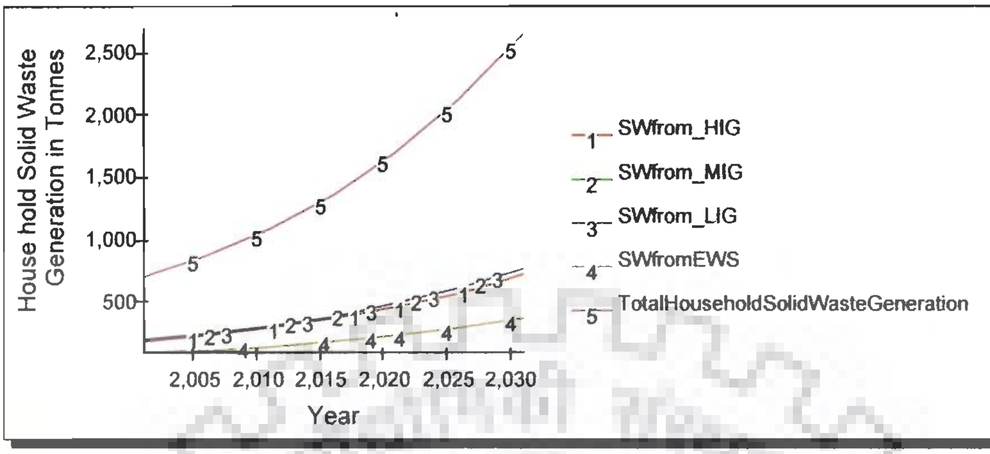

Fig. 5.17: Household Solid Waste Generation by the year 2031 A.D.

5.10.2.2 Waste generation from commercial and market activity

Waste generation from commercial and market activities in the projected year 2031 A.D. is presented in Table 5.8 and Fig. 5.18 and 5.19.

Table 5.8: Solid Waste Generation from Commercial Activity

S.No.	Year	Com.Activity SW	SW Market Activity	Total SW from all Commercial Activities	HZ Comm SW	NHZ Comm SW	Comm Recyclable SW	Comm NonRecyclable SW
1	2,006	543.75	93.53	637.28	12.75	624.53	299.77	324.76
2	2,011	591.33	101.71	693.04	13.86	679.18	326.00	353.17
3	2,016	643.07	110.61	753.68	15.07	738.60	354.53	384.07
4	2,021	699.34	120.29	819.62	16.39	803.23	385.55	417.68
5	2,026	760.53	130.81	891.34	17.83	873.51	419.29	454.23
6	2,031	827.08	142.26	969.33	19.39	949.95	455.97	493.97

It is observed that the waste coming from commercial and market activities would be 827.08 and 142.26 tons respectively in the year 2031 A.D. A further categorisation of this waste shows that of the generated waste, 19.39 tons would be hazardous in nature and the rest 949.95 tons non-hazardous waste would have 455.97 tons as recyclables and the remaining 493.97 tons as non-recyclables.

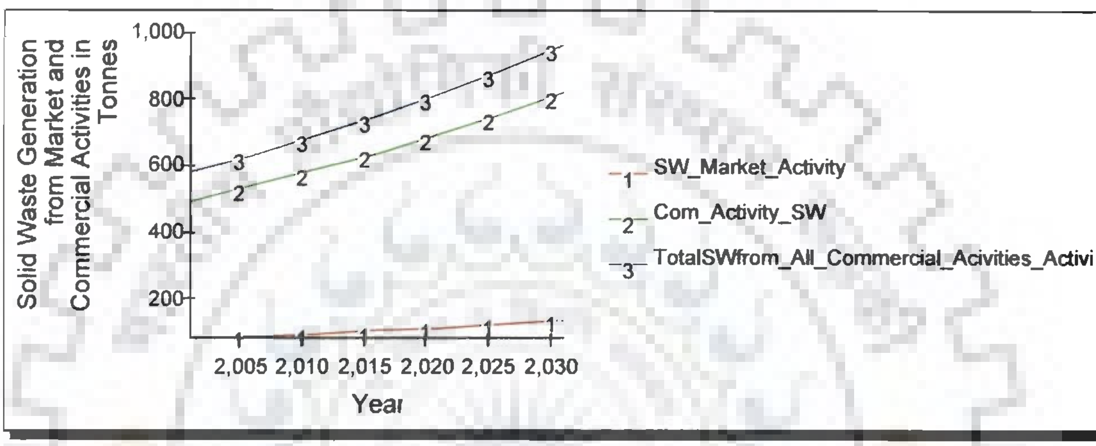

Fig. 5.18: Solid Waste Generation from Commercial and Market Activity by the year 2031 A.D.

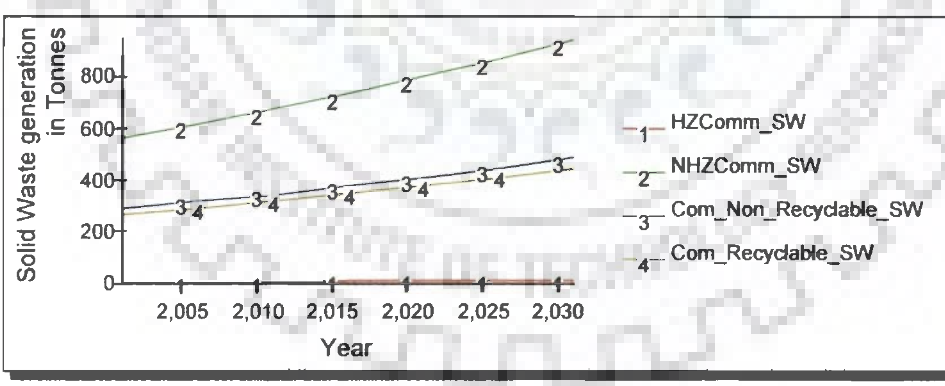

Fig. 5.19: Hazardous, Non hazardous, Recyclable and Non-recyclable Solid Waste Generation from Commercial and Market activity by the year 2031 A.D.

5.10.2.3 Waste generation from Industries

Waste generation from industries, primarily tanneries, in the projected year 2031 A.D. is presented in Table 5.9 and Fig. 5.20. It is observed that the total industrial solid waste from tanneries would be 392.19 tons in the year 2031 A.D. Of this, 137.27 tons would be hazardous in nature while 254.93 tons non-hazardous in nature.

Table 5.9: Solid Waste Generation from Industries

S.No.	Year	Ind SW	HZ Ind SW	NHZ Ind SW	Ind Non-Recyclable SW	Ind Recyclable SW
1	2,006	142.17	49.76	92.41	21.25	71.16
2	2,011	174.16	60.96	113.21	26.04	87.17
3	2,016	213.35	74.67	138.68	31.90	106.78
4	2,021	261.35	91.47	169.88	39.07	130.81
5	2,026	320.16	112.05	208.10	47.86	160.24
6	2,031	392.19	137.27	254.93	58.63	196.29

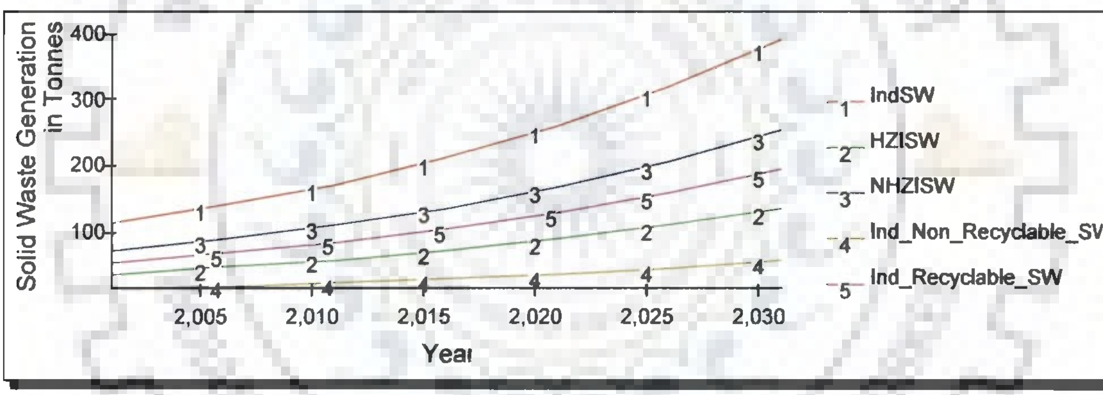

Fig. 5.20: Hazardous, Non hazardous, Recyclable and Non Recyclable and Total Solid Waste Generation from Industrial Activity by the year 2031 A.D.

5.10.2.4 Waste generation from Hospitals

The results of the waste generation from hospitals in the projected year 2031 A.D is presented in Table 5.10 and Fig. 5.21 and 5.22. It is observed that the total hospital waste generation would be 17.63 tons in the year 2031 A.D., of which 13.22 tons would be hazardous in nature and the remaining 1.31 tons non-hazardous. A part of the generated waste goes for illegal recycling and a small fraction goes for incineration as well. Thus, the net hospital waste would be 5.24 tons in the year 2031 A.D.

Table 5.10: Solid Waste Generation from Hospitals

S.No.	Year	Total Hospital SW	Net Hospital SW	HZ Hospital SW	NHZ Hospital SW	Hospital Recycla ble SW	Hospital Non-Recyclable SW
1	2,006	7.70	2.29	5.78	0.57	0.29	0.29
2	2,011	9.09	2.70	6.82	0.68	0.34	0.34
3	2,016	10.73	3.19	8.05	0.80	0.40	0.40
4	2,021	12.66	3.76	9.49	0.94	0.47	0.47
5	2,026	14.94	4.44	11.20	1.11	0.55	0.55
6	2,031	17.63	5.24	13.22	1.31	0.65	0.65

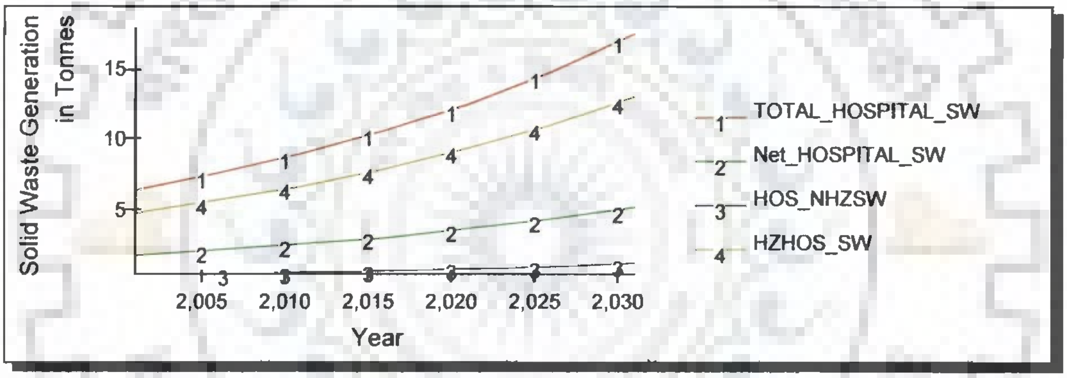

Fig. 5.21: Hazardous, Non hazardous and Total Solid Waste Generation from Hospital by the year 2031 A.D.

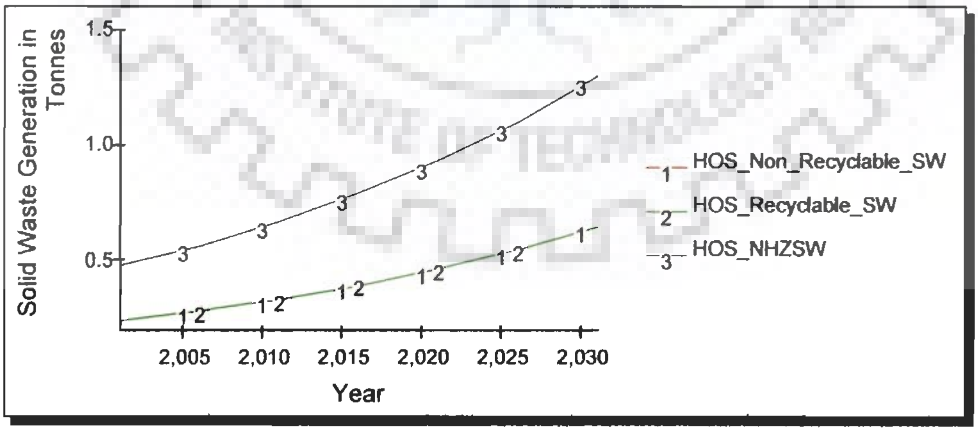

Fig. 5.22: Non hazardous, Recyclable and Non Recyclable Solid Waste Generation from Hospital by the year 2031 A.D.

It is thus observed that the total generated waste from the above sources in the year 2031 A.D. would be 4038.58 tons (Table 5.11 and Fig. 5.23)

Table 5.11: Total Hazardous, Non-hazardous, Recyclable, Non-recyclable generated waste

S.No.	Year	Total HZ SW	Total NHZ SW	Total Non-recyclable SW	Total Recyclable SW	Total Waste generation
1	2,006	112.67	1560.85	751.10	809.75	1673.52
2	2,011	136.93	1843.57	883.79	959.78	1980.50
3	2,016	166.67	2186.67	1044.49	1142.18	2353.34
4	2,021	203.15	2604.13	1239.66	1364.47	2807.28
5	2,026	247.96	3113.28	1477.31	1635.97	3361.24
6	2,031	303.00	3735.58	1767.37	1968.21	4038.58

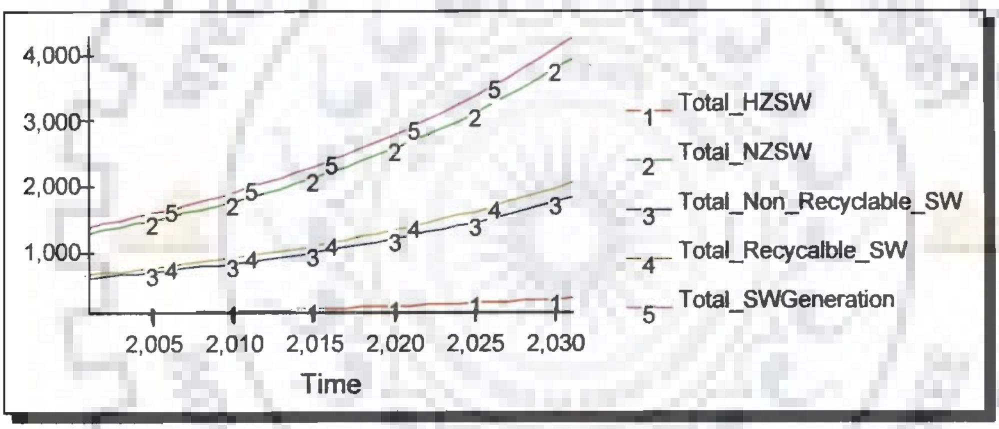

Fig. 5.23: Total Hazardous, Non hazardous, Non-Recyclable, Recyclable and Total Solid Waste Generation fróm all sources by the year 2031 A.D.

5.10.3 Waste Collection, treatment, Disposal and Recycling

Solid Waste Management system is influenced by the level of waste collection, treatment, disposal and recycling parameters. These parameters have therefore, been projected in the year 2031 A.D. and presented in Table 5.12 and Fig. 5.24, 5.25 and 5.26.

The results show that the total solid waste collection would be 1700.04 tons in the year 2031 A.D. The waste going for treatment would be only 18.42 tons and the net waste going for disposal as 1681.63 tons. The waste going for direct recycling from generation by the informal sector would be 686.56 tons.

Table 5.12: Total Solid Waste collection, treatment, disposal, recycling

S.No.	Year	Total SW Collection	Total Uncollected SW	Total SW Treated	Direct Recycling from Generation	Net SW Disposed
1	2,006	703.82	969.69	7.56	284.50	696.26
2	2,011	833.11	1147.39	8.97	336.68	824.14
3	2,016	990.15	1363.19	10.68	400.07	979.47
4	2,021	1181.36	1625.93	12.76	477.24	1168.60
5	2,026	1414.70	1946.53	15.31	571.41	1399.40
6	2,031	1700.04	2338.53	18.42	686.56	1681.63

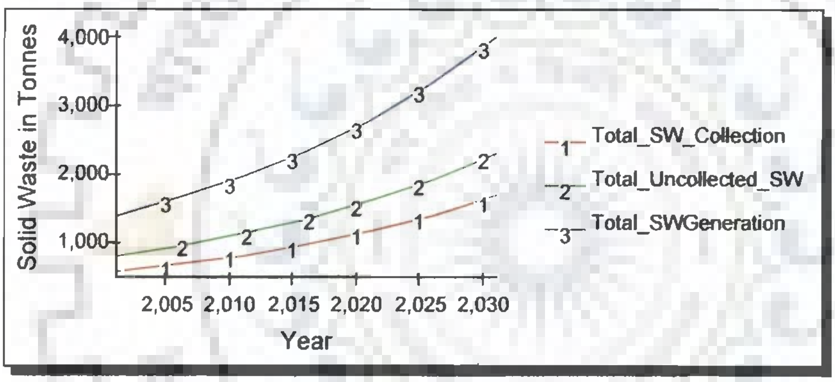

Fig. 5.24: Total Waste Collection, Uncollected waste and Total Solid Waste Generation by the year 2031 A.D.

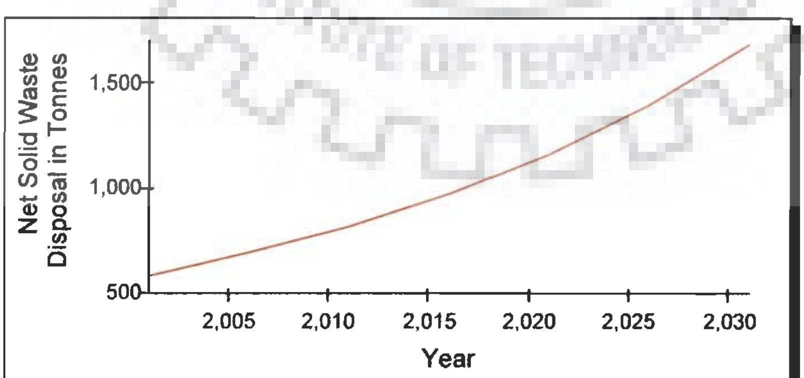

Fig. 5.25: Net Solid Waste Disposal by the year 2031 A.D.

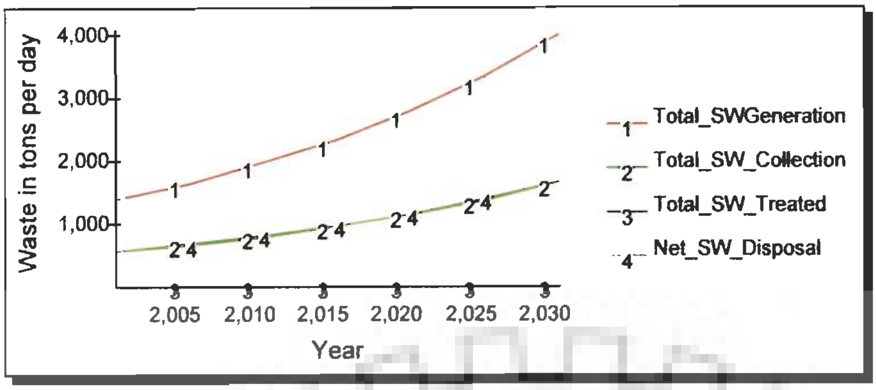

Fig. 5.26: Total Waste Generation, Collection, Treatment and Disposal of waste by the year 2031 A.D.

5.10.4 LAND REQUIREMENT FOR DISPOSAL, COLLECTION VEHICLES, MANPOWER REQUIREMENTS IN FORMAL AND INFORMAL SECTORS

The projected requirements like land required for disposal of collected waste, vehicles requirement and manpower required in formal and informal sectors are presented in Table 5.13 and Fig. 5.27, 5.28 and 5.29. It is observed that 240.47 sq m of land will be required for disposal of collected waste (assuming a standard height of 10 m of cell) in the year 2031 A.D. The number of collection vehicles requirement will increase to 43. The total manpower requirement in the formal sector and informal sectors will be 7641 and 19910 respectively.

Table 5.13: Land required for disposal, number of vehicles, and manpower requirements in formal and informal sector

S.No.	Year	Land req. for disposal	Number of Vehicles	Formal sector total manpower requirement	Informal Sector Manpower req for recycling
1	2,006	99.57	18	3,163	8,250
2	2,011	117.85	21	3,745	9,764
3	2,016	140.06	25	4,450	11,602
4	2,021	167.11	30	5,310	13,840
5	2,026	200.11	35	6,359	16,571
6	2,031	240.47	43	7,641	19,910

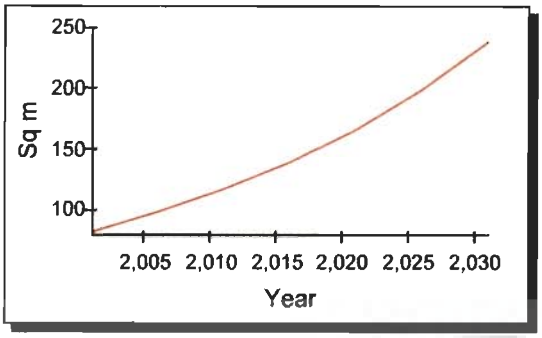

Fig. 5.27: Land required for waste disposal

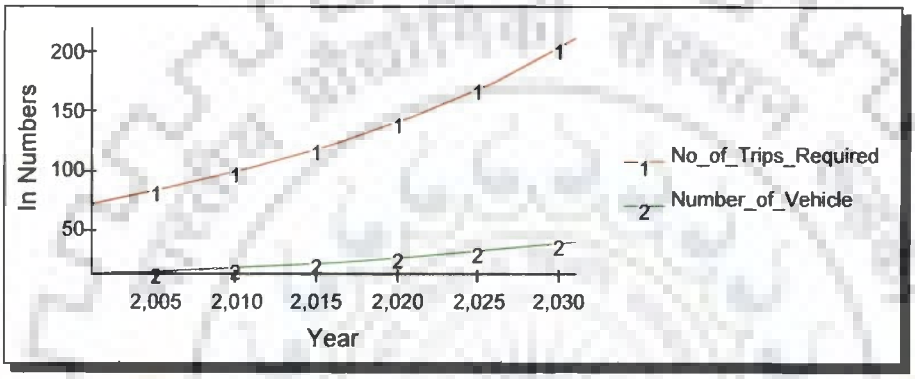

Fig. 5.28: Number of Trips and Number of Vehicles required for Solid Waste Collection by the year 2031 A.D

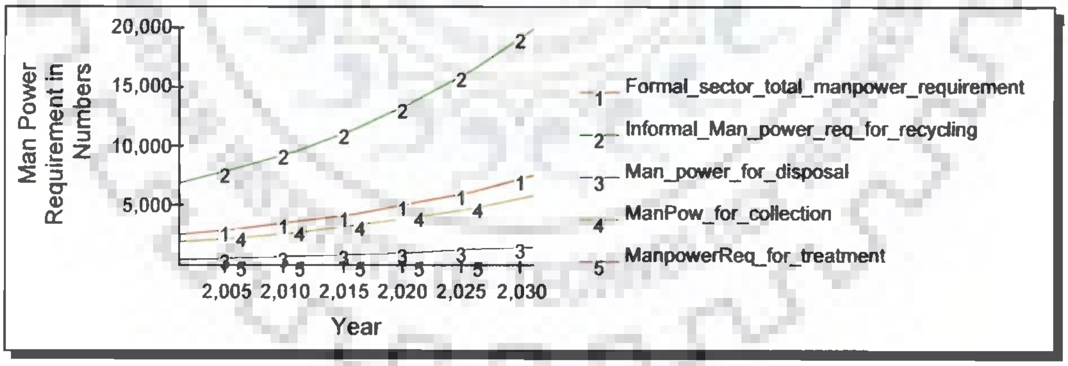

Fig. 5.29: Manpower Requirement in different Solid Waste related activities by the year 2031 A.D

5.10.5 EFFICIENCY OF THE SYSTEM

The collection efficiency, treatment efficiency, disposal efficiency and the combined composite efficiency of the solid waste management system for the projected year (2031A.D.)

is presented in Table 5.14 and Fig. 5.30. It is observed that the composite efficiency will remain stagnant at 0.24 under the given circumstances.

Table 5.14: Efficiency of the System

S.No.	Year	Collection efficiency	Treatment efficiency	Disposal efficiency	Composite efficiency
1	2,006	0.51	0.05	0.08	0.24
2	2,011	0.51	0.05	0.08	0.24
3	2,016	0.51	0.05	0.08	0.24
4	2,021	0.51	0.05	0.08	0.24
5	2,026	0.51	0.05	0.08	0.24
6	2,031	0.51	0.05	0.08	0.24

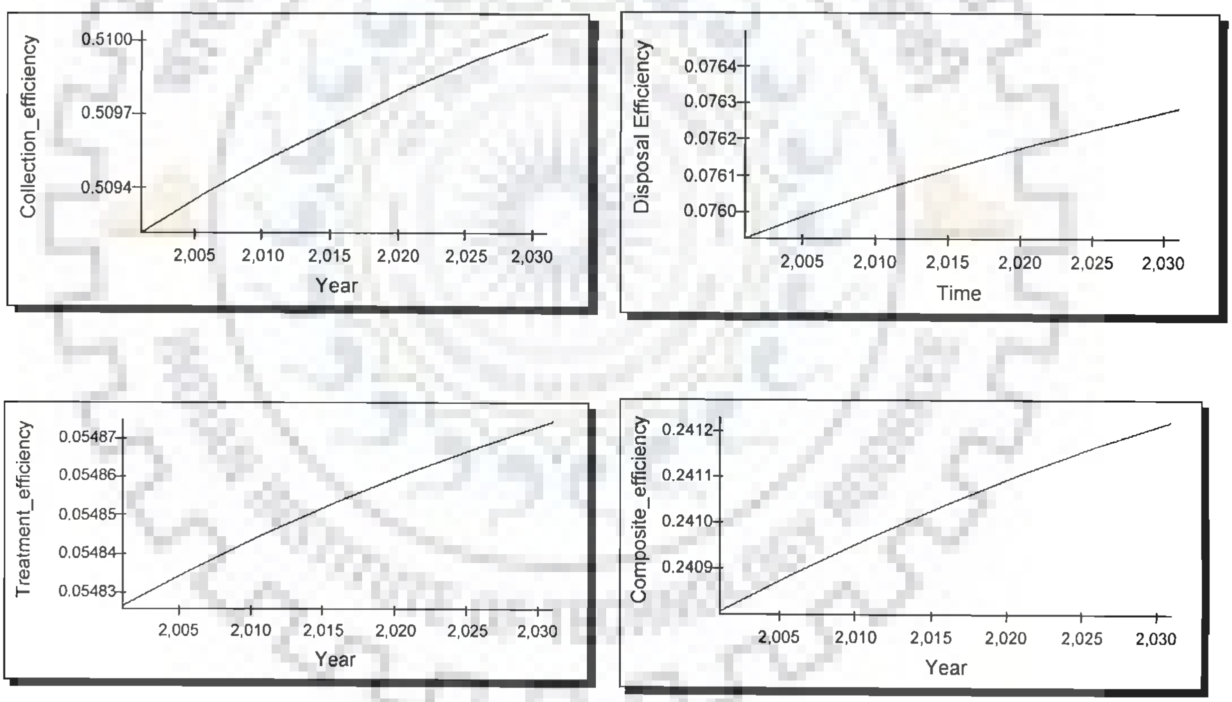

Fig. 5.30: Collection efficiency, Treatment efficiency, Disposal efficiency and Composite efficiency by the year 2031A.D.

5.10.6 ENVIRONMENTAL STRESS

The environmental stress due to uncollected and untreated waste, collection of waste, treatment of waste, disposal ,recycling and the resultant composite environmental stress are presented in Table 5.15 and Fig. 5.31. It has been considered that 0 represents zero stress and 1 represents maximum environmental stress for representation. The table and figure reveal that the composite environmental stress would be 0.72 in the projected year 2031 A.D.

Table 5.15: Environmental Stress

S.No.	Year	ES1	ES2	ES3	ES4	ES5	CES
1	2,006	0.55	0.04	0.00	0.10	0.02	0.72
2	2,011	0.55	0.04	0.00	0.10	0.02	0.72
3	2,016	0.55	0.04	0.00	0.10	0.02	0.72
4	2,021	0.55	0.04	0.00	0.10	0.02	0.72
5	2,026	0.55	0.04	0.00	0.10	0.02	0.72
6	2,031	0.55	0.04	0.00	0.10	0.02	0.72

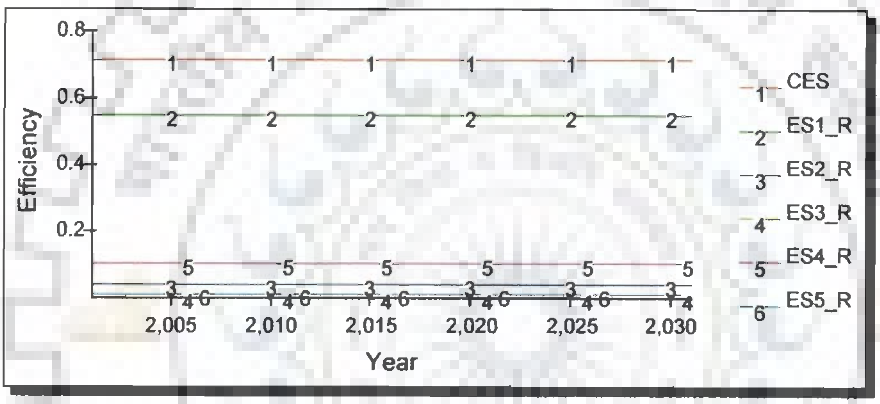

Fig. 5.31: Various Environmental Stress by the year 2031 A.D

5.10.7 COST OF COLLECTION, TREATMENT AND DISPOSAL

The cost of various collection, treatment and disposal services is a very important component of any solid waste management plan. Under the given circumstances, the costs will continue to increase due to substantial increase in the total quantity of waste generated as presented in Table 5.16 and Fig. 5.32. The collection costs will be very high and become 24.4 lakhs per day by the end of year 2031 A.D. Treatment costs will remain nil as there is no treatment facility as of now for the municipal waste generated.

Table 5.16: Cost of collection, disposal and total cost (Indian Rupees/day)

Sl. No.	Year	Cost of collection (INR/day)	Cost of disposal (INR/day)	Total cost (INR/day)
1.	2006	1014211.53	6962.60	1021174.13
2.	2011	1200511.67	8241.39	1208753.06
3.	2016	1426801.14	9794.66	1436595.80
4..	2021	1702336.93	11685.95	1714022.88
5.	2026	2038586.90	13993.97	2052580.87
6.	2031	2449764.41	16816.29	2466580.70

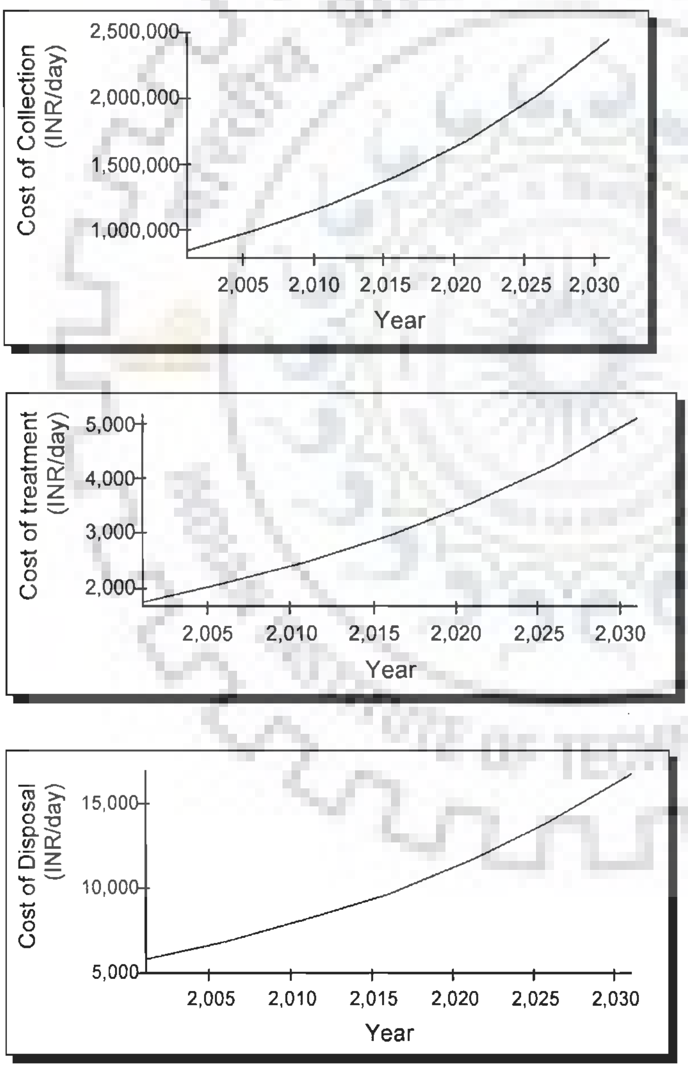

Fig. 5.32: Cost of collection, treatment and disposal by the year 2031 A.D.

5.11 RESULTS SUMMARY

The results of the various indicators of solid waste management in the system have been summarized and presented in Table 5.17, 5.18 and 5.19. The various indicators considered are total household solid waste generation, total solid waste generating from all commercial activities, industrial solid waste generation, hospital solid waste generation, total waste generation, collected waste, uncollected waste, treated waste, waste going for direct recycling from generation, net solid waste disposed, land required for disposal, number of vehicles required for collection of waste, number of trips required for collection, employment opportunities in formal and informal sector. Table 5.17 reveals that the total household solid waste generation, commercial waste generation, industrial and hospital waste generation would increase by 273.61 per cent (from 712.64 tons in 2001 A.D. to 2662.52 tons in 2031 A.D.), 65.41 per cent (from 586 tons in 2001 A.D. to 969.33 tons in 2031 A.D.), 237.92 per cent (from 116.06 tons in 2001 A.D. to 392.19 tons in 2031 A.D.) and 169.98 per cent (from 6.53 tons in 2001 A.D. to 17.63 tons in 2031 A.D.) respectively, with an overall increase of 184.39 per cent in the total solid waste generation in the projected year 2031 A.D. (from 1420.08 tons in 2001 A.D. to 4038.58 tons in 2031 A.D.). The waste collection by the formal sector (Municipal Corporation) would increase to 1700.04 tons in 2031 A.D. from 597.10 tons in 2001 A.D. (i.e., 184.72 per cent) while the waste remaining uncollected would increase to 2338.53 tons in the projected year 2031 A.D. from 822.98 tons in 2001 A.D. i.e., 184.15 per cent (Table 5.18). The table further shows that the waste going for treatment would increase only to 18.42 tons in 2031 A.D. from 6.40 tons in 2001 A.D. (an increase of 18.42 per cent) whereas the waste going for disposal would increase to 1681.63 tons in the projected year 2031 A.D. from 590.7 tons in 2001 A.D. (an increase of 184.68 per cent). The percentage increase in the waste going for direct recycling would also increase by 184.40 percent (from 241.41 tons in 2001 A.D to 686.56 tons in 2031 A.D).

Table 5.19 further reveals that the land required for disposal of collected/treated waste would increase by 184.68 per cent (from 84.47 sq m in 2001 A.D. to 240.47 sq. m in the projected year 2031 A.D.) while the number of vehicles and number of required trips for collection of waste would increase by 186.67 per cent (from 15 in 2001 A.D. to 43 in 2031 A.D.) and 184.71 per cent (from 75 in 2001 A.D. to 213 in 2031 A.D.) respectively in the projected year 2031 A.D. from the base year 2001 A.D. Employment opportunities in the formal sector would increase from 2684 in 2001 A.D. to 7641 in 2031 A.D. (i.e., 184.69 per cent). Employment opportunities in the informal sector would increase from 7001 in the base year 2001 A.D. to 19910 in the projected year 2031 A.D. (an increase of 184.39 per cent).

Table 5.17: Projected Year Results Summary

Year	Total Household Solid Waste Generation	Per cent increase over year 2001	Total SW from all Commercial Activities	Per cent increase over year 2001	Ind SW	Per cent increase over year 2001	Total Hospital SW	Per cent increase over year 2001	Total Waste generation	Per cent increase over year 2001
2006	887.72	24.57	637.28	8.75	142.17	22.50	7.70	17.92	1673.52	17.85
2011	1105.81	55.17	693.04	18.27	174.16	50.06	9.09	39.20	1980.50	39.46
2016	1377.47	93.29	753.68	28.61	213.35	83.83	10.73	64.32	2353.34	65.72
2021	1715.88	140.78	819.62	39.87	261.35	125.19	12.66	93.87	2807.28	97.68
2026	2137.42	199.93	891.34	52.11	320.16	175.86	14.94	128.79	3361.24	136.69
2031	2662.52	273.61	969.33	65.41	392.19	237.92	17.63	169.98	4038.58	184.39

Table 5.18: Projected Year Results Summary

Year	Total SW Collection	Per cent increase over year 2001	Total Uncollected SW	Per cent increase over year 2001	Total SW Treated	Per cent increase over year 2001	Direct Recycling from Generation	Per cent increase over year 2001	Net SW Disposed	Per cent increase over year 2001
2006	703.82	17.87	969.69	17.83	7.56	18.13	284.50	17.85	696.26	17.87
2011	833.11	39.53	1147.39	39.42	8.97	40.16	336.68	39.46	824.14	39.52
2016	990.15	65.83	1363.19	65.64	10.68	66.88	400.07	65.72	979.47	65.82
2021	1181.36	97.85	1625.93	97.57	12.76	99.38	477.24	97.69	1168.6	97.83
2026	1414.70	136.93	1946.53	136.52	15.31	139.22	571.41	136.70	1399.4	136.91
2031	1700.04	184.72	2338.53	184.15	18.42	187.81	686.56	184.40	1681.63	184.68

Table 5.19: Projected Year Results Summary

Year	Land req. for disposal	Per cent increase over year 2001	Number of Vehicles	Per cent increase over year 2001	Number of trips required	Per cent increase over year 2001	Formal sector total manpower requirement	Per cent increase over year 2001	Informal Sector Manpower req for recycling	Per cent increase over year 2001	Total cost of collection, treatment and disposal	Per cent increase over year 2001
2006	99.57	17.88	18	20.00	88	17.87	3,163	17.85	8,250	17.84	1021174.13	17.87
2011	117.85	39.52	21	40.00	104	39.52	3,745	39.53	9,764	39.47	1208753.06	39.53
2016	140.06	65.81	25	66.67	124	65.82	4,450	65.80	11,602	65.72	1436595.80	65.83
2021	167.11	97.83	30	100.00	148	97.84	5,310	97.84	13,840	97.69	1714022.88	97.85
2026	200.11	136.90	35	133.33	177	136.92	6,359	136.92	16,571	136.69	2052580.87	136.93
2031	240.47	184.68	43	186.67	213	184.71	7,641	184.69	19,910	184.39	2466580.70	184.72

5.12 SCENARIOS

A set of plausible scenarios have been developed based on the government policies, expert opinion and aspirations of the people, to test in the projected year model 2031 A.D. to arrive at plausible decisions. The following control parameters have been considered as discussed above, to develop the various scenarios:

i) Increase in Awareness level

ii) Increase in Investments

iii) Increase in Organised sector

iv) Change in Recycling Fraction

v) Change in Treatment Fraction

Based on these five control parameters, a good number of policy runs are made and scenarios are generated by considering these parameters individually and in combination. Of these, the simulations which have a considerable impact on various parameters of Solid Waste management have been short listed for scenario building. The scenarios which are tested in the projected year model with their values are presented in Table 5.20, 5.21, 5.22, 5.23 and 5.24. It was observed while scenario testing that change in control parameters in small amount (say 1 per cent, 2 per cent, etc.) did not give much effect in the results. Therefore, higher degree of change was attempted at. This shows that the system has acute problems pertaining to solid waste management. The most important tested scenarios and their results are presented in the following section.

SCENARIO 1: ZERO RECYCLING OF WASTE

It has been observed that the informal Recycling sector plays a very important role in the system by collecting a fraction of the generated wastes, thus reducing the gap between collected and uncollected wastes, saving virgin materials by reusing/recycling of materials, and generating a considerable amount of employment generation. This is all done without any formal support by the government. An estimated 17 per cent of the generated wastes went for recycling/reuse in the year 2001. An attempt has, therefore, been made to understand the condition of the system if this recycling fraction becomes zero and the informal sector engaged in waste recycling is closed. The model results are presented in Table 5.20 to 5.24 and Fig. 5.33.

It has been observed that the uncollected waste, which comprises of formal collection by the Kanpur Municipality and informal collection by waste pickers and Itinerant waste buyers, increases by 22.69 per cent. There is a slight decrease in the composite efficiency from 0.241 to 0.193 also as the total collection efficiency decreases. The Composite environmental stress however, shows a slight reduction of 2.38 per cent from 0.715 to 0.698 as the collection process and prevalent recycling activity produces some environmental stress. There is also a massive loss of employment opportunities as in the projected year model for 2031 AD, it has been observed that a total number of 19910 are estimated to loose their jobs, who will work in informal waste recycling/reuse sector.

SCENARIO 2: INCREASE IN AWARENESS BY 30 PER CENT AND 30 PER CENT INCREASE IN INVESTMENTS

Awareness has a profound impact in reducing the waste generation itself. It also helps in improving the overall efficiency of solid waste management as increased public concern puts pressure on the governing body. Therefore, a scenario was tested with 30 per cent increase in awareness and 30 per cent increase in investments and the model results are presented in Table 5.20 to 5.24 and Fig. 5.34.

It has been observed that there is an overall reduction of 16.71 per cent in total waste generation. The household waste generation reduces by 10.71 per cent, commercial/market wastes by 27.6 per cent, whereas industrial and hospital waste generation reduces by 30 per cent each. There is a slight improvement in the overall collection (1.59 per cent); treatment also increases by 19.06 per cent, disposal and recycling increases by 1.40 and 3.28 per cent respectively. The collection efficiency shows an improvement by 35.49 per cent due to which the overall composite Solid Waste Management efficiency also increases by 30.71 per cent. However, the land requirement for disposal increases by 1.4 per cent due to increased quantity of waste collection. The environmental stress due to uncollected and untreated wastes decreases by 5.99 per cent while the Composite Environmental Stress increases slightly by 0.42 per cent. The manpower requirement for formal sector slightly increases by 1.57 per cent while the overall employment generation in the informal sector increases to 20563 persons.

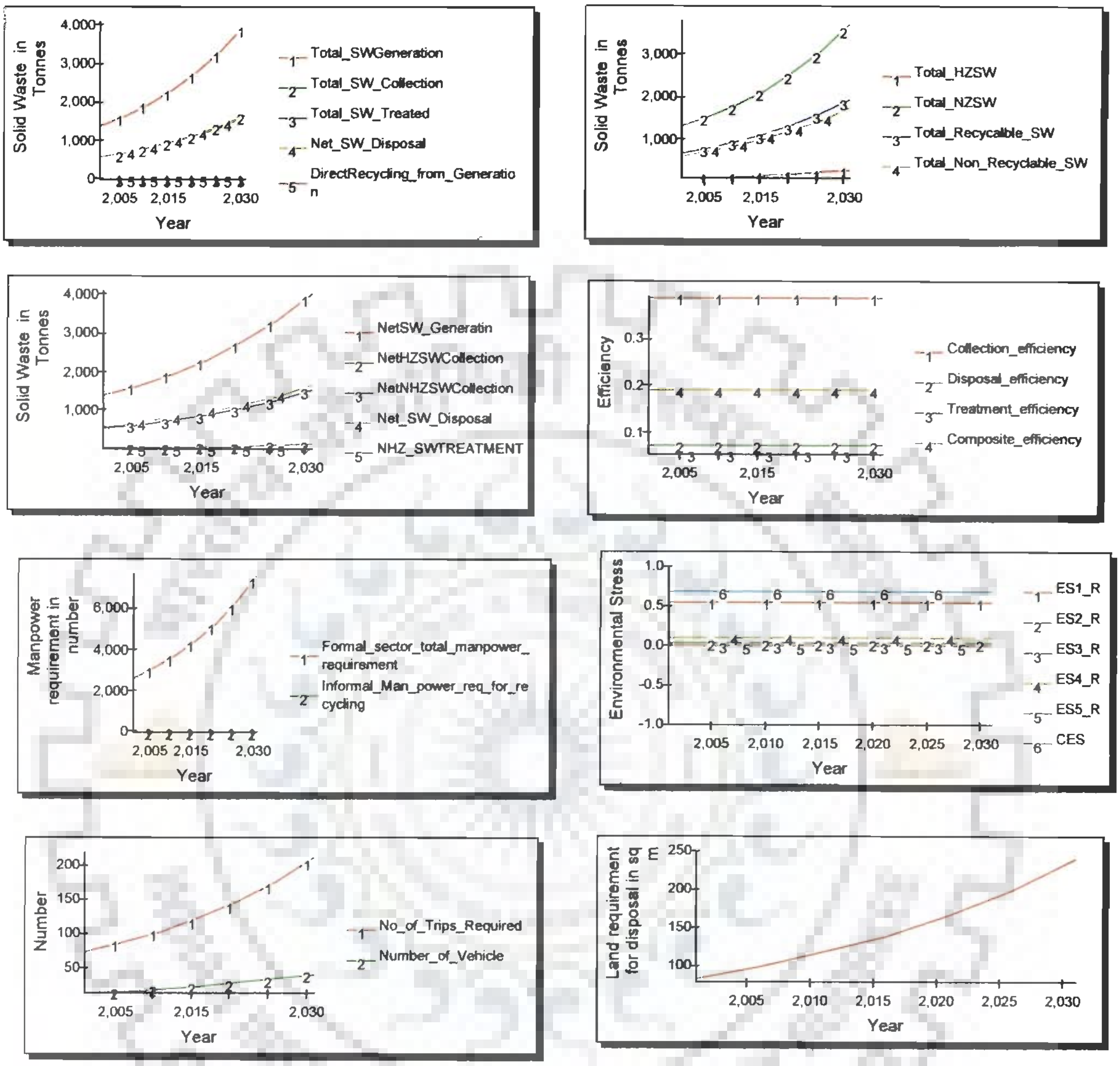

Fig. 5.33: Scenario 1

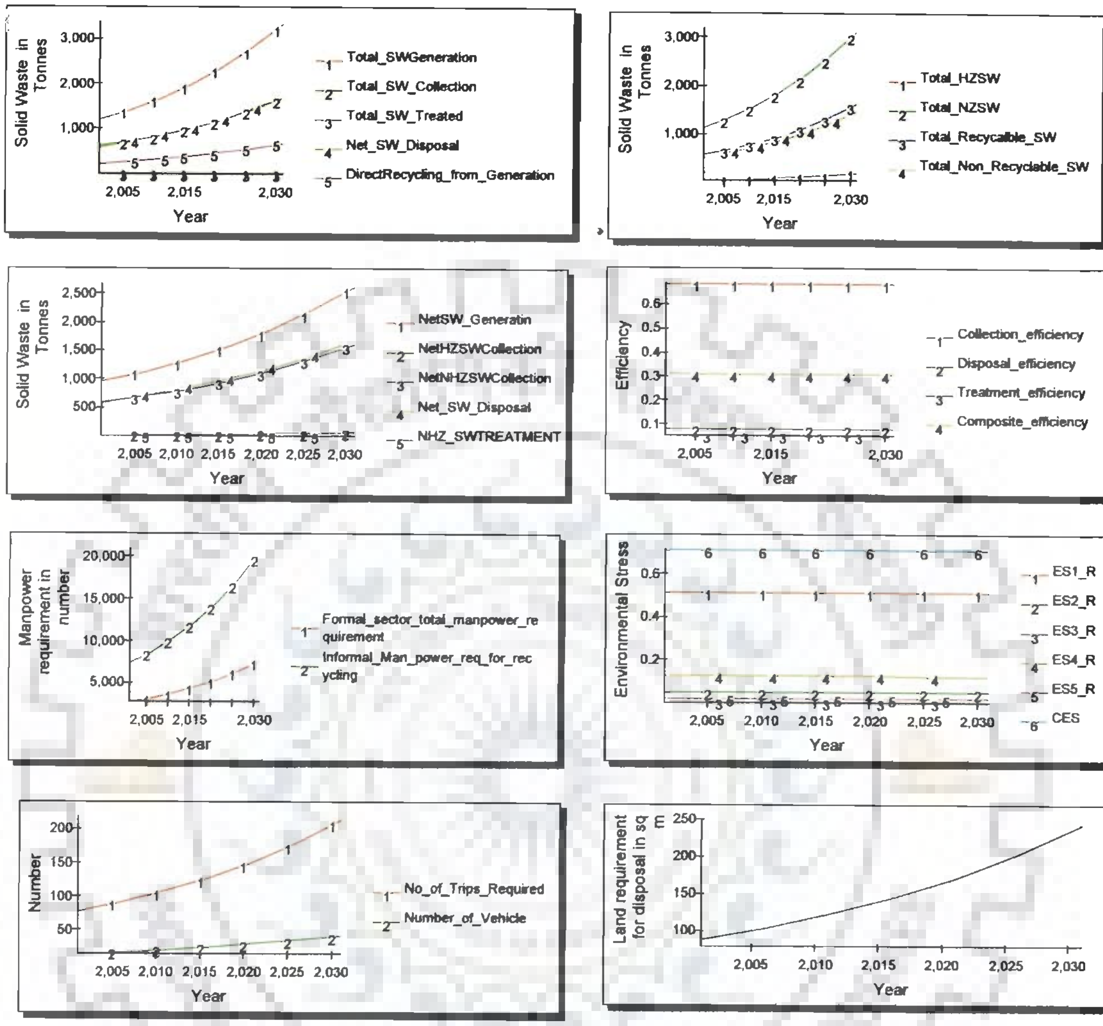

Fig. 5.34: Scenario 2

Scenario 3: Increase in Awareness By 70 per cent, 30 per cent increase in Investments and 70 per cent increase in Organised sector

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the existing awareness by 70 per cent, 30 per cent increase in investments and 70 per cent increase in organised sector. On increasing the organised sector, the personnel in formal sector (Kanpur municipality) shall increase and the informal sector people will also increase due to the legal recognition provided by the government. The model results are presented in Table 5.20 to 5.24 and Fig. 5.35.

It has been observed that the household waste generation reduces by 19.83 per cent, commercial/market wastes by 42.22 per cent, whereas industrial and hospital waste generation reduces by 42 per cent and 50.03 per cent respectively. Thus, there is an overall reduction of 27.47 per cent in waste generation. The total collection increases by 8.08 per cent while treatment increases by 53.42 per cent. The quantity of wastes remaining uncollected reduces considerably by 53.30 per cent while recycling increases only slightly by 5.90 per cent. The collection efficiency shows a positive improvement of 69.02 per cent due to which the composite Solid Waste Management efficiency increases by 60.17 per cent. However, the composite environmental stress increases slightly by 0.84 per cent. There is a favourable increase in employment generation in both formal and informal sectors by 8.02 per cent and 5.90 per cent respectively.

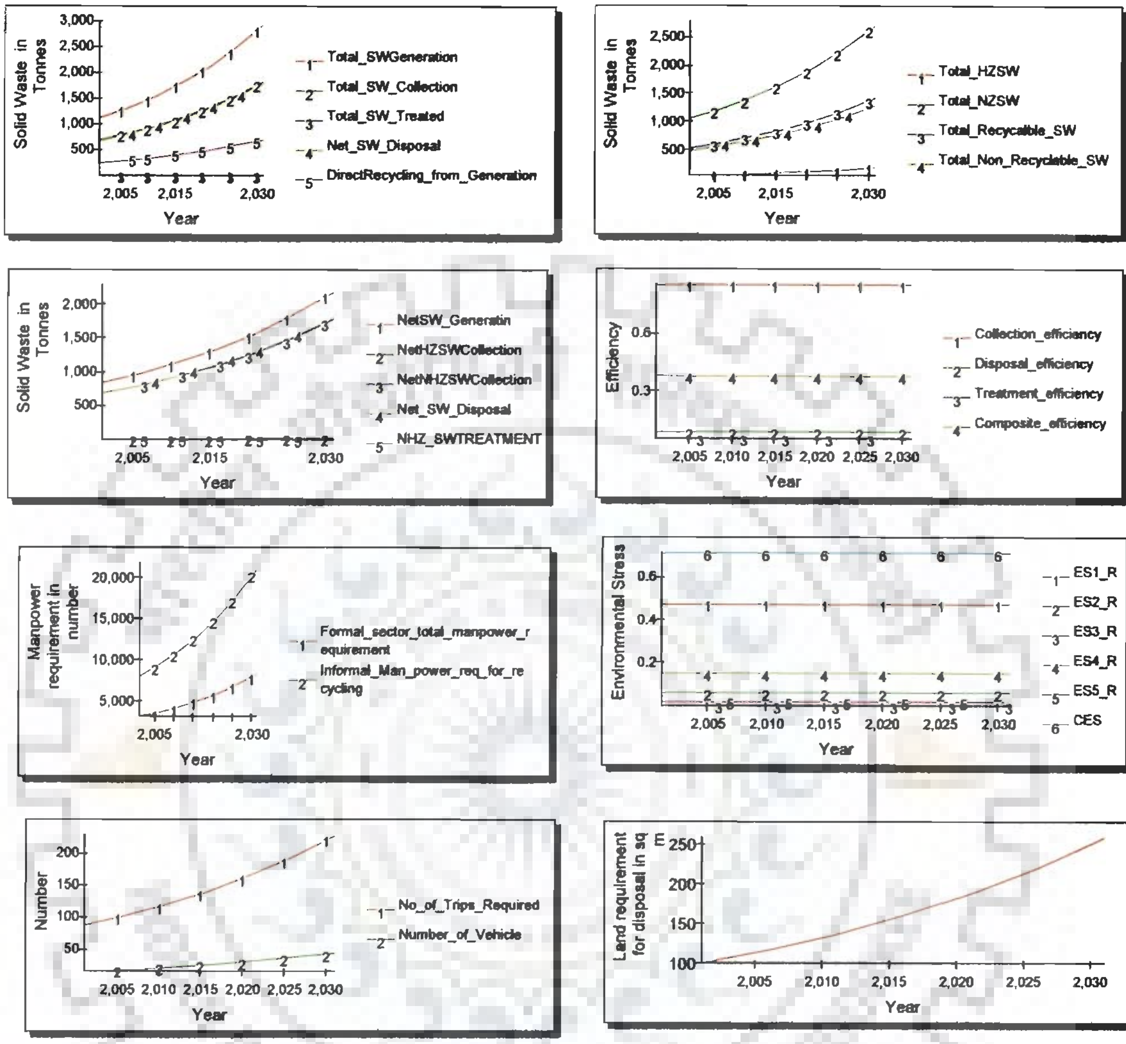

Fig. 5.35: Scenario 3

SCENARIO 4: INCREASE IN AWARENESS BY 80 PER CENT, 10 PER CENT INCREASE IN INVESTMENTS AND 60 PER CENT INCREASE IN ORGANISED SECTOR

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the existing awareness by 80 per cent, 10 per cent increase in investments and 60 per cent increase in organised sector. The model results are presented in Table 5.20 to 5.24 and Fig. 5.36.

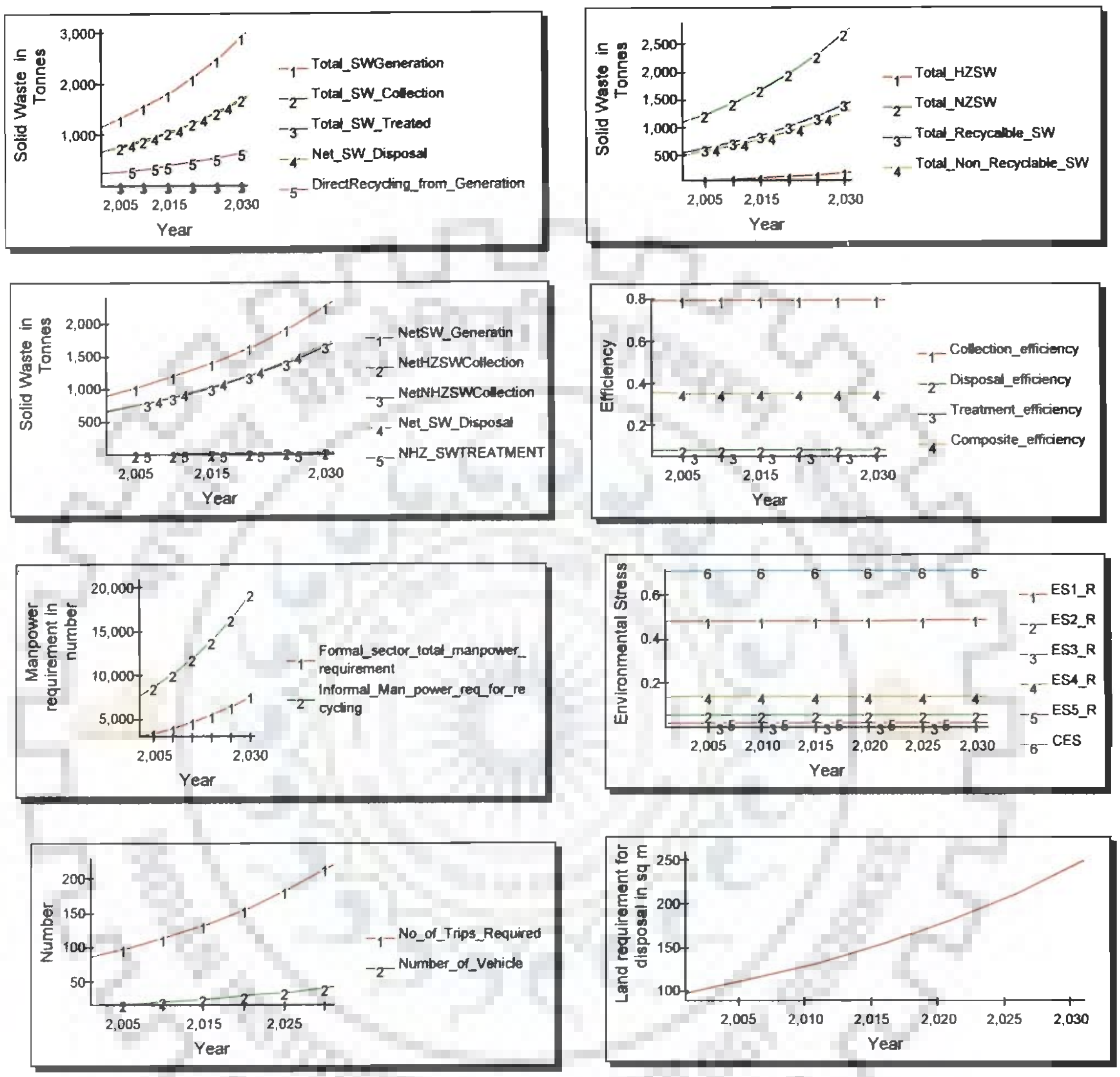

Fig. 5.36: Scenario 4

The simulation results show that the household waste generation reduces by 20.14 per cent, commercial/market waste generation reduces by 34.92 per cent, hospital and industrial waste generation reduces by 45.04 per cent and 31.00 per cent respectively, with a total reduction of 24.83 per cent. The total collection is stipulated to be 1775.6 tons/day, an increase of 4.4 per cent, while treatment increases by 38.60 per cent. The collection efficiency increases to 0.79 (56.27 per cent increase) thus making the overall composite efficiency as 0.359 (an increase of

48.96 per cent). The land requirement increases by 4.07 per cent due to increased collection of wastes. There is 10 per cent downfall in the environmental stress due to uncollected and untreated wastes (ES1). However, it is compensated by a slight increase in the environmental stresses due to collection, treatment, disposal and recycling with an overall composite environmental stress of 0.719. The employment generation in formal sector increases by 4.4 per cent whereas informal employment generation increases by a sheer 0.73 per cent.

SCENARIO 5: INCREASE IN AWARENESS BY 80 PER CENT, 20 PER CENT INCREASE IN INVESTMENTS AND 60 PER CENT INCREASE IN ORGANISED SECTOR

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the existing awareness by 80 per cent, 20 per cent increase in investments and 60 per cent increase in organised sector. The model results are presented in Table 5.20 to 5.24 and Fig. 5.37.

It is observed in the simulation results that the overall waste generation reduces by 27.45 per cent, with a maximum reduction in the hospital waste generation (50.03 per cent), followed by that in commercial/market waste generation. The total quantity of treated wastes increases by 42.89 per cent due to increased investments. Collection and recycling of wastes however, show only a slight improvement of 4.44 and 1.56 per cent respectively. The composite efficiency of solid waste management becomes 0.375, an increase of 55.60 per cent. The composite environmental stress becomes 0.72. The employment generation in formal sector increases by 4.4 per cent whereas informal employment generation increases by a sheer 1.56 per cent.

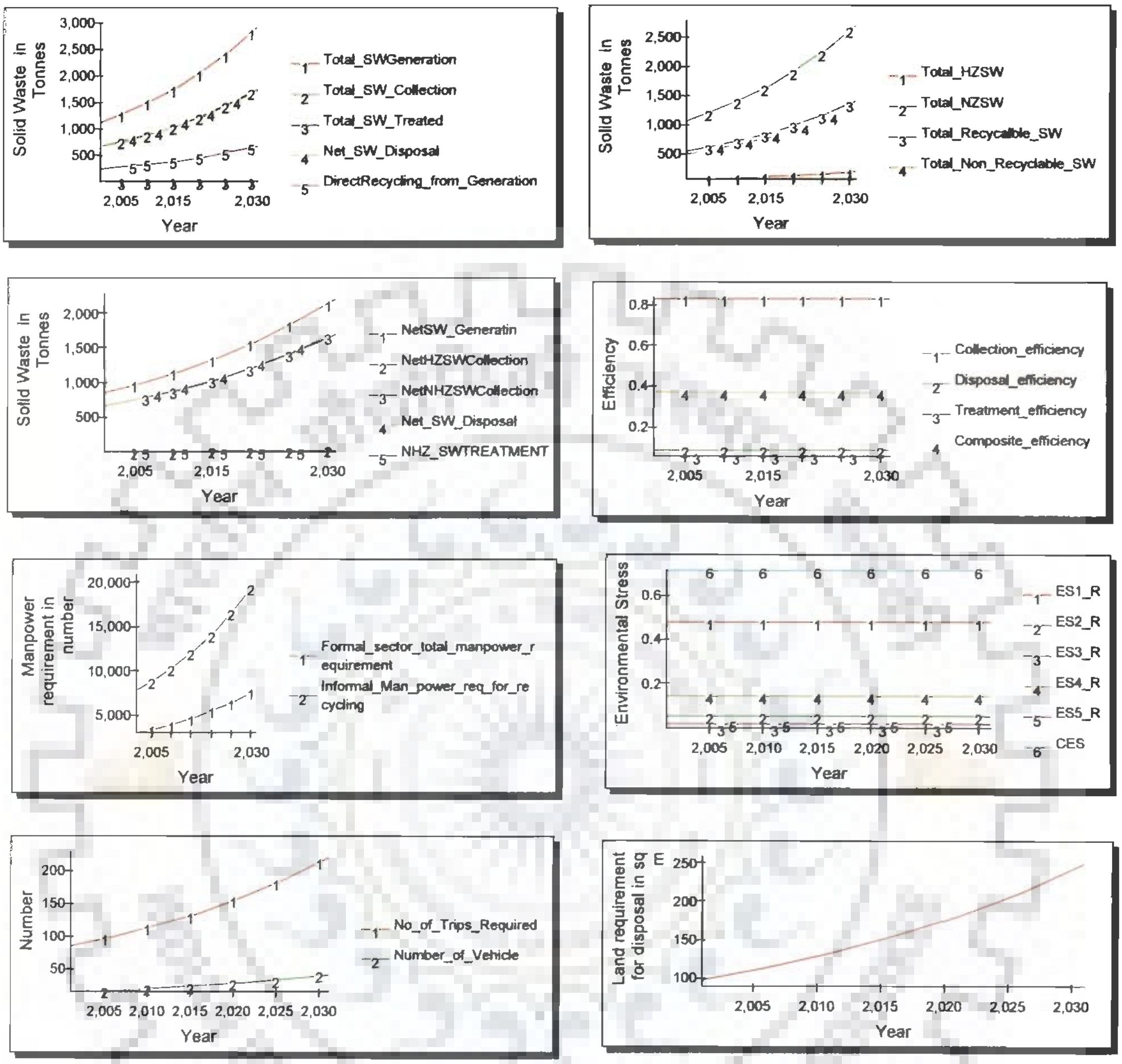

Fig. 5.37: Scenario 5

Scenario 6: Increase in Awareness By 80 per cent, 20 per cent increase in Investments and 70 per cent increase in Organised sector

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the existing awareness by 80 per cent, 20 per cent increase in investments and 70 per cent increase in organised sector. The model results are presented in Table 5.20 to 5.24 and Fig. 5.38.

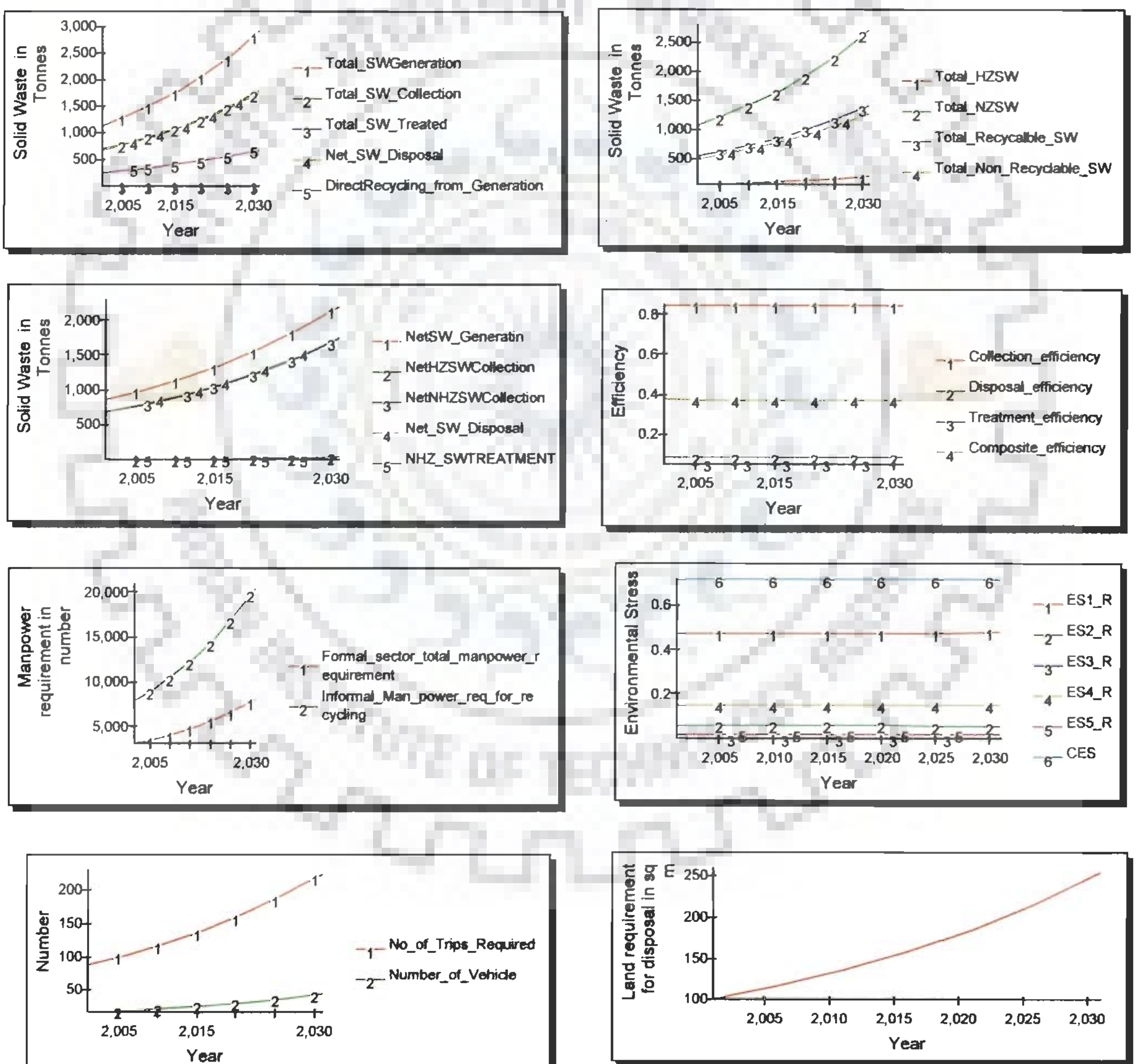

Fig. 5.38: Scenario 6

It is observed that in the simulation results, there is no change in waste reduction from that observed in Scenario 5. The overall collection increases by 6.22 per cent and recycling increases by 3.02 per cent. As a result, there is an appreciable increase in the collection efficiency and the composite solid waste management efficiency of 66.27 per cent and 57.68 per cent respectively. The land requirement for disposal also increases to 254.32 square meter, an increase of 5.76 per cent. The environmental stress due to uncollected and untreated wastes reduces by 12.70 per cent while the composite environmental stress remains high at 0.72. The total employment generation in formal sector becomes 8112 (an increase of 6.17 per cent) while that in informal sector becomes 20510, an increase of 3.01 per cent.

Scenario 7: Increase in Awareness By 80 per cent, 20 per cent increase in Investments and 80 per cent increase in Organised sector

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the existing awareness by 80 per cent, 20 per cent increase in investments and 80 per cent increase in organised sector. The model results are presented in Table 5.20 to 5.24 and Fig. 5.39.

It is observed in the simulation results that the overall waste generation reduces by 27.45 per cent, with a maximum reduction in the hospital waste generation (50.03 per cent), followed by that in commercial/market waste generation, similar to Scenario 5 and 6. The total quantity of collected wastes per day increases to 1835.88 tons, 28.25 tons of waste gets treated and recycling increases by 4.47 per cent. The composite efficiency, as a result increases by 59.75 per cent. However, it is still found to be low at 0.385. The land requirement for disposal becomes 258.49 sq meter. The Composite environmental stress remains high at 0.72. The total employment generation in formal sector becomes 8247 (an increase of 7.94 per cent) while that in informal sector becomes 20799, an increase of 4.47 per cent.

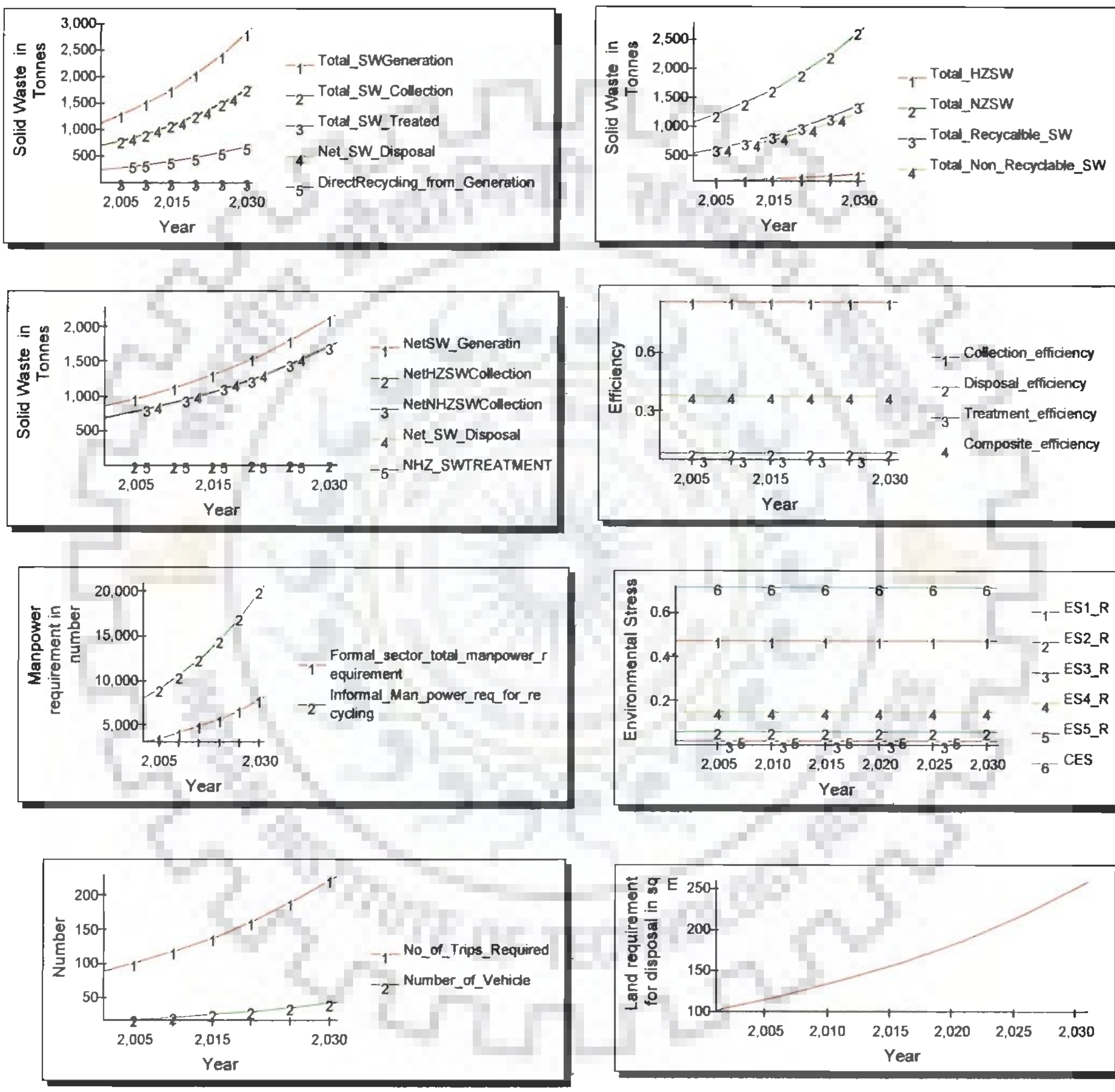

Fig. 5.39: Scenario 7

SCENARIO 8: INCREASE IN AWARENESS BY 80 PER CENT, 30 PER CENT INCREASE IN INVESTMENTS AND 80 PER CENT INCREASE IN ORGANISED SECTOR

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the existing awareness by 80 per cent, 10 per cent increase in investments and 60 per cent increase in organised sector. The model results are presented in Table 5.20 to 5.24 and Fig. 5.40.

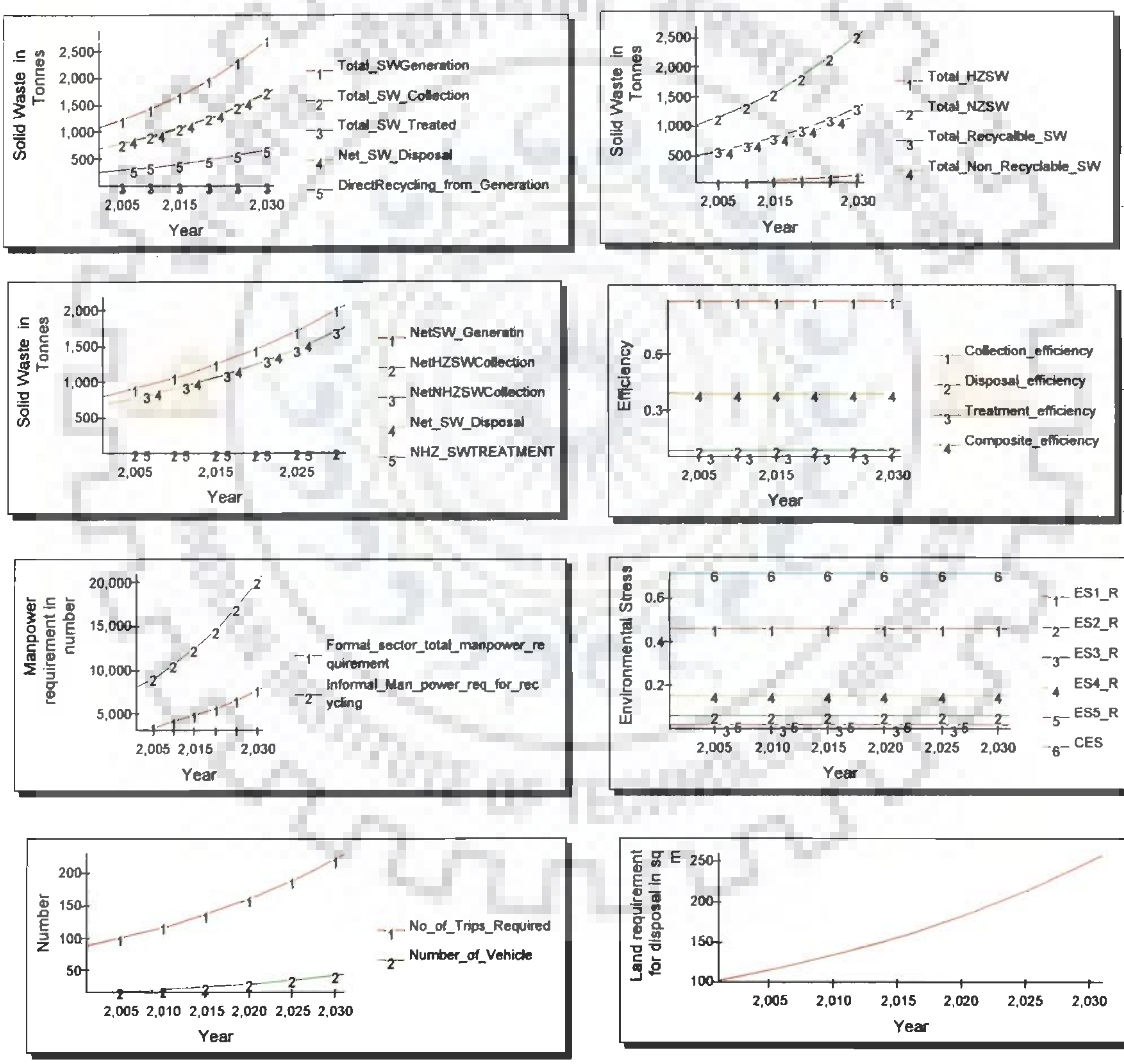

Fig. 5.40: Scenario 8

The simulation results show that the household waste generation reduces by 21.98 per cent, commercial/market waste generation reduces by 45.87 per cent, hospital and industrial waste generation by 55.02 per cent and 45.00 per cent respectively, with a total reduction of 30.07 per cent. The total collection is stipulated to be 1830.25 tons/day, an increase of 7.66 per cent, treatment increases by 57.38 per cent and recycling increases by 4.9 per cent. The total uncollected waste reduces to 993.95 tons per day. The collection efficiency increases to 0.88 (73.53 per cent increase) thus making the overall composite efficiency as 0.396 (an increase of 64.32 per cent). The land requirement for disposal of wastes increases by 7.12 per cent due to increased collection of wastes. There is 14.7 per cent downfall in the environmental stress due to uncollected and untreated wastes. However, it is compensated by a slight increase in the environmental stresses due to collection, treatment, disposal and recycling with an overall composite environmental stress of 0.721. The employment generation in formal sector increases by 7.6 per cent whereas informal employment generation increases by 4.9 per cent.

Scenario 9: Increase in Awareness By 90 per cent, 10 per cent increase in Investments and 10 per cent increase in Organised sector

The current level of awareness among the people regarding the necessity of waste reduction and the ecological and environmental impacts due to uncollected and untreated wastes is currently very low in the study area. Attempt has therefore, been made in this scenario to simulate the overall impact if the awareness level is increased to 90 per cent. The increase in investments and organised sector is kept at 10 per cent. The model results are presented in Table 5.20 to 5.24 and Fig. 5.41.

The simulation results show that the household waste generation reduces by 22.29 per cent, commercial/market waste generation reduces by 38.57 per cent, hospital and industrial waste generation by 50.03 per cent and 34.00 per cent respectively, with a total reduction of 27.43 per cent. The total collection is stipulated to be 1594.11 tons/day, a decrease of 6.23 per cent, treatment increases by 13.74 per cent and recycling decreases by 8.57 per cent. As the household waste decreases most, the informal sector which is much dependent on the household sector is affected badly and the recycling activity decreases by 8.57 per cent. The collection efficiency increases slightly as the waste generation reduces with an overall composite efficiency of 0.332 (an increase of 37.76 per cent). The land requirement for disposal of wastes almost remains same. The composite environmental stress is observed to be 0.719. The employment generation in both formal and informal sector suffers, with a decrease of 6.26 per cent in formal sector and 8.57 per cent in informal sector.

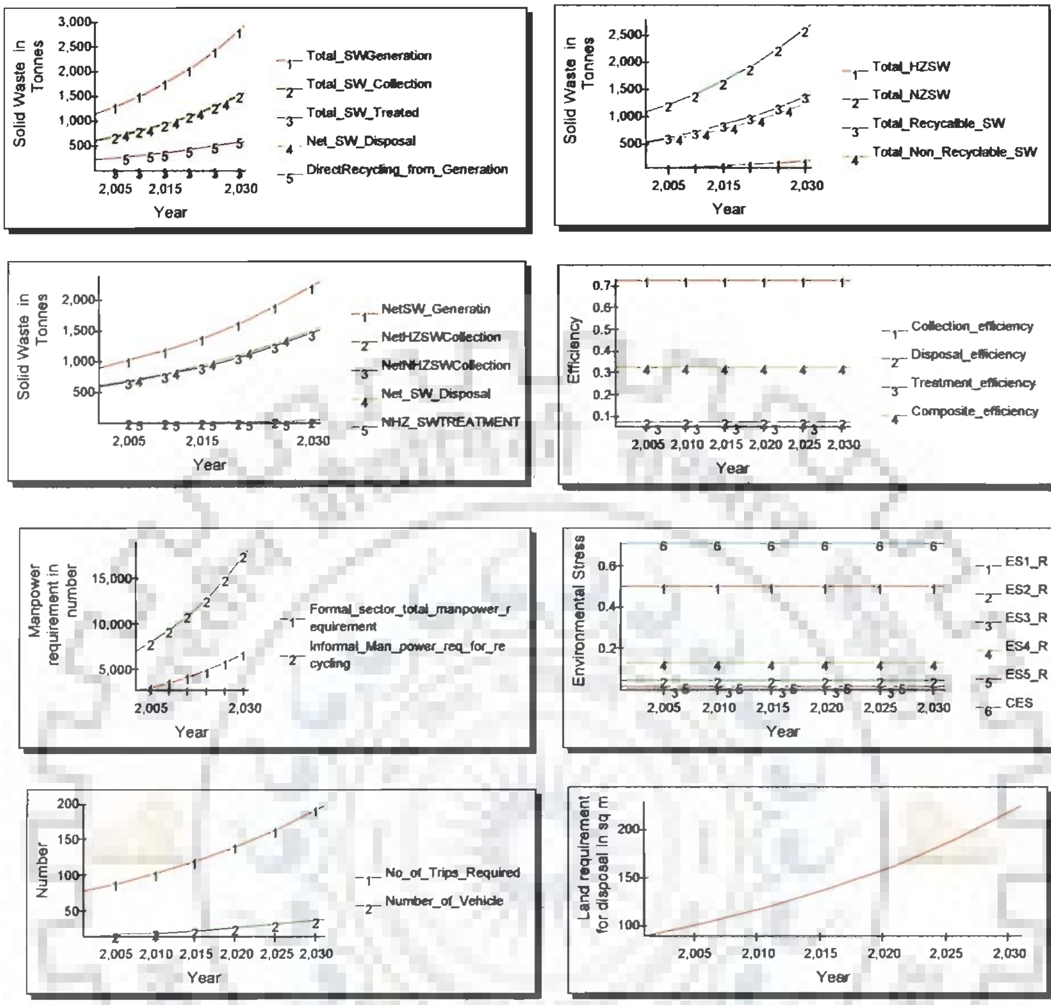

Fig. 5.41: Scenario 9

SCENARIO 10: INCREASE IN AWARENESS BY 90 PER CENT, 20 PER CENT INCREASE IN INVESTMENTS AND 50 PER CENT INCREASE IN ORGANISED SECTOR

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the existing awareness by 80 per cent, 20 per cent increase in investments and 50 per cent increase in organised sector. The model results are presented in Table 5.20 to 5.24 and Fig. 5.42.

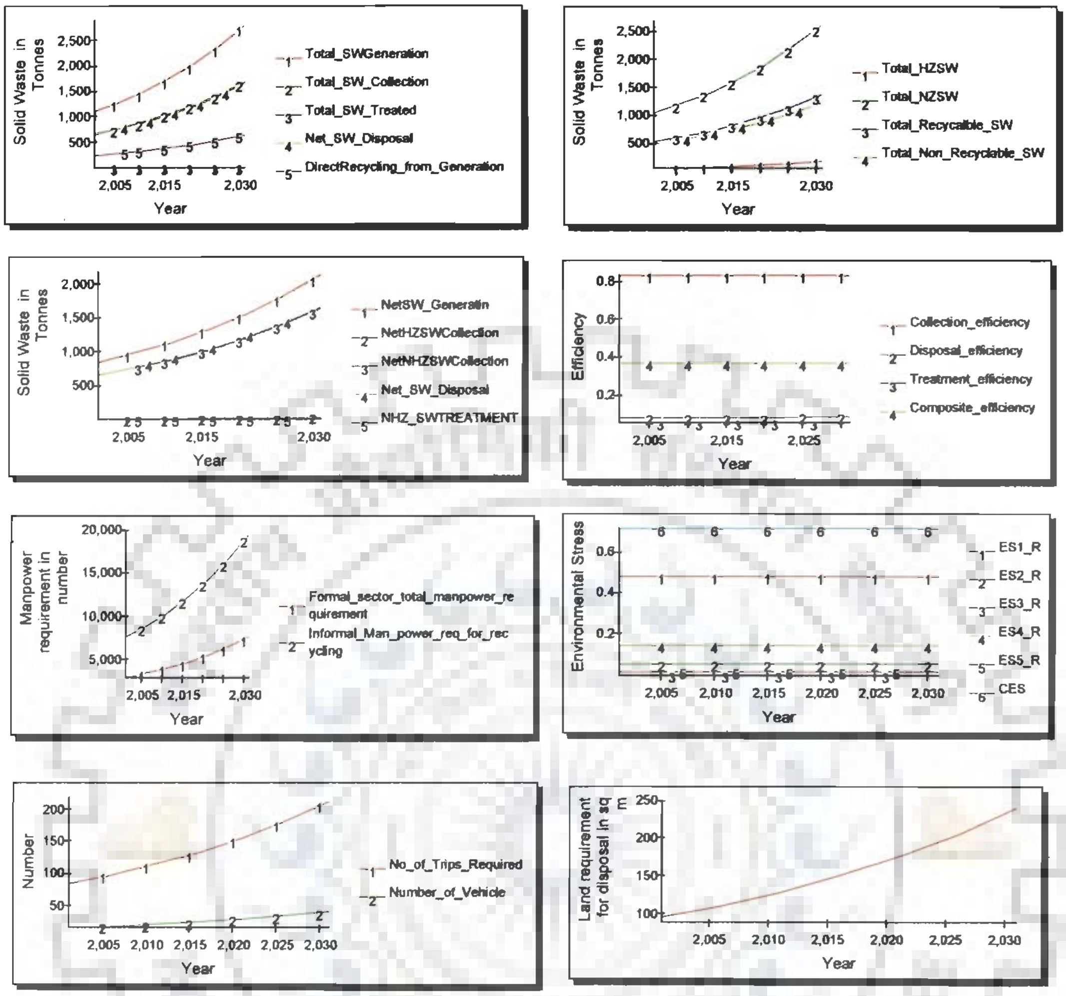

Fig. 5.42: Scenario 10

The simulation results show that the household waste generation reduces by 23.19 per cent, commercial/market waste generation reduces by 44.04 per cent, hospital and industrial waste generation by 55.02 per cent and 41.00 per cent respectively, with a total reduction of 30.04 per cent. The reduction in waste generation results in recycling being affected (a 2.06 per cent decrease). The collection efficiency increases by 63.73 per cent, treatment efficiency by 3.1 per cent while the composite solid waste management efficiency becomes 0.375 (an increase of 55.6 per cent). The composite environmental stress is observed to be 0.72. The employment generation in formal sector almost remains same at 7694 persons while there is a slight decrease of 2.06 per cent in the informal sector employment.

SCENARIO 11: INCREASE OF TREATMENT FRACTION TO 40 PERCENT, NO INCREASE IN AWARENESS , INVESTMENTS AND ORGANISED SECTOR

It is observed in the above scenarios that though there is an improvement in the composite solid waste management efficiency, the composite environmental stress remains high in all the scenarios. An attempt has therefore, been made in this scenario to increase the treatment fraction to 40 per cent. The model results are presented in Table 5.20 to 5.24 and Fig. 5.43.

The existing hazardous waste treatment fraction is 2 per cent while that of non hazardous is 1 per cent. The simulation results show that there is no change in the waste generation quantities. The treated quantity of waste increases to 680.02 tons from 18.42 tons. As a result, the composite efficiency increases to 0.512 (a 112.45 per cent increase). The land requirement for disposal of collected wastes decreases by 39.34 per cent. The composite environmental stress reduces by 9.09 per cent. The employment generation in informal sector remains unaffected while that in formal sector reduces by 5.44 per cent. Some employment will, however, be generated in the treatment sector as there is a considerable increase in the treated quantity of waste. It has however, not been considered in the simulation.

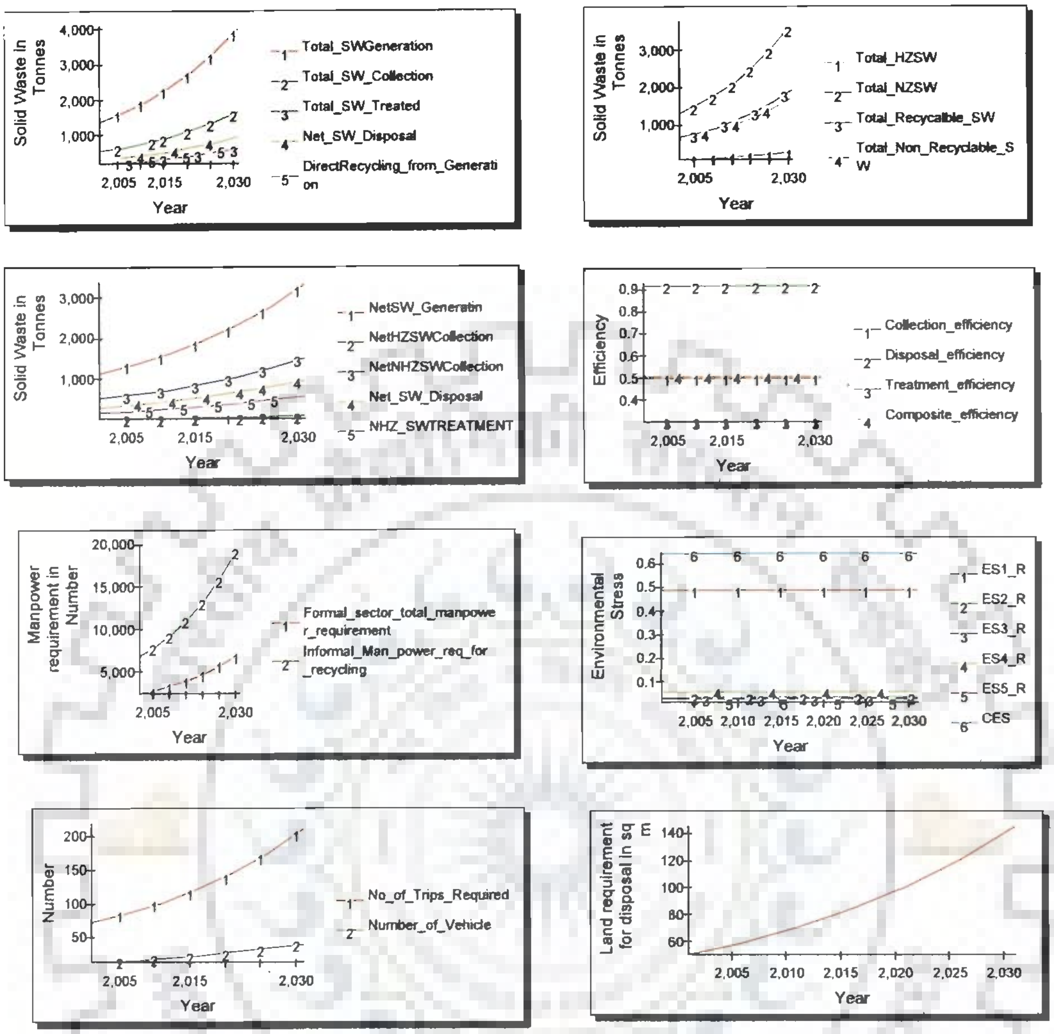

Fig. 5.43: Scenario 11

SCENARIO 12: INCREASE OF RECYCLING FRACTION TO 25 PER CENT, INCREASE OF TREATMENT FRACTION TO 40 PERCENT, NO INCREASE IN AWARENESS, INVESTMENTS AND ORGANISED SECTOR

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the existing recycling fraction to 25 per cent, treatment fraction of hazardous and non-hazardous fraction to 40 per cent, and no change in awareness, investments and organised sector. The model results are presented in Table 5.20 to 5.24 and Fig. 5.44.

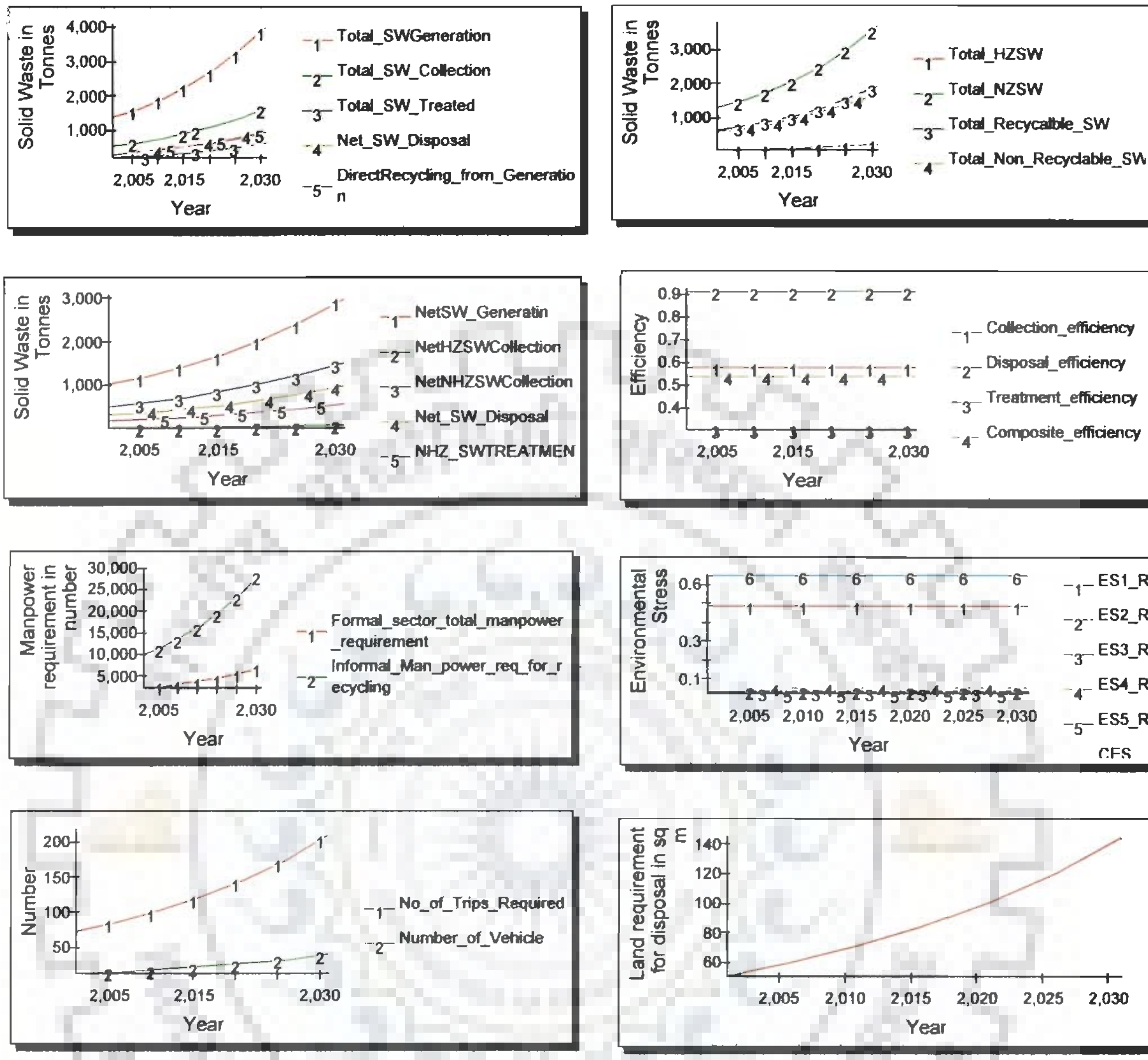

Fig. 5.44: Scenario 12

The simulation results show that there is no change in the waste generation; collection also remains same. The treated quantity becomes 680.02 tons per day, an increase of 3591 per cent. This reflects the dismal state of treatment in the base model. Recycling increases to 1009.64 tons of waste per day, an increase of 47.06 per cent. As a result, the composite efficiency of solid waste management increases to 0.542, an increase of 124.90 per cent. The composite environmental stress shows some improvement due to increased treatment and recycling and it becomes 0.658, a reduction by 7.97 per cent. The employment generation in formal sector decreases by 5.44 per cent. However, this is compensated by a drastic increase in the employment generation in the informal sector, which becomes 29279, an increase of 47.06 per cent.

SCENARIO 13: INCREASE OF RECYCLING FRACTION TO 25 PER CENT, INCREASE OF TREATMENT FRACTION TO 50 PERCENT, 80 PER CENT INCREASE IN AWARENESS, 20 PER CENT INCREASE IN INVESTMENTS AND NO INCREASE IN ORGANISED SECTOR

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the existing recycling fraction to 25 per cent, treatment fraction of hazardous and non-hazardous fraction to 50 per cent, 80 per cent increase in awareness, 20 per cent increase in investments and no increase in organised sector. The model results are presented in Table 5.20 to 5.24 and Fig. 5.45.

The simulation results show that the household waste generation reduces by 21.07 per cent, commercial/market waste generation reduces by 40.40 per cent, hospital and industrial waste generation by 50.03 per cent and 38.00 per cent respectively, with a total reduction of 27.45 per cent. The total collection is stipulated to be 1594.62 tons/day, a decrease of 6.20 per cent, treatment shows a massive increase by 5353.91 per cent and recycling increases by 36.56 per cent. The collection efficiency increases by 64.71 as the waste generation reduces, treatment efficiency increases by 1003.83 per cent with an overall composite efficiency of 0.775 (an increase of 221.58 per cent). The land requirement for disposal of wastes decreases by 64.91 per cent. The composite environmental stress is observed to be 0.595, a favourable decrease of 16.78 per cent. Employment generation in formal sector decreases by 12.66 per cent whereas that in informal sector increases appreciably by 36.56 per cent.

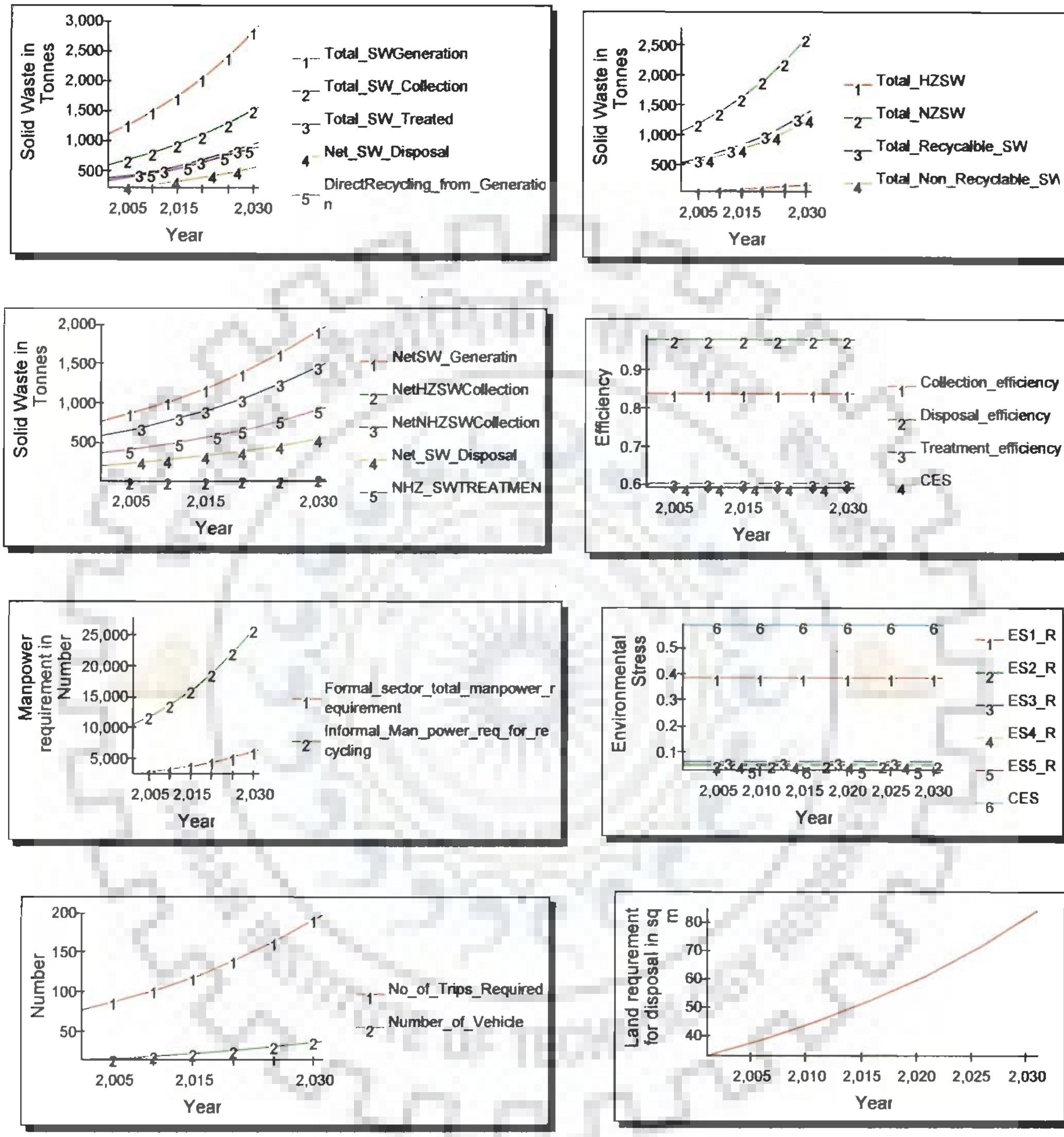

Fig. 5.45: Scenario 13

SCENARIO 14: INCREASE OF TREATMENT FRACTION TO 50 PERCENT, 80 PER CENT INCREASE IN AWARENESS, 20 PER CENT INCREASE IN INVESTMENTS AND NO INCREASE IN ORGANISED SECTOR AND RECYCLING FRACTION

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the treatment fraction of hazardous and non-hazardous fraction to 50 per cent, 80 per cent increase in awareness, 20 per cent increase in investments and no increase in organised sector and recycling fraction. The model results are presented in Table 5.20 to 5.24 and Fig. 5.46.

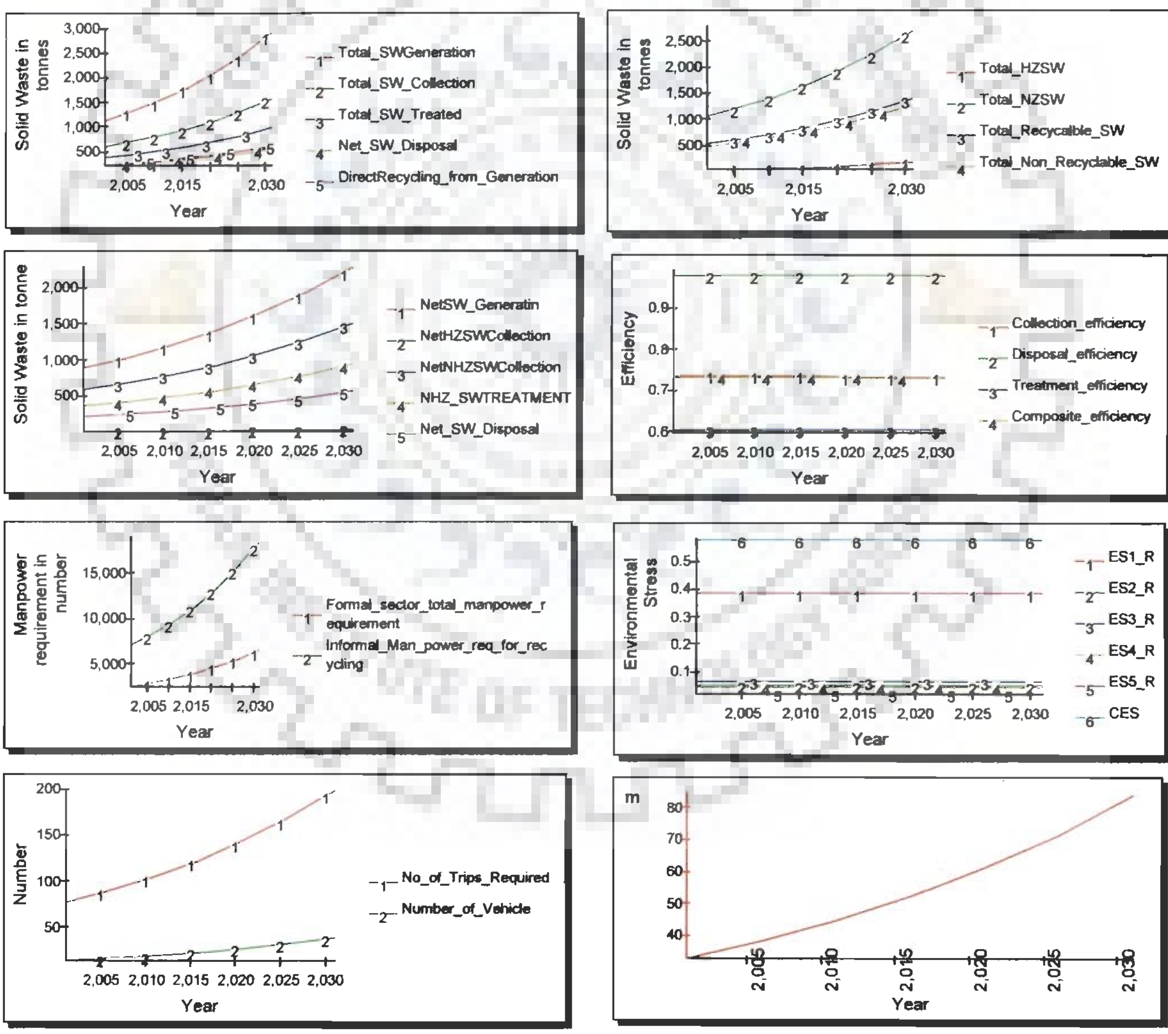

Fig. 5.46: Scenario 14

The simulation results show that the household waste generation reduces by 21.07 per cent, commercial/market waste generation reduces by 40.40 per cent, hospital and industrial waste generation by 50.03 per cent and 38.00 per cent respectively, with a total reduction of 27.45 per cent. The total collection decreases by 6.20 per cent due to reduction in the waste generation, treatment shows a massive increase by 5353.91 per cent. Recycling also decreases due to reduction in waste generation and absence of any extra efforts to promote recycling. The collection efficiency increases by 44.31 per cent as the waste generation reduces, treatment efficiency increases by 1003.83 per cent with an overall composite efficiency of 0.733 (an increase of 204.15 per cent). The land requirement for disposal decreases by 29.4 per cent due to increased treatment and reduced generation of waste. The composite environmental stress becomes 0.585 (a decrease of 18.18 per cent). There is a loss of employment generation in both formal and informal sectors by 12.66 and 7.14 per cent respectively.

SCENARIO 15: INCREASE OF TREATMENT FRACTION TO 30 PERCENT, 80 PER CENT INCREASE IN AWARENESS, 20 PER CENT INCREASE IN INVESTMENTS AND 50 PER CENT INCREASE IN ORGANISED SECTOR AND NO INCREASE IN RECYCLING FRACTION

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the treatment fraction of hazardous and non-hazardous fraction to 30 per cent, 80 per cent increase in awareness, 20 per cent increase in investments, 50 per cent increase in organised sector and no change in recycling fraction. The model results are presented in Table 5.20 to 5.24 and Fig. 5.47.

The simulation results show that the total waste generation reduces by 27.45 per cent similar to scenario 14. The collection increases by 2.67 per cent, treatment increases by 3908.20 per cent while recycling almost remains unaffected. The composite efficiency becomes 0.649 (an increase of 169.29 per cent). The land requirement for disposal decreases by 40.11 per cent. The composite environmental stress is observed to be 0.623, a decrease of 12.87 per cent. Employment generation in informal sector almost remains unchanged while that in formal sector decreases slightly by 2.04 per cent.

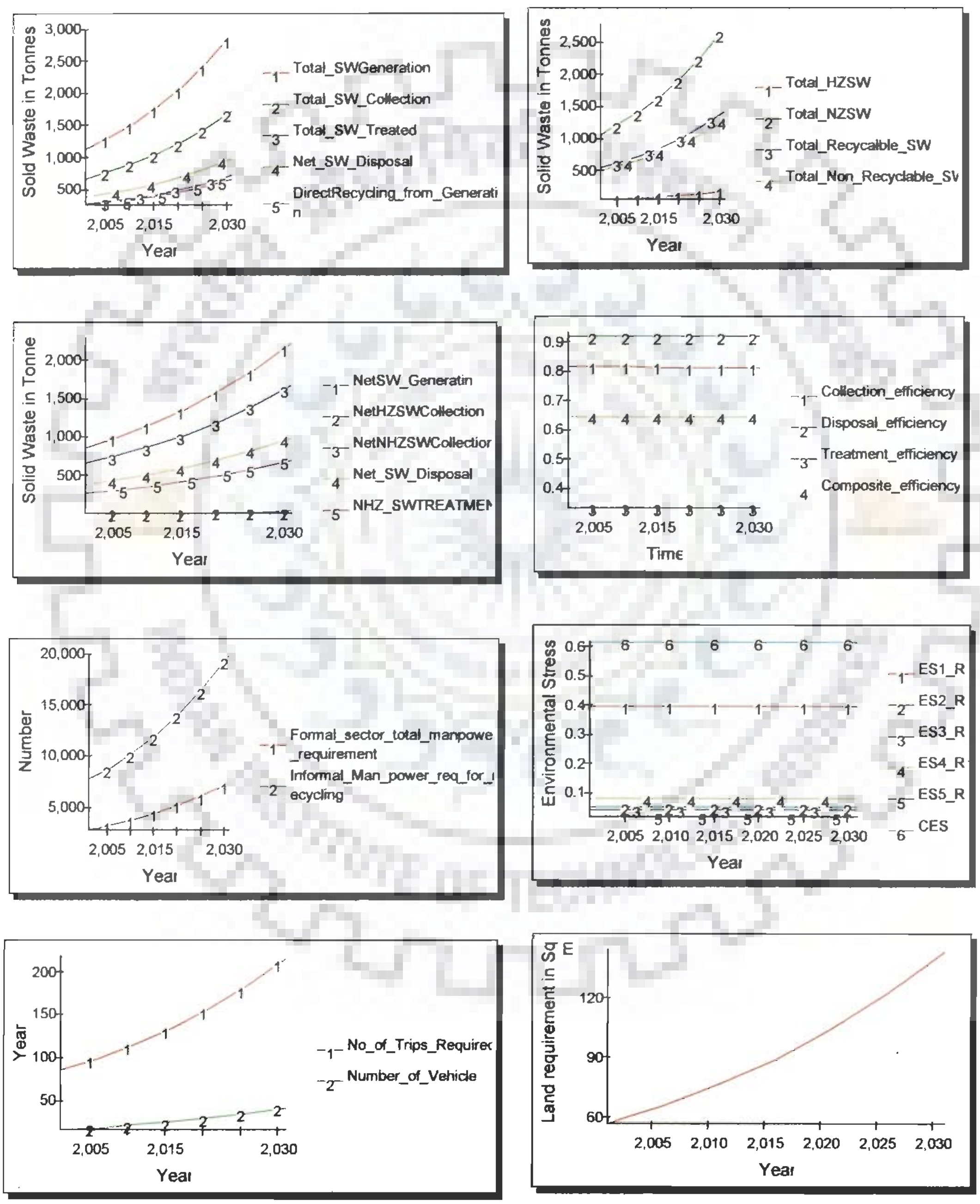

Fig. 5.47: Scenario 15

SCENARIO 16: INCREASE OF TREATMENT FRACTION TO 40 PERCENT, 80 PER CENT INCREASE IN AWARENESS, 20 PER CENT INCREASE IN INVESTMENTS AND 50 PER CENT INCREASE IN ORGANISED SECTOR AND NO INCREASE IN RECYCLING FRACTION

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the treatment fraction of hazardous and non-hazardous fraction to 40 per cent, 80 per cent increase in awareness, 20 per cent increase in investments, 50 per cent increase in organised sector and no change in recycling fraction. The model results are presented in Table 5.20 to 5.24 and Fig. 5.48.

The simulation results show that the total waste generation reduces by 27.45 per cent similar to scenario 14 and 15. The collection increases by 2.67 per cent, treatment increases by 5244.25 per cent while recycling increases by 10.84 per cent. The composite efficiency increases to a favourable 0.73. The land requirement for disposal decreases by 54.75 per cent. The composite environmental stress is observed to be 0.589, a decrease of 17.62 per cent. Employment generation in informal sector almost remains unchanged while that in formal sector decreases slightly by 3.65 per cent.

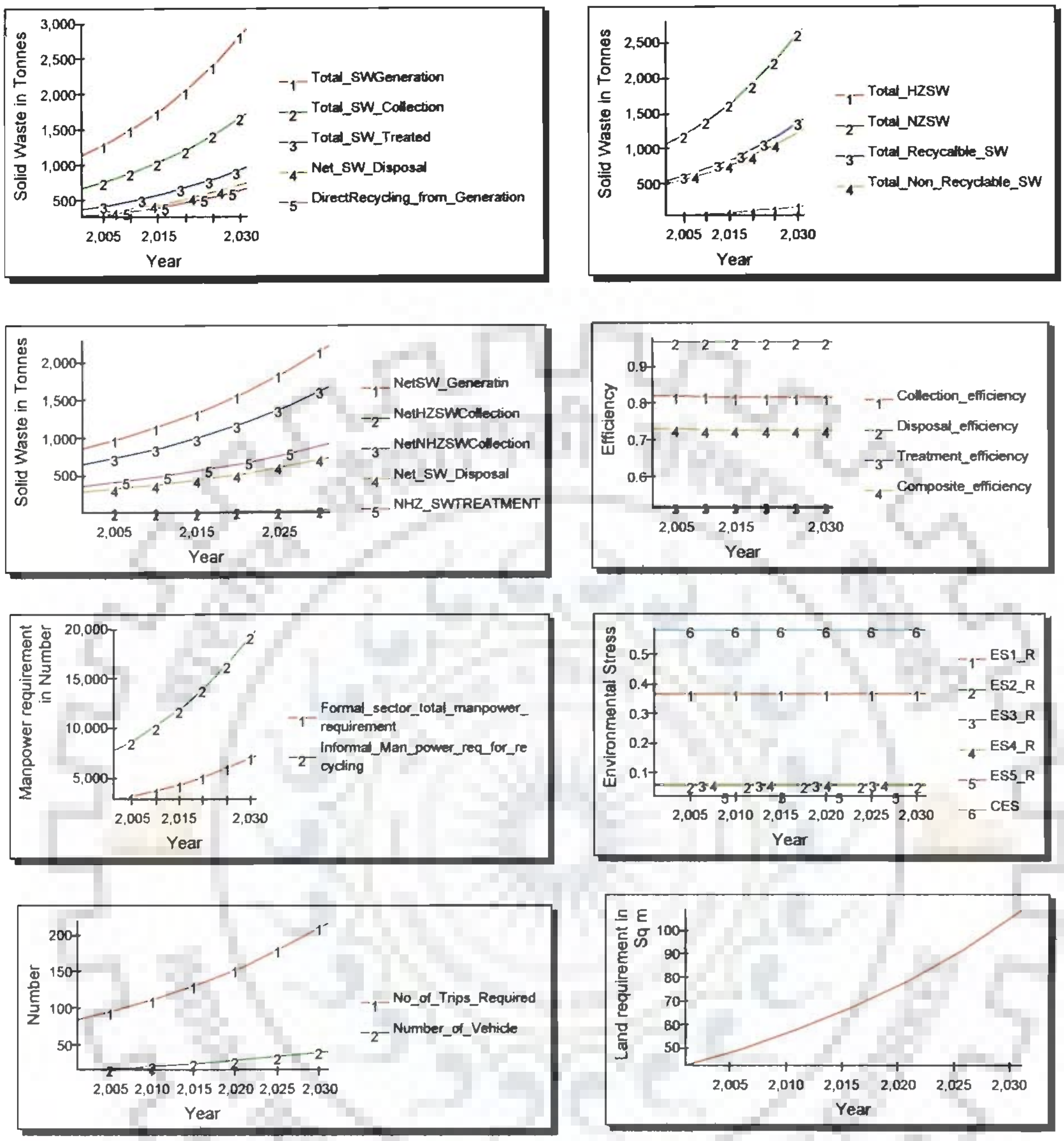

Fig. 5.48: Scenario 16

SCENARIO 17: INCREASE OF TREATMENT FRACTION TO 50 PERCENT, 80 PER CENT INCREASE IN AWARENESS, 20 PER CENT INCREASE IN INVESTMENTS AND 50 PER CENT INCREASE IN ORGANISED SECTOR AND NO INCREASE IN RECYCLING FRACTION

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the treatment fraction of hazardous and non-hazardous fraction to 40 per cent, 80 per cent increase in awareness, 20 per cent increase in investments, 50 per cent increase in organised sector and no change in recycling fraction. The model results are presented in Table 5.20 to 5.24 and Fig. 5.49.

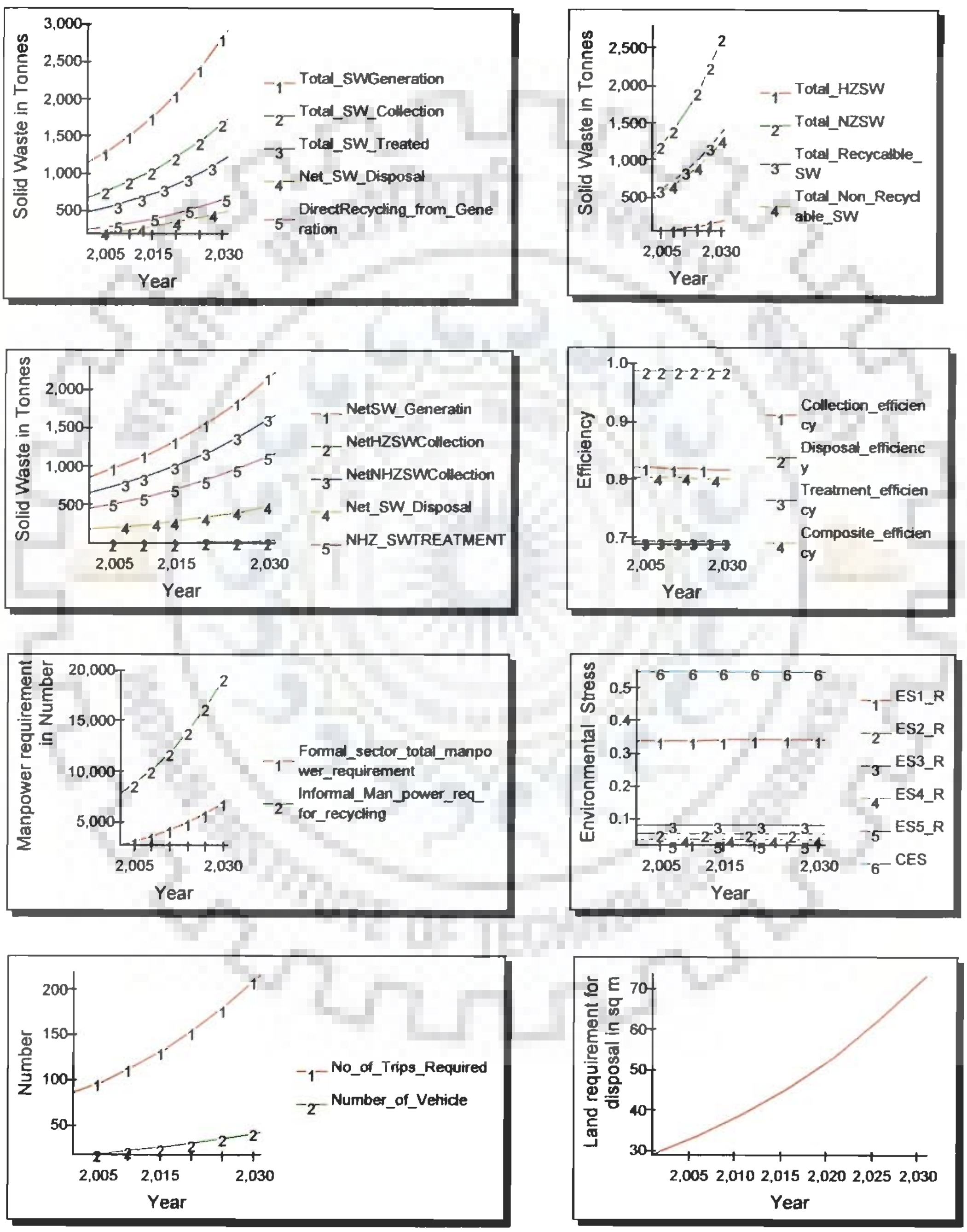

Fig. 5.49: Scenario 17

The simulation results show that the total waste generation reduces by 27.45 per cent similar to previous scenario. The total treated quantity increases to 1230.51 tons per day, an increase of 6580.29 per cent. Recycling however reduces by 25 per cent due to increased collection and treatment. The composite efficiency of solid waste management becomes 0.991, an increase of 1198.82 per cent. The land requirement for disposal reduces to 73.63 sq meters. The composite environmental stress also shows an improvement by reducing to 0.555, a decrease of 22.38 per cent. Employment generation in both the informal and formal almost remains unaffected.

SCENARIO 18: INCREASE OF TREATMENT FRACTION TO 50 PERCENT, 80 PER CENT INCREASE IN AWARENESS, 20 PER CENT INCREASE IN INVESTMENTS AND 80 PER CENT INCREASE IN ORGANISED SECTOR AND NO INCREASE IN RECYCLING FRACTION

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the treatment fraction of hazardous and non-hazardous fraction to 40 per cent, 80 per cent increase in awareness, 20 per cent increase in investments, 80 per cent increase in organised sector and no change in recycling fraction. The model results are presented in Table 5.20 to 5.24 and Fig. 5.50.

The simulation results show that the total waste generation reduces by 27.45 per cent similar to previous scenario. The total collection increases to 1835.88 tons per day, treatment increases to 1376.91 tons per day while recycling increases by 4.47 per cent. The composite efficiency of solid waste management becomes 0.843, an improvement by 249.79 per cent. The composite environmental stress further reduces to 0.536, a decrease by 25.03 per cent. The total employment generation reduces slightly by 3.58 per cent.

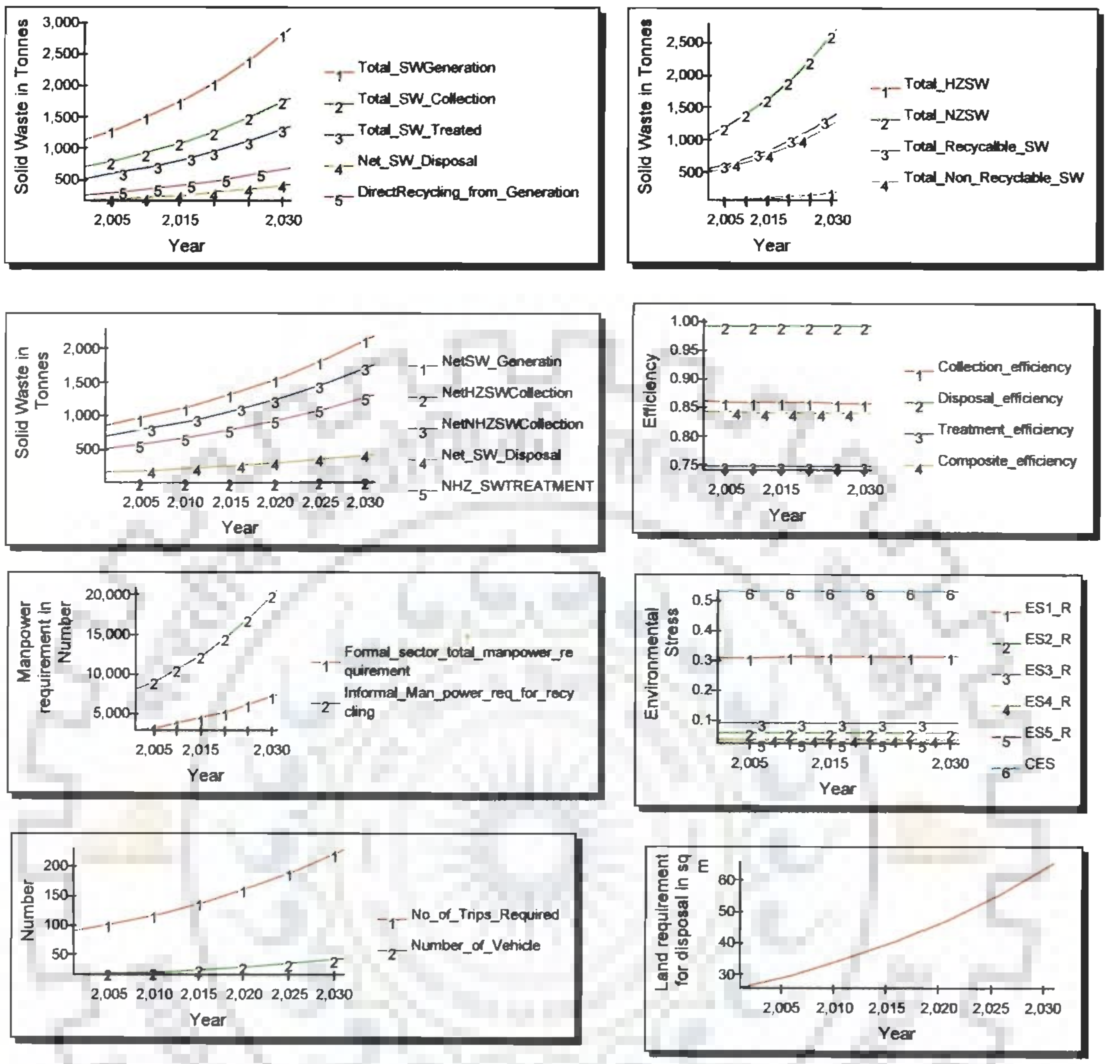

Fig. 5.50: Scenario 18

SCENARIO 19: INCREASE OF RECYCLING FRACTION TO 25 PER CENT, INCREASE OF TREATMENT FRACTION TO 40 PER CENT, 80 PER CENT INCREASE IN AWARENESS, 20 PER CENT INCREASE IN INVESTMENTS AND 50 PER CENT INCREASE IN ORGANISED SECTOR

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the existing recycling fraction to 25 per cent, treatment fraction of hazardous and non-hazardous fraction to 40 per cent, 80 per cent increase in awareness, 20 per cent increase in investments and 50 per cent increase in organised sector. The model results are presented in Table 5.20 to 5.24 and Fig. 5.51.

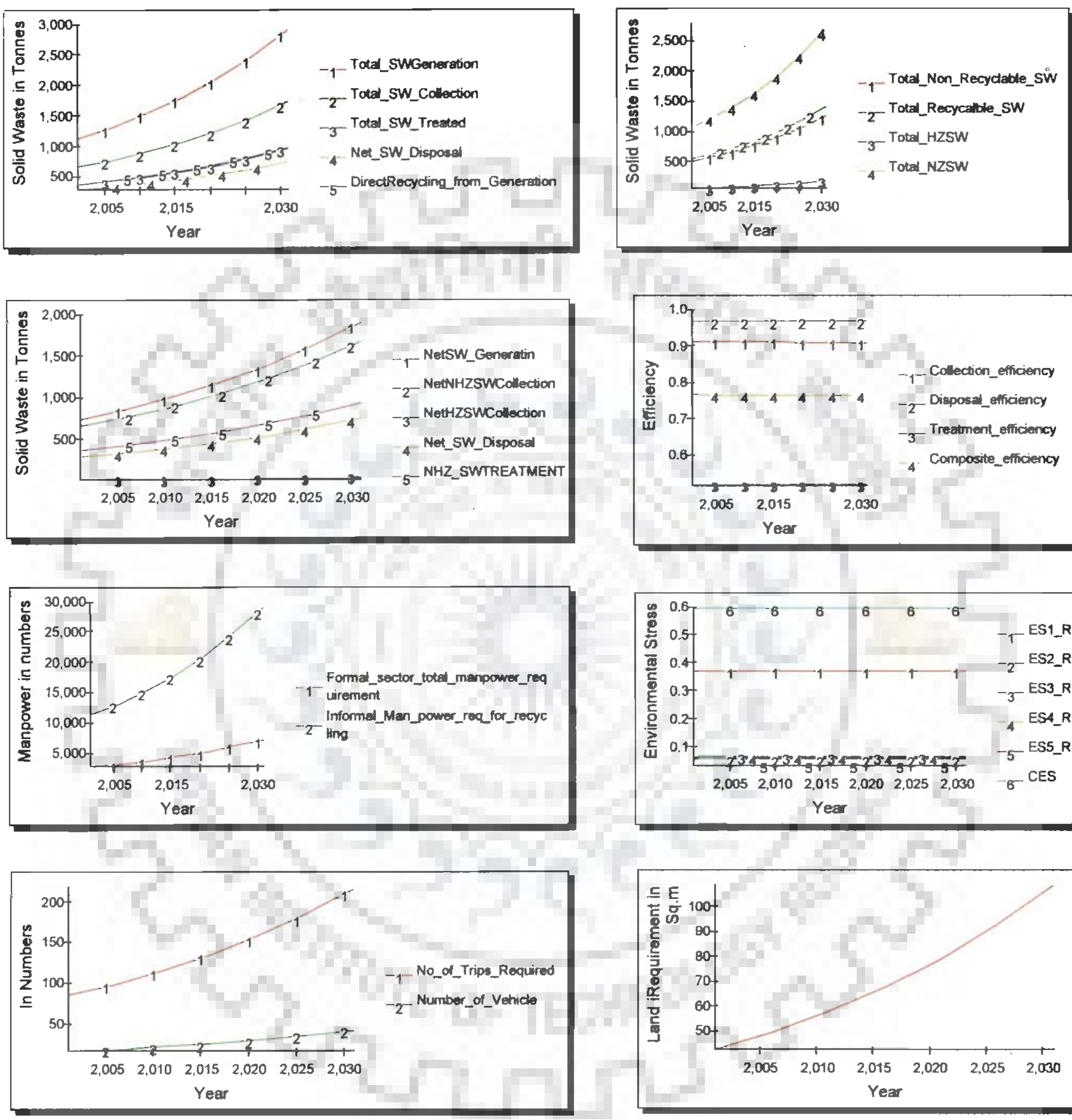

Fig. 5.51: Scenario 19

The simulation results show that the total waste generation reduces by 27.45 per cent similar to previous scenario. The total collection becomes 1745.41 tons per day, while treatment becomes 984.41 tons (an increase by 5244.25 per cent). The composite efficiency increases to 0.768, an overall improvement by 218.67 per cent. The composite environmental stress reduces to 0.6. The employment generation in informal sector shows an appreciable improvement by 47.23 per cent.

SCENARIO 20: INCREASE OF RECYCLING FRACTION TO 25 PER CENT, INCREASE OF TREATMENT FRACTION TO 40 PERCENT, 80 PER CENT INCREASE IN AWARENESS, 20 PER CENT INCREASE IN INVESTMENTS AND 80 PER CENT INCREASE IN ORGANISED SECTOR

This scenario attempts to simulate the impact on overall solid waste management system of Kanpur city by increasing the existing recycling fraction to 25 per cent, treatment fraction of hazardous and non-hazardous fraction to 40 per cent, 80 per cent increase in awareness, 20 per cent increase in investments and 80 per cent increase in organised sector. The model results are presented in Table 5.20 to 5.24 and Fig. 5.52.

The simulation results show that the total waste generation reduces by 27.45 per cent similar to previous scenario. The total collection is stipulated to be 1835.88 tons/day, an increase of 7.99 per cent, treatment shows a massive increase by 5880.08 per cent and recycling increases by 53.63 per cent. The collection efficiency increases by 87.45 per cent as the waste generation reduces, treatment efficiency increases by 938.25 per cent with an overall composite efficiency of 0.807 (an increase of 234.85 per cent). The land requirement for disposal of wastes decreases by 56.33 per cent. The composite environmental stress is observed to be 0.586, a favourable decrease by 18.04 per cent. The employment generation in formal sector almost remains unaffected while that in informal sector increases by 53.63 per cent.

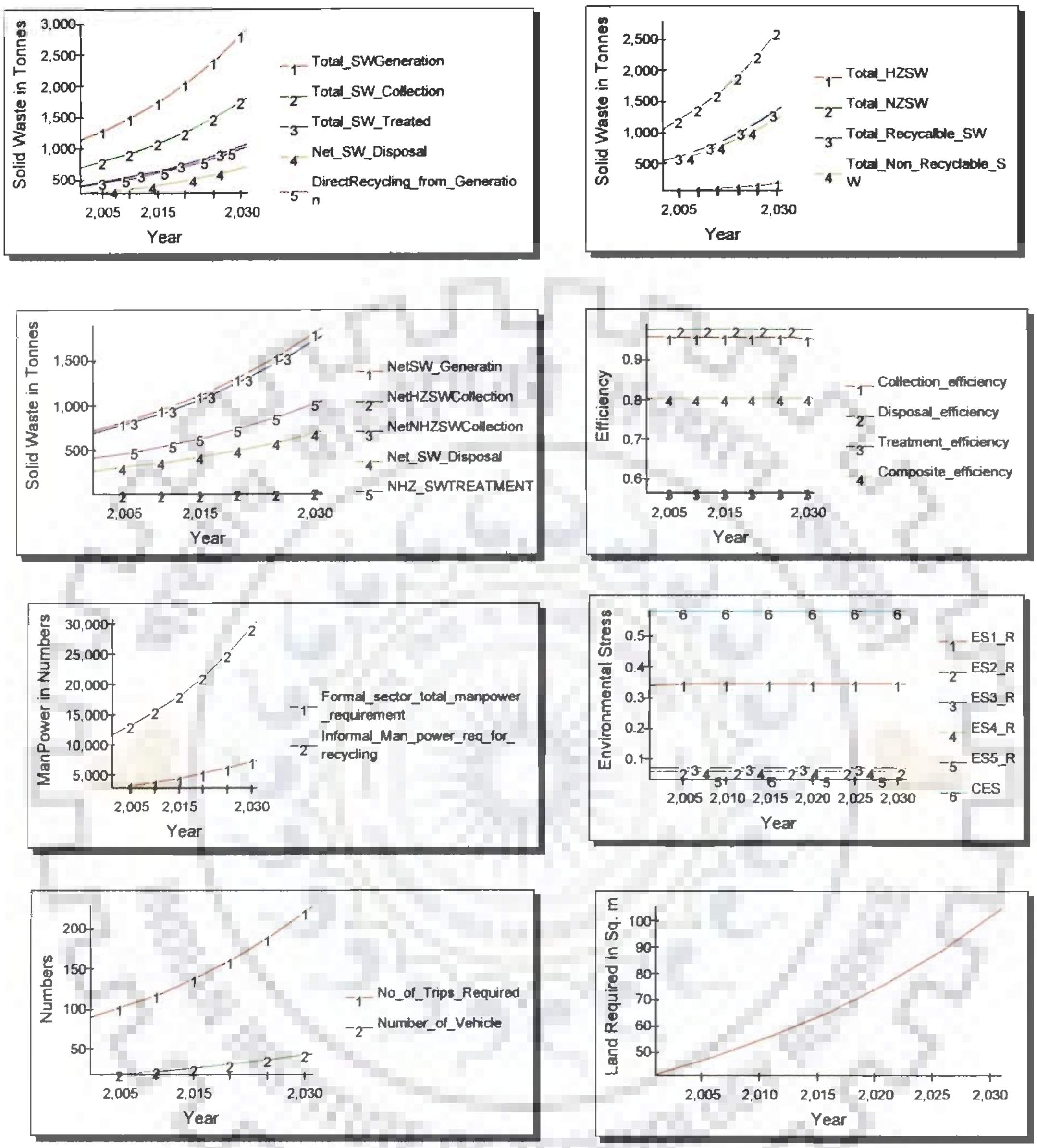

Fig. 5.52 Scenario 20

Table 5.20: Scenarios and Projected Results

S. No.	Scenarios With growth rate of control parameters (per cent)		HH gen	Per cent variation	Com. gen	Per cent variation	Hosp gen	Per cent variation	Ind. Gen	Per cent variation
1		Projected Year Result	2662.52		969.33		17.63		392.19	
2	S_1	RCF=0,HZTF=0.02, NHZTF=0.01, 0A+0I+0Org	2662.52	0	969.33	0	17.63	0.00	392.19	0
3	S_2	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.3A+0.3I+0 Org	2377.32	-10.71	701.81	-27.60	12.34	-30.01	274.53	-30.00
4	S_3	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.7A+0.3I+0.7Org	2134.57	-19.83	560.07	-42.22	8.81	-50.03	227.47	-42.00
5	S_4	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.8A+0.1I+0.6Org	2126.29	-20.14	630.86	-34.92	9.69	-45.04	270.61	-31.00
6	S_5	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.6Org	2101.64	-21.07	577.75	-40.40	8.81	-50.03	243.16	-38.00
7	S_6	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.7Org	2101.64	-21.07	577.75	-40.40	8.81	-50.03	243.16	-38.00
8	S_7	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.8 Org	2101.64	-21.07	577.75	-40.40	8.81	-50.03	243.16	-38.00
9	S_8	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.3I+0.8 Org	2077.22	-21.98	524.73	-45.87	7.93	-55.02	215.71	-45.00
10	S_9	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.9A+0.1I+0.1 Org	2069.13	-22.29	595.45	-38.57	8.81	-50.03	258.85	-34.00
11	S_{10}	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.9A+0.2I+0.5 Org	2045.03	-23.19	542.4	-44.04	7.93	-55.02	231.39	-41.00
12	S_{11}	RCF=0.17,HZTF=0.4, NHZTF=0.4,0A+0I+0Org	2662.52	0.00	969.33	0.00	17.63	0.00	392.19	0.00
13	S_{12}	RCF=0.25,HZTF=0.4,NHZTF=0.4,0A+0I+0Org	2662.52	0.00	969.33	0.00	17.63	0.00	392.19	0.00
14	S_{13}	RCF=0.25,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0Org	2101.64	-21.07	577.75	-40.40	8.81	-50.03	243.16	-38.00
15	S_{14}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0Org	2101.64	-21.07	577.75	-40.40	8.81	-50.03	243.16	-38.00
16	S_{15}	RCF=0.17,HZTF=0.3, NHZTF=0.3,0.8A+0.2I+0.5Org	2101.64	-21.07	577.75	-40.40	8.81	-50.03	243.16	-38.00
17	S_{16}	RCF=0.17,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.5Org	2101.64	-21.07	577.75	-40.40	8.81	-50.03	243.16	-38.00
18	S_{17}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0.5Org	2101.64	-21.07	577.75	-40.40	8.81	-50.03	243.16	-38.00
19	S_{18}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0.8Org	2101.64	-21.07	577.75	-40.40	8.81	-50.03	243.16	-38.00
20	S_{19}	RCF=0.25,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.5Org	2101.64	-21.07	577.75	-40.40	8.81	-50.03	243.16	-38.00
21	S_{20}	RCF=0.25,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.8Org	2101.64	-21.07	577.75	-40.40	8.81	-50.03	243.16	-38.00

Note: RCF-Recycling fraction; HZTF-Hazardous Treatment fraction; NHZTF-Non-hazardous treatment fraction, A-awareness, I-Investment and Org-Organised sector

Table 5.21: Scenarios and Projected Results

S. No.	Scenarios With growth rate of control parameters (per cent)		Total Waste gen	Per cent variation	Total HZ waste	Per cent variation	Total NHZ waste	Per cent variation
1		Projected Year Result	4038.58		303		3735.58	
2	S_1	RCF=0,HZTF=0.02, NHZTF=0.01, 0A+0I+0Org	4038.58	0	303	0.00	3735.58	0.00
3	S_2	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.3A+0.3I+0 Org	3363.84	-16.71	238.24	-21.37	3125.6	-16.33
4	S_3	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.7A+0.3I+0.7Org	2929.37	-27.47	204.15	-32.62	2725.22	-27.05
5	S_4	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.8A+0.1I+0.6Org	3035.76	-24.83	220.92	-27.09	2814.84	-24.65
6	S_5	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.6Org	2929.81	-27.45	208.35	-31.24	2721.46	-27.15
7	S_6	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.7Org	2929.81	-27.45	208.35	-31.24	2721.46	-27.15
8	S_7	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.8 Org	2929.81	-27.45	208.35	-31.24	2721.46	-27.15
9	S_8	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.3I+0.8 Org	2824.19	-30.07	195.8	-35.38	2628.39	-29.64
10	S_9	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.9A+0.1I+0.1 Org	2930.69	-27.43	212.57	-29.84	2718.12	-27.24
11	S_{10}	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.9A+0.2I+0.5 Org	2825.36	-30.04	200.04	-33.98	2625.32	-29.72
12	S_{11}	RCF=0.17,HZTF=0.4, NHZTF=0.4,0A+0I+0Org	4038.58	0.00	303	0.00	3735.58	0.00
13	S_{12}	RCF=0.25,HZTF=0.4,NHZTF=0.4,0A+0I+0Org	4038.58	0.00	303	0.00	3735.58	0.00
14	S_{13}	RCF=0.25,HZTF=0.5,NHZTF=0.5,0.8A+0.2I+0Org	2929.81	-27.45	208.35	-31.24	2721.46	-27.15
15	S_{14}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0Org	2929.81	-27.45	208.35	-31.24	2721.46	-27.15
16	S_{15}	RCF=0.17,HZTF=0.3,NHZTF=0.3,0.8A+0.2I+0.5Org	2929.81	-27.45	208.35	-31.24	2721.46	-27.15
17	S_{16}	RCF=0.17,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.5Org	2929.81	-27.45	208.35	-31.24	2721.46	-27.15
18	S_{17}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0.5Org	2929.81	-27.45	208.35	-31.24	2721.46	-27.15
19	S_{18}	RCF=0.17,HZTF=0.5,NHZTF=0.5,0.8A+0.2I+0.8Org	2929.81	-27.45	208.35	-31.24	2721.46	-27.15
20	S_{19}	RCF=0.25,HZTF=0.4,NHZTF=0.4,0.8A+0.2I+0.5Org	2929.81	-27.45	208.35	-31.24	2721.46	-27.15
21	S_{20}	RCF=0.25,HZTF=0.4,NHZTF=0.4,0.8A+0.2I+0.8Org	2929.81	-27.45	208.35	-31.24	2721.46	-27.15

Note: RCF-Recycling fraction; HZTF-Hazardous Treatment fraction; NHZTF-Non-hazardous treatment fraction, A-awareness, I-Investment and Org-Organised sector

Table 5.22: Scenarios and Projected Results

S. No.	Scenarios With growth rate of control parameters (per cent)		Collection	Per cent variation	Treatment	Per cent variation	Uncollected	Per cent variation	Recycling	Per cent variation
1		Projected Year Result	1700.04		18.42		2338.53		686.56	
2	S_1	RCF=0,HZTF=0.02, NHZTF=0.01, 0A+0I+0Org	1700.04	0.00	18.42	0.00	2338.53	0.00	0	-100.0
3	S_2	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.3A+0.3I+0 Org	1727.14	1.59	21.93	19.06	1636.70	-30.01	709.1	3.28
4	S_3	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.7A+0.3I+0.7Org	1837.40	8.08	28.26	53.42	1091.98	-53.30	727.07	5.90
5	S_4	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.1I+0.6Org	1775.60	4.44	25.53	38.60	1260.16	-46.11	691.55	0.73
6	S_5	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.6Org	1775.57	4.44	26.32	42.89	1154.25	-50.64	697.3	1.56
7	S_6	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.7Org	1805.73	6.22	27.28	48.10	1124.09	-51.93	707.26	3.02
8	S_7	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.8 Org	1835.88	7.99	28.25	53.37	1093.93	-53.22	717.22	4.47
9	S_8	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.3I+0.8 Org	1830.25	7.66	28.99	57.38	993.95	-57.50	720.17	4.90
10	S_9	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.9A+0.1I+0.1 Org	1594.11	-6.23	20.95	13.74	1336.58	-42.85	627.75	-8.57
11	S_{10}	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.9A+0.2I+0.5 Org	1712.6	0.74	25.21	36.86	1112.76	-52.42	672.44	-2.06
12	S_{11}	RCF=0.17,HZTF=0.4, NHZTF=0.4,0A+0I+0Org	1700.04	0.00	680.02	3591.75	2338.54	0.00	686.56	0.00
13	S_{12}	RCF=0.25,HZTF=0.4, NHZTF=0.4,0A+0I+0Org	1700.04	0.00	680.02	3591.75	2338.53	0.00	1009.64	47.06
14	S_{13}	RCF=0.25,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0Org	1594.62	-6.20	1004.61	5353.91	1335.19	-42.90	937.54	36.56
15	S_{14}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0Org	1594.62	-6.20	1004.61	5353.91	1335.19	-42.90	637.53	-7.14
16	S_{15}	RCF=0.17,HZTF=0.3, NHZTF=0.3,0.8A+0.2I+0.5Org	1745.41	2.67	738.31	3908.20	1184.4	-49.35	687.33	0.11
17	S_{16}	RCF=0.17,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.5Org	1745.41	2.67	984.41	5244.25	1184.4	-49.35	761	10.84
18	S_{17}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0.5Org	1745.41	2.67	1230.51	6580.29	1184.4	-49.35	514.9	-25.00
19	S_{18}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0.8Org	1835.88	7.99	1376.91	7375.08	1093.93	-53.22	717.22	4.47
20	S_{19}	RCF=0.25,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.5Org	1745.41	2.67	984.41	5244.25	1184.4	-49.35	1010.79	47.23
21	S_{20}	RCF=0.25,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.8Org	1835.88	7.99	1101.53	5880.08	1093.93	-53.22	1054.73	53.63

Note: RCF-Recycling fraction; HZTF-Hazardous Treatment fraction; NHZTF-Non-hazardous treatment fraction, A-awareness, I-Investment and Org-Organised sector

Table 5.23: Scenarios and Projected Results

S. No.	Scenarios With growth rate of control parameters (per cent)		Comp. effi.	Per cent variation	Land req. for disposal	Per cent variation	CES	Per cent variation
1		Projected Year Result	0.241		240.47		0.715	
2	S_1	RCF=0,HZTF=0.02, NHZTF=0.01, 0A+0I+0Org	0.193	-19.92	240.47	0.00	0.698	-2.38
3	S_2	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.3A+0.3I+0 Org	0.315	30.71	243.84	1.40	0.718	0.42
4	S_3	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.7A+0.3I+0.7Org	0.386	60.17	258.71	7.59	0.721	0.84
5	S_4	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.8A+0.1I+0.6Org	0.359	48.96	250.26	4.07	0.719	0.56
6	S_5	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.6Org	0.375	55.60	250.14	4.02	0.720	0.70
7	S_6	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.7Org	0.38	57.68	254.32	5.76	0.720	0.70
8	S_7	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.8 Org	0.385	59.75	258.49	7.49	0.721	0.84
9	S_8	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.3I+0.8 Org	0.396	64.32	257.58	7.12	0.721	0.84
10	S_9	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.9A+0.1I+0.1 Org	0.332	37.76	224.96	-6.45	0.719	0.56
11	S_{10}	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.9A+0.2I+0.5 Org	0.375	55.60	241.3	0.35	0.720	0.70
12	S_{11}	RCF=0.17,HZTF=0.4, NHZTF=0.4,0A+0I+0Org	0.512	112.45	145.86	-39.34	0.650	-9.09
13	S_{12}	RCF=0.25,HZTF=0.4, NHZTF=0.4,0A+0I+0Org	0.542	124.90	145.86	-39.34	0.658	-7.97
14	S_{13}	RCF=0.25,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0Org	0.775	221.58	84.37	-64.91	0.595	-16.78
15	S_{14}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0Org	0.733	204.15	84.37	-64.91	0.585	-18.18
16	S_{15}	RCF=0.17,HZTF=0.3,NHZTF=0.3,0.8A+0.2I+0.5Org	0.649	169.29	144.02	-40.11	0.623	-12.87
17	S_{16}	RCF=0.17,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.5Org	0.73	202.90	108.82	-54.75	0.589	-17.62
18	S_{17}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0.5Org	0.804	233.61	73.63	-69.38	0.555	-22.38
19	S_{18}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0.8Org	0.843	249.79	65.63	-72.71	0.536	-25.03
20	S_{19}	RCF=0.25,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.5Org	0.768	218.67	108.82	-54.75	0.600	-16.08
21	S_{20}	RCF=0.25,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.8Org	0.807	234.85	105.01	-56.33	0.586	-18.04

Note: RCF-Recycling fraction; HZTF-Hazardous Treatment fraction; NHZTF-Non-hazardous treatment fraction, A-awareness, I-Investment and Org-Organised sector

Table 5.24: Scenarios and Projected Results

S. No.	Scenarios With growth rate of control parameters (per cent)		Manpower req. (Formal)	Per cent variation	Manpower req. (Informal)	Per cent variation
1		Projected Year Result	7640.99		19910.19	
2	S_1	RCF=0,HZTF=0.02, NHZTF=0.01, 0A+0I+0Org	7640.99	0.00	0	-100
3	S_2	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.3A+0.3I+0 Org	7761.16	1.57	20563.82	3.28
4	S_3	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.7A+0.3I+0.7Org	8254.16	8.02	21085.03	5.90
5	S_4	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.8A+0.1I+0.6Org	7977.43	4.40	20054.84	0.73
6	S_5	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.8A+0.2I+0.6Org	7976.9	4.40	20221.58	1.56
7	S_6	RCF=0.17, HZTF=0.02, NHZTF=0.01,0.8A+0.2I+0.7Org	8112.13	6.17	20510.46	3.01
8	S_7	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.2I+0.8 Org	8247.35	7.94	20799.34	4.47
9	S_8	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.8A+0.3I+0.8 Org	8221.62	7.60	20884.92	4.90
10	S_9	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.9A+0.1I+0.1 Org	7163.03	-6.26	18204.87	-8.57
11	S_{10}	RCF=0.17, HZTF=0.02, NHZTF=0.01, 0.9A+0.2I+0.5 Org	7694.11	0.70	19500.62	-2.06
12	S_{11}	RCF=0.17,HZTF=0.4, NHZTF=0.4,0A+0I+0Org	7310.19	-4.33	19910.19	0.00
13	S_{12}	RCF=0.25,HZTF=0.4, NHZTF=0.4,0A+0I+0Org	7225.19	-5.44	29279.69	47.06
14	S_{13}	RCF=0.25,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0Org	6673.5	-12.66	27188.68	36.56
15	S_{14}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0Org	6673.5	-12.66	18488.3	-7.14
16	S_{15}	RCF=0.17,HZTF=0.3, NHZTF=0.3,0.8A+0.2I+0.5Org	7485.19	-2.04	19932.7	0.11
17	S_{16}	RCF=0.17,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.5Org	7362.14	-3.65	19932.7	0.11
18	S_{17}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0.5Org	7239.09	-5.26	19932.7	0.11
19	S_{18}	RCF=0.17,HZTF=0.5, NHZTF=0.5,0.8A+0.2I+0.8Org	7573.02	-0.89	20799.34	4.47
20	S_{19}	RCF=0.25,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.5Org	7362.14	-3.65	29312.8	47.23
21	S_{20}	RCF=0.25,HZTF=0.4, NHZTF=0.4,0.8A+0.2I+0.8Org	7710.71	0.91	30587.27	53.63

Note: RCF-Recycling fraction; HZTF-Hazardous Treatment fraction; NHZTF-Non-hazardous treatment fraction, A-awareness, I-Investment and Org-Organised sector

5.13 ASSESSMENT OF THE DEGREE OF INTEGRATED SUSTAINABILITY

A range of criteria are used for assessment of the degree of 'integrated sustainability'. These criteria are both quantitative and qualitative indicators. Some examples of indicators of 'integrated sustainability' are given below [189, 253]:

1. Technical: - amount of waste collected by area of the city and per source

- durability of equipment

- existence of a separate hazardous waste management system

- existence of preventive maintenance procedures

2. Environmental: - amount and percentage of waste recycled

- extent of pollution of air, soil and water (emissions, etc.)

- amount of energy and of natural resources saved through recycling

3. Financial: - degree of cost recovery

- overall cost of waste management services provided

- labour productivity (amount of waste collected per worker)

4. Socio-economic: - service coverage (percentage of citizens receiving minimum required waste collection service, e.g. twice a week)

- working conditions (number and duration of sick leaves, health complaints)

- user satisfaction with the service by area of the city

5. Institutional: - degree of formalisation of informal sectors (number of licensed CBOs, cooperatives, micro-and small-scale enterprises)

- existence of feedback mechanisms for citizens (complaint desks, etc.)

6. Policy/Legal: - degree of decentralisation of authority and funds

- height of budget earmarked for waste management

The following table (Table 5.25) attempts to assess the degree of "Integrated Sustainability" achieved in the projected year model and the various scenarios through the assessment of different indicators under the four main goals of sustainable integrated solid waste management. Based on this, an attempt has been further made to assess the achievement of various sustainability goals in various short listed scenarios. Each of the indicators has been marked as low, medium or high depending on the degree of achievement of the sub-goals. Based on these, the results of the projected year model and the scenarios are analysed and presented in Table 5.26 to 5.46.

Table 5.25: Assessment of Integrated Sustainability

S. No.	Ecological Goals	Environmental health goals	Technical goals	Socio-economic goals
1.	Reduction in Amt of waste generated	Minimise occupational health hazards (Formal sector)	Vehicle maintenance	Participation
2.	Extent of reuse/recycling	Minimise occupational health hazards (Informal sector)	New treatment facility	Cost recovery
3.	Disposal of remaining waste in controlled manner	Extent of pollution of air, water and soil	Technical improvement in recycling process	Effective monitoring, enforcement of standards
4.	Environmental stress	Amt of energy and natural resources saved through recycling	Separate handling of biomedical and hazardous waste	Employment (Formal)
5.				Employment (Informal)
6.				Legitimacy of informal sector
7.				Service coverage
8.				User satisfaction

Table 5.26: Assessment of Integrated Sustainability and Base year model

Base Model			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
Low	Medium	Low	Low
Medium	Low	Low	Low
Low	High	Low	Low
High	Medium	Low	Medium
			Medium
			Low
			Medium
			Low

Table 5.27: Assessment of Integrated Sustainability and Scenario 1

Scenario 1			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
Low	Medium	Low	Low
Low	Low	Low	Low
Low	High	Low	Low
High	Low	Low	Medium
			Low
			Low
			Medium
			Low

Table 5.28: Assessment of Integrated Sustainability and Scenario 2

Scenario 2			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
Medium	Medium	High	Medium
Medium	Low	Medium	Medium
Medium	High	Low	Low
High	Medium	Low	Medium
			Medium
			Low
			Medium
			Medium

Table 5.29: Assessment of Integrated Sustainability and Scenario 3

Scenario 3			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	High	High
Medium	Medium	Medium	Medium
Medium	High	Low	Medium
High	Medium	Medium	Medium
			Medium
			Medium
			Medium
			Medium

Table 5.30: Assessment of Integrated Sustainability and Scenario 4

Scenario 4			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Medium	Low	Medium
Low	High	Low	Low
High	Medium	Medium	Medium
			Medium
			Medium
			Medium
			Low

Table 5.31: Assessment of Integrated Sustainability and Scenario 5

Scenario 5			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Medium	Low	Medium
Medium	High	Low	Medium
High	Medium	Medium	Medium
			Medium
			Medium
			Medium
			Medium

Table 5.32: Assessment of Integrated Sustainability and Scenario 6

Scenario 6			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Medium	Low	Medium
Medium	High	Low	Medium
High	Medium	Medium	Medium
			Medium
			Medium
			Medium
			Medium

Table 5.33: Assessment of Integrated Sustainability and Scenario 7

Scenario 7			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Medium	Low	Medium
Medium	High	Medium	Medium
High	Medium	Medium	Medium
			Medium
			High
			Medium
			Medium

Table 5.34: Assessment of Integrated Sustainability and Scenario 8

Scenario 8			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	High	High
Medium	Medium	Medium	Medium
Medium	High	Medium	Medium
High	Medium	High	Medium
			Medium
			High
			Medium
			Medium

Table 5.35: Assessment of Integrated Sustainability and Scenario 9

Scenario 9			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	Medium
Medium	Low	Low	Medium
Low	High	Low	Low
High	Medium	Low	Medium
			Medium
			Low
			Medium
			Low

Table 5.36: Assessment of Integrated Sustainability and Scenario 10

Scenario 10			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Low	Low	Medium
Medium	High	Low	Medium
High	Medium	High	Medium
			Medium
			Medium
			Medium
			Medium

Table 5.37: Assessment of Integrated Sustainability and Scenario 11

Scenario 11			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
Low	Medium	Low	Low
Medium	Low	High	Low
Medium	High	Low	Low
High	Medium	Low	Medium
			Medium
			Low
			Medium
			Low

Table 5.38: Assessment of Integrated Sustainability and Scenario 12

Scenario 12			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
Low	Medium	Low	Low
High	Medium	High	Medium
Medium	High	Medium	Low
High	High	Low	Medium
			High
			High
			Medium
			Medium

Table 5.39: Assessment of Integrated Sustainability and Scenario 13

Scenario 13			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Low	Low
High	Medium	High	Medium
High	Medium	Medium	Low
Medium	High	Low	Medium
			High
			High
			Medium
			High

Table 5.40: Assessment of Integrated Sustainability and Scenario 14

Scenario 14			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Low	High	Medium
High	Medium	Low	Medium
Medium	Medium	High	Medium
			Medium
			Low
			Medium
			Medium

Table 5.41: Assessment of Integrated Sustainability and Scenario 15

Scenario 15			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Low	Medium	Medium
High	Medium	Low	Medium
Medium	Medium	High	Medium
			Medium
			Medium
			Medium
			Medium

Table 5.42: Assessment of Integrated Sustainability and Scenario 16

Scenario 16			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Low	High	Medium
High	Medium	Low	Medium
Medium	Medium	High	Medium
			Medium
			Medium
			Medium
			Medium

Table 5.43: Assessment of Integrated Sustainability and Scenario 17

Scenario 17			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Low	High	Medium
High	Medium	Low	Medium
Medium	Medium	High	Medium
			Medium
			Medium
			Medium
			Medium

Table 5.44: Assessment of Integrated Sustainability and Scenario 18

Scenario 18			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Low	High	Medium
High	Medium	Medium	Medium
Medium	Medium	High	Medium
			Medium
			High
			High
			High

Table 5.45: Assessment of Integrated Sustainability and Scenario 19

Scenario 19			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Medium	High	Medium
High	Medium	Medium	Medium
Medium	Medium	High	Medium
			High
			High
			High
			High

Table 5.46: Assessment of Integrated Sustainability and Scenario 20

Scenario 20			
Ecological Sustainability	**Environmental health**	**Technical**	**Socio-economic goals**
High	Medium	Medium	High
Medium	Medium	High	Medium
High	Medium	Medium	Medium
Medium	Medium	High	Medium
			High
			High
			High
			High

5.14 CONCLUSIONS

In this Chapter, the Investigator has identified the control parameters, which decide the functions of the system. Correlation analysis and multiple regression analysis have been done to establish the parameters, which directly influence the expenditure pattern of the population and the quantity of solid waste generated by different income groups of the study area. System Dynamics model for Integrated Solid Waste Management System has thereafter, been developed representing the existing solid waste management of the study area. Both formal and informal sectors have been considered for model development. The developed model was thereafter, successfully validated. This validated model is used to develop a projected year model for the year 2031 A.D. This projected year model is employed for analysis work. Subsequently, scenarios were developed by changing various deciding parameters. Of the total scenarios developed, 20 scenarios which gave satisfactory results were shortlisted for analysis. Further, an attempt was made to analyse the degree of integrated sustainability achieved by each of the developed scenarios. The results are presented in the subsequent Chapter 6.

Chapter 6

RESULTS, DISCUSSION AND FINDINGS

6.0 INTRODUCTION

In this present investigation, different kinds of analysis are made at various stages, such as, review of literature, analysis of secondary data, analysis of primary data (household survey data), analysis of informal sector survey, analysis of regression model results, and analysis of System Dynamics model results. The results of the analysis are thoroughly discussed in this chapter to arrive at inferences. The inferences derived from the results are grouped into three categories, such as, inferences based on literature and primary surveys, inferences based on field observations and inferences based on System Dynamics model analysis, which have been used for evolving policies and plausible recommendations for integrated solid waste management of the system and are presented in the subsequent sections as below :

6.1 FINDINGS BASED ON THE STUDY AREA PROFILE

At the outset, the results of the various parameters related to the study area, which are enumerated in the preceding chapters are discussed thoroughly and are as follows:

1. The study area of Kanpur Urban Agglomeration lies towards the North-eastern part of District Kanpur Nagar, on the right bank of the river Ganga with a total area of 298.98 sq km.
2. It is the most populated metropolitan city of Uttar Pradesh and the State's chief industrial city. It enjoys a central position in Uttar Pradesh and is at a distance of 63 km from Lucknow and 425 km from the national capital Delhi.

3. The climate is tropical, characterized by a hot summer and general dryness except in the South-west monsoon seasons.
4. The area constitutes an alluvial plain sloping gradually from North-west to South-east, following the line of rivers Ganga and Pandu. Soil is mainly light and fertile loam in the area.
5. Kanpur Urban agglomeration has two major water bodies in the form of rivers Ganga and Pandu in North and South respectively.
6. Kanpur Urban Agglomeration comprises of Kanpur Municipal Corporation, Cantonment, Armapur Estate, Northern Railway Colony and Chakeri.
7. The population of the study area shows an increasing trend from 1921 onwards. The decadal variation of 24.3 per cent was observed during 1981-91 which increased to 36.1 per cent in 1991-2001. As far as the absolute population size is concerned, Kanpur is the most populated metropolis of the state of Uttar Pradesh. The study area comprises of 110 wards. The city reveals a heterogeneous development with wide variations in population density.
8. The density of Kanpur Municipal Corporation shows an increasing trend. It was 3274 persons per sq. km in 1961 and gradually increased to 9275 persons per sq km in 2001.
9. Among the total literates, 56.69 per cent are males while the remaining 43.31 per cent are females. The literacy rate of Kanpur Municipal Corporation was 78.7 per cent, which is higher than the national literacy rate (65.38 per cent).
10. Sex composition of the study area shows that male-female ratio regularly declined from 770 per thousand in 1901 to 645 per thousand in 1941, but started improving after independence, and reached 857 in the Census year 2001.

11. Kanpur, like all other metropolitan cities suffers with housing shortage and the resultant proliferation of slums spread all over the city. It has an estimated 0.3 million people living in slums (Census 2001). This slum population resides in 296 identified slums in the city, especially in areas adjoining the industrial estate and is not supported by proper infrastructure.
12. Kanpur has a very prominent industrial character and manufacturing, services, trade and commerce dominate the occupational structure of the city.
13. The city can be easily delineated into three distinct zones, *viz.*, areas with very high, intermediate and low population densities and referred to as Core zone, Intermediate zone and Peripheral zone respectively. The Core zone comprises of densely populated wards with densities ranging between 116-739 (1981) and 216-1329 (1991) persons per hectare. The Intermediate zone comprises of wards with densities ranging between 40-342(1981) and 69-403 (1991) persons per hectare, while the Peripheral zone comprises of wards with low population with densities ranging between 7-62 (1981) and 8-78 (1991) persons per hectare.
14. The growth pattern suggests that there will be maximum growth of population in the Intermediate zone, followed by the Western and South-western part of Peripheral zone. The core areas will continue to have natural growth of population or may be even some shifting of population to other less congested areas.
15. The land values within the municipal limits of Kanpur vary from Rs. 61 to Rs. 2800 per sq m. The core city wards have higher market price for land as compared to the peripheral wards.
16. Kanpur is well connected by roads to major cities, towns and villages of the region. The regional road network comprises of two National Highways and two State highways.

National highway NH-2 connects Kanpur with Delhi and Calcutta, NH-25 connects with Lucknow and Jhansi, while State highway SH-22 connects Kanpur with Etawah and SH-17 with Hamirpur respectively.

17. The number of registered vehicles in Kanpur grew from 1.69 lakh in 1991 to 2.50 lakh in 2001. These vehicles contribute to 3550 kg/hr of pollution load and are a major source of air and noise pollution.
18. The public transport system in the city is poor and comprises of private buses, tempos and auto rickshaws. The tempos are most common and ply on fixed routes and are available at frequent intervals.
19. The study area has an installed capacity of water supply of 300 million litres per day (for 17 lakhs population) with average daily rate of supply of 147 litres per capita per day. For proper supply and distribution of water, the city has been divided into four districts, *viz.,* East, West, South and City . There is shortage of water in all the districts except for the City. There is an average deficit of 122.4 million litres per day.
20. The total estimated waste water generated in the city is 426 mld, while the installed treatment capacity for domestic/industrial wastewater is only 171 mld, which too does not run at its full capacity.
21. The study area has about 71 large and medium scale industries which followed western direction of expansion along the railway line and G.T. road. These industries include famous units like, Elgin mills, Muir mills, Cawnpore woolen mills, Ordinance factories, New Victoria mills, M.P. Udyog , HVOC and Lalimli. All these mills suffer from old technology problems, gigantic work force, high input cost with low output.
22. Apart from the large scale industries, there are some 5457 mixed type of Small Scale Industries which grew as ancillary to the major units. The Small Scale Industries produce

variety of goods and products, ranging from metal products to leather goods, paper and textiles, etc. There are more than 175 tanneries in Jajmau area on the bank of the river Ganga.

23. The City Development Index, an index to compare the performance of a city and made of five sub-indices for infrastructure, waste management, health, education and city product, is estimated to be 39.2 for the study area and is very low.

6.2 FINDINGS BASED ON LITERATURE AND PRIMARY SURVEY

The following very important inferences are drawn based on the extensive literature survey and intensive primary survey conducted during this investigation. They are:

6.2.1 FINDINGS BASED ON LITERATURE

The important findings based on literature study have been grouped under three categories of Solid Waste Management in developed countries, developing countries and Indian cities. They are presented as under:

6.2.1.1 Solid Waste Management in Developed countries

Some of the features of Solid Waste Management in the developed countries are as follows:

1. Waste generation rates are high in all developed nations. It has lower density and has high calorific value.
2. Collection is mostly 100 per cent, professionalized and even covers the poorly accessible and low-income areas.
3. Most of developed countries have municipally sponsored source separation and collection systems.

4. These nations try to reduce the waste to be deposited in landfills by adopting various processing methods and promoting recycling.
5. There are well designed Local and Regional waste management plans, which are also well integrated.
6. Composting and Materials recovery facilities are centralized, formalized and technically strong.
7. Informal sector engaged in Solid Waste Management does not exist in these countries. Recycling is therefore, institutionalized in the form of Materials Recovery Facilities and Recycling Centers.
8. Street sweeping is seen as a separate function and not related to waste collection.
9. Public-private participation is quite strong and the government more often, acts as a facilitator and regulator for the provision of efficient solid waste management services.
10. Awareness about the ill-effects of poorly managed solid waste is strong among the community and hence, community participation is stronger in these countries.
11. Various laws governing different aspects of Solid Waste Management are efficiently enforced and implemented.

6.2.1.2 Solid Waste Management in Developing Countries

Some of the features of Solid Waste Management in the developing countries are as follows:

1. The moisture content and organic content of the waste is generally high in developing countries, as compared to the developed nations. The calorific value is also found to be low.
2. The waste generated in developing nations is generally very dense with high amount of silt, ash and other inert materials. Hence, the vehicle and equipments replicated/imported from developed nations often fail to deal with these waste types.

3. Collection is mostly manual, inefficient and with smaller coverage.
4. Incineration of waste and waste-to-energy recovery have often failed in these countries. Recycling is informal and has a long tradition. Private participation is less and limited to collection of wastes only. Centralized composting has mostly failed in these countries. Decentralized composting is however, popular at many places. Disposal of waste is in the form of open or controlled dumps. Sanitary landfill is a rarity in these countries.
5. There is an inadequate management of hazardous and healthcare waste in these countries and often get mixed with municipal waste.
6. Cost recovery by the local government for the provision of solid waste management services is either absent or poor, furthering its financial constraints.

6.2.1.3 Solid Waste Management in Indian Cities

Some of the features of Solid Waste Management in Indian cities are as follows:

1. The density of waste generated is generally high in Indian cities with wide variations in the composition of waste among various cities and different income-groups of people.
2. The moisture content and organic content of waste is high, while the calorific value is generally low.
3. Incineration and other Waste-to energy projects would not be self-sustaining and require external energy input. Methane generation and composting techniques are more feasible for such waste characteristics.
4. A large sector works in the informal waste sector and renders important service, though unrecognized and unacknowledged by the society.
5. Collection of wastes is generally poor in all Indian cities.

6. Municipalities are unable to cope with the growing problem of increasing solid waste generation due to financial constraints, poor management, lack of expertise, low productivity of Solid Waste Management staff and equipment, organizational constraints, lack of co-ordination among various departments involved in providing infrastructure services, etc.
7. The implementation and enforcement of various laws and rules pertaining to solid waste management is very poor.
8. Community participation in the solid waste management service is generally, low.
9. Public-private and Public-community alliances are not common in Indian cities but have started to emerge in some cities with mixed results.

6.2.2 Findings based on primary survey of Households

Some of the important findings based on the primary survey of households are presented as under:

1. The primary survey reveals that there is an average family size of 6. Besides, it is observed that the average family size increases gradually as the income increases. It is 4.2 for the lowest income group and increases to 5 for the fifth income-group. This is in contradiction to the general notion that lower income-groups have larger family size.
2. Higher income groups show better education level both among males and females. It is observed that 53.33 per cent of the total households have males with maximum education level of Graduation while that of females is only 35.67 per cent.
3. In case of primary occupation, 60.67 per cent of the total surveyed households are employed in government job, 17 per cent in own business and 8.33 per cent in private service.

4. A majority of surveyed residents use personalized vehicles amounting to 87.33 per cent followed by 10 per cent people using tempo (6-seaters) for mobility and only 1.33 per cent using a combination of bus, tempo and own vehicle as per the need. A very low percentage of people are found to be using buses, indicating the poor state of the public-transport system in the study area.
5. As far as satisfaction with the public transport among the surveyed residents is concerned, only 21.33 per cent of the respondents say it is good, 65 per cent say it is average while 13.67 per cent say it is in a dismal state and needs improvement.
6. It is observed that the owner-occupied houses are considerable in number and suggest that people prefer to live in self-owned houses. Of the surveyed households, 69 per cent of the houses are self-owned, 18.33 per cent are rented and 12.67 per cent are owned by government organizations.
7. Housing finance system was also studied and it was observed that the maximum number of houses are self-financed (45.33 per cent), 16.33 per cent houses are ancestral and only 7 per cent are financed by the bank.
8. Power supply status is in poor shape in the study area. It was observed that during summers 46.33 per cent of the surveyed households do not have electricity for 10 to 15 hours per day on an average while 36.67 per cent do not have power supply for more than 15 hours per day. During winters, 81.33 per cent do not have power in their houses for 5 to 10 hours daily on an average.
9. The city though blessed by a perennial source of water is facing water shortage-both quantity and quality wise. It was observed that more than two-third of the total surveyed households get public water supply of less than 2 hours per day, which is grossly inadequate. Besides, 69 per cent of the surveyed households reported presence

of particles in the water supplied while another 24 per cent also complained of odour in water.

10. The city is not completely covered by sewer line. Survey results show that 60 per cent of the surveyed households have soak pits, 29 per cent use septic tanks and only 11 per cent of the surveyed households are connected to the sewer line.
11. Drainage is also a problem in the city. Studies found that 66.67 per cent of the people have overflowing drains during rainy season, mostly due to frequent blockage by the presence of plastics and other wastes in the open drains.
12. It was observed during the household survey that on an average, 44 per cent of the surveyed households generate 200 to 400 grams of solid waste daily, 24.33 per cent generate less than 200 grams of solid waste daily and only 11 per cent of the households generate greater than 600 grams of waste per day. Higher income groups were found to generate more waste compared to the lower income groups.
13. Household level composting of organic waste is not prevalent among the residents. Only 2 per cent try to compost the organic part of the waste and 5.33 per cent of the residents burn the generated waste.
14. Survey results show that 20.33 per cent of the surveyed people say that waste is collected daily from their areas, 16.67 per cent say it on alternate days, 31 per cent find the municipal waste collection service once a week, while 16.33 per cent never have any waste collection by the municipality, and waste is collected only after repeated complaints. This problem is more in areas dominated by lower-income group people.
15. The average number of plastics present in daily waste is found to be increasing with income.

16. It is also observed that 78.67 per cent of the surveyed residents are very unhappy about the waste collection services in their area.
17. More than four-fifth of the respondents are found to be willing to hand over secondary waste collection service to private sector as they find the private sector to be more competent.
18. Public apathy in keeping the environs clean is also observed in the study area. Studies found that 52.33 per cent of the respondents are silent spectators and do not attempt to get the waste cleared from their vicinity in case of lapse on the part of the government.
19. The problems related to infrastructure as perceived by the people in various income-groups vary. In all the income-groups, power supply is perceived to be the biggest problem.
20. The survey illustrates that the average expenditure on food gradually increases from Rs 1374 to Rs 7929 per month as the income increases from less than Rs 50,000 annually to greater than Rs 250,000 annually. The minimum expenditure on food was found to be Rs 500 while the maximum as Rs 10,000 per month.
21. It is further observed that the average expenditure per month on clothes increases gradually from Rs 241 to Rs 2600 as the income increases from less than Rs 50,000 annually to greater than Rs 250,000 annually while in case of expenditure on education, it increases gradually from Rs 495 to Rs 6112 as the income increases.
22. Survey results show that the average expenditure per month on health increases gradually from Rs 81 to Rs 671 as the income increases from less than Rs 50,000 to greater than Rs 250,000 annually. The lower-income groups mostly go to government hospitals while the higher-income groups prefer the services of private doctors, nursing homes and hospitals.

23. The average expenditure per month on recreation increases gradually from Rs 34 to Rs 986 as the income increases from less than Rs 50,000 annually to greater than Rs 250,000 annually.
24. It has been observed that the average expenditure on transportation increases from Rs 239 per month for the lowest income-group to Rs 3186 per month for the highest income group.
25. The average monthly expenditure on electricity shows a gradual increase from Rs 180 for the first income-group to Rs 1014 for the last income-group.
26. It has been observed that 61.33 per cent of the people spend Rs 300 to 400 per month on cooking gas, 18.33 per cent spend Rs 200 to 300, 8.67 per cent spend Rs 400 to 500 while 7.67 per cent spend more than Rs 500 per month on cooking gas. Kerosene is mostly used by the people from low income-group for cooking purpose. It is found that 48.57 per cent of the people of this group use kerosene, of which 22.86 per cent spend between Rs 50 and 100 per month on purchasing kerosene.
27. It has been observed that 56.33 per cent of the surveyed households spend up to Rs 1000 per month on petrol alone, 19 per cent do not spend any money on petrol which means they do not have any personal motorised vehicles and they mostly belong to the lower income-groups.

6.2.3 FINDINGS BASED ON PRIMARY SURVEY OF INFORMAL SECTOR

Some of the major findings observed based on the primary survey of informal sector are presented as follows:

1. There are an estimated 10,000-15,000 people working in different capacities in the informal sector related to waste segment. There is no support whatsoever by the local government to them.

2. The private-private alliance is strong in Kanpur and the various segments work in an organized manner in the city.
3. The sector comprises of waste-pickers and itinerant waste buyers (*Kabadi)*, dump pickers, jogies, traders and wholesalers.
4. For most of the waste pickers, it is their only source of livelihood and they live on subsistence level. However, it is also observed that some do it as an additional support to the family's income.
5. A gender-bias is observed in this segment. Field studies indicate that dump-pickers are mostly women while waste-pickers in Kanpur were found to be all males.
6. Child-labour is rampant in this segment and children of all age-group (5 to 16 years) are found to be engaged in waste-picking.
7. Place of residence:

   i. Waste-pickers are found to be living in slums near Railway line and Kalyanpur.

   ii. Dump-pickers are found to be living next to dump-sites at Bingawan and Panki.

   iii. Jogies live in Parade ground and Jogiana, close to the markets where the collected materials are resold.

   iv. Traders/dealers are found to be spread almost all over the city with principal agglomerations in Juhi, Lucknow-Kanpur byepass (State-highway), Kalyanpur, Jajmau, Harjindernagar, etc.

   v. Wholesalers are concentrated in areas like Kalyanpur and Afim ki kothi and are often well-to-do people.
8. Waste-pickers and dump-pickers are found to be mostly Hindus while the wholesalers and traders were found to be mostly Muslims.

9. The prominent ailments among the pickers are viral infections, broncho-respiratory infections, skin problems and stomach disorders besides regular cuts and wounds encountered during waste picking.
10. There is a wide variation in the income of various actors of this informal waste sector with the income variation between Rs. 1,527 for waste-pickers and Rs. 10,700 per month for wholesalers. The waste pickers have an average daily income of Rs 50.9.
11. Field studies done in Kanpur by the Author for the quantity of waste collection by the informal sector reveal that the average collection by a waste-picker is 38.35 kg per day, while that for retailers/traders (small and medium) is about 377.5 kg per day.

6.3 FINDINGS BASED ON FIELD OBSERVATIONS

6.3.1 WASTE GENERATION

There is no data maintained by the Authorities regarding the waste generation by various sources. Data pertaining to seasonal variation is also completely absent.

6.3.2 PRIMARY STORAGE

Source-separation of waste is not practiced at various generation points like households, institutions, commercial establishments, markets and not even hospitals. Only recyclables with resale value like magazines, newspaper, bottles, etc., are source separated and sold to the itinerant waste buyers by the people. Primary storage is done in plastic bags, containers, etc.

6.3.3 Primary collection

1. Primary collection of wastes comes under the purview of the Health Department of Kanpur Nagar Nigam (KNN). The city is divided into six zones for primary waste collection.
2. Three different types of waste storage facilities are used in Kanpur city namely, (i) Rubbish depots, (ii) Open depots and (iii) Containers. There are 748 such collection points available in the study area.
3. Collection points are not conveniently located or equally distributed as per the requirements. The bins are mostly in a dilapidated state so people just throw waste around the bins. Public apathy results in further littering.
4. The walls and floors of the rubbish depots are mostly damaged or broken, which makes the lifting of waste by loader difficult.
5. Burning of wastes by the municipal sweepers in the containers is a common practice. The RC skip-containers are also in a dilapidated state, which leads to littering of waste all around.
6. Inadequate supervision of municipal workers leads to less working hours of the sweepers. Malpractices in the form of contracting out of jobs by sweepers are also observed in the city.
7. The equipments provided to the sweepers are inadequate.

6.3.4 Secondary collection and transportation

1. Secondary collection and transportation of waste comes under the purview of the City Cleansing department of the Municipal Corporation.
2. The average utilization rate of vehicles is very low at 48 per cent.

3. Poor maintenance results in frequent breakdown of vehicles, furthering the poor collection of waste. Workshops are in poor shape and most of the repair work is contracted out.
4. Planning for deployment of vehicles and collection routes is absent and done randomly.
5. There is shortage of drivers employed. Besides, a large number of drivers are often on leave.
6. Only day shifts is practiced in Kanpur city, which often results in road blockages and longer time for waste collection in busy and congested areas.
7. Waste transportation in open trucks result in lot of littering.
8. Fuel allocation to the vehicles is on a daily basis on a fixed basis and results in mal practices.
9. Waste is often not lifted regularly from the collection points. The situation is worst in the peripheral wards.
10. Field studies done by ICDP in 1999-2000 show that secondary collection of waste is only 680 tons per day on an average.
11. There is no co-ordination between the City Cleansing department and the Health department, which looks after the primary collection of waste.

6.3.5 Disposal

There is no sanitary landfill or controlled dump site in Kanpur city. Waste is simply dumped at the designated sites without taking any appropriate technical measures. Besides, dumping in low-lying areas is a common practice in the city. There are five dump sites at Panki, Krishna Nagar, Bingawan, Rooma(for waste coming from treatment plants) and Bhauti (for medical waste coming from incinerator). There is gross violation of the rules laid down in Municipal Waste Management and Handling Rules, 2000.

6.3.6 Treatment

There is no treatment facility for the processing of municipal solid waste in the study area.

6.3.7 Expenditure on Solid Waste Management

The expenditure on solid waste management comes under the 'Sanitation' head in the financial overview of the Kanpur Nagar Nigam. The expenditure on Sanitation shows an increasing trend. However, when observed in terms of percentage of the total budget, it shows an increasing trend till 1997 when it became 51 per cent of the total municipal budget and then gradually decreased to 28.45 per cent of the total budget in the financial year 2005-06. It increased from 158 million in 1990-91 to 462 million in 2005-06.

6.3.8 Model Based Findings

System Dynamics model has been developed in this investigation to present the system in its current form and projections have been made based on the developed model. The important findings of the model are presented in three categories as i) Base year findings, ii) Projected year findings and iii) Simulation based findings

6.3.8.1 Base Year findings

The base year (2001) results of the developed model using System Dynamics state that the population available in the study area is 2,725,207 with a density of 9118 per square kilometer. It is also observed that the population belonging to HIG, MIG, LIG and EWS are 408781, 545041, 1090082, and 681301 respectively. The solid waste generation from these income-groups is 196.21, 207.12, 207.12, 102.2 tons respectively, thus making the total household solid waste generation as 712.64 tons. The waste coming from commercial activity and market activity in the study area is 500 and 86 tons respectively, thus making the total waste as 586 tons. The hazardous and non-hazardous commercial waste is further calculated as 11.72 and 574.28 tons respectively. Waste coming primarily from leather industries and forming a part of the municipal solid waste is 116.06 tons with hazardous and non-hazardous part as 40.62 tons and 75.44 tons respectively. Among the non-hazardous industrial waste, the recyclables comprise 58.09 tons while non-recyclables as 17.35 tons. The total hospital waste comes out to be 6.53 tons. Of the total generated municipal solid waste, 597.1 tons is being collected and only a small fraction of 6.4 tons going for treatment (incineration of hospital waste). Direct recycling from the point of generation by the informal sector (*Kabadi* and waste pickers) is coming as 241.41 tons. The land requirement for disposal of collected waste is 84.47 sq. m. per day while number of vehicles required by the collection and disposal crew of the formal sector is 15. The employment generation in the formal sector (Municipal Corporation) is 2684 while that in the informal sector (for recycling) is 7001. Efficiency of the system in terms of collection efficiency is 0.51, treatment efficiency is 0.05, disposal efficiency as 0.08 and the composite efficiency as 0.24. It is also observed that the composite environmental stress in the base year is 0.72.

6.3.8.2 Projected year findings

The developed model has been further used for projections up to the year 2031 A.D. The results of the projected year for various variables related to solid waste management are as follows:

6.3.8.2.1 Population

The population of the study area would experience an increasing trend. It is observed that it will increase to 6919211 by the year 2031 A.D. The density of the population would also increase whereas the perceived density will be much higher if the government policies are implemented as proposed. The density of the population would be 13430 persons per sq km against the existing density of 9118 persons per sq km in the year 2001 A.D. The perceived area of the study area as a result of various government policies is expected to be 366.35 sq. km in the year 2031 A.D. Similarly, the extent of the study area is bound to increase in East and West directions, unless some measures are taken to check the further expansion of the city.

6.3.8.2.2 WASTE GENERATION

Waste generation in the developed model is based on waste coming from four principal generation points, *viz.*, households, commercial activities, industries and hospitals. Each of these four generation sources and the quantity of waste generated is discussed as under:

6.3.8.2.2.1 Household waste generation

Household waste generation is based on waste coming from four principal income groups-high income group, middle income group, low income group and economically weaker section. Population in each of the income groups would experience an increasing trend. It is observed that the population in HIG, MIG, LIG and EWS will become 1037882, 1383842, 277684 and 1729803 respectively, in the year 2031 A.D. The solid waste generation in each income group would be 733.08, 773.81, 773.81 and 381.81 tons respectively in the year 2031 A.D., if the consumption pattern does not change drastically. The total household solid waste generation thus turns out to be 2662.52 tons.

6.3.8.2.2.2 Commercial and market activity waste generation

The model findings illustrate that the waste coming from commercial and market activities would be 827.08 and 142.26 tons respectively in the year 2031 A.D. The total waste thus coming from this segment would be 969.33 tons.

6.3.8.2.2.3 Industrial waste generation

In the generated model, waste coming primarily from tanneries has been considered. The total industrial solid waste from tanneries would be 392.19 tons in the year 2031 A.D. of which, 137.27 tons would be hazardous in nature while 254.93 tons non-hazardous in nature.

6.3.8.2.2.4 Hospital waste generation

Model findings show that the total hospital waste generation would be 17.63 tons in the year 2031 A.D., of which 13.22 tons would be hazardous in nature, and the remaining 1.31 tons non-hazardous. A part of the generated waste goes for illegal recycling and a small fraction goes for incineration. Thus, the net estimated hospital waste would be 5.24 tons in the year 2031 A.D.

6.3.8.2.2.5 Hazardous and non-hazardous waste generation

Of the generated 4038.58 tons from the above four sources, it is observed that 303 tons would be hazardous in nature while the remaining 3735.58 tons as non-hazardous in nature. The total recyclable content of the non-hazardous waste would be 1968.21 tons in the year 2031 A.D.

6.3.8.2.3 WASTE COLLECTION, TREATMENT, DISPOSAL AND RECYCLING

It is observed in the generated model that the total solid waste collection would be 1700.04 tons in the year 2031 A.D. The waste going for treatment would be only 18.42 tons and the net waste going for disposal would be 1681.63 tons. An estimated 686.56 tons of waste would go directly for direct recycling from generation by the informal sector in the year 2031 A.D.

6.3.8.2.4 LAND REQUIREMENT FOR DISPOSAL, COLLECTION VEHICLES, MAN POWER REQUIREMENTS IN FORMAL AND INFORMAL SECTORS

The model findings illustrate that 240.47 sq m of land would be required per day for disposal of collected waste (assuming a standard height of 10 m of cell) in the year 2031 A.D. The number of collection vehicles requirement would increase to 43. The total manpower requirement in the formal sector and informal sectors would be 7641 and 19910 respectively in the year 2031 A.D.

6.3.8.2.5 Efficiency of the System

Efficiency of the System is a strong indicator of the success of the program and the extent to which the given system is clean and healthy. It has therefore, been considered in the developed model. The model findings illustrate that the collection efficiency, treatment efficiency, disposal efficiency and the combined composite efficiency of the solid waste management system would be 0.51, 0.05, 0.08 and 0.24 respectively.

6.3.8.2.6 Environmental Stress

Environmental stress due to various activities of solid waste management has been attempted in the developed model. The environmental stress due to uncollected and untreated waste, collection of waste, treatment of waste, disposal, recycling and the resultant composite environmental stress would be 0.55, 0.04, 0, 0.10, 0.02 and 0.72 respectively in the year 2031 A.D.

6.3.8.3 Simulation based findings

Scenario 1: With zero recycling

It has been observed that the uncollected waste would be increased by 22.69 per cent. There is a slight decrease in the composite efficiency from 0.241 to 0.193 also as the total collection efficiency decreases. The Composite environmental stress however, shows a slight reduction of 2.38 per cent from 0.715 to 0.698 as the collection process and prevalent recycling activity produces some environmental stress. There is also a massive loss of employment opportunities as in the projected base model for 2031 AD, some 19910 people are estimated to work in informal waste recycling/reuse sector.

Scenario 2: Increase in awareness by 30 per cent and 30 per cent increase in investments

It has been observed that there is an overall reduction of 16.71 per cent in total waste generation. The household waste generation reduces by 10.71 percent, commercial/market wastes by 27.6 per cent whereas industrial and hospital waste generation reduces by 30 per cent each. There is a slight improvement in the overall collection (1.59 per cent), treatment also increases by 19.06 per cent, disposal and recycling increases by 1.40 and 3.28 per cent respectively. The collection efficiency shows an improvement by 35.49 per cent due to which the overall composite solid waste management efficiency also increases by 30.71 per cent. However, due to increased quantity of waste collection the land requirement for disposal increases by 1.4 per cent. The environmental stress due to uncollected and untreated wastes decreases by 5.99 per cent while the composite environmental stress increases slightly by 0.42 per cent. The manpower requirement for Formal sector slightly increases by 1.57 per cent while the overall employment generation increases to 20563 persons.

Scenario 3: Increase in awareness by 70 per cent, 30 per cent increase in investments and 70 per cent increase in organised sector

It has been observed that the household waste generation reduces by 19.83 percent, commercial/market wastes by 42.22 per cent whereas industrial and hospital waste generation reduces by 42 per cent and 50.03 per cent respectively. Thus, there is an overall reduction of 27.47 per cent in waste generation. The total collection increases by 8.08 per cent while treatment increases by 53.42 per cent. The quantity of wastes remaining uncollected reduces considerably by 53.30 per cent, while recycling increases only slightly by 5.90 per cent. The collection efficiency shows a positive improvement of 69.02 per cent due to which the composite solid waste management efficiency increases by 60.17 per cent. However, the composite environmental stress increases slightly by 0.84 per cent. There is a favourable increase in employment generation in both formal and informal sectors by 8.02 per cent and 5.90 per cent respectively.

Scenario 4: Increase in awareness by 80 per cent, 10 per cent increase in investments and 60 per cent increase in organised sector

The simulation results show that the household waste generation reduces by 20.14 per cent, commercial/market waste generation reduces by 34.92 per cent, hospital and industrial waste generation by 45.04 per cent and 31.00 per cent respectively, with a total reduction of 24.83 per cent. The total collection is stipulated to be 1775.6 tons/day, an increase of 4.4 per cent, while treatment increases by 38.60 per cent. The collection efficiency increases to 0.79(56.27 per cent increase) thus making the overall composite efficiency as 0.359 (an increase of 48.96 per cent). The land requirement increases by 4.07 per cent due to increased collection of wastes. There is 10 per cent downfall in the environmental stress due to uncollected and untreated wastes. However, it is compensated by a slight increase in the environmental stresses due to collection, treatment, disposal and recycling with an overall composite environmental stress of 0.719. The employment generation in formal sector increases by 4.4 per cent, whereas informal employment generation increases by a sheer 0.73 per cent.

Scenario 5: Increase in awareness by 80 per cent, 20 per cent increase in investments and 60 per cent increase in organised sector

It is observed in the simulation results that the overall waste generation reduces by 27.45 per cent, with a maximum reduction in the hospital waste generation (50.03 per cent), followed by that in commercial/market waste generation. The total quantity of treated wastes increases by 42.89 per cent due to increased investments. Collection and recycling of wastes however, show only a slight improvement of 4.44 and 1.56 per cent respectively. The composite efficiency of solid waste management becomes 0.375, an increase of 55.60 per cent. The composite environmental stress becomes 0.72. The employment generation in formal sector increases by 4.4 per cent, whereas informal employment generation increases by a sheer 1.56 per cent.

Scenario 6: Increase in awareness by 80 per cent, 20 per cent increase in investments and 70 per cent increase in organised sector

It is observed that in the simulation results, there is no change in waste reduction from that observed in Scenario 5. The overall collection increases by 6.22 per cent and recycling increases by 3.02 per cent. As a result, there is an appreciable increase in the collection efficiency and the composite SWM efficiency of 66.27 per cent and 57.68 per cent respectively. The land requirement for disposal also increases to 254.32 square meter, an increase of 5.76 per cent. The environmental stress due to uncollected and untreated wastes reduces by 12.70 per cent while the composite environmental stress remains high at 0.72. The total employment generation in formal sector becomes 8112 (an increase of 6.17 per cent), while that in informal sector becomes 20510, an increase of 3.01 per cent.

Scenario 7: Increase in awareness by 80 per cent, 20 per cent increase in investments and 80 per cent increase in organised sector

It is observed in the simulation results that the overall waste generation reduces by 27.45 per cent, with a maximum reduction in the hospital waste generation (50.03 per cent), followed by that in commercial/market waste generation, similar to Scenario 5 and 6. The total quantity of collected wastes per day increases to 1835.88 tons, 28.25 tons of waste gets treated and recycling increases by 4.47 per cent. The composite efficiency, as a result increases by 59.75 per cent. However, it is still found to be low at 0.385. The land requirement for disposal becomes 258.49 sq meter. The Composite environmental stress remains high at 0.72. The total employment generation in formal sector becomes 8247(an increase of 7.94 per cent), while that in informal sector becomes 20799, an increase of 4.47 per cent.

Scenario 8: Increase in awareness by 80 per cent, 30 per cent increase in investments and 80 per cent increase in organised sector

The simulation results show that the household waste generation reduces by 21.98 per cent, commercial/market waste generation reduces by 45.87 per cent, hospital and industrial waste generation by 55.02 per cent and 45.00 per cent respectively, with a total reduction of 30.07 per cent. The total collection is stipulated to be 1830.25 tons/day, an increase of 7.66 per cent, treatment increases by 57.38 per cent and recycling increases by 4.9 per cent. The total uncollected waste reduces to 993.95 tons per day. The collection efficiency increases to 0.88(73.53 per cent increase) thus making the overall composite efficiency as 0.396 (an increase of 64.32 per cent). The land requirement for disposal of wastes increases by 7.12 per cent due to increased collection of wastes. There is 14.7 per cent downfall in the environmental stress due to uncollected and untreated wastes. However, it is compensated by a slight increase in the environmental stresses due to collection, treatment, disposal and recycling with an overall composite environmental stress of 0.721. The employment generation in formal sector increases by 7.6 per cent whereas informal employment generation increases by 4.9 per cent.

Scenario 9: Increase in awareness by 90 per cent, 10 per cent increase in investments and 10 per cent increase in organised sector

The simulation results show that the household waste generation reduces by 22.29 per cent, commercial/market waste generation reduces by 38.57 per cent, hospital and industrial waste generation by 50.03 per cent and 34.00 per cent respectively, with a total reduction of 27.43 per cent. The total collection is stipulated to be 1594.11 tons/day, a decrease of 6.23 per cent, treatment increases by 13.74 per cent and recycling decreases by 8.57 per cent. As the household waste decreases most, the informal sector which is much dependent on the household sector is affected badly and the recycling activity decreases by 8.57 per cent. The collection efficiency increases slightly as the waste generation reduces with an overall composite efficiency of 0.332 (an increase of 37.76 per cent). The land requirement for disposal of wastes almost remains same. The composite environmental stress is observed to be 0.719. The employment generation in both formal and informal sector suffers, with a decrease of 6.26 per cent in formal sector and 8.57 per cent in informal sector.

Scenario 10: Increase in awareness by 90 per cent, 20 per cent increase in investments and 50 per cent increase in organised sector

The simulation results show that the household waste generation reduces by 23.19 per cent, commercial/market waste generation reduces by 44.04 per cent, hospital and industrial waste generation by 55.02 per cent and 41.00 per cent respectively, with a total reduction of 30.04 per cent. The reduction in waste generation results in recycling being affected (a 2.06 per cent decrease). The collection efficiency increases by 63.73 per cent, treatment efficiency by 3.1 per cent while the composite SWM efficiency becomes 0.375 (an increase of 55.6 per cent). The composite environmental stress is observed to be 0.72. The employment generation in formal sector almost remains same at 7694 persons while there is a slight decrease of 2.06 per cent in the informal sector employment.

Scenario 11: Increase of treatment fraction to 40 percent, no increase in awareness, investments and organised sector

The simulation results show that there is no change in the waste generation quantities. The treated quantity of waste increases to 680.02 tons from 18.42 tons. As a result, the composite efficiency increases to 0.512 (a 112.45 per cent increase). The land requirement for disposal of collected wastes decreases by 39.34 per cent. The composite environmental stress reduces by 9.09 per cent. The employment generation in informal sector remains unaffected while that in formal sector reduces by 5.44 per cent. Some employment will however be generated in the treatment sector as there is a considerable increase in the treated quantity of waste. It has however, not been considered in the simulation.

Scenario 12: Increase of recycling fraction to 25 per cent, increase of treatment fraction to 40 percent, no increase in awareness, investments and organised sector

The simulation results show that there is no change in the waste generation; collection also remains same. The treated quantity becomes 680.02 tons per day, an increase of 3591 per cent. This reflects the dismal state of treatment in the base model. Recycling increases to 1009.64 tons of waste per day, an increase of 47.06 per cent. As a result, the composite efficiency of SWM increases to 0.542, an increase of 124.90 per cent. The composite environmental stress shows some improvement due to increased treatment and recycling and it becomes 0.658, a reduction by 7.97 per cent. The employment generation in formal sector decreases by 5.44 per cent. However, this is compensated by a drastic increase in the employment generation in the informal sector, which becomes 29279, an increase of 47.06 per cent.

Scenario 13: Increase of recycling fraction to 25 per cent, increase of treatment fraction to 50 percent, 80 per cent increase in awareness, 20 per cent increase in investments and no increase in organised sector

The simulation results show that the household waste generation reduces by 21.07 per cent, commercial/market waste generation reduces by 40.40 per cent, hospital and industrial waste generation by 50.03 per cent and 38.00 per cent respectively, with a total reduction of 27.45 per cent. The total collection is stipulated to be 1594.62 tons/day, a decrease of 6.20 per cent, treatment shows a massive increase by 5353.91 per cent and recycling increases by 36.56 per cent. The collection efficiency increases by 64.71 as the waste generation reduces, treatment efficiency increases by 1003.83 per cent with an overall composite efficiency of 0.775 (an increase of 221.58 per cent). The land requirement for disposal of wastes decreases by 64.91 per cent. The composite environmental stress is observed to be 0.595, a favourable decrease by 16.78 per cent. The employment generation in both formal and informal sector suffers, with a decrease of 6.26 per cent in formal sector and 8.57 per cent in informal sector. Employment generation in formal sector decreases by 12.66 per cent whereas that in informal sector increases appreciably by 36.56 per cent.

Scenario 14: Increase of treatment fraction to 50 percent, 80 per cent increase in awareness, 20 per cent increase in investments and no increase in organised sector and recycling fraction

The simulation results show that the household waste generation reduces by 21.07 per cent, commercial/market waste generation reduces by 40.40 per cent, hospital and industrial waste generation by 50.03 per cent and 38.00 per cent respectively, with a total reduction of 27.45 per cent. The total collection decreases by 6.20 per cent due to reduction in the waste generation, treatment shows a massive increase by 5353.91 per cent. Recycling also decreases due to reduction in waste generation and absence of any extra efforts to promote recycling. The collection efficiency increases by 44.31 per cent as the waste generation reduces, treatment efficiency increases by 1003.83 per cent with an overall composite efficiency of 0.733 (an increase of 204.15 per cent). The land requirement for disposal decreases by 29.4 per cent due to increased treatment and reduced generation of waste. The composite environmental stress becomes 0.585 (a decrease of 18.18 per cent). There is a loss of employment generation in both formal and informal sectors by 12.66 and 7.14 per cent respectively.

Scenario 15: Increase of treatment fraction to 30 percent, 80 per cent increase in awareness, 20 per cent increase in investments and 50 per cent increase in organised sector and no increase in recycling fraction

The simulation results show that the total waste generation reduces by 27.45 per cent similar to scenario 14. The collection increases by 2.67 per cent, treatment increases by 3908.20 per cent while recycling almost remains unaffected. The composite efficiency becomes 0.649 (an increase of 169.29 per cent). The land requirement for disposal decreases by 40.11 per cent. The composite environmental stress is observed to be 0.623, a decrease of 12.87 per cent. Employment generation in informal sector almost remains unchanged, while that in formal sector decreases slightly by 2.04 per cent.

Scenario 16: Increase of treatment fraction to 40 percent, 80 per cent increase in awareness, 20 per cent increase in investments and 50 per cent increase in organised sector and no increase in recycling fraction

The simulation results show that the total waste generation reduces by 27.45 per cent similar to scenario 14 and 15. The collection increases by 2.67 per cent, treatment increases by 5244.25 per cent, while recycling increases by 10.84 per cent. The composite efficiency increases to a favourable 0.73. The land requirement for disposal decreases by 54.75 per cent. The composite environmental stress is observed to be 0.589, a decrease of 17.62 per cent. Employment generation in informal sector almost remains unchanged, while that in formal sector decreases slightly by 3.65 per cent.

Scenario 17: Increase of treatment fraction to 50 percent, 80 per cent increase in awareness, 20 per cent increase in investments and 50 per cent increase in organised sector and no increase in recycling fraction

The simulation results show that the total waste generation reduces by 27.45 per cent similar to previous scenario. The total treated quantity increases to 1230.51 tons per day, an increase of 6580.29 per cent. Recycling however reduces by 25 per cent due to increased collection and treatment. The composite efficiency of Solid Waste Management becomes 0.991, an increase of 1198.82 per cent. The land requirement for disposal reduces to 73.63 sq meters. The composite environmental stress also shows an improvement by reducing to 0.555, a decrease of 22.38 per cent. Employment generation in both the informal and formal almost remains unaffected.

Scenario 18: Increase of treatment fraction to 50 percent, 80 per cent increase in awareness, 20 per cent increase in investments and 80 per cent increase in organised sector and no increase in recycling fraction

The simulation results show that the total waste generation reduces by 27.45 per cent similar to previous scenario. The total collection increases to 1835.88 tons per day, treatment increases to 1376.91 tons per day while recycling increases by 4.47 per cent. The composite efficiency of solid waste management becomes 0.843, an improvement by 249.79 per cent. The composite environmental stress further reduces to 0.536, a decrease by 25.03 per cent. The total employment generation reduces slightly by 3.58 per cent.

Scenario 19: Increase of recycling fraction to 25 per cent, increase of treatment fraction to 40 percent, 80 per cent increase in awareness, 20 per cent increase in investments and 50 per cent increase in organised sector

The simulation results show that the total waste generation reduces by 27.45 per cent similar to previous scenario. The total collection becomes 1745.41 tons per day, while treatment becomes 984.41 tons (an increase by 5244.25 per cent). The composite efficiency increases to 0.768, an overall improvement by 218.67 per cent. The composite environmental stress reduces to 0.6. The employment generation in informal sector shows an appreciable improvement by 47.23 per cent.

Scenario 20: Increase of recycling fraction to 25 per cent, increase of treatment fraction to 40 percent, 80 per cent increase in awareness, 20 per cent increase in investments and 80 per cent increase in organised sector

The simulation results show that the total waste generation reduces by 27.45 per cent similar to previous scenario. The total collection is stipulated to be 1835.88 tons/day, an increase of 7.99

per cent, treatment shows a massive increase by 5880.08 per cent and recycling increases by 53.63 per cent. The collection efficiency increases by 87.45 per cent as the waste generation reduces, treatment efficiency increases by 938.25 per cent with an overall composite efficiency of 0.807 (an increase of 234.85 per cent). The land requirement for disposal of wastes decreases by 56.33 per cent. The composite environmental stress is observed to be 0.586, a favorable decrease by 18.04 per cent. The employment generation in formal sector almost remains unaffected while that in informal sector increases by 53.63 per cent.

6.4 CONCLUSIONS

In this section, an attempt has been made to present the findings of the investigation, based on the literature survey, survey results, field observations and System dynamic model results. These findings cover all aspects of waste management and various socio-economic, cultural habits and preferences of the residents, which have a direct impact on waste generation in the study area. It also covers the institutional arrangements for rendering this important service and the socio-economic background of the waste-pickers who form the very base of the informal waste recycling sector, which runs parallel to the formal waste collection and management. The literature based findings give important clues as to the alternative policies and methods, which could prove successful for effective management of municipal waste in the city and caution against adopting methods prevalent in developed countries as they are ill-suited for Indian conditions. The System Dynamic model results based findings give the results of various short-listed scenarios, which could bring an overall improvement in the municipal waste management in the study area. All the above findings eventually helped in evolving a set of policy guidelines and plausible recommendations for an integrated solid waste management of the study area as discussed in the subsequent Chapter 7.

Chapter 7

POLICIES, RECOMMENDATIONS AND CONCLUSION

7.0 INTRODUCTION

The study area is one of the biggest metropolitan cities of the Uttar Pradesh State with an ever-increasing push of urban and rural population from far and near due to the city's marked presence as an important industrial, commercial and educational centre in the region. The built environment of the study area however, increasingly poses serious environmental problems. One of the increasing problems is posed by the tremendous quantity of the solid waste generated by various segments, including municipal solid waste. The city is already known as one of the most polluted and 'tuberculosis' city with poor visual aesthetics. The study area thus, presents a grim picture pertaining to the non-collection and poor management of the generated waste. The situation is bound to worsen if there is no immediate measures taken in short term and long term and will eventually affect the socio-economic and environmental health of the city and its inhabitants. In this situation, it is felt inevitable to develop and implement a strategic integrated municipal solid waste management plan in the city.

7.1 SYSTEM CONCEPT

System Concept has been employed to develop an integrated municipal solid waste management plan for the city, based on the most influential control parameters, which decide the functions of the study area pertaining to waste generation and management, in order to maximise the composite efficiency of the waste management, reducing the generation of waste, maximising the source-segregation of waste, a reasonably tolerable environmental stress without hampering the vast segment of the population engaged in informal waste recycling. It is observed that stakeholders' participation could prove to be a key element in achieving integrated municipal solid waste management in the study area. Private sector participation in the field of waste management is very low in the city and needs to be encouraged. There is a lot of administrative and management flaws in the existing set up of the various departments of Kanpur Municipal Corporation dealing with solid waste management. It is further, observed that inter-departmental cooperation and co-ordination is completely absent. There is an urgent need to improve the governance and management of the Kanpur Municipal Corporation. Corruption among sweepers is rampant. Public apathy towards cleanliness is very high among the residents. Environmental awareness is also observed to be quite low. People are however ready to pay some user charge towards regular cleaning of the waste and/or door to door collection of waste. The important role played by the informal waste recycling sector has also been closely observed and studied in the study area and considered as one of the important parameters towards developing an integrated municipal solid waste management plan. Keeping these parameters of the study area in mind, a set of broad policy guidelines and plausible recommendations are made based on the in-depth investigation done, i.e., survey findings, model results, observations made during field visits, discussions with administrators, solid waste management experts and the consumers(residents).

In order to develop a set of broad policy guidelines and plausible recommendations, the following broad strategies have been adopted. They are:

1. Gradual increase of treatment fraction to 40 per cent by the year 2031
2. Gradual increase of awareness from the existing state to 80 per cent

3. Gradual increase of investment fraction to 20 per cent
4. Increase in the organised sector to 80 per cent
5. Improving the recycling fraction from the existing 17 per cent to 25 per cent
6. People's participation at source-segregation and involvement of community based organizations and non-government organizations (NGOs) for decentralized treatment (composting) of organic waste in the study area.
7. A proactive support of the government to the informal recycling sector, especially the waste pickers and itinerant waste buyers to improve their socio-economic conditions and social recognition in some way to the services rendered by them
8. Encouragement of private sector participation in various forms to make the various activities of waste management economically sustainable.
9. Administrative improvement in the Kanpur Municipal Corporation
10. Adoption of relevant technology at various levels
11. Preparation of separate solid waste management plans for every five year and consideration of this aspect by the planners while preparation of Master Plans.

Further, the perceived improvement in the efficiency of waste management and for 2031 A.D. are calculated based on the model results and policy run results (scenarios) and the results of various parameters are presented in Table 7.1 and 7.2.

Table 7.1: Policy Scenarios

Sl. No.	Projected year model and policy scenarios		HH gen (t/d)	Com.gen (t/d)	Hosp gen(t/d)	Ind. Gen(t/d)	Total gen (t/d)	Total HZ (t/d)	Total NHZ(t/d)	Collection (t/d)	Treatment (t/d)
1	Policies	Projected year model Result	2662.52	969.33	17.63	392.19	4038.58	303	3735.58	1700.04	18.42
2	Policy 1	Rec 0%	2662.52	969.33	17.63	392.19	4038.58	303	3735.58	1700.04	18.42
3	Policy 2	A 30%+ I 30%	2377.32	701.81	12.34	274.53	3363.84	238.24	3125.6	1727.14	21.93
4	Policy 3	A 70%+ I 30%+ O 70%	2134.57	560.07	8.81	227.47	2929.37	204.15	2725.22	1837.4	28.26
5	Policy 4	A 80%+ I 10%+ O 60%	2126.29	630.86	9.69	270.61	3035.76	220.92	2814.84	1775.6	25.53
6	Policy 5	A 80%+ I 20%+ O 60%	2101.64	577.75	8.81	243.16	2929.81	208.35	2721.46	1775.57	26.32
7	Policy 6	A 80%+ I 20%+ O 70%	2101.64	577.75	8.81	243.16	2929.81	208.35	2721.46	1805.73	27.28
8	Policy 7	A 80%+ I 20%+ O 80%	2101.64	577.75	8.81	243.16	2929.81	208.35	2721.46	1835.88	28.25
9	Policy 8	A 80%+ I 30%+ O 80%	2077.22	524.73	7.93	215.71	2824.19	195.8	2628.39	1830.25	28.99
10	Policy 9	A 90%+ I 10%+ O 10%	2069.13	595.45	8.81	258.85	2930.69	212.57	2718.12	1594.11	20.95
11	Policy 10	A 90%+ I 20%+ O 50%	2045.03	542.4	7.93	231.39	2825.36	200.04	2625.32	1712.6	25.21
12	Policy 11	A 0%+ I 0%+O 0%+ T 40%	2662.52	969.33	17.63	392.19	4038.58	303	3735.58	1700.04	680.02
13	Policy 12	A 0%+ I 0%+ O 0%+ T 40%+ Rec 25%	2662.52	969.33	17.63	392.19	4038.58	303	3735.58	1700.04	680.02
14	Policy 13	A 80%+ I 20% +O 0%+ T 50%+Rec 25%	2101.64	577.75	8.81	243.16	2929.81	208.35	2721.46	1594.62	1004.61
15	Policy 14	A 80,%+ I 20% + O 0%+ T 50%+ Rec 17%	2101.64	577.75	8.81	243.16	2929.81	208.35	2721.46	1594.62	1004.61
16	Policy 15	A 80%+ I 20%+ O 50%+ T 30%+Rec 17%	2101.64	577.75	8.81	243.16	2929.81	208.35	2721.46	1745.41	738.31
17	Policy 16	A 80%+ I 20%+ O 50%+ T 40%+Rec 17%	2101.64	577.75	8.81	243.16	2929.81	208.35	2721.46	1745.41	984.41
18	Policy 17	A 80%+ I 20%+O 50%+ T 50%+Rec 17%	2101.64	577.75	8.81	243.16	2929.81	208.35	2721.46	1745.41	1230.51
19	Policy 18	A 80%+ I 20%+ O 80%+ T 50%+Rec 17%	2101.64	577.75	8.81	243.16	2929.81	208.35	2721.46	1835.88	1376.91
20	Policy 19	A 80%+ I 20%+O 50%+ T 40%+Rec 25%	2101.64	577.75	8.81	243.16	2929.81	208.35	2721.46	1745.41	984.41
21	Policy 20	A 80%+ I 20%+ O 80%+ T 40%+Rec 25%	2101.64	577.75	8.81	243.16	2929.81	208.35	2721.46	1835.88	1101.53

Note: A- Awareness, I-Investment, O-Organised sector, T-Treatment, Rec-Recycling

Table 7.2: Policy Scenarios

Sl. No.	Projected year model and policy scenarios		Uncollected (t/d)	Recycling (t/d)	Comp. efficiency	Land req. for disposal (sq. m/d)	CES	Manpower req. in Formal sector	Manpower req. in Informal sector
1	Policies	Projected year model Result	2338.53	686.56	0.241	240.47	0.715	7640.99	19910.19
2	Policy 1	Rec 0%	2338.53	0	0.193	240.47	0.698	7640.99	0
3	Policy 2	A 30%+ I 30%	1636.7	709.1	0.315	243.84	0.718	7761.16	20563.82
4	Policy 3	A 70%+ I 30%+ O 70%	1091.98	727.07	0.386	258.71	0.721	8254.16	21085.03
5	Policy 4	A 80%+ I 10%+ O 60%	1260.16	691.55	0.359	250.26	0.719	7977.43	20054.84
6	Policy 5	A 80%+ I 20%+ O 60%	1154.25	697.3	0.375	250.14	0.72	7976.9	20221.58
7	Policy 6	A 80%+ I 20%+ O 70%	1124.09	707.26	0.38	254.32	0.72	8112.13	20510.46
8	Policy 7	A 80%+ I 20%+ O 80%	1093.93	717.22	0.385	258.49	0.721	8247.35	20799.34
9	Policy 8	A 80%+ I 30%+ O 80%	993.95	720.17	0.396	257.58	0.721	8221.62	20884.92
10	Policy 9	A 90%+ I 10%+ O 10%	1336.58	627.75	0.332	224.96	0.719	7163.03	18204.87
11	Policy 10	A 90%+ I 20%+ O 50%	1112.76	672.44	0.375	241.3	0.72	7694.11	19500.62
12	Policy 11	A 0%+ I 0%+O 0%+ T 40%	2338.54	686.56	0.512	145.86	0.65	7310.19	19910.19
13	Policy 12	A 0%+ I 0%+ O 0%+ T 40%+ Rec 25%	2338.53	1009.64	0.542	145.86	0.658	7225.19	29279.69
14	Policy 13	A 80%+ I 20% +O 0%+ T 50%+Rec 25%	1335.19	937.54	0.775	84.37	0.595	6673.5	27188.68
15	Policy 14	A 80,%+ I 20% + O 0%+ T 50%+ Rec 17%	1335.19	637.53	0.733	84.37	0.585	6673.5	18488.3
16	Policy 15	A 80%+ I 20%+ O 50%+ T 30%+Rec 17%	1184.4	687.33	0.649	144.02	0.623	7485.19	19932.7
17	Policy 16	A 80%+ I 20%+ O 50%+ T 40%+Rec 17%	1184.4	761	0.73	108.82	0.589	7362.14	19932.7
18	Policy 17	A 80%+ I 20%+O 50%+ T 50%+Rec 17%	1184.4	514.9	0.804	73.63	0.555	7239.09	19932.7
19	Policy 18	A 80%+ I 20%+ O 80%+ T 50%+Rec 17%	1093.93	717.22	0.843	65.63	0.536	7573.02	20799.34
20	Policy 19	A 80%+ I 20%+O 50%+ T 40%+Rec 25%	1184.4	1010.79	0.768	108.82	0.6	7362.14	29312.8
21	Policy 20	A 80%+ I 20%+ O 80%+ T 40%+Rec 25%	1093.93	1054.73	0.807	105.01	0.586	7710.71	30587.27

Note: A- Awareness, I-Investment, O-Organised sector, T-Treatment, Rec-Recycling

7.2 ALTERNATE POLICY SCENARIOS

A number of alternative policy scenarios have been evolved based on the various scenarios developed in the projected year model (2031 A.D.) by considering the various parameters and the perceived results are obtained and are presented as below:

7.2.1 POLICY 1

A policy has been developed by considering the informal recycling fraction as zero from the existing 17 per cent. It shows that the uncollected waste, which comprises of formal collection by the Kanpur Municipality and informal collection by waste pickers and Itinerant waste buyers, would increase from 2338.53 tons to 3025.09 tons (22.69 per cent). There is a slight decrease in the composite efficiency from 0.241 to 0.193 also as the total collection efficiency decreases. The Composite environmental stress however, shows a slight reduction of 2.38 per cent from 0.715 to 0.698 as the collection process and prevalent recycling activity produces some environmental stress. There is also a massive loss of employment opportunities as in the projected year model for 2031 AD, some 19,910 people would lose their jobs, who are estimated to work in informal waste recycling/reuse sector if the recycling continues at the current rate.

7.2.2 POLICY 2

A policy has been developed by considering the increase in Awareness by 30 per cent and 30 per cent increase in Investments in the projected year model (2031 A.D.) It shows that the total waste generation would reduce from 4038.58 tons to 3363.84 tons (16.71 per cent). The household waste generation would reduce from 2662.52 tons to 2377.32 tons (10.71 per cent), commercial/market wastes reduce from 969.33 tons to 701.81 tons (27.60 per cent) whereas industrial waste generation would reduce from 392.19 tons to 274.53 tons (30 per cent) and hospital waste generation would reduce from 17.63 tons to 12.34 tons (30 per cent). There would be a slight improvement in the overall collection from 1700.04 tons to 1727.14 tons (1.59 per cent), treatment would increase from 18.42 tons to 21.93 tons (19.06 per cent), recycling would increase from 686.56 tons to 709.1 tons (3.28 per cent) and land requirement for disposal per day would increase from 240.47 sq. m. to 243.84 sq. m. (1.40 per cent). The composite solid waste management efficiency increases from 0.241 to 0.315. The composite environmental stress increases slightly from 0.715 to 0.718. The manpower requirement for formal sector slightly increases from 7,640 to 7,761 persons while the overall employment generation in the informal sector increases from 19,910 to 20,563 persons.

7.2.3 POLICY 3

A policy has been developed by considering the increase in Awareness by 70 per cent and 30 per cent increase in Investments and 70 per cent increase in Organised sector in the projected year model (2031 A.D.) The policy result shows that the household waste generation would reduce from 2662.52 tons to 2134.57 tons (19.83 per cent), commercial/market wastes from 969.33 tons to 560.07 tons (42.22 per cent) whereas industrial waste generation would reduce from 392.19 tons to 227.47 tons (42 per cent) and hospital waste generation would reduce from 17.63 tons to 8.81 tons (50.03 per cent). Thus, there is an overall reduction of 27.47 per cent in total waste generation. The total collection increases from 1700.04 tons to 1837.40 tons (8.08 per cent). The quantity of wastes remaining uncollected reduces considerably from 2338.53 tons to 1091.98 tons (53.30 per cent) while recycling increases only slightly from 686.56 tons to 727.07 tons (5.90 per cent). The composite solid waste management efficiency increases from 0.241 to 0.386 (60.17 per cent). However, the composite environmental stress increases slightly from 0.715 to 0.721(0.84 per cent). There is a favourable increase in employment generation in both formal and informal sectors from 7,640 to 8,254 persons and 19,910 to 21,085 persons respectively.

7.2.4 Policy 4

A policy has been developed by considering the increase in Awareness by 80 per cent and 10 per cent increase in Investments and 60 per cent increase in Organised sector in the projected year model (2031 A.D.). The policy result shows that the total waste generation would reduce from 4038.58 tons to 3035.76 tons (24.83 per cent). The total collection is stipulated to be 1775.6 tons/day from 1700.04 tons/day, an increase of 4.44 per cent, while treatment would increase from 18.42 tons to 25.53 tons (38.60 per cent). The overall composite efficiency increases from 0.241 to 0.359 (an increase of 48.96 per cent). The land requirement for disposal of collected waste would increase from 240.47 sq. m. to 250.2 sq. m. per day due to increased collection of wastes. The overall composite environmental stress would almost remain same at 0.719 (an increase of 0.56 per cent). The employment generation in formal sector would increase from 7,640 to 7,977 persons whereas informal employment generation would increase slightly from 19,910 to 20,054 persons.

7.2.5 Policy 5

A policy has been developed by considering the increase in Awareness by 80 per cent and 20 per cent increase in Investments and 60 per cent increase in Organised sector in the projected year model (2031 A.D.). It is observed in the policy results that the overall waste generation would reduce from 4038.58 tons to 2929.91 tons (27.45 per cent), with a maximum reduction in the hospital waste generation, followed by that in commercial/market waste generation. The total quantity of treated wastes would increase from 18.42 tons to 26.32 tons (42.89 per cent) due to increased investments. Collection and recycling of wastes however, show only a slight improvement from 1700.04 tons to 1775.57 tons (4.44 per cent) and from 686.56 tons to 697.30 tons respectively (1.56 per cent). The composite efficiency of solid waste management would increase slightly from 0.241 to 0.375 (55.60 per cent). The composite environmental stress would increase from 0.715 to 0.720. The employment generation in formal sector would increase from 7,640 to 7,976 persons whereas informal employment generation would increase slightly from 19,910 to 20,221 persons.

7.2.6 POLICY 6

A policy has been developed by considering the increase in Awareness by 80 per cent and 20 per cent increase in Investments and 70 per cent increase in Organised sector in the projected year model (2031 A.D.). It is observed that in the policy results, there is no change in waste reduction from that observed in Scenario 5. The overall collection would increase from 1700.04 tons to 1805.73 tons (6.22 per cent) and recycling would increase from 686.56 tons to 707.26 tons (3.02 per cent). As a result, there is an appreciable increase in the collection efficiency; the composite solid waste management efficiency increases from 0.241 to 0.380 (57.68 per cent). The land requirement for disposal would also increases from 240.47 to 254.32 sq. m. per day (5.76 per cent). The composite environmental stress would remain high at 0.720. The total employment generation in formal sector would increase from 7,640 to 8,112 persons (6.17 per cent) while that in informal sector would increase from 19,910 to 20,510 persons (3.01 per cent).

7.2.7 Policy 7

A policy has been developed by considering the increase in Awareness by 80 per cent and 20 per cent increase in Investments and 80 per cent increase in Organised sector in the projected year model (2031 A.D.). It is observed in the policy results that the overall waste generation would reduce from 4038.58 tons to 2929 tons (27.45 per cent) with a maximum reduction in the hospital waste generation from 17.63 tons to 8.81 tons (50.03 per cent). The total quantity of collected wastes per day would increase from 1700.04 tons to 1835.88 tons (7.99 per cent), treatment would increase from 18.42 tons to 28.25 tons (53.37 per cent) and recycling would increase from 686.56 tons to 717.22 tons (4.47 per cent). The composite efficiency, as a result would increase from 0.241 to 0.385 (59.75 per cent). The land requirement for disposal would increase from 240.47 sq. m. to 258.49 sq. m. per day (7.49 per cent). The composite environmental stress would remain high at 0.721. The total employment generation in formal sector would increase from 7,640 to 8,247 persons (7.94 per cent) while that in informal sector would increase from 19,910 to 20,799 persons (4.47 per cent).

7.2.8 Policy 8

A policy has been developed by considering the increase in Awareness by 80 per cent and 30 per cent increase in Investments and 80 per cent increase in Organised sector in the projected year model (2031 A.D.). The policy results show that the total waste generation would reduce from 4038.58 tons to 2824.19 tons (30.07 per cent). The total collection is stipulated to increase from 1700.04 tons to 1830.25 tons/day (7.66 per cent), treatment would increase from 18.42 tons to 28.99 tons (57.38 per cent) and recycling would increase from 686.56 tons to 720.17 tons (4.9 per cent). The total uncollected waste would reduce from 2338.53 tons to 993.95 tons per day (57.50 per cent). The overall composite efficiency would increase from

0.241 to 0.396 (64.32 per cent). The land requirement for disposal of wastes would increase from 240.47 to 257.58 sq. m. per day (7.12 per cent) due to increased collection of wastes. The overall composite environmental stress would increase from 0.715 to 0.721. The employment generation in formal sector would increase from 7,640 to 8,221 persons (7.60 per cent) whereas informal employment generation would increase from 19,910 to 20,884 persons (4.90 per cent).

7.2.9 POLICY 9

A policy has been developed by considering the increase in Awareness by 90 per cent and 10 per cent increase in Investments and 10 per cent increase in Organised sector in the projected year model (2031 A.D.).The policy results show that the total waste generation would reduce from 4038.58 tons to 2930.69 tons (27.43 per cent). The total collection would decrease from 1700.04 tons to 1594.11 tons/day, a decrease of 6.23 per cent, treatment would increase from 18.42 tons to 20.95 tons (13.74 per cent) and recycling would decrease from 686.56 to 627.75 tons. As the household waste decreases most, the informal sector which is much dependent on the household sector is affected badly and the recycling activity decreases by 8.57 per cent. The collection efficiency would increase slightly. The overall composite solid waste management efficiency would increase from 0.241 to 0.332 (37.76 per cent). The land requirement for disposal of wastes would reduce from 240.47 sq. m. to 224.96 sq. m. per day (6.45 per cent). The composite environmental stress would increase from 0.715 to 0.719. The employment generation in both formal and informal sector would suffer. It would decrease from 7,640 to 7,163 persons (6.26 per cent) in formal sector and from 19,910 to 18,204 persons (8.57 per cent) in informal sector.

7.2.10 POLICY 10

A policy has been developed by considering the increase in Awareness by 90 per cent and 20 per cent increase in Investments and 50 per cent increase in Organised sector in the projected year model (2031 A.D.). The policy results show that the household waste generation would reduce from 2662.52 tons to 2045.03 tons (23.19 per cent), while the total waste generation would reduce from 4038.58 tons to 2825.36 tons (30.04 per cent). As a result, the recycling sector would be affected and recycling would decrease from 686.56 tons to 672.44 tons (2.06 per cent). The composite solid waste management efficiency would increase from 0.241 to 0.375 (55.60 per cent). The composite environmental stress would increase from 0.715 to 0.720. The employment generation in formal sector almost remains same at 7,694 persons (0.70 per cent) while the informal sector employment would reduce slightly from 19,910 to 19,500 persons (2.06 per cent).

7.2.11 POLICY 11

A policy has been developed by considering no increase in Awareness, Investments or Organised sector and 40 per cent increase in the treatment fraction of generated waste in the projected year model (2031 A.D.). The policy results show that there is no change in the waste generation quantities. The treated quantity of waste would increase from 18.42 tons to 680.02 tons (3591.75 per cent). As a result, the composite efficiency would increase from 0.241 to 0.512 (112.45 per cent). The land requirement for disposal of collected waste would decrease from 240.47 sq. m. to 145 sq. m. per day (39.34 per cent). The composite environmental stress would reduce from 0.715 to 0.650 (9.09 per cent). The employment generation in informal sector remains unaffected while that in formal sector (comprising of primarily, primary and secondary collection) would reduce from 7,640 to 7,310 persons (4.33 per cent). Some employment will however be generated in the treatment sector as there is a considerable increase in the treated quantity of waste.

7.2.12 POLICY 12

A policy has been developed by considering no increase in Awareness, Investments or Organised sector, 40 per cent increase in the treatment fraction of generated waste and increasing the recycling fraction to 25 per cent in the projected year model (2031 A.D.). The policy results show that there is no change in the waste generation; collection also remains same. The treated quantity would increase considerably from 18.42 tons to 680.02 tons per day (3591.75 per cent). This reflects the dismal state of treatment in the base model. Recycling would increase from 686.56 tons to 1009.64 tons of waste (47.06 per cent). As a result, the composite efficiency of solid waste management would increase from 0.241 to 0.542 (124.90 per cent). The composite environmental stress would also show some improvement and become 0.658 from 0.715 (7.97 per cent). The employment generation in formal sector would reduce slightly. However, this is compensated by a drastic increase in the employment generation in the informal sector, which becomes 29,279 from 19,910 persons (an increase of 47.06 per cent).

7.2.13 POLICY 13

A policy has been developed by considering the increase in Awareness by 80 per cent and 20 per cent increase in Investments, no increase in Organised sector, 50 per cent increase in the treatment fraction of generated waste and increasing the recycling fraction to 25 per cent in the projected year model (2031 A.D.). The policy results show that the total waste generation would reduce from 4038.58 tons to 2929.81 tons (27.45 per cent) while the total collection would reduce from 1700.04 tons to 1594.62 tons/day (6.20 per cent), treatment would show a massive increase from 18.42 tons to 1004 tons (5353.91 per cent) and recycling would increase from 686.56 tons to 937.54 tons (36.56 per cent). As a result, the composite efficiency of solid waste management would increase from 0.241 to 0.775 (221.58 per cent) while the composite environmental stress would reduce from 0.715 to 0.595 (16.78 per cent). Employment generation in formal sector would decrease from 7,640 to 6,673 persons (12.66 per cent) whereas that in informal sector increases appreciably from 19,910 to 27,188 persons (36.56 per cent).

7.2.14 POLICY 14

A policy has been developed by considering the increase in Awareness by 80 per cent and 20 per cent increase in Investments, no increase in Organised sector, 50 per cent increase in the treatment fraction of generated waste in the projected year model (2031 A.D.). The policy results show that the total waste generation would reduce from 4038.58 tons to 2929 tons (27.45 per cent). The total waste collection would decrease from 1700.04 tons to 1594.62 tons (6.20 per cent) due to reduction in the waste generation, treatment would increase appreciably from 18.42 tons to 1004.61 tons (5353.91 per cent). Recycling would also decrease from 686.56 tons to 637.53 tons due to reduction in waste generation and absence of any extra efforts to promote recycling. The overall composite efficiency would increase from 0.241 to 0.733 (204.15 per cent). The land requirement for disposal would decrease from 240.47 sq. m. to 84 sq. m. per day (64.91 per cent) due to increased treatment and reduced generation of waste. The composite environmental stress would reduce from 0.715 to 0.585 (18.18 per cent). There would be a certain loss of employment in both formal and informal sectors. The manpower requirement in formal sector would decrease from 7,640 persons to 6,673 persons

(12.66 per cent) and that in informal sector would decrease from 19,910 to 18,488 persons (7.14 per cent).

7.2.15 Policy 15

A policy has been developed by considering the increase in Awareness by 80 per cent, 20 per cent increase in Investments, 50 per cent increase in Organised sector and 30 per cent increase in the treatment fraction of generated waste in the projected year model (2031 A.D.). The policy results show that the total waste generation would reduce from 4038.58 tons to 2929.81 tons (27.45 per cent) similar to policy 14. The collection would increase slightly from 1700.04 tons to 1745.41 tons (2.67 per cent), treatment would increase from 18.42 tons to 738.31 tons (3908.20 per cent) while recycling almost remains unaffected. The land requirement for disposal would decrease from 240.47 sq. m. to 144 sq. m. per day (40.11 per cent). The composite efficiency would increase from 0.241 to 0.649 (169.29 per cent) while the composite environmental stress would reduce from 0.715 to 0.623 (12.87 per cent). Employment generation in informal sector would almost remain unchanged while that in formal sector would decrease slightly from 7,640 to 7,485 persons (2.04 per cent).

7.2.16 Policy 16

A policy has been developed by considering the increase in Awareness by 80 per cent, 20 per cent increase in Investments, 50 per cent increase in Organised sector and 40 per cent increase in the treatment fraction of generated waste in the projected year model (2031 A.D.).The policy results show that the total waste generation would reduce from 4038.58 tons to 2929.81 tons similar to policies 14 and 15. The collection would increase from 1700.04 tons to 1745.41 tons (2.67 per cent), treatment would increase considerably from 18.42 tons to 984.41 tons

(5244.25 per cent) while recycling would increase from 686.56 tons to 761.0 tons (10.84 per cent). The composite efficiency would increase from 0.241 to a favourable 0.73 (202.90 per cent). The land requirement for disposal would decrease from 240.47 sq. m. to 108 sq. m. per day (54.75 per cent). The composite environmental stress would reduce from 0.715 to 0.589 (17.62 per cent). Employment generation in informal sector almost remains unchanged (a reduction of 0.11 per cent) while that in formal sector decreases slightly from 7,640 to 7,362 persons (3.65 per cent).

7.2.17 POLICY 17

A policy has been developed by considering the increase in Awareness by 80 per cent, 20 per cent increase in Investments, 50 per cent increase in Organised sector and 50 per cent increase in the treatment fraction of generated waste in the projected year model (2031 A.D.). The policy results show that the total waste generation would reduce from 4038.58 tons to 2929 tons (27.45 per cent) similar to previous scenarios. The total treated quantity would increase from 18.42 tons to 1230.51 tons per day (6580.29 per cent), recycling however would reduce from 686.56 tons to 514.90 tons (25 per cent) due to increased collection and treatment. The land requirement for disposal would reduce from 240.47 sq. m. to 73.63 sq. m. per day (69.38 per cent). The composite efficiency of solid waste management would increase from 0.241 to 0.804 (233.61 per cent) whereas the composite environmental stress would also show an improvement by reducing from 0.715 to 0.555 (22.38 per cent). Employment generation in both the informal and formal sectors would almost remain unaffected.

7.2.18 POLICY 18

A policy has been developed by considering the increase in Awareness by 80 per cent, 20 per cent increase in Investments, 80 per cent increase in Organised sector and 50 per cent increase in the treatment fraction of generated waste in the projected year model (2031 A.D.). The policy results show that the total waste generation would reduce from 4038.58 tons to 2929 tons similar to previous scenarios. The total collection would increase from 1700.04 tons to 1835.88 tons per day (7.99 per cent), treatment would increase from 18.42 tons to 1376.91 tons per day (7375.08 per cent) and recycling would increase from 686.56 tons to 717.22 tons per day (4.47 per cent). The composite efficiency of solid waste management would improve from 0.241 to 0.843 (an increase of 249.79 per cent). The composite environmental stress would further reduce from 0.715 to 0.536 (25.03 per cent). The total employment generation in formal sector would reduce slightly from 7,640 to 7,573 persons (0.89 per cent) while that in informal sector would increase from 19,910 to 20,799 persons (4.47 per cent).

7.2.19 POLICY 19

A policy has been developed by considering the increase in Awareness by 80 per cent, 20 per cent increase in Investments, 50 per cent increase in Organised sector, 40 per cent increase in the treatment fraction of generated waste and increasing the recycling fraction to 25 per cent in the projected year model (2031 A.D.). The simulation results show that the total waste generation would reduce from 4038.58 tons to 2929.81 tons similar to previous scenarios. The total collection would increase from 1700.04 tons to 1745.41 tons per day (2.67 per cent), while treatment would increase from 18.42 tons to 984.41 tons (5244.25 per cent) and recycling would increase from 686.56 tons to 1010.79 tons (47.23 per cent). The composite efficiency would increase from 0.241 to 0.768 (218.67 per cent) and the composite environmental stress would reduce from 0.715 to 0.600 (16.08 per cent). The employment generation in informal sector would show an appreciable increase from 19,910 to 29,312 persons (47.23 per cent) while that in formal sector would decrease from 7,640 to 7,362 persons (3.65 per cent).

7.2.20 POLICY 20

A policy has been developed by considering the increase in Awareness by 80 per cent, 20 per cent increase in Investments, 80 per cent increase in Organised sector, 40 per cent increase in the treatment fraction of generated waste and increasing the recycling fraction to 25 per cent in the projected year model (2031 A.D.). The policy results show that the total waste generation would reduce from 4038.58 tons to 2929.81 tons similar to previous scenarios. The total collection would increase from 1700.04 tons to 1835.88 tons per day (7.99 per cent), treatment would increase from 18.42 tons to 1101 tons (5880.08 per cent) while recycling would increase from 686.56 tons to 1054.73 tons (53.63 per cent). The overall composite efficiency would increase from 0.241 to 0.807 (234.85 per cent). The land requirement for disposal of wastes would decrease from 240.47 sq. m. to 105 sq. m. per day (56.33 per cent). The composite environmental stress would reduce from 0.715 to 0.586 (18.04 per cent). The employment generation in formal sector almost remains unaffected while that in informal sector would increase from 19,910 to 30,587 persons (53.63 per cent).

7.3 RECOMMENDED POLICIES

Selection of the most appropriate policy is important to further design a detailed strategic waste management plan to achieve the desired objectives. Among the selected 20 policies, an attempt has therefore, been made using a scoring index to decide the most appropriate policy. The following section elaborates this further.

7.3.1 Score Index for Policy Results

The score index followed to have a better assessment of the various short-listed scenarios is presented in Table 7.3. The lower the total score of the index better is the overall performance of the urban system and vice versa. While giving the scores, employment in informal sector has been promoted keeping in view the fact that a large section of population depends on waste recycling for their livelihood in the study area.

Based on the presented score index, scores have been calculated for each of the twenty scenarios and are presented in Table 7.4. The table clearly shows that Scenario 20 gives the lowest score of 22, followed by Scenario 18 with an overall score of 23.

The Investigator observed that the policy number 20 would be more suitable for achieving an integrated solid waste management in the study area based on the detailed analysis of the policies and their results. The policy is developed based on the composite scenario by considering an increase in awareness by 80 per cent, 20 per cent increase in investments, 80 per cent increase in organised sector, 40 per cent increase in the treatment fraction of generated waste and increasing the recycling fraction to 25 per cent in the projected year model.

Table 7.3: Score index followed to evaluate the performance of various policies

S. No.	Type	Range	Range	Range	Range
1.	HH waste generation	<2100 tons	2100-2500 tons	>2500 tons	
	Score	1	2	3	
2.	Commercial/market waste generation	<550 tons	550-650 tons	650-750 tons	>750 tons
	Score	1	2	3	4
3.	Hospital waste generation	<12 tons	12-15 tons	>15 tons	
	Score	1	2	3	
4.	Industrial waste generation	<250 tons	250-300 tons	>300 tons	
	Score	1	2	3	
5.	Total Waste generation	<2900 tons	2900-3400 tons	>3400 tons	
	Score	1	2	3	
6.	Total HZ waste generation	<225 tons	225-250 tons	>250 tons	
	Score	1	2	3	
7.	Total Non HZ waste generation	<2800 tons	2800-3200 tons	>3200 tons	
	Score	1	2	3	
8.	Collection	>1800 tons	1600-1800 tons	<1600 tons	
	Score	1	2	3	
9.	Treatment	>1000 tons	100-1000 tons	<100 tons	
	Score	1	2	3	
10.	Uncollected waste	<1000 tons	1000-2000 tons	>2000 tons	
	Score	1	2	3	
11.	Recycling	>800 tons	600-800 tons	<600 tons	
	Score	1	2	3	
12.	Composite SWM efficiency	>0.7	0.5-0.7	0.3-0.5	<0.3
	Score	1	2	3	4
13.	Land required for disposal	<75 sq m	75-150 sq m	150-225 sq. m	>225 sq. m
	Score	1	2	3	4
14.	Composite Environmental Stress	<0.600	0.600-0.700	>0.700	
	Score	1	2	3	
15.	Manpower reqd. for Formal sector	>8000	7000-8000	<7000	
	Score	1	2	3	
16.	Manpower reqd. for Informal sector	>29000	19-29000	<19000	0
	Score	1	2	3	4

Note: Higher score means a poorer performance

Table 7.4: Policy results based on scoring index

S. No.	Policy	HH gen	Com. gen	Hos gen	Ind Gen	Total gen	Total HZ	Total NHZ	Collection	Treatment	Uncollected	Recycling	Comp effi.	Land for disp	CES	Formal	Informal	Total Score
1	Projected year 2031	3	4	3	3	3	3	3	2	3	3	2	4	4	3	2	2	**47**
2	Policy1	3	4	3	3	3	3	3	2	3	3	3	4	4	2	2	4	**49**
3	Policy2	2	3	2	2	2	2	2	2	3	2	2	3	4	3	3	2	**39**
4	Policy3	2	2	1	1	2	1	1	2	3	2	2	3	4	3	1	2	**32**
5	Policy4	2	2	1	2	2	1	2	2	3	2	2	3	4	3	2	2	**35**
6	Policy5	2	2	1	1	2	1	1	2	3	2	2	3	4	3	2	2	**33**
7	Policy6	2	2	1	1	2	1	1	1	3	2	2	3	4	3	1	2	**31**
8	Policy7	2	2	1	1	2	1	1	1	3	2	2	3	4	3	1	2	**31**
9	Policy8	1	1	1	1	1	1	1	1	3	1	2	3	4	3	1	2	**27**
10	Policy9	1	2	1	2	2	1	1	3	3	2	2	3	3	3	2	3	**34**
11	Policy10	1	1	1	1	1	1	1	2	3	2	2	3	4	3	2	2	**30**
12	Policy11	3	4	3	3	3	3	3	2	2	3	2	2	2	2	2	2	**41**
13	Policy12	3	4	3	3	3	3	3	2	2	3	1	2	2	2	2	1	**39**
14	Policy13	2	2	1	1	2	1	1	3	1	2	1	1	2	1	3	2	**26**
15	Policy14	2	2	1	1	2	1	1	3	1	2	2	1	2	1	3	3	**28**
16	Policy15	2	2	1	1	2	1	1	2	2	2	2	2	2	2	2	2	**28**
17	Policy16	2	2	1	1	2	1	1	2	2	2	2	1	2	1	2	2	**26**
18	Policy17	2	2	1	1	2	1	1	2	1	2	3	1	1	1	2	2	**25**
19	Policy18	2	2	1	1	2	1	1	1	1	2	2	1	1	1	2	2	**23**
20	Policy19	2	2	1	1	2	1	1	2	2	2	1	1	2	2	2	1	**25**
21	Policy20	2	2	1	1	2	1	1	1	1	2	1	1	2	1	2	1	**22**

The Investigator, therefore, has considered this policy for recommendation, and evolved a detailed strategic waste management plan for the study area. The phase wise solid waste generation in various segments, collection, treatment and recycling achievements, composite efficiency and environmental stress creation are calculated from 2006 to 2031 A.D., and presented in Table 7.5, 7.6, 7.7, 7.8, 7.9 and 7.10.

Table 7.5: Phase-wise Solid waste generation due to adoption of recommended policy in the study area (tons/day)

Sl. No.	Year	Household waste Generation	Commercial & Market waste generation	Hospital waste generation	Industrial waste generation	Total waste generation
1	2006-2011	1021.96	425.78	4.55	107.98	1559.46
2	2011-2016	1223.81	459.39	5.36	132.28	1819.90
3	2016-2021	1465.53	495.77	6.33	162.04	2128.55
4	2021-2026	1755.00	535.14	7.47	198.50	2494.79
5	2026-2031	2101.64	577.75	8.81	243.16	2929.81

Table 7.6: Phase-wise hazardous, non-hazardous, non-recyclables, recyclables generation due to adoption of recommended policy (tons/day)

Sl. No.	Year	Total Haz. waste	Total Non-haz. waste	Total non-recyclables	Total recyclables
1	2006-2011	100.82	1458.65	699.30	759.35
2	2011-2016	120.70	1699.20	812.14	887.06
3	2016-2021	144.65	1983.90	945.38	1038.52
4	2021-2026	173.53	2321.26	1102.94	1218.32
5	2026-2031	208.35	2721.46	1289.45	1432.01

Table 7.7: Phase-wise total solid waste collection, treatment, uncollected waste, going for recycling and disposal due to adoption of recommended policy (tons/day)

Sl. No.	Year	Total SW collected	Total SW treated	Total SW uncollected	Direct recycling from generation	SW going for disposal
1	2006-2011	981.53	588.92	577.94	561.41	392.61
2	2011-2016	1144.14	686.48	675.76	655.16	457.66
3	2016-2021	1336.68	802.01	791.87	766.28	534.67
4	2021-2026	1564.96	938.97	929.83	898.12	625.98
5	2026-2031	1835.88	1101.53	1093.93	1054.73	734.35

Table 7.8: Phase-wise collection, treatment, disposal and composite efficiency due to adoption of recommended policy

Sl. No.	Year	Collection efficiency	Treatment efficiency	Disposal efficiency	Composite efficiency
1	2006-2011	0.959	0.570	0.980	0.808
2	2011-2016	0.959	0.570	0.980	0.807
3	2016-2021	0.958	0.570	0.980	0.807
4	2021-2026	0.957	0.570	0.980	0.807
5	2026-2031	0.956	0.570	0.980	0.807

Table 7.9: Phase-wise environmental stress due to uncollected and untreated waste, collection of waste, treatment of waste, disposal, recycling and the resultant composite environmental stress due to adoption of recommended policy

Sl. No.	Year	ES1	ES2	ES3	ES4	ES5	Composite Environmental Stress
1	2006-2011	0.348	0.063	0.076	0.063	0.036	0.585
2	2011-2016	0.348	0.063	0.075	0.063	0.036	0.585
3	2016-2021	0.348	0.063	0.075	0.063	0.036	0.585
4	2021-2026	0.349	0.063	0.075	0.063	0.036	0.585
5	2026-2031	0.349	0.063	0.075	0.063	0.036	0.585

Table 7.10: Phase-wise land requirement for disposal of waste, manpower requirement in formal and informal sectors due to adoption of recommended policy

Sl. No.	Year	Land req. for disposal (sq. m./day)	Manpower req. in Formal sector (no.)	Manpower req. in Informal sector (no.)
1	2006-2011	56.14	4122	16281
2	2011-2016	65.44	4805	19000
3	2016-2021	76.46	5614	22222
4	2021-2026	89.52	6573	26046
5	2026-2031	105.01	7711	30587

7. 4 PHASE-WISE STRATEGIC MUNICIPAL SOLID WASTE MANAGEMENT PLAN

Strategic Municipal Solid Waste Management plan has been prepared for five phases and dealt with element wise. There are five functional elements associated with the management of solid waste, apart from the waste generation. They are (crf, Chapter 1):

i) Waste handling and separation and storage

ii) Collection

iii) Treatment and Processing

iv) Transfer and Transport

v) Disposal

Phase 1: 2006-2011

Phase 2: 2011-2016

Phase 3: 2016-2021

Phase 4: 2021-2026

Phase 5: 2026-2031

7.4.1 WASTE HANDLING, SEPARATION AND STORAGE

7.4.1.1 Storage of residential waste

The storage of waste generated in residences shall be dealt with based on economic groups. The amount and type of waste vary according to the income-group. It usually increases with increase in income.

a) <u>Storage of Waste in HIG and MIG households</u>

Door-to-door collection of waste will be done for high-income group and middle income group households. The segregation of wastes into WET and DRY waste shall be made compulsory. Two bins storage system will be practiced and the bins shall be procured and maintained by the households.

Biodegradable/vegetative waste or the wet waste shall be stored in a plastic/metallic bin while dry wastes like paper, metals, glass, leather, textile, etc., will be stored separately. It shall be mandatory to store harmful chemicals like, dry cells, batteries, medicines, insecticides, paints, varnishes, etc., separately and inform the collector while handing him over.

b) **Storage of Waste in Low Income Group households**

Households will be required to store wet and dry wet wastes separately. Door-to-door collection service will be provided to the households. The Sweeper will blow a whistle when he comes with his cart/tricycle and the residents shall bring their stored separated dry and wet wastes and hand over to the Sweeper.

Decentralized composting shall be practised for the treatment of wet wastes. Local monitoring group from among the community shall be formed for proper monitoring and processing of the stored wastes.

c) **Storage of Waste in Slums/squatters**

Communal bins will be provided and one-bin system shall be followed. The bin will carry dry waste of non-food origin. Hundred litres capacity metallic drum type bins shall be provided as such areas are congested and have very narrow lanes. Wet wastes shall be stored at the household level and collected by the local group for decentralized composting. Local monitoring group from among the community shall be formed for proper monitoring of the stored waste.

The take-away bucket system is proposed for inaccessible areas where it is difficult for even a hand cart to enter. Such system is successfully running in a Mumbai slum (Premnagar).

7.4.1.2 Storage of Commercial and Institutional waste

Kanpur city is an active manufacturing and commercial centre. This results in a huge quantity of waste generated out of these commercial activities. The primary waste collection as well as collection of payments for the services provided should be handed over to private independent agency.

a) **Commercial premises generating only dry waste**

The individual proprietors shall store the dry waste within their premises including floor sweepings and shall hand over to the collection vehicle.

b) **Commercial premises generating both dry and wet waste**

The individual proprietors shall store the dry and wet waste separately within their premises including floor sweepings and shall hand over to the collection vehicle.

c) **Wastes generated in Schools, colleges and other educational institutions**

All educational institutions should store the waste generated separately for wet and dry waste within their campus. The capacity of the bins will depend on the quantity of waste generated.

d) **Wastes generated in marriage halls, community centres, etc.**

It needs persuasion and enforcement to manage waste in marriage halls, community centres, etc. The centres can be provided with adequate capacity bins for dry and wet waste storage which shall have to be:

- Extra-income can be made if the wet wastes are sold to the piggery owners. Pigs prefer high-protein non-vegetarian food waste.

- The wet waste can be composted on the site itself and the compost can be used for maintenance of the garden.
- The dry waste has to be immediately cleared by the authority against the payment of charges by the owners of the marriage halls, community centres, etc.
- Routine checks shall be made to such centres to check the compliance of the above.

e) **Waste generated by hawkers, peddlers and mobile vendors**

Incentives can be given to the mobile vendors and hawkers for storing the biodegradable waste generated and transferring later to the nearest composting facility or the community bins provided. Hawking is mostly illegal. They can be permitted to conduct their businesses in exchange that they keep their surroundings spotlessly clean.

7.4.1.3 Storage of Biomedical waste

There is an immediate need to enlist the entire existing healthcare and biomedical facilities ward wise and bed capacity wise, inclusive of the pathological labs. As per the Biomedical waste (Management and Handling Rules) 1998 and 2000, the biomedical wastes have to be stored and managed separately. However, in the existing scenario the hazardous wastes are routinely disposed along with the municipal wastes. This is true for big hospitals as well as small nursing homes and clinics. There is an urgent requirement to check this malpractice by routine checks and imposing fines. The Rules already exists; it only needs to be enforced. In no way, it should be allowed to get the bio-medical waste mixed with the municipal waste.

Waste needs to be segregated and stored in all the health care facilities as prescribed by the schedule II of the *Bio-Medical Waste (Management & Handling) Rules, 1998.* It means that the yellow container is used for incinerable waste (body parts and tissues, cotton and bandage), the red/blue container for waste that needs disinfection, in the white bin all type of sharps and all general waste should be put in the black container.

7.4.1.4 Storage of Industrial waste

This covers only tannery waste and waste coming from footwear industry.

TANNERY WASTE: Strict enforcement by the Kanpur Nagar Nigam for separate storage of generated waste by the tanneries on the principle "Polluter pays" is required.

Three type of waste is generated by the tannery operations:

a) Fleshings: Fleshings are scraped from the inside of hides before processing. When these are scraped prior to chrome-tanning, they can be composted and hence can be stored separately. However, blue fleshings which contain hazardous chromium, shall be stored separately and transported to the secured engineered landfill by Kanpur Nagar Nigam or any private organisation.

b) Shavings and buffings: Shavings and buffings are produced after hides are tanned and when they are being split or finished to produce leather. The coarser fraction of this waste is used for producing 'leatherboard' from which suitcases, etc., are made and is sold off.

The finest fractions unsuitable for sale as by-products shall be stored separately and collected by Kanpur Nagar Nigam or any private organisation.

FOOTWEAR INDUSTRY WASTE: Footwear is a major cottage industry in Kanpur and waste coming from it primarily comprises of 'rubber cuttings' from the making of slipper holes and 'light weight sheeting' made of Ethylene Vinyl Acetate (EVA). It shall be made mandatory for the owners of such footwear industry to compulsorily store the waste separately and to be collected by the Kanpur Nagar Nigam against a monthly payment.

7.4.2 COLLECTION

Collection is one of the most important elements of an integrated solid waste management plan as its consequences are most perceptible. The existing collection system involves the collection of wastes generated at source by the non-motorised/small collection vehicles. When the collection points are full to the capacity, they are emptied into secondary collection vehicle and taken to processing/disposal facility. The study area has many types of collection points like carrier bins, dalaos, etc. These are however, not recommended owing to the following reasons:

a) Waste is often found strewn all around the dalao/open dump rather than inside the bins.

b) Animals and rag-pickers strew the waste while collecting the usable from the waste in these communal bins.

c) Such communal storage bins are mostly open and breed flies, vermin and various disease vectors.

d) As the communal storage bins are often randomly placed and are not a part of the road design, they pose an ugly sight and often obstruct the traffic.

The collection element has been covered under two major heads:

i) Types of collection services in various areas and collection frequency

ii) Types of collection systems, equipment and man power required

i) <u>Types of collection services in various areas and collection frequency</u>

There shall be different type of collection services depending on the areas covered, accessibility of the areas, type of land use, etc. They are as follows:

a. Collection of solid waste from residential areas accessible by bigger collection vehicles:

   The collection crew will go from door-to-door, ring the bell and get the separated dry and wet wastes and put into the modified trailers/vikrams.

b. Collection of solid waste from residential areas not accessible by bigger collection vehicles:

   The collection crew will go from door-to-door, ring the bell or simply blow the whistle and get the separated dry and wet wastes and put into the 6-bin hand carts or pedal tricycles. When full, the hand carts/tricycles shall be taken to the secondary collection vehicle-modified trailers/vikrams for further processing/disposal.

c. Collection of solid waste from commercial areas accessible by bigger collection vehicles:

   Commercial areas which are accessible to bigger vehicles will have relay system of modified trailers parked at appropriate places. The collection crew will go from door-to-door, ring the bell and get the separated dry and wet wastes and put into the modified trailers/vikrams. It shall be replaced by another empty trailer when full and the former taken to processing/disposal facility.

d. Collection of solid waste from commercial areas not accessible by bigger collection vehicles:

   Initial collection of wastes from areas inaccessible to larger vehicles shall be done by hand carts/pedal tricycles and immediately transported to relay system of trailers/vikrams parked at appropriate places.

e. Collection of solid waste from institutional areas accessible by bigger collection vehicles:

Wastes can be collected every alternate days from Institutional areas accessible to bigger vehicles and appropriately charged for the services (Rs/tonne). In congested areas, the wastes shall be first brought in pedal tricycles or 6-bin hand carts and then transported to the nearest parked modified trailers.

f. Collection of silt and solids removed from sewers

It has been observed that during the desilting process, the silt and solids removed from the sewers lie in small heaps at every nook and corner of the city roads. To check this malpractice, open trailers need to be co-located with the machines. The desilting process need to be done at night to prevent traffic interference and overcome the shortage of collection vehicles or else the normal collection procedure might get disrupted.

ii) Types of collection system, equipment and manpower requirements

It is proposed to use hauled container system in combination with short-range transfer. In the hauled-container system, the containers used for the storage of wastes are hauled to the disposal/treatment site, emptied and returned to their original locations or new location. In short-range transfer, the refuse collection is divided into two phases of primary and secondary collection. Primary collection is done door-to-door by smaller vehicles and when full these vehicles are brought to the site of larger motorized mobile collection vehicle and emptied into it. Exchange container mode shall be followed to reduce the travelling distance and time for full circuit of operation.

Details of collection vehicles and manpower required for <u>Primary</u> collection in Phase I (2006-11) assuming density of municipal wastes in the city as 873 kg/m^3.

a) Collection by handcarts in residential areas

Handcart capacity = 400 litres

One handcart load capacity @ 873 kg/m^3 density solid waste = 350 kg

Number of households served per handcart load @5persons/Household generating 550 gm /capita/day waste = 127

However, the number of households served per trip collection will be restricted to 60 to keep the load manageable

Thus, load carried by handcart per trip = 171 kg

Door-to-door collection time @ 2 minutes/ household = 120 minutes

Travel time to secondary collection and back 500m * 2 @ 3 kmph = 20 minutes

Unloading time at secondary collection point = 15 minutes

Delay allowance for complete trip = 15 minutes

Total time taken for one complete trip = 170 minutes

Total number of households served per trip = 60

Total solid wastes collected per trip = 171 kg

Number of trips per day = 02

Total solid wastes collected per hand cart per day=342 kg

Total number of low income group (LIG) and slums (EWS) households to be serviced by handcarts = 50% of 483313 = 241656.5 = 241657 (say)

number of hand carts required = 241657/120 = 2013

Total number of high income group (HIG) and middle income group (MIG) households to be serviced by handcarts = 50% of 260245 = 130123 number of hand carts required = 130123/120 = 1085 (say)

Total number of hand carts required = 2013+1085 = 3098

Total number of personnel required @1 per hand cart=3098

b) Collection by pedal tricycles in residential areas

Tricycle capacity = 400 litres

One Tricycle load capacity @ 873 kg/m^3 density solid waste = 350 kg

Number of households served per tricycle load @ 5 persons/ household generating 570 gm /capita/day waste = 122

However, the number of households served per trip collection will be restricted to 60 to keep the load manageable

Thus, load carried by tricycle per trip = 171 kg

Door-to-door collection time @ 2 minutes/ household = 120 minutes

Travel time to secondary collection and back 500m *2 @ 5 kmph = 12 minutes

Unloading time at secondary collection point = 15 minutes

Delay allowance for complete trip = 10 minutes

Total time taken for one complete trip = 157 minutes

Total number of households served per trip = 60

Total solid wastes collected per trip = 171 kg

Number of trips per day = 03

Total solid wastes collected per tricycle per day = 513 kg

Total number of low income group (LIG) and economically weaker section (EWS) households to be serviced by tricycles = 50% of 483313 = 241656.5 = 241657 (say)

number of tricycles required = 241657/180 = 1342 (say)

Total number of high income group (HIG) and middle income group (MIG) households to be serviced by tricycles

= 50% of 260245 = 130123

number of tricycles required = 130123/180 = 723(say)

Total number of tricycles required = 1342 + 723 = 2065

Total number of personnel required @ 1 per tricycle = 2065

c) Motor tricycles shall be used for Secondary collection in Residential areas

Capacity of one motor tricycle = 2 m^3

One tricycle capacity @ 873 kg/m^3 density solid waste = 1746 kg

Number of hand carts/pedal tricycles load one motor tricycle can handle = 10

Unloading time @ 15 min per hand cart/tricycle = 150 minutes

Travel time to processing/disposal facility and back 9 km*2 @15 kmph = 20 minutes

Unloading time at disposal/processing facility = 15 minutes

Delay allowance for complete trip = 15 minutes

Total time taken for one complete trip = 200 minutes

Number of trips per day = 02

Total solid wastes collected per motor tricycle per day = 3492 kg (=3.4 tons)

Number of motor tricycles required = 2* (3098+2065)/10 = 258

If 50% secondary collection done by motor tricycles, no. required = 258/2 = 129

No. of personnel required @ 2 per tricycle = 129*2 = 258

d) Secondary collection in Residential areas

Waste collected by handcarts, pedal tricycles has to be taken for secondary collection by modified trailers/motor tricycles

Tractor-trailers used for secondary collection from residential areas (50% of the remaining collected waste)

Total Solid wastes collected per tractor/trailer per day (assuming 4 no. of trips per day; capacity of one trailer of $6m^3$ as 5.2 tons) = 5.2*4 = 20.8 tons

No. of tractor-trailer required = 511/20.8 = 24.5 = 25 (say)

e) Secondary collection in Commercial areas: An approximate 331 tons of waste will generate from commercial areas at the end of year 2011. A mobile system of secondary collection of wastes in modified trailer-tractor and/or tipper-trailer is proposed.

Assumptions made: Working time per day = 8 hours

Average speed of tractors with trailers is 15 kmph and that of tipper truck as 20 kmph.

Trailers loading capacity of 6 m^3 = 5.2 tons

Tipper truck loading capacity of 10 tons

<u>Collection details of modified trailer collected by Tractors</u>

Time for exchanging trailers by tractors = 5 minutes

Time for travelling to the processing/disposal site (average maximum distance of 9 km) = 36 minutes

Unloading of wastes at disposal/processing facility = 15minutes

Delay time = 5 minutes

Total time for one complete trip = 97 minutes

Number of trips per day = 4

Total Solid wastes collected per tractor per day = 5.2*4 = 20.8 tons

Number of tractor-trailers required for secondary collection from commercial areas = 331/20.8 = 16 (say)

Number of personnel required @ 2 per tractor-trailer = 32

Tipper Trucks

The use of tipper-trucks is not recommended for collection of wastes in the study area due to the following reasons:

- Tipper trucks are suitable to collect wastes from open dumps and open storage devices only. They cannot be sued for collecting wastes from modified trailers, hand carts, etc.
- The vehicles size is large and needs bigger parking space. Hence, it cannot be used for mobile collection/storage vehicles as proposed in the plan.
- It can, however, be used for collecting large quantities of industrial wastes on requests or market areas, where enough parking space is available and large quantities of wastes is generated.

f) Secondary collection of wastes from hotel/restaurant, vegetable/fruit markets, marriage halls, etc.

Total solid waste that can be collected per tractor-trailer per day @ 4 trips per day

= 20.8 tons

Waste to be collected from hotels, markets, marriage halls, etc. = 95 tons

No. of tractor-trailers required = 95/20.8 = 5

No. of personnel required @ 2 per tractor-trailer = 2*5 = 10

In market areas, where large quantities of waste is generated, relay system of parked waste-collection vehicles is proposed. Tipper-trucks/Tractor-trailers shall be parked near a permanent iron ladder and shopkeepers will be required to bring their individual shops' dustbins to the truck, climb the ladder and empty in it. As soon as the first truck is almost full, another empty truck shall take its place and the full truck will be driven to the treatment or disposal facility. The tipper-trucks shall be modified with two divisions made:

one each for dry and wet wastes. As tipper-trucks cannot be parked in congested areas, trailer-tractors shall be used in congested areas.

g) Secondary collection in Industrial areas:

For tanneries, a bi-weekly system of collection by trucks is proposed against payment of user-fees to the Kanpur Nagar Nigam (say 40 per cent of the total waste comes from tanneries).

Waste collected by a truck @ 4 trips per day = 6*4 = 24 tons per day

No. of trucks required for bi-weekly collection of tannery waste = 151/24 = 6

No. of personnel required @ 2 per truck = 6*2 = 12

For footwear industry, collection by motor tricycles in congested areas and tractor-trailers in less congested areas is proposed. Of the total footwear waste, 50 per cent shall be collected by motor tricycles and the rest by tractor-trailer daily.

No. of motor tricycles required @ 2 trips per day per vehicle = 10

No. of tractor-trailer required @ 4 trips per day per vehicle = 2

Similarly calculations for the requirement of vehicles and personnel have been done for other phases and are presented in Table 7.11, 7.12, 7.13, 7.14 and 7.15 and Fig. 7.1, 7.2 and 7.3.

Table 7.11: Vehicles and personnel requirement for door-to-door collection in Residential areas **(number)**

S. No.	Phase	50% HIG+MIG Households	Handcarts req.	Tricycle req.	Total vehicles	Personnel
1.	2006-2011	130123	1084	723	1807	1807
2.	2011-2016	151983	1267	844	2111	2111
3.	2016-2021	177517	1479	986	2466	2466
4.	2021-2026	207339	1728	1152	2880	2880
5.	2026-2031	242172	2018	1345	3364	3364

Table 7.12: Vehicles and personnel requirement for door-to-door collection in Residential areas (number)

S. No.	Phase	50% LIG+EWS Households	Handcarts req.	Tricycle req.	Total vehicles	Personnel
1.	2006-2011	241657	2014	1343	3356	3356
2.	2011-2016	282255	2352	1568	3920	3920
3.	2016-2021	329674	2747	1832	4579	4579
4.	2021-2026	385059	3209	2139	5348	5348
5.	2026-2031	449749	3748	2499	6247	6247

Table 7.13: Vehicles and personnel requirement for secondary collection in Residential areas (number)

S. No.	Phase	Vikram/motor tricycle	Personnel	Trailer	Personnel	Tot al Personnel
1.	2006-2011	129	258	25	50	308
2.	2011-2016	151	302	29	58	360
3.	2016-2021	176	352	35	70	422
4.	2021-2026	206	411	42	84	495
5.	2026-2031	240	481	51	102	583

Table 7.14: Vehicles and personnel requirement for waste collection in Commercial areas

S. No.	Phase	No.of trailers (no.)	Personnel (no.)
1.	2006-2011	20	40
2.	2011-2016	22	44
3.	2016-2021	24	48
4.	2021-2026	26	52
5.	2026-2031	28	56

Table 7.15: Vehicles and personnel requirement for collection of Industrial waste (no.)

S. No.	Phase	Trucks	Personnel	Motor-tricycle	Personnel	Trailer	Personnel
1.	2006-2011	6	12	10	20	2	4
2.	2011-2016	8	16	12	24	2	4
3.	2016-2021	9	18	14	28	2	4
4.	2021-2026	12	24	18	36	3	6
5.	2026-2031	14	28	21	42	4	8

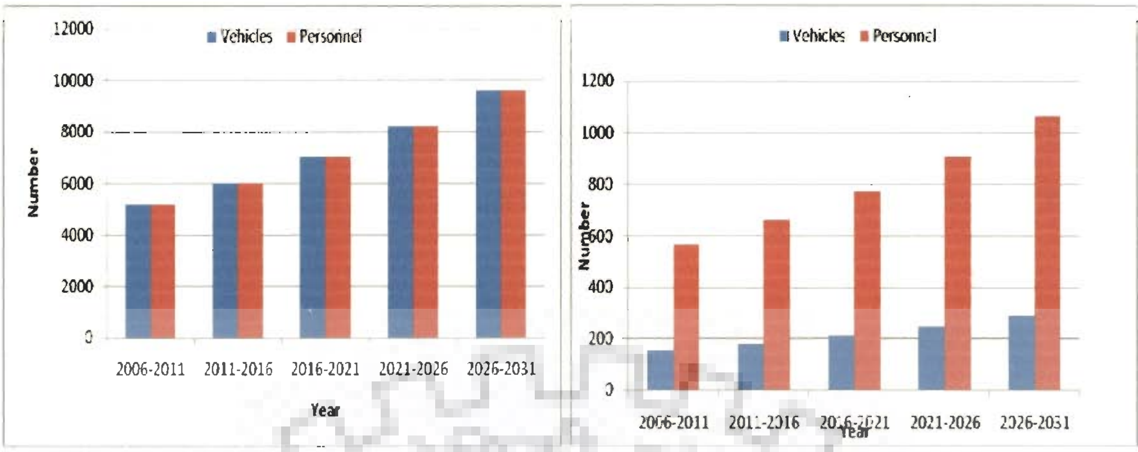

Fig.7.1: Vehicles and personnel required for primary and secondary collection of waste in Residential areas

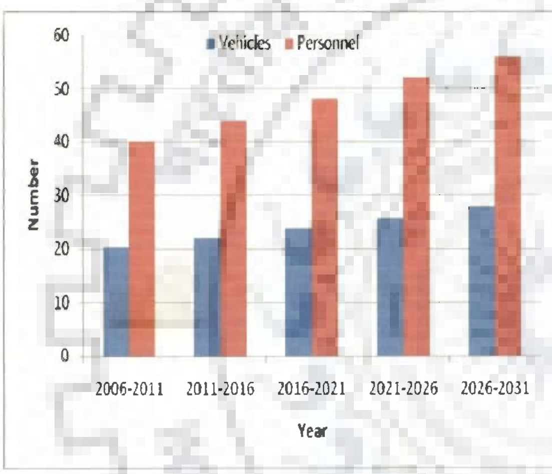

Fig. 7.2: Vehicles and personnel required for waste collection in Commercial areas

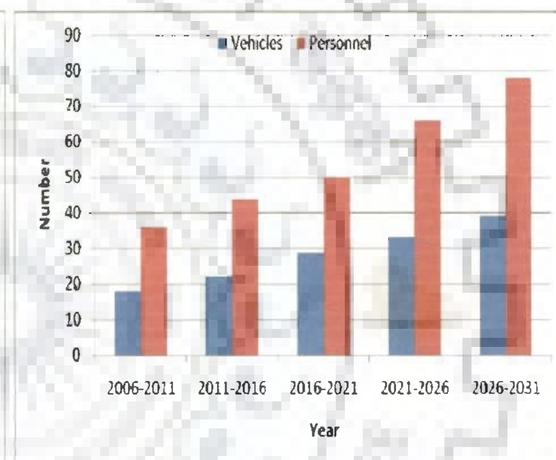

Fig. 7.3: Vehicles and personnel required for waste collection in Industrial areas

Secondary collection in Public areas

This includes street sweeping. Manual sweeping is practiced in this city. For effective planning of sweeping, it is necessary to first classify streets according to the required frequency of sweeping in the streets. This city lacks a well planned strategy for sweeping of roads. The Report of the Commission by the Honourable Supreme Court of India, recommends standards for road length to be swept by each sweeper (Safai Karamachari) as 600 to 1000 running meters of the road, depending on the density of the area, road width and local conditions. The number of beats and the frequency of sweeping in various public areas shall be as prescribed in Table 7.16. To collect the road sweepings, the existing fleet of 1000 handcarts can be used and another 600 handcarts lying in the store for want of repairs can be used.

Table 7.16: Typical Classification of streets and the frequency of sweeping

Class	Character of street	Frequency of sweeping	Beat length
A	City Centre shopping	Daily	600m
B	Market areas	Daily	600m
C	City centre and minor streets	Daily	700m
D	Sub-urban shopping streets	Daily	700m
E	Residential streets	Daily	700-800m
F	Roads and streets having no households/establishments on either sides	Once a week	1000m
G	Sub-urban main streets	Twice a week	1000m
H	Open space	Minimum once a fortnight	

Source: Kam-Avida, 2004

Table 7.17 and 7.18 show that even under the existing conditions and the vehicle fleet, the waste collection capacity can be increased. Two scenarios have been developed. In Scenario A, the average number of trip is increased from the existing 3 to 5 and the existing utilization rate remains same, it is observed that the collection increases from 701 tons to 1216 tons per day. In Scenario B, the average number of trips is taken as 5 and the average utilization rate of vehicles is increased to 80 per cent. It is observed that the daily collection capacity increases to 1958 tons per day, which can cater to the waste generation in the proposed scenario.

Table 7.17: Existing Collection Capacity of vehicles

S. No.	Vehicle type	No. of vehicles	Average load per trip (kg/trip)	Prescribed load per trip (kg/trip)	Utilization rate (%) of vehicles	Estimated waste collected(with average no of trip as 3 and average load)
1.	Ashok Leyland	33	6085	6000	53	319279
2.	Mazda tipper	5	3649	4000	65	35577
3.	Tata truck	27	6045	6000	52	254615
4.	DP big	5	2172	4000	57	18570
5.	DP small	17	1336	2000	46	31342
6.	RC big	3	2889	6000	14	3640
7.	RC small	6	2034	3000	26	9519
8.	Tractor	13	2106	1500	35	28746
	Total					701288
	Total (in tons)					*701*

Table 7.18: Proposed collection capacity with the existing vehicle fleet

S. No.	Vehicle type	ScenarioA: Average no. of trip as 5, Existing utilization rate Prescribed load	ScenarioB: Average no. of trip as 5, Utilization (80%) Prescribed load
1.	Ashok Leyland	524700	792000
2.	Mazda tipper	65000	80000
3.	Tata truck	421200	648000
4.	DP big	57000	80000
5.	DP small	78200	136000
6.	RC big	12600	72000
7.	RC small	23400	72000
8.	Tractor	34125	78000
	Total	1216225	1958000
	Total (in tons)	*1216*	*1958*

Type and location of waste-collection points

The primary survey reveals that different types of containers-big and small Dumper-placers, big and small RCs are randomly placed. It is essential that one type of container is used in one geographical area to ease the secondary collection by vehicles. However, it is proposed that all the containers are removed and mobile-collection vehicles be used as proposed in the strategic management plan to achieve a bin-free clean city.

Use of mobile dustbins and mobile collection points

Mobile dustbins provide solution to the door-to-door collection problem. It is proposed to use a tractor-trailer as a mobile kooda-ghar (collection point/dust bin). Even tempo or Vikram can also be used as mobile kooda-ghar for congested areas with narrow streets. For secondary collection, mobile collection points is proposed in which vehicles shall move along a regular route receiving waste directly from the handcarts or trolley-rickshaws or directly collecting waste from the neighbourhoods or commercial premises.

Calculations for Frequency of Collection vehicles requirement

In the case of seven days a week collection, the daily collection capacity requirement will be equal to the total amount of solid wastes generated per day. In the case of six days a week collection, the vehicles required will automatically be double of that required for seven days a week collection. Thus, as the frequency of collection is reduced the requirement of storage space, collection vehicles, handling tools and equipments, plant and machinery for treatment of waste and the collection staff increases manifolds; e.g. in case of six-days a week collection frequency it just gets doubled. It is therefore, recommended that the collection of waste is done seven days a week.

7.4.3 TREATMENT AND PROCESSING OF WASTE

A set of options available for treatment/processing of Municipal Solid Waste in Indian context has been prepared by the Investigator based on observations and discussion with experts in the field and presented in Table 7.19. A scoring index has been prepared by the Investigator after discussion with experts and taking into consideration factors like capital costs, operation and maintenance costs, physical and chemical composition of the residual matter, and possible environmental hazards due to the treatment facility, potential for cost recovery and Carbon and Nitrogen fixation to soil. The table clearly illustrates that all the three types of composting- anaerobic, vermin and windrow, give better scores than the rest and are hence recommended. Vermi and aerobic composting can be done in-vessel in all sorts of bins, containers, earthen pots, horizontal rectangular and circular tanks, etc.

Landfill with gas extraction gives a high score of 37 but still it can be practised as a large quantity of waste will continue to go in landfills in the next few years due to the high capital and operation cost of treatment facilities which, a city like Kanpur cannot afford.

Table 7.19: Scoring Index for various treatment/processing options in Kanpur

S. No	Treatment method	Capital cost	O & M	Physical composition	Chemical composition	Environmental hazards	Cost recovery	Tested or not	C&N fixation to soil	Total
1.	Sanitary land fill	2	2	10	10	9	10	No	2	49
2.	Anaerobic	2	2	3	3	3	4	Yes	4	21
3.	Vermi	4	4	1	1	1	1	Yes	1	13
4.	Windrow	3	3	2	2	2	2	Yes	2	16
5.	Bio methenation	5	5	5	5	4	3	No	6	33
6.	Pelletisation	7	7	6	6	7	7	No	10	50
7.	Incineration/combustion	8	8	9	9	8	10	No	10	63
8.	Pyrolisis	9	9	7	8	7	10	No	10	61
9.	Gasification	10	10	8	7	6	5	No	10	56
10.	Landfill with gas extraction	5	5	8	8	8	1	No	2	37

Note: A scale for 1-10 for Best to Worst
O & M- Operation and maintenance; C & N: Carbon and Nitrogen

Proposed Phase wise Treatment fraction:

The following phase wise treatment fraction is proposed in the strategic solid waste management plan:

Phase I: up to 5%

Phase II: up to 10%

Phase III: up to 20%

Phase IV: up to 30%

Phase V: up to 40%

7.4.3.1 Centralised vs decentralised composting system

A comparative study done by the Toxicslink show that centralized composting systems which are usually mechanized have been a failure in India, with few exceptions like EXCEL, which could achieve a break even point in four years (Toxicslink, 2005). These plants are very capital intensive and run in crores with other constraints of an unabated supply of segregated municipal waste. The cost analysis done by the Investigator proposes for a decentralized composting system with participation of various stakeholders. The establishment costs for such systems are low and can be a success if the government gives subsidy similar to fertilizers and some incentives for maintenance and achievement of compost standards. It is therefore, proposed to go for vermin and windrow composting for the organic fraction of the collected waste. The incremental increase in the portion of biodegradable waste recommended for composting in each phase is presented in Table 7.20.

Table 7.20: Waste going for composting at the end of each phase

S. No.	Phase	Total Waste generation (t/d)	Biodegradable waste (35%) t/d	Proposed waste going for Composting t/d
1.	2006-2011	1559.46	545.81	27.29
2.	2011-2016	1819.90	636.97	63.70
3.	2016-2021	2128.55	744.99	149.00
4.	2021-2026	2494.79	873.18	261.95
5.	2026-2031	2929.81	1025.43	410.17

High quality compost is recommended for sale and the rest of the leftovers and low quality compost could be used for landfill cover.

Further, use of any optimisation technique is proposed for appropriate combination of the treatment technology mix to arrive at optimum solution given the economic, environmental and technological constraints in the study area.

7.4.4 Recycling

It is proposed to allow the waste pickers and dump pickers to collect the recyclables from the composting yards and the dump sites only on the condition that they get badges or Identity Card from the Corporation. Segregated waste (dry and wet categories) shall be collected in the proposed plan, which will ensure that the waste pickers get better quality of waste and hence, more recyclables shall be retrieved for recycling purpose. Organisations like Indian Institute of Technology, Kanpur can be encouraged to evolve innovative and cost-effective technologies for recycling of various kinds of waste and the recyclers shall be trained by the Government to incorporate the developed technologies. The prime objective shall be to encourage recycling of waste in a sustainable manner.

7.4.5 Transfer and Transport

There are two issues related to collection of waste: vehicles used and vehicle routing

7.4.5.1 Vehicles used

One of the drawbacks of the vehicles used for collection of wastes is that they are mostly imported and not suitable for the prevalent conditions. The same situation prevails in the study area. Most of the vehicles purchased recently are not suitable for the site conditions. The following collection vehicles are proposed (Fig. 7.4, 7.5, 7.6 and 7.7):

a) Hand-carts

b) Pedal tricycle (Tricycle rickshaw or tricycle carts)

c) Motor-tricycle with hydraulic tipping container (Vikram or tempo)

d) Tipper trucks

e) Tractor-trailers

Fig. 7.4: Use of trolley-rickshaw or tricycle carts and handcarts

Fig. 7.5: Use of Vikram or tempo as a "mobile dustbin"

Fig. 7.6: Direct collection into covered vehicles

Fig. 7.7: Mobile transfer stations

Primary-collection carts

The study area does not have enough carts and/or trolley-rickshaw carts to achieve door-to-door collection of waste and those available are in a poor state due to various reasons. It is, therefore, proposed to improvise the existing fleet of hand carts by taking the following measures and to purchase rest of the required carts.

- use of garbage resistant corrosion resistant mild steel sheets from SAIL for the handcarts.
- painting the handcarts with two-coats of anti-corrosive bituminous black paint instead of the existing practice of enamel paint.
- making three one-cm diameter holes at the farthest and lowest point of the handcart to drain off any trapped rainwater to minimise rusting.
- providing rubber handles

Transport vehicles

The study area has 142 transport vehicles of various types (crf Chapter 3), of which most are not suitable and inconvenient to the drivers. For future purchase of the transport vehicles, it is proposed to buy lower tipper-body heights make vehicles, which are easier to manually load the garbage.

Vehicle repair and maintenance

Of the two workshops in Kanpur, the Fazalganj workshop does its own repairs while the Chunniganj workshop gives everything on contract (crf Chapter 3). The repair work is generally of very poor quality due to underpayment or delayed payment to the private contractors. The existing system of maintenance and repair of vehicles is very weak in the study area and needs immediate remedial measures. It is proposed to estimate the annual budget required for each model (used by the Corporation) and age of vehicle. Each vehicle should then be assigned to a particular Service station, which will service and repair the vehicle as per the annual maintenance budget.

Another problem faced by the personnel of solid waste management in the Corporation is no financial authority without prior sanction to spend even a single penny for even urgent repairs. It is therefore, proposed to keep an imprest amount with each level of official, including Safai Naiks, Cleaners and Drivers to spend at their discretion without prior permission an amount equal to a week's salary.

Fuel pumping station

Both engineering workshops in the study area have fuel-filling stations but are not working in want of repairs and vehicles are currently filled at off-site pumps and a lot of diesel theft and wastage is observed due to this (crf Chapter 3). It is, therefore, proposed to revive both the pumping stations to improvise diesel consumption and prevent theft. Besides, each vehicle shall have a working mileometer to check fuel efficiency and shall be maintained on a daily basis by the drivers and handed over to the depot-in-charge.

7.4.5.2 Vehicles routing

Proper routing of vehicles has the potential to save cost but requires a lot of data. Its primary objective is to find out the travel path of a vehicle so that pickup can be done at minimum cost. The routing of vehicles for collection of waste is a complex task. A number of computer programming concepts are used in developed countries [115, 262, 330]; a manual routing is preferred in Indian conditions [323]. It can also be done with the use of Geographic Information Systems [135]. The study area has a Goegraphic Information System (GIS) lab in the Kanpur Municipal Authority which can be used for computerized routing of vehicles.

There are three different routing needs: macrorouting, route balancing and microrouting. Macrorouting deals with optimising the collection routes based on location of disposal and/ or treatment facilities. It is essential if more than one site is available for dealing with the collected waste. Hence, this will be required at the end of Phase I after the development of treatment facility.

Route balancing deals with distribution of workload for the collection crew so that workers in each route spend more or less same time on the job. It can thus help in deciding the size of each collection area/district. This shall be required right from the start of Phase I.

Microrouting involves laying out the exact travel paths for each collection vehicle so that the collection time is minimized. Geographic Information Systems are best suited for this and shall be used in the study area for developing microrouting plans at the start of each phase.

7.4.6 Disposal

This is the most prevalent method of dealing with waste in developing countries as the collected waste straightaway go to dumpsites for disposal without any treatment/processing. There are two major steps to be taken namely, design of new sanitary landfills/controlled dumps and remediation of old open dumps.

a) Design of new sanitary landfills/controlled dumps

It is mandatory for the Governments as per the Municipal Waste Management and handling Rules, 2000 to develop new scientifically designed landfills (sanitary landfills). Before designing new sanitary landfill, it is required to estimate the land requirement for disposal in landfills. The following section attempts to calculate the land requirement for disposal in landfills assuming the worst scenario that there is no processing/treatment of waste other than recycling.

Projection of Urban Solid Waste generation and land area required for disposal

The field studies conducted by Institutional Community Development Project in 2001, show the average waste generation rate of 0.55 kg/capita/day, hence, it has been used as the base waste generation rate in 2001. The annual rate of increase in quantity of waste generation is taken as 1.33 per cent per annum based on similar studies. The projected waste generated and land requirement for its disposal excluding the waste going for recycling (informal sector) is presented in Table 7.21 and Fig. 7.8.

Table 7.21: Projected waste generation and land required for disposal (landfills) at the end of each phase

S. No.	Phase	Annual waste generation (tons)	Annual Waste going for composting (tons)	Waste going for recycling (tons)	Waste going for disposal (tons)	Annual Land req. (sq m.)	Total land req. (sq. m)
1.	2006-2011	569202.90	9961.05	204914.7	354327.20	50668.79	60802.55
2.	2011-2016	664263.50	23249.22	239133.4	401880.88	57468.97	68962.76
3.	2016-2021	776920.75	54384.45	279692.2	442844.10	63326.71	75992.05
4.	2021-2026	910598.35	95612.83	327813.8	487171.72	69665.56	83598.67
5.	2026-2031	1069380.65	149713.29	384976.5	534690.91	76460.80	91752.96

Calculations have been done assuming area demanded for landfilling is 0.143 m^2 per tonne of waste, and taking a standard height of landfill as 10 meter. The actual land requirement is however, greater than the computed value as some additional land is required for a buffer zone (as per the Municipal Rules), access roads, utility access, office etc. It can be taken as 20 per cent of the computed value. The total land requirement including this computed value is presented in Table 7.21.

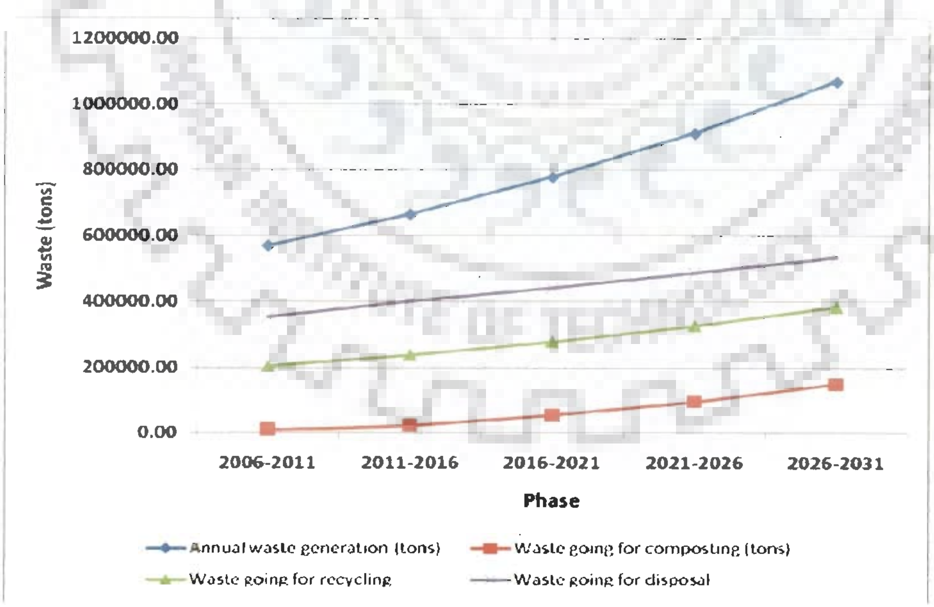

Fig. 7.8: Waste going for composting, recycling and disposal in each phase

LAND AVAILABILITY

The current vacant/open/agricultural land available within the city limits is presented in Fig 7.9. Out of this, vacant land is 17.5 sq km, which is just 5.8 per cent of the total municipal area[349]. The available ground water level is high in this area and the land is close to either agricultural land or residences. Hence, most of this vacant land can be eliminated for landfill siting due to various reasons. Further, due to the slope constraints only the Western part of the vacant land can be short listed for selection. There is however, need to carry out a detailed analysis to check the suitability of land for future landfills.

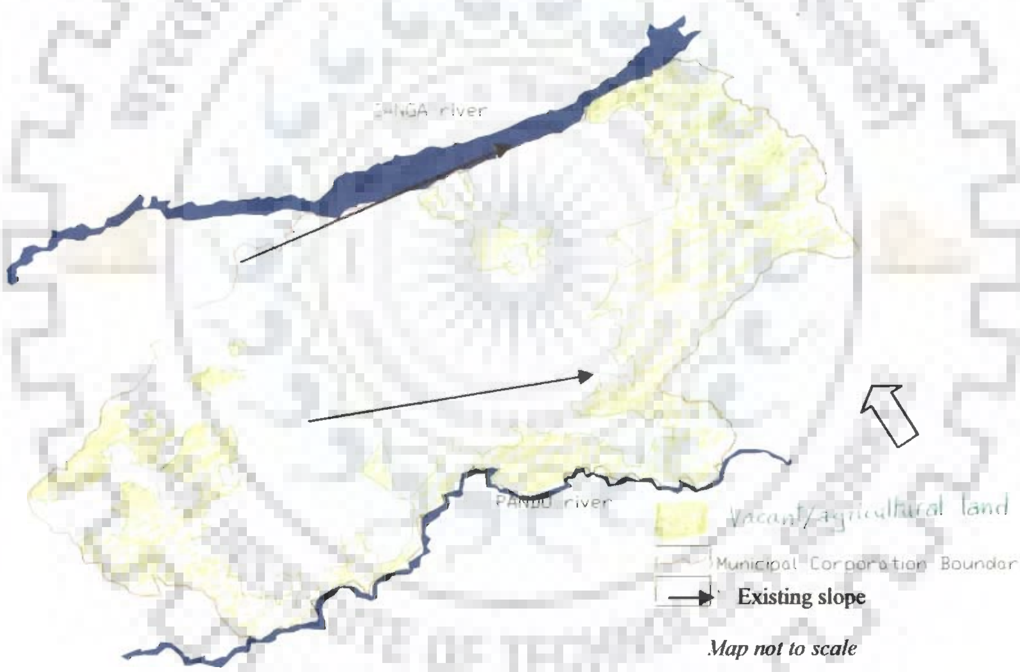

Fig. 7.9: Map showing vacant/agricultural land in Kanpur city

LAND SUITABILITY FACTORS FOR LANDFILL

Selection of land for landfill is the first step in designing of sanitary landfill. The siting of landfill is a difficult task and needs careful study before selecting the land. It is based on the physical, economic and social characteristics of the urban system. Some of the criteria used for evaluation of suitable land for landfill are: (a) topography and soil conditions; (b) accessibility (distance to the road network); (c) distance to water bodies and flooding areas; (d) distance to parks and areas of environmental protection; (e) distance to airports; (f) climatological conditions; (g) available land area; (h) geologic and hydrogeologic conditions; (i) availability of soil material to cover wastes; (j) potential ultimate uses for the completed site [202, 303].

Schedule III of Municipal Solid Waste (Management and Handling) Rules, 2000 clearly gives specifications for landfill sites like:

- The landfill site shall be large enough to last for 20-25 years.
- A buffer zone of no-development shall be maintained around landfill site and shall be incorporated in the Town Planning Department's land-use plans.
- Landfill site shall be fenced or hedged and provided with proper gate to monitor incoming vehicles or other modes of transportation.
- The landfill site shall be well protected to prevent entry of unauthorized persons and stray animals.
- Provisions like weigh bridge to measure quantity of waste brought at landfill site, fire protection equipments and other facilities as may be required shall be provided
- Wastes shall be covered immediately or at the end of each working day with minimum 10 cm of soil, inert debris or construction material till such time waste processing facilities for composting or recycling or energy recovery are set up as per Schedule I.
- Prior to the commencement of monsoon season, an intermediate cover of 40-65 cm thickness of soil shall be placed on the landfill with proper compaction and grading to prevent infiltration during monsoon. Proper drainage berms shall be constructed to divert run-off away from the active cell of the landfill.

Further, there should be regular water quality monitoring, and ambient air quality monitoring, besides provisions for post-closure care for landfills as stated in Schedule III of Municipal Waste Management and Handling Rules, 2000. The impact of various liquid management practices on cover settlement should be considered while designing of municipal solid waste landfills as presented in Table 7.22.

Table 7.22: Impact of Liquids Management Practice on Cover Settlement at Municipal Solid Waste landfills

S. No.	Leachate Management Practice	Total Settlement		Differential Settlement	
		Amount	Time	Amount	Time
1.	Leachate Recirculation	10-20%	≤15 yrs	Moderate to major	≤10 yrs
2.	Standard Leachate Withdrawal	10-20%	≤30 yrs	Little to moderate	≤20 yrs
3.	None, e.g. at abandoned landfills or dumps	Up to 30%	>30 yrs	Unknown	>20yrs

Source: Koerner, R.M. et al, 1997

b) Remedial measures to treat the abandoned dumps and existing dumps to stop further damage to the ecosystem and public health

As discussed in Chapter 3, there are five official dumpsites in Kanpur city, of which two (Panki and Krishna nagar dumpsite) are already closed as they are full beyond their capacity. The existing dumpsite at Bingawan is adjacent to agricultural fields and close to residential areas. There is an immediate need to stop further dumping of waste and to take immediate remedial action to prevent leachate penetration and other harmful impacts of open unchecked dumping. The site at Rooma (for disposal of chromium sludge) also needs scientific treatment to check the disposal of hazardous and toxic wastes. There is no existing use of soil cover or any other preventive measures to curtail the possible environmental pollution.

FINAL COVERS FOR ABANDONED DUMPS

Covers (also called "caps") are typically multi component cover systems that are constructed directly on top of the waste shortly after a specific unit or cell has been filled to its capacity [193]. The usual problems with covers for abandoned dumps are that there is no liner system beneath the dumps and the type, composition, thickness, etc., of waste not defined.

There are six-typical layers for final cover design and is presented in Fig. 7.10.

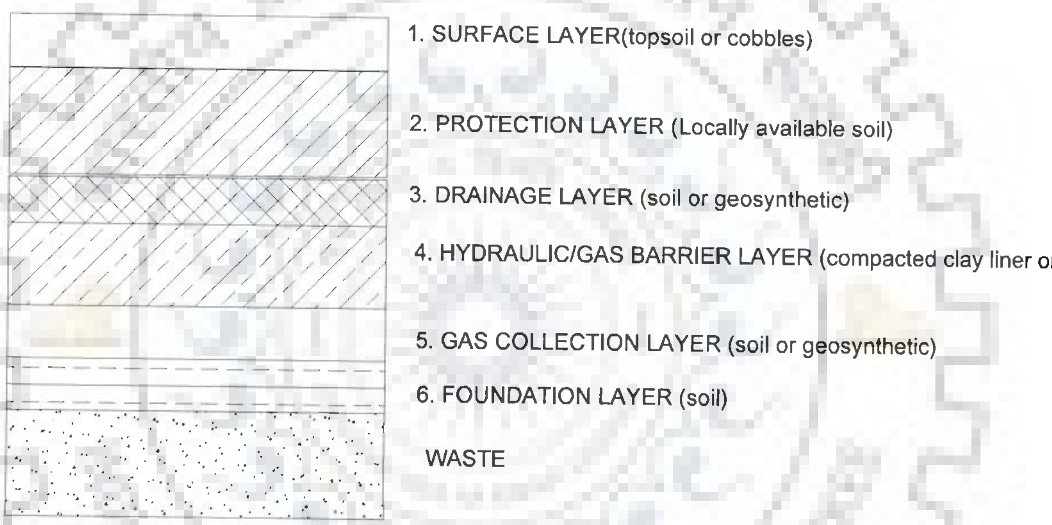

Fig. 7.10 Six layers of the Final Cover

i. Topsoil layer: minimum thickness of 150 mm
ii. Protection layer: can be separate or combined with topsoil layer, thickness depends on many site-specific factors (Koerner, et al, 1997)
iii. Drainage layer (if granular, minimum thickness of 300 mm)
iv. Hydraulic/gas barrier layer: can be geomembranes, geosynthetic clay liners or compacted clay liners. If cost-constraints exist, compacted clay liners of minimum 150 mm thickness can be used in the system.

v. Gas collection layer: if using natural soils (recommended in this case due to cost constraints), it should be minimum 300 mm thick

vi. Foundation layer: It is granular soil of minimum thickness 300 mm and is heavily compacted

As these abandoned dumps are non engineered facilities, they lack any bottom liner and leachate management system. To check these, Vertical cut-off walls, pump-and-treat systems, and other remediation methods are recommended.

COST-EFFECTIVE MEASURES FOR DESIGN OF SUSTAINABLE LANDFILLS

Developing and maintaining an Engineered landfills is a costly affair. It is therefore, not recommended in the first phase. Rather, a stage wise procedure shall be adopted for moving from open dumps to controlled dumps to engineered landfill and finally to sustainable landfill. The general philosophy of "Best practicable environmental option" is suggested with attainability and sustainability being the key parameters for the upgradation of the disposal methods.

LANDFILL GASES

Wastes in landfills/open dumps undergo a series of biological reactions. These are dependent upon a series of conditions (e.g., moisture content of waste composition, availability of oxygen (redox potential), temperature, microflora, and compaction rate) [179]. Methane and carbon dioxide are often the primary gases generated, under strict anaerobic conditions. When generated in a landfill, this gas is often referred as landfill gas (LFG). However, in uncontrolled situations as in open dumps, it is difficult to predict the level of biodegradation and the time required for the formation of landfill gases.

Estimates of Landfill gas (LFG) generation

Landfill mining has the capacity to reduce the volume of wastes by 30-60 per cent. Besides, in an energy starved city like Kanpur the extraction of landfill gas for electricity production can bring extra dividends. It is generally accepted that a maximum volume of around 200 Nm^3 (20.2 tm^3) of landfill gas can be generated from 1 tonne of landfilled Municipal Solid Waste due to uneven and incomplete biodegradation [179]. However, it is not possible to capture the total volume of gas generated due to various factors. Normal recovery rates are found to be in the range of 40-50 per cent. The upper yield of landfill gas generated for practical commercial recovery is about 100 Nm^3/tonne of waste in place, generated over 15-20 years [104]. Use of enhanced bioreactor landfill techniques brings down the time period to 5-10 years and increases the annual flow of landfill gas. The estimated landfill gas generation from the disposed waste (excluding from the old dumps) at the end of each phase is given in Table 7.23. The calculations have been done based on the assumption of average production of 10 m^3 landfill gas from 1 tonne of waste.

Table 7.23: Estimation of Landfill gas generation

S. No.	Phase	Waste going for disposal	Landfill gas (m^3)	Cumulative landfill gas (m^3)
1.	2006-2011	354327.2	3543272	3543272
2.	2011-2016	401880.9	4018809	7562081
3.	2016-2021	442844.1	4428441	11990522
4.	2021-2026	487171.7	4871717	16862239
5.	2026-2031	534690.9	5346909	22209148

The generated landfill gas could be used for energy generation and a detailed cost-benefit analysis (feasibility analysis) is proposed in the study area. Landfill gas extraction is also proposed for the closed dumps.

7.4.7 GARBAGE IN DRAINS

The study area has a serious problem of frequent blockage of drains due to the presence of garbage. It causes flooding in low-lying areas, stagnation of water with steep rise in malaria cases, building of more silt due to reduced flow and pollution in the major rivers (Ganga river and Pandu river). The proposed door-to-door collection of waste along with a mosquito-control drive shall solve all the above problems and improve the health of people and environment in the long run. This shall be done in the first phase itself and continue in the rest of the phases.

7.4.8 DRAIN SILT

In the existing practice, many vehicles from the fleet for solid waste management are diverted to collect the sit recovered from drains (crf Chapter 3), resulting in a lot of uncollected dumps of silt all over the city, besides disturbance in the regular collection of generated municipal waste. It is proposed to purchase specialized machinery for desilting of drains (Fig.7.11) as the existing practice is an environmental hazard in the study area. The collected silt should be immediately disposed as landfill cover for waste and old dumps (it acts as an inert layer and prevents rain water; vegetation also grows well on drain silt).

Fig. 7.11: The traditional way vs the recommended way of cleaning drain silt

7.5 PUBLIC-PRIVATE PARTICIPATION ON THE BASIS OF COST ANALYSIS

One of the basic requirements for effective solid waste management is consideration of the costs constraints. There are three options available in the study area: to continue with the centralized system of waste management being handled entirely by the local government, to involve public-private partnership or to go for community participation. The following section tries to analyze the costs and benefits of all these three alternatives to arrive at optimum solutions.

(all the calculations have been done for the base year 2001)

There are three possible approaches which can be adopted in Kanpur city. They are:

a) Community participation: Local govt., NGOs and CBOs- Decentralized;
b) Public-Private Partnership (PPP): Local govt. and private organizations-Centralized;
c) Municipal Corporation-Centralized.

a) Community Participation

It will be based on the concept of cooperation and partnership amongst CBOs, NGOs and Kanpur Municipal Corporation (KNN).

Proposed Functional model:

Each NGO will be assigned to look after a ward or two, depending on the density and area of the ward. The locality covered shall form a committee Kanpur Sewa Samiti (KSS), responsible for planning and implementing various aspects of ward/locality development. The NGO shall coordinate with the committee and Kanpur Nagar Nigam and the local people. Meanwhile, Kanpur Nagar Nigam shall appoint an officer at ward level by the Kanpur Nagar Nigam for redressal of complaints

All the residents shall segregate the waste generated into wet, dry and hazardous. Waste-pickers trained by NGO shall collect these wastes from door-to-door. The waste-pickers will sell the recyclables and compost the bio-degradable fraction of waste. The decentralized compost plants/pits will be developed by the Kanpur Nagar Nigam.

Number of required Committees 110 @ one committee per ward

Number of compost plants of average capacity 5 tons/day = 110

The capacity of each plant can be gradually increased as the amount of per capita waste generation is bound to increase to some extent in future. Residents shall contribute towards the payment of rag-pickers salary while Kanpur Nagar Nigam will bear the capital cost of the plants and other equipments required by the waste-pickers.

Economics of SWM with Community participation

The economic valuation for community participation can be divided into two parts:

i. Costs and benefits associated with CBOs and NGOs

ii. Costs and benefits of Kanpur Nagar Nigam.

The cost of waste management under the community participation scenario is calculated as follows:

i. Costs and benefits associated with CBOs and NGOs

Labor and supervision cost

Labor and supervision costs are calculated as follows:

Waste handled by Kanpur Sewa Samiti (KSS) per day (ton) (only household, commercial and market waste is being considered)

$$= WKSS = 1298.74$$

Fraction of biodegradable waste of Household waste = $f_{HH} = 0.46$

Fraction of biodegradable waste of Commercial/market waste = f_{Comm} = 0.32

Waste composted per day under Kanpur Sewa Samiti (ton)

= 712.64*0.46 + 586*0.32 = 513.3

Wage of KSS workers (Rs./day) = 75

Number of workers required = 6776 + 1355 = 8131

(as calculated in the preceding sections)

Number of supervisors required @ 1 supervisor per centre = 110

Wage of supervisor (Rs/day) = 150

Total number of workers = 8131+110 = 8241

Therefore, labor and supervision cost per ton per day = Rs 482.00

Other miscellaneous costs = 0.20 * labor and supervision costs

= 96.4

Total costs (Rs per ton of waste per day) = 482+96.4 = 578.4

<u>Land cost</u>

Cost of land (L) per ton of waste per day = Rs 280

Assuming a rental rate of Rs 10 (per sq ft) per month

And land requirement of 840 ft^2 for 1 ton of waste

<u>Benefits per ton of waste management</u>

Compost produced by weight = 25% of input

= 0.25*513.3

= 128.3 t/day

Price of compost (Rs./ton) = Rs 750 (from literature studies)

Revenue from compost (Rs.) per day = 750*128.3

= Rs 96,225

Price of paper(Rs/t) $P_p = 1500$ (based on field studies)

Price of plastic(Rs/t) $P_L = 2000$ (based on field studies)

Price of metal(Rs/t) $P_M = 4000$ (based on field studies)

Price of glass(Rs/t) $P_G = 750$ (based on field studies)

Price of Rubber/leather (Rs/t)$P_R = 2000$ (based on field studies)

Quantity of paper recovered (Q_P) = 28.70t (3.69 per cent of dry weight to household and commercial waste)

Quantity of plastics recovered (Q_L) = 48.50t (6.22 per cent of dry weight to household and commercial waste)

Quantity of metal recovered (Q_M) = 0.08t (0.01 per cent of dry weight to household and commercial waste)

Quantity of glass recovered (Q_G) = 0.16t (0.02 per cent of dry weight to household and commercial waste)

Quantity of Rubber/leather recovered (Q_R)

= 20.96t (2.69 per cent of dry weight to household and commercial waste)

Revenue generated by the sale of recyclables

$= (P_p * Q_P + P_L * Q_L + P_M * Q_M + P_G * Q_G + P_R * Q_R)$

= 43050 + 97000 + 320 + 120 + 41920

= 182410

Total revenue generated=Revenue from sale of compost + revenue form sale of recyclables

= 96,225 + 182,410

= 278635

Benefits of waste management under community participation (Rs/t/day) = 214.6

Costs borne by Kanpur Nagar Nigam (for transportation and disposal of inert materials)

Primary Collection cost per ton of waste management

(This includes street sweeping) = 0.50*1178 = Rs 589

Secondary Collection and transportation cost per ton of waste management = Rs 263

Disposal cost per ton of waste management = Rs 2.5

Land cost per ton of waste management = Rs 2.6

Inert fraction of waste = 0.38

Cost borne by KNN (Rs per ton per day) = (589+263+2.5+2.6)*0.38

= 325.7

Net cost (Rs per ton of waste management per day)

= (578.4+280+325.7)-214.6

= 969.5

b) PUBLIC-PRIVATE PARTNERSHIP

Proposed model: One Aerobic Composting plant of capacity 100 tons/day to be set up by private sector (on BOO basis) along with sale of recyclables

<u>Cost calculations for the Composting plant</u>

Capital cost per ton of waste = Rs 79

Operation and maintenance cost per ton of waste = Rs 18

Building cost per ton of waste = Rs 68

Expenditure on salaries of employees per ton of waste = Rs 42

Land cost per ton of waste = Rs 280

Total cost of composting per ton of waste = Rs 487

Benefits of composting and revenue earned from selling of recyclables per ton of waste

= Rs 214.6

Cost borne by Kanpur Nagar Nigam for primary and secondary collection, transportation to the composting plant and disposal of remaining waste (per ton of waste management)

= (263+2652) + (2.5+2.6)*0.38

= Rs 2916.9

Net cost per ton of waste management = 2916.9 + 487 - 214.6

= 3189.3

c) KANPUR NAGAR NIGAM (KNN)

Cost borne by Kanpur Nagar Nigam if the work is entirely done by it and it goes for door-to-door collection of waste.

Primary collection cost per ton of waste management = Rs 2652

Secondary collection and transportation cost per ton of waste management = Rs 263

Disposal cost per ton of waste management = Rs 2.5

Land cost per ton of waste management = Rs 2.6

Total cost borne by Kanpur Nagar Nigam per ton of waste management = Rs 2920.1

Thus, the cost per ton of waste management with community participation is coming as least. Hence, it is the recommended model.

7.6 PUBLIC INFORMATION

Public cooperation is an essential component for the success of any proposed collection, treatment and disposal program. It is a part of the awareness component. It is necessary to inform the public and invoke support and cooperation from them to promote segregation of waste and get support for door-to-door collection or ring-the-bell type collection. There are many ways to inform and motivate the public, through newspaper, print media, cable TV, distributing pamphlets by the Sanitary Inspector, Safai Naiks and local Councilors in their respective wards. The publicity should be done only in the target area and shortly before the beginning of the new proposed collection system. A long-term program should be taken at school level as kids are the best target group to reinforce the value of a clean and green environment. Green school programs promoted by Centre for Science and Environment (CSE) including waste management should be promoted by the schools as it can bring in long-term benefits. Besides, a social marketing campaign can be taken up by a professional advertising agency if the budget permits.

The study area is a religiously sensitive place and has a predominant Hindu and Muslim population. The religious heads of temples, mosques, churches and Gurudwaras (place of worships of Hindus, Muslims, Christians and Sikhs) can play a strong role in motivating their people during their captive congregations. The Municipal Commissioner and District Magistrate should personally meet the religious heads and get support for various cleaning programs and improving the quality of life of the residents.

7.7 REGULATORY ASPECT TO PREVENT LITTERING OF WASTE

The Investigator proposes to introduce the practice of spot "administrative charges" to check littering of waste by the residents. This regulatory feature was found to be successful in Surat, one of the cleanest cities of India. The proposed rate of spot charges is presented in Table 7.24. The Sanitary Inspectors should be empowered to collect 'spot administrative charges' to prevent littering of wastes.

Table 7.24: Proposed Spot charges for littering of waste

S.No.	Type	Charges per day in INR First time offence	Second time offence	Third time offence
1	Residential	50	100	150
2	Commercial	100	200	300
3	Small industry	300	600	900
4	Industry	500	1,000	1,500

7.8 MANAGEMENT INFORMATION SYSTEM FOR SOLID WASTE MANAGEMENT IN KANPUR CITY

Management Information System is defined as *"an integrated, user-machine system for providing information to support operations, management, and decision-making functions in an organization. The system utilizes computer hardware and software; manual procedures; models for analysis, planning, control and decision making; and a database"* [140]. It is in fact, an effective summary of all the yard sticks of performance. It can play an important role in the success of any waste management program. The Supreme Court, Government of India, strongly suggests for adopting an Management Information System model by the Local Government. It is therefore, proposed to establish a Management Information System model for Solid Waste Management in Kanpur City.

There are three activities in an Information system, which produce the information an organization requires for making decisions, controlling operations, analyzing problems and rendering services. They are input, processing and output. Input collects raw data from within the organization and/or external environment; processing converts this data into more meaningful form and output transfers the processed information to the people where it is used.

From a management perspective, information systems are far more than input output in a vacuum. The components of the proposed Management Information System are as follows:

- Reports – Daily (On Primary collection, Secondary collection and transportation, tonnage of waste taken to composting plants and disposal sites), weekly, monthly and annual.
- Levels - City level, Zone level, Ward level
- Details:

  - Quantum of waste (both dry & wet) and source wise

  - Bins, handcarts, tricycles, motor tricycles (Vikram), tractor-trailer, etc.

  - Routing analysis - collection points in the route and the quantum of waste (Existing and the optimal route)

  - Location analysis - Sorting area (ward level), Decentralized composting area (ward level)

  - Frequency of clearance of waste

  - Location of dumping sites

  - Workers (Permanent and contract basis)

The proposed Management Information System model should be integrated with the Geographic Information System (GIS) already present in the Computer Section of the Corporation so as to add spatial elements and analysis of vehicle routing. Initially for the development of Management Information System, an external agency can be hired or a project can be given to the I.I.T-Kanpur, which is in close vicinity. The formats of all the reports should be simple, precise and non ambiguous. They should be prepared in consultation with the municipal workers. Training should also be provided to different staff categories on how to fill out the various reports (forms) correctly, compiling and analysis of the daily and weekly reports. The flow of information in the proposed Management Information System is presented in Fig. 7.12 and 7.13. A summary report of all the daily reports coming from various departments shall be summarized and given to the Commissioner on a daily basis. Based on the daily reports, weekly information and monthly reports shall be made by the officials in the Computer Section. The monthly report will also have information about each vehicle type (like time of purchase, time of repair, maintenance schedule, daily consumption of diesel, etc.).

A computerized weighbridge is proposed at the disposal site, which will also keep the record for tonnage of waste brought in by every vehicle to the dumpsite, for every trip. A summary of all the vehicles on a daily basis shall go to the Corporation office. This practice shall prevent illegal dumping/burning of waste by the workers and diesel theft, besides an insight about seasonal variations in the waste generation, which would eventually help in better fleet management and utilization.

The proposed Management Information System model (External) as given in Fig. 7.12 shows the inter department and intra department information exchange of the Kanpur Municipal Corporation along with information exchange with the consumers, Non-government organisations and Community building organisations, private institutions and organisations directly or indirectly involved with any activities of solid waste management and the informal sector engaged in waste recycling. This shall help in identifying problems, solving problems and building consensus for the implementable policies for better waste management services. Fig. 7.13 further, shows the information exchange among the workforce involved in municipal solid waste management of the Corporation. Weekly and monthly meetings shall be called by the Municipal Commissioner where even sweepers, drivers, etc., will have direct access with the Commissioner and shall give their feedback on problems faced by them and suggestions to improve their working conditions and overall efficiency of waste management.

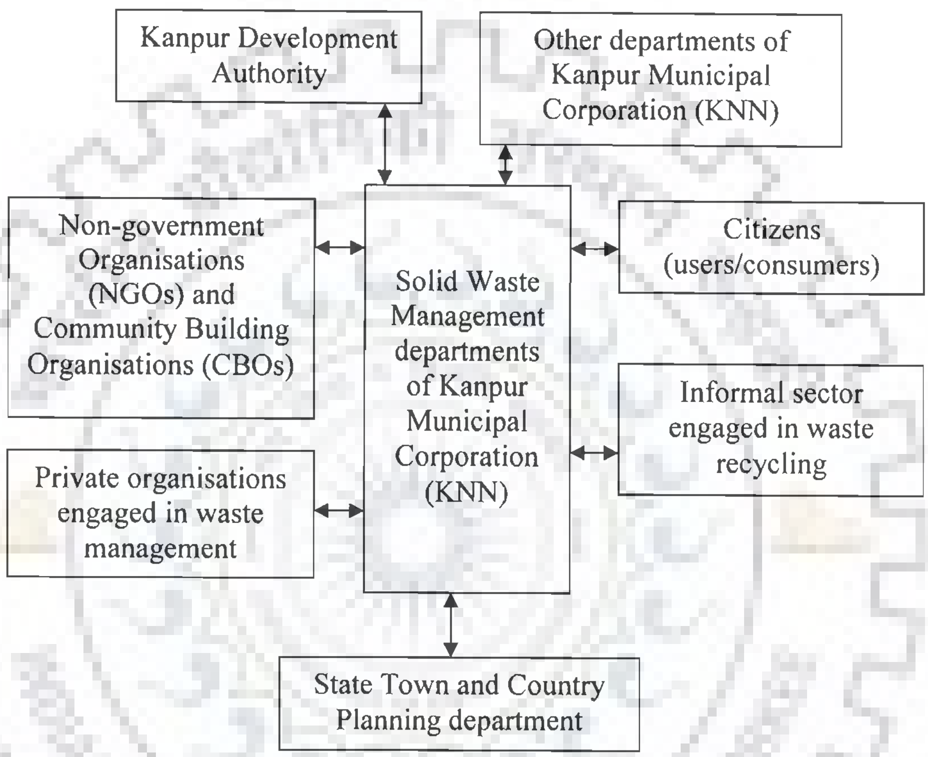

Fig. 7.12: Proposed Management Information System model (External)

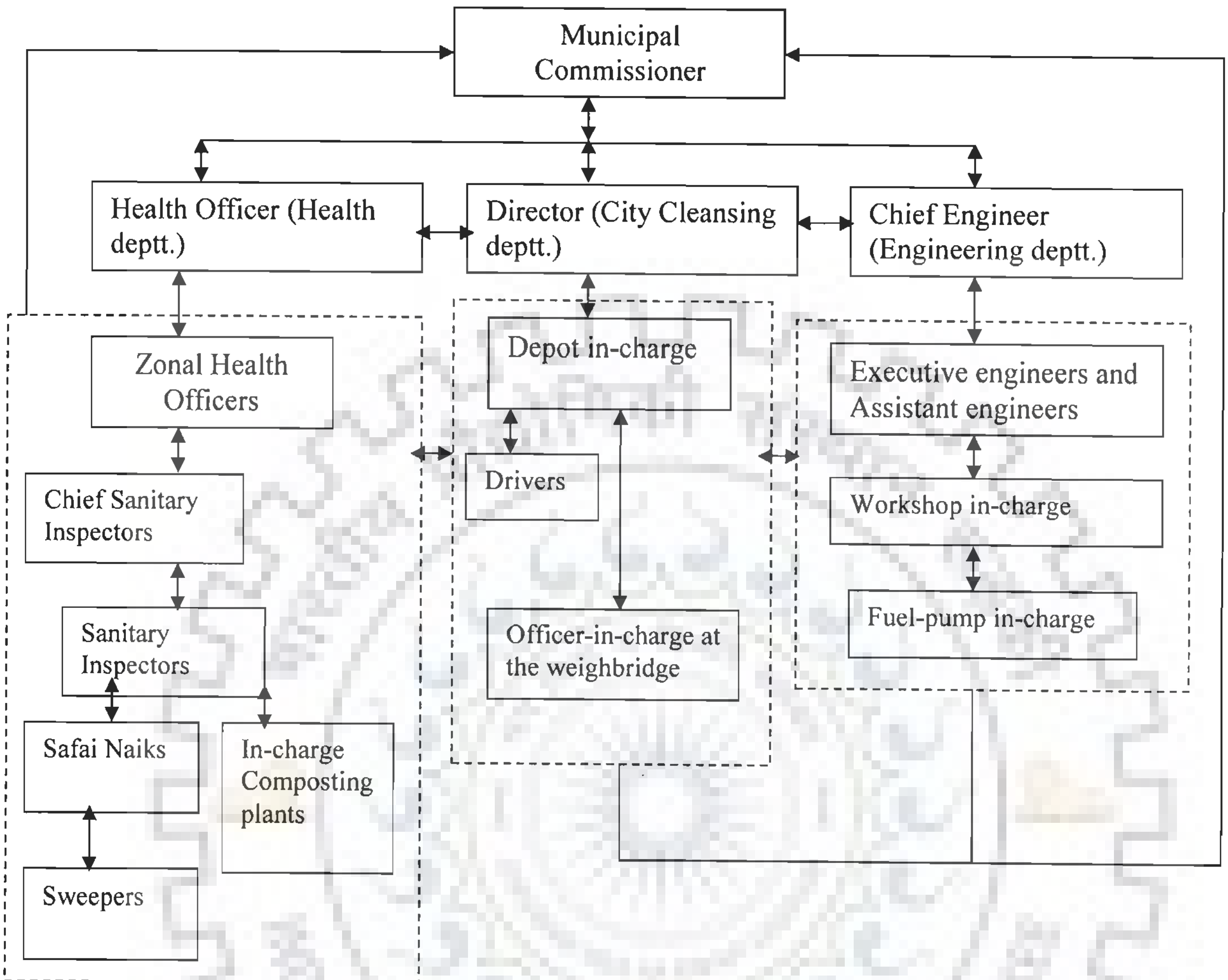

Fig. 7.13: Proposed Management Information System model (Internal)

7.9 FULL COST ACCOUNTING

Full cost accounting is proposed to be followed by the Waste Management departments of the Kanpur Municipal Corporation. Full cost accounting is a systematic approach for identifying, summing, and reporting the actual costs of solid waste management, taking into account past and future outlays, oversight and support service (overhead) costs, and operating costs. Currently, cash-flow accounting method is followed by the Corporation which records outlays when cash is actually paid for goods and services, whereas full cost accounting focuses on the flow of economic resources (assets) and accrues (recognizes) costs, as resources are used or committed irrespective of when the money is spent. For solid waste management, it basically covers three types of costs, viz., cost-up-front costs (public education and outreach, capital costs of plants and vehicles, equipments, building construction, etc.), operating costs and back-end costs (site closure, post-closure care, etc.). Other costs like remediation costs (for the discarded dumps), environmental costs (environmental degradation, downstream impacts, etc.) and social costs (effects on property values, quality of life, aesthetic impacts, etc.) may also be included. The sample format for organizing the framework is presented in Table 7.25.

The proposed full cost accounting shall recognize certain revenues associated with the solid waste management to calculate the Net costs, which shall be calculated by deducting the by-product revenues, service revenues and transfer revenues. By-product revenues are revenues coming from the sale of by-products, such as, recyclables, compost and landfill gas from the full costs of the solid waste management. Service revenues are fees derived from the users for waste management, such as unit pricing for collection or landfill tipping fees, etc. Transfer reveues are funds provided from the State or Central Government as grants or some form of revenue sharing.

Table 7.25: Sample Organizing framework for solid waste management

Solid Waste Management activities	Financial accounts				
	Labour	Vehicles Equipment	Rent	Interest	Other payment
1. Collection - Up-front - Operating - Back end					
2. Transfer Stations - Up-front - Operating - Back end					
3. Transport - Up-front - Operating - Back end					
4. Facilities (Composting, etc.) - Up-front - Operating - Back end					
5. Sales - Up-front - Operating - Back end					
6. Education and Outreach - Up-front - Operating - Back end					
7. Support services - Accounting - Billing - Building Operations - Clerical - Communications - Data Processing - Insurance - Legal - Payroll - Personnel - Purchasing - Records Management - Other					
8. Oversight					
9. Others					

Source: EPA, 1997

7.10 GENERAL RECOMMENDATIONS

Some of the general recommendations based on survey, discussion with the experts and the Government policies are given as under:

- In lieu of the tight financial conditions of the Local Government and the high cost associated with design and operation of a fully engineered landfill (sanitary landfills), it is suggested to go stage wise by initially adopting a controlled dumping and then gradually shifting to sanitary landfills with improvement in the financial status of the community and the Government.
- Lack of data pertaining to the exact generation of waste by the various waste producers and the physical and chemical characteristics and the seasonal variation in the volume and quality of generated waste is a serious problem faced by almost all the cities and towns of India, including the study area. There is therefore, an urgent need to take regular samples for the generation of primary data related to waste generation, followed by annual updating of the database. In Kanpur, the environment department of IIT can be requested to take annual data by giving its students project related to this.
- It is required to prepare a five-year vision document for Integrated Solid waste Management along with detailed annual plans and setting of targets at the end of each year. The five year plan should also have details of the existing and proposed landfill, their capacities, so that timely action could be taken for the next landfill site before the closing of existing one. This shall be well integrated with the Master Plans as the landfills and treatment plants have profound impact on the real estate and land use of the surroundings. The existing methodology adopted for preparation of Master Plans needs to be rectified and an integrated approach should be adopted.

- An index card should also be prepared to assess the improvements achieved at the end of each year regarding the quality of life, health, infrastructure and solid waste management. Some of the indicators to be included in the suggested index card are:

- Birth weight: Birth weight is a strong indicator of the overall socio-economic status of the reproducing population within an area.
- Quality of air: An increase in hospital admissions due to broncho-respiratory diseases are strong indicators of the degrading quality of air in a place.
- Rate of diseases: Rate of diseases like, diabetes, heart-diseases, hypertension, strokes, skin ailments, broncho-respiratory diseases, etc.
- Transportation related indicators:
  - Number of personalized vehicles.
  - Availability and level of service of public transport.
  - Accident rate.
- Area under Green cover.
- Extent of planned public spaces.
- Shelter occupancy rates and presence of slums.
- Housing conditions.
- Voter turnout.
- Employment rate.
- Education level.
- Consumption of energy in all major sectors like domestic, commercial, industrial, transport, etc (qualitative and quantitative data).
- Status of Solid Waste Management like, the total quantity of solid waste generated, quantity of waste collected, quantity of waste going for various treatment facilities,

quantity of waste going for final disposal, status of the landfill, air, water quality of the surroundings of treatment plants and disposal sites, etc.

- Status of water supply, sewerage and drainage.
- Quality of surface and underground water.

The above list is not comprehensive and can be further extended.

- A short term and long term promotional campaign to generate awareness among the people of the ill consequences of poor management of generated waste can bring in rich dividends. Various sorts of methods should be employed for this. In the campaign, instead of highlighting about the environmental pollution the economic loss incurred by the people should be highlighted as it would invoke more penetration of the message.
- Door-to-door campaigns should be taken up by the Corporation with the Municipal Commissioner himself visiting and talking to all sections of people. Law breakers of the highest income-group should be first targeted so that the public gets the right message of justice and to get wide support.
- Subject matter specialist should be appointed as the head of the Health and City Cleansing department to bring a real improvement in the built environment of the city. This holds true for all the Indian cities and towns.
- Proper municipal accounting can bring rich dividends. There should be more transparency in the working of the Corporation. It is observed that intra-departmental interaction is least in the Municipal Corporation. Lack of interaction among the Corporation and Kanpur Development Authority is also observed, resulting in poor rendering of essential services. It is therefore, suggested to call regular inter-

departmental and intra-departmental meetings of the various governing agencies of the city.

- Informal recycling sector forms an important part of the proposed waste management system. However, the socio-economic conditions of its lower segment people (waste pickers and dump pickers and itinerant waste buyers) need special attention. Legal sanction should be given to them by issuing identity cards to them and maintaining a record of them. Efforts should be made to promote formation of micro and small enterprises of them. They could also be employed for waste segregation and at the decentralised composting yards. Provisions should be made to impart technological advancement knowledge to the recyclers and provisions should be made to provide micro-credits to the small scale waste traders, waste pickers and itinerant waste buyers.
- Special care should be taken for waste management in slums and squatters as they are the often ignored section of the society by the policy makers and administrators.
- Having a strong financial status by a city's local government is essential to render the basic services to its citizens, including waste management. It is observed (as discussed in Chapter 3) that more than 100 per cent of the non-capital income is spent on the salaries of the municipal staff itself. The property tax collection, a major source of income, is quite poor. It is therefore, proposed to improve the tax-collection efficiency. The city should introduce an income-based administrative charge/special cleaning charge/user fee for waste management services. Floating of municipal bonds and other micro-financing methods should be tried to improve the overall financial status of the city.
- *Rapid complaint redressal system* needs to be installed by the municipal corporation and it can help earn the support of the people. Complaints shall be issued a red or white

card, assuring the complainant an answer within a specified period. Different categories of complaints along with the time required for remedial actions have to be evolved and strictly followed.

- Last but not least, strict implementation of the rules and serious enforcement of the taxes and levies is crucial for the success of any strategic solid waste management program and shall, therefore, be undertaken.

7.11 SUMMARY

An attempt has been made in this Chapter to prepare a strategic integrated municipal solid waste management plan. The results are summarised as follows:

1. Having validated and tested the model, a number of simulation runs were done to arrive at alternative policy decisions. Among the short listed 20 policies, it was observed that policy number 20 gives the best results. The policy is developed based on the composite scenario by considering an increase in awareness by 80 per cent, 20 per cent increase in investments, 80 per cent increase in organised sector, 40 per cent increase in the treatment fraction of generated waste and increasing the recycling fraction to 25 per cent in the projected year model.
2. A phase-wise strategic municipal solid waste management plan was developed based on the results of the recommended policy number 20.
3. Door-to-door collection of residential waste is recommended. The plan aims for removal of dalaos and secondary storage bins. Mobile collections points have been recommended for commercial and industrial waste. Strict enforcement of bio-medical waste is recommended to keep it away from the municipal waste.

4. The vehicles and personnel requirement for the primary and secondary collection of residential, commercial and industrial waste would be 5355 vehicles and 5547 personnel (formal sector) in the first phase 2006-2011; 6255 vehicles and 6479 personnel in the second phase 2011-2016; 7302 vehicles and 7565 personnel in the third phase 2016-2021; 8535 vehicles and 8841 personnel in the fourth phase 2021-2026 and 9969 vehicles and 10328 personnel in the fifth phase 2026-2031.
5. The collection capacity can be increased even with the existing vehicle fleet by increasing the number of trips and/or vehicle utilization rate. It is observed that with the existing vehicle utilization rate and number of trips as 5, the collection capacity will increase to 1216 tons per day from the existing 701 tons; while it will increase to 1958 tons per day by increasing the number of trips to 5 and vehicle utilization rate to 80 per cent.
6. Seven days a week collection frequency is recommended in the proposed plan.
7. Among the various treatment options, it is observed that composting is best suited given the various technological, financial and waste quality constraints. Decentralized composting is proposed in the study area. The treatment fraction shall be gradually increased from 5 per cent in the first phase to 40 per cent in the fifth phase.
8. Regular maintenance of vehicles is strongly recommended and strengthening of both the engineering workshops is required.
9. Vehicle routing shall be followed by using the GIS lab facility available in the Computer centre of the Kanpur Municipal Corporation.
10. Identification of new sites for disposal of future waste is recommended.
11. Remedial measures for treatment of abandoned dumpsites and the existing ones are recommended.

12. Landfill gas extraction is recommended. It is observed that the potential landfill gas produced in different phases shall be 3.5 million m^3 in the first phase, 4.0 million m^3 in the second phase, 4.4 million m^3 in the third phase, 4.9 million m^3 in the fourth phase and 5.4 million m^3 in the fifth phase respectively.
13. The results of the sample cost analysis done for three options of cost per ton of waste management with community participation, public-private partnership and Kanpur Municipal Corporation alone shows that community participation is the most cost-effective solution; hence it is recommended in the study area.
14. Spot charges are proposed to prevent littering of waste by the waste generators.
15. A Management Information System is also recommended for the study area for effective monitoring and implementation of the proposed strategies of the municipal waste management plan.
16. Full cost accounting is proposed to be followed by the various departments of the Corporation dealing with municipal waste.

7.12 FURTHER RESEARCH

- An integrated solid waste management plan shall be made covering industrial waste, category wise and bio-medical waste as the existing waste management of these waste types is very poor in the study area and a threat to the built environment and ecology of the place.

- A further research is proposed to find the appropriate optimization model for various alternative scenarios for evolving a sustainable integrated solid waste management plan in Indian context. A regional level waste management plan also needs to be made covering the whole region and viability of sharing of treatment and disposal facilities by various towns and cities could be considered. Currently, there are no studies available on Solid waste Management at Regional level in India. It is often bound to administrative boundaries of cities. To promote reuse and recycling of resources, a wider area than the city needs to be included and to distribute the absorption capacity of local and regional sinks to minimize the environmental impacts of waste disposal.

- A detailed economic analysis for operating, maintaining, monitoring and starting of various new treatment facilities needs to be worked upon and will be crucial for increasing the treatment facilities by 40 per cent. Further, a detailed feasibility analysis by employing Discounted Cash Flow (DCF) techniques in terms of collection, treatment and disposal for Centralized, Decentralized and with public-private partnerships needs to be done.

- There is a need to do an in-depth search on appropriate pricing strategies for improved cost recovery. A comparative cost-benefit analysis of discriminatory pricing approaches, (e.g., charges based on quantity and type of wastes collected for commercial or industrial consumers; charges based on the quality of services provided in upper-income neighborhoods) separable demand approaches (e.g., charge for collection services where there is relatively inelastic demand, use local taxes or intergovernmental transfers to pay for disposal), intra-urban cross-subsidies (e.g., charge commercial and upper income residential customers sufficiently for high quality services so that minimum acceptable collection services can be extended to low-income peri-urban areas), etc., should be done and use of Strength, Weakness, Opportunities and Threats (SWOT) or Analytical Hierarchy Process (AHP) for appropriate selection of the approach to be adopted in a given city could be explored.

- There is no clear cut taxation policy or user charge concept for solid waste management (and other infrastructure services) in India resulting in poor cost recovery leading to poor municipal solid waste management. User charge tried with mixed results in pilot cases. There is a need to develop methodologies for determining the willingness to pay for solid waste services. The research on willingness to pay should also study how health and hygiene education influences the willingness to pay. Additional research efforts are also needed in studying and developing alternative cost-recovery mechanisms. This research should include investigation of alternative models for financing the sector if or when the costs cannot be covered by beneficiaries.
- Waste generation:

  Only estimates are available (if any) for the wastes coming out but excludes the generation at source as some gets out of the stream due to wastes given to Itinerant Waste Buyers or given in charity. Besides, waste produced by bulk generators is not considered. There is a lack of knowledge about the factors that affect the waste generation variations, generators' attitudes in different socio-cultural backgrounds, behaviours and needs.
- Forecasting of waste generation is essential for appropriate planning of solid waste management. Not enough studies are available for appropriate forecasting of waste generation in India.
- There is an urgent need for uniform data collection methodology for collection of solid wastes data.
- Interface between urban growth/sprawl, dynamics and solid waste management needs to be studied specially for the megapolis and big metros.

- The existing system of waste management in the country is a centralized model with top-bottom approach and no public participation whatsoever. Attempts to study Decentralized model are scarce and only small pilot studies have been undertaken. There is a research gap in this area also. An optimal Decentralized (operational and spatial) model catering to low, middle and high income groups and various bulk generators with socio-economic, technical and environmental feasibility can be attempted.
- There is a research gap for comparative studies on community based solid waste management involving NGOs, CBOs and Private organizations especially in low-income neighborhoods in various cities (although such projects are only on experimental basis and cover only small neighborhoods), comparing situations in different cultural settings and physical conditions. Special emphasis in the study requires financial feasibility. This will give useful result in trying a decentralized model where best practices can be successfully employed on a larger scale. Such studies need to answer issues like community management, motivation, education, finance, gender issues, etc.
- There is a need to analyse all available treatment and processing technologies in terms of the local climate and physical conditions, financial and human resource capabilities, and social or cultural acceptability. This study can be helpful for appropriate selection of technology and will prevent the current chaotic condition prevalent in municipalities with regard to adoption of technology.
- Macro-economic context of pricing materials: Not much studies available for Material flow analysis in solid waste sector in Indian context. Competition from imported virgin materials and imported waste of higher quality can remove the incentives to recover waste materials locally. This needs to be studied.

- The lack of research and development activities in developing countries leads to the selection of inappropriate technology in terms of the local climatic and physical conditions, financial and human resource capabilities, and social or cultural acceptability. As a result, the technology selected can never be used, wasting the resources spent and making the project unsustainable. Comparative studies of competitive equipment & their application in local conditions need to be undertaken. The lack of industry manufacturing solid waste equipment and spare parts and a limited foreign exchange for importing such equipment/spare parts are the rule rather than exception in developing countries and should be explored.
- There is a need to study the process of privatization in solid waste management (covering all cities and towns where it has been tried) evaluated on the basis of adverse social impacts, these may indeed be worse in low income developing countries and in the absence of social security systems. As reported in case of Bangalore and Chennai, the condition of pourikarmas (sweepers) is very poor. The study should throw light as to how we can promote privatization to achieve better efficiency along with ensuring better working conditions for the lower rung workers and sweepers.
- Role of solid waste management in creating livelihoods for urban poor - this will look into waste pickers, Itinerant waste buyers and employment creation by the recycling industry. This should also cover quantification in terms of materials conservation, energy, emissions, etc., due to recycling. There is also a need to study how the recycling sector can be strengthened without having adverse environmental impacts.
- Additional research efforts on socio-cultural aspects are mainly needed with regard to hygiene behaviour and with regard to finding appropriate ways of mobilising community

support for and participation in the provision of sustainable water supply, sanitation and solid waste schemes in rural, urban fringe and slum areas.

- There are also research needs for the development of realistic methods and indicators for determining the impact of sanitation improvements (health, economic and environmental impacts).
- Need to study potential for developing market for compost. It is the major reason for failure of most centralized and bigger scale composting plants.
- There is very little literature on the policy, planning and institutional aspects to integrate existing micro-enterprises as a privatization strategy in primary collection
- Need to develop an optimal financial reporting system for municipalities as most of them do not actually know the various components that are responsible for municipal solid waste management and the associated financial management.

7.13 CONCLUSIONS

Uncollected huge heaps of waste and garbage have become a hallmark and quintessential part of consumerism driven modern civilization. Among various critical problems which are offspring of the unsustainable way of living is "waste crisis". This crisis has grown to huge proportions especially in Indian metropolitan cities. Kanpur city, the study area, is one of the dirtiest cities of Northern India with an ineffective waste management system. The primary objective of this study is to convert Kanpur into a dust-bin free clean and healthy city. This requires a feasible and detailed waste management plan and plausible policy guidelines for which thorough grassroots level investigation is required. The responsibility of managing municipal waste lies with the Local Authority, Kanpur Municipal Corporation in this case. A huge portion of the annual expenditure of the Corporation goes in managing municipal waste.

Inspite of this, it is observed that the city is full of illegal waste dumps, uncollected heaps of garbage, blocked drains, frequent flooding, etc., which eventually affect the health of the people and is still unaccounted for. It is also observed that the existing system of waste management in the city lacks an integrated approach at all levels. Segregation of waste at the generator's level is completely absent. The Authority has an apathetic attitude towards waste management. Stakeholders' participation is more or less absent. No efforts are seen to treat the collected waste, to convert the open dumpsites to more environment friendly sanitary landfills or to integrate the informal waste recycling sector with the formal one. In the light of such appalling conditions, an investigation of such kind has become further more essential. In this investigation, an attempt has been made to evolve plausible policy guidelines and recommendations and a detailed strategic municipal waste management plan by considering most important control parameters, which decides the functions of this sub sub-system. At the outset, a thorough grassroots level investigation has been carried out by the Investigator through primary survey and exploration of available literature, to understand the various parameters which influence waste generation and the existing system of municipal waste management with various links and sub-links. Further, the most important control parameters of this sub-system and interlinked and interdependent other sub-systems have been considered for evolving System Dynamics models for an integrated Municipal waste management of the whole system. The developed model has been validated and tested followed by long-range projections to understand waste generation by four major sectors (households, industrial, commercial and market activity and hospital), the amount of waste collected, transported, treated and disposed of by the Authorities, the composite solid waste management efficiency and environmental stress in the overall system in the projected year 2031 A.D. The functions of the system under various alternative conditions have been closely examined by developing various scenarios and tested by employing simulations to arrive at alternative policy decisions. Optimal policy has been selected from the set of short-listed policies based on a score-index developed for this purpose by considering various sustainability indicators. Finally, a detailed strategic municipal waste management plan and a set of policy guidelines has been prepared by phase-wise requirements for the recommended policy to achieve an integrated municipal solid waste management in the study area. The investigation concludes that if the recommended waste management plan and policies are considered and implemented in time involving all the stakeholders, Kanpur city can definitely become a clean and healthy city.

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Physical, Socio- Economic Survey of Households

1. Demographic and Socio-Economic Characteristics:
    a. Name of the Family head:
    b. House no. Ward no.
    c. Mohalla Street name:
    d. Religion:
    e. Family Details:

	Name of person	Relation with family head	Age in years	Married/unmarried	Max. education attained	Monthly income (Rs)
1.						
2.						
3.						
4.						
5.						
6.						
7.						
8.						
9.						
10.						
11.						
12.						
13.						
14.						
15.						

2. Income of the Family Members: (Monthly)
    2.1 Income level Family members

Sl.No.	Gender	Rs
1.	Male	
2.	Female	

2.2 Present Primary occupation: (Tick ✓ the correct the option(s)

a. Agriculture/ mining b. Manufacturing c. Construction
d. Wholesale trade e. retail trade f. transport
g. communication h. Own Business i. Private Service j. finance k. real estate l. Government job

Monthly Income generated: Rs……….

2.3. Secondary occupation of Family Members: (Tick ✓ the correct the option(s)

a. Agriculture/ mining b. Manufacturing c. Construction
d. Wholesale trade e. Retail trade f. transport
g. communication h. Own Business i. Private Service j. finance k. real estate l. Government job

Monthly Income generated: Rs……….

2.4. Monthly Income of the family from different sources

Sl.No.	Particulars	Amount (Rs)
1	Govt. Service	
2	Private Service	
3	Agriculture	
4	Horticulture	
5	Animal Husbandry	
6	Trade and commerce	
7	Industry (Specify)	
8	Pisciculture (fish)	
9	Self Employed (Professional)	
10	Others (Specify)	

3. Monthly Expenditure (Rs)

a. Food…….. b. Cloths……. c. Education…….
d. Health….. e. Recreation……. f. Transportation……..
g. Electricity…… h. Water supply…… i. Cooking gas……..
j. Kerosene….. k. Telephone/mobile phone……..
l. Loan Repayment……m. Utility goods (toiletries like soap,powder,etc.)…….
n. Any other……. o. newspaper/magazine/internet…..
Petrol……….. Charcoal……… Wood………..

4. Physical Infrastructure:

5.1. Housing: (Tick ✓ the correct the options)

- Type of house: Detached/ Semi-detached/ Apartment/Row
- Age of house (in years) ……..
- Physical condition: Good/ livable/ Dilapidated
- Ownership: Rented/owned/other
- If Rented- monthly rent: Rs……
- Financed by: Bank/ self/ancestral/any other
- Time since been living in the current house……..
- No. of rooms……. No. of floors……
- Plot area (sq./ft)
  <1500….. 1500-2600…… >2600
- Built up area (sq. ft)
  <1500….. 1500-3000…. 3000-4500….. >4500…..

5.2. Transportation Facility in the area: (Tick ✓ the correct the options)

- Condition of road: Pucca/ kutcha
- Well maintained/ poorly maintained/ no maintenance

- Mode of Transportation: Train/ Bus/tempo/auto/own vehicles/on foot

- If own vehicle:
  Car (no.)….. / two wheeler (no.)….. / Bicycle (no.)…..
- Public transport service: good/ average/ poor
- Place of work (distance from house in km)……
- Place for shopping……… Distance from house in km……
- Frequency of shopping (no of times in a week)……
- Frequency of visits for entertainment (movie, park, picnic, restaurant, etc) in a month………
- Quantity of fuel consumed (in litres per week):
  Petrol……. Diesel……..

5.3. Water Supply: (Tick ✓ the correct the options where necessary)

- Supply system: Public supply system/ own source/ both
- Time of supply (hrs)……
- Tariff rate….. Frequency of payment in a year…….
- Consumption (litres per day)
  Nov-Feb……. March-June…… July-Oct…..
- Storage tank capacity (litre):
  <500….. 500-1000…. 1000-1500….. >1500….
- Depth of hand pump/bore well
  <100'….. 100-150'…… >150'…..
- Water connection (ferrule size):
  ½"…. ¾"….. 1"…..
- Quality of water: good/average/ bad
- Water pressure: Sufficient….. Insufficient…..
- Shortage of water in month(s) of………………
- Use of equipments: filter/ Zero-B/ Aquaguard/ any other
- Other Water supply related problems: colour/ presence of particles/ Smell

5.4. Electricity: (Tick ✓ the correct the options where necessary)

- Available/ not available
- Metered/ Non- metered
- Tariff: Monthly/ Flat rate
- Units consumed per month……. Average bill per month…..
- Average daily power cut (hours) in summers……
- Average daily power cut (hours) in winters ……
- voltage fluctuation: more/ less
- Use of: invertor/ generator/ voltage stabilizer
- Non-conventional sources of energy: Photo voltaic cells/ other

5.5. Sanitation: (Tick ✓ the correct the options)

- Septic tank /soak pit / sewer / no sanitation facility
- Open drains/ covered drains/ no drainage
- If using public toilet: expenditure per month (Rs)…….
- Overflow of drains during rainy season: Yes/ No
- Problems faced: clogging of drains/ overflow/ bad odour

5.6. Waste Disposal: (Tick ✓ the correct the options)

- Average daily solid waste produced (in grams).......
- Ratio of organic waste (kitchen waste, paper, garden waste) and inorganic (plastics, metal, rubber, etc.).........
- Is segregation being practiced at the house? a)Yes b)No
- Method of collection at house
  a)storage container b) dust bin/PVC bag c)burning d)throwing out
- Type of disposal: thrown on street/ municipal dustbin/ composting/ burned openly/ any other
- Frequency of Municipal collection from the area
  a)daily b)alternate days c)3 days d)4 days e)weekly
- Quantity of plastics in daily waste (average number).......
- What kind of solid waste collection facility do you have in your area?
  a)NagarNigam b)private agency appointed by Nagarnigam
  c)Private agency d)no collection facility
- How is the solid waste collection system in your area?
  a)regularly collected b)collected but not regular
  c)collected but on complaints d)not collected
- Is the service provided by government satisfactory? a) yes b)No
- Normal waste collection hours a)morning b)noon c)evening
- Present system of collection and storage of waste
  a. Door-to-door collection Yes/no
  b. community bin system Yes/no
- Are you willing to pay if better services are provided? a)yes b)no
- How do you lodge complaints regarding collection?
  a)use your personal contacts with the department official
  b)go personally to the concerned office
  c)complain telephonically
  d)wait and watch instead of complaining
- Is there a response to your complaint?
  a)always b)within 2 days c)more than 2 days d)never
- Will you like the handling over of waste collection to the private sector?
  a)yes b)No

5.7. Household appliances: (number)

Refrigerator........ Stove..... A.C........Cooler.....Mixer/grinder.....Computer....
Geyser...... Immersion rod.... T.V.....Tape recorder....Oven.....Washing machine.....
Solar cooker.....microwave..... pressure cooker......

6. Health status (Tick ✓ the correct the options)

Type of disease	No. of persons suffered(ing) in a year	Frequency (in a year)	Place for medical aid(clinic or govt hospital) specify	Distance in km	Expenditure on treatment (yearly) Rs
Gastroentritis					
TB					
Malaria					
Filaria					
Typhoid					
Respiratory					
Heart related					
Cholera					
Diarrhea					
Hepatitis/Jaundice					
Others					

7. Public participation:
Willingness to pay more tax if improved water supply, sewerage and solid waste disposal is provided: Yes/ No

8. Quality of environment: (Tick ✓ the correct the options)
a) Water: Good/ moderate/ poor/ very poor
b) Land: Good/ moderate/ poor/ very poor
c) Air: Good/ moderate/ poor/ very poor
d) Noise: Very high/ high/ moderate/ low

9. Rank wise infrastructure problems in your area(put numbers)
a. Water supply problem……
b. Solid waste management problem…….
c. Sewerage/ drainage…….
d. Air pollution…….
e. Noise pollution…….
f. Roads related problems……..

10. Suggestions for improving the water supply, sewerage, solid waste management

11. Grievances with the local body/administration

Appendix-II

Informal Sector survey

1.Name of the respondent......

2. Age.........

3. Category of informal sector: Waste picker/IWB/retailer/jogi/bone merchant/wholesaler
4. Place of living..........
5. Type of house.........
6. Monthly income......
7. Daily collection (kg) Rate at which bought from HHs/inst. Rate at which sold to retailers (Rs/kg) *(for IWB)*

- Polypack
- Thin Plastic
- Paper
- Magazine
- Leather
- Metals
- Bones
- Clothes

8. Are there any seasonal fluctuations in collected waste(quantity or qualitywise)

Peak time(months)...... Lean time(months)........
Max. qty in yr (kg)..... Max. Rate of selling(Rs/kg)
Min qty in yr (kg)...... Min. rate of selling (Rs/kg)

9. Do you sort the material before selling?yes/no
10. No. of persons engaged for sorting and/or other processing.....
11. Expenditure incurred for pretreatment.....
12. Do you gather anything for personal use?
13. Mode of Transportation: Train/ Bus/tempo/auto/own vehicles/on foot
14. If own vehicle: Car (no.)..... / two wheeler (no.)..... / Bicycle (no.)...../Thela (no.)
15. Place of work (distance from house in km)......
16. Health status (Tick ✓ the correct the options)

Type of disease	Frequency (in a year)	Place for medical aid(clinic or govt hospital) specify
Gastroentritis		
TB		
Malaria		
Filaria		
Typhoid		
Respiratory		
Heart related		
Cholera		
Diarrhea		
Hepatitis/Jaundice		
Skin problems		
Others		

17. Grievances with the local body/administration
18. Police harassment? Yes/no
19. Any type of payment to authorities(Rs)
20. Use of drugs and/or alcohol
21. List of problems

Wardwise population of Kanpur U.A.(2001)

Ward No.	Ward Name	Population
1.	Laxmi purwa	26583
2.	Makrawat ganj	22004
3.	Khalasi line	15606
4.	Jawahar nagar	14250
5.	Kalyanpur	52879
6.	Nankari	12551
7.	Rawat pur gaon	38846
8.	Old Kanpur	24118
9.	Chakeri	19482
10.	Colonelgunj	8756
11.	Dada nagar ind./ kabir nagar	27501
12.	Transport nagar	19690
13.	Bhannanapurwa	21090
14.	Kaka dev/sarvoday nagar	15175
15.	Gwaltoli	21169
16.	Sisamau	23670
17.	Om purwa	23548
18.	Raipurwa	21253
19.	Vijay nagar	24433
20.	Ashok nagar	26870
21.	Arya nagar	20154
22.	Saraymeeta/panki ind.estate- all	30536
23.	Bakar ganj	24569
24.	Sanigavan	23182
25.	Tilak nagar/swaroop nagar	28101
26.	Anwar ganj	14553
27.	Nawab ganj	28748
28.	Sesamau first	18388
29.	Coolie bazar	14617
30.	Azad nagar/vishnu puri	18927
31.	Ghau khera	25242
32.	Kalyanpur naubasta	26201
33.	Panki katra,ratan pur,kapli	28253
34.	Chunni gunj	12923
35.	Yashoda nagar ,block-p	55282
36.	Juhi/vinoba nagar	29025
37.	Dabauli goun,dabauli nai basti & dabauli colony	19782
38.	Naubasta east	52893
39.	Fahimabad	8883
40.	Tiwari pur	30607

41.	Barra world bank	58315
42.	Maswan pur	24863
43.	Ram bagh/gandhi nagar	16583
44.	Naubasta	51392
45.	Kidwai nagar	23245
46.	Nehru nagar	13925
47.	Vikas nagar/lakhanpur	15154
48.	Gujaini goun/gujaini colony	28942
49.	Sarojni nagar	18081
50.	Lajpat nagar	19450
51.	Gandhi nagar	13254
52.	Civil lines	17683
53.	herjender nagar	22642
54.	Doodh wala bangla	19073
55.	Parmat	13619
56.	Sujat ganj gaon	50846
57.	Naseemabad	20416
58.	Jajmau	39432
59.	Pandav nagar h-1,h-2 block	19338
60.	Panki b, block, c block	13686
61.	Shastri nagar colony 1/2	19198
62.	Cooper ganj	12104
63.	Darsanpurwa	13636
64.	Gwaltoli/sooter ganj	20214
65.	Barra-1,2, chedi singh ka purva, nai basti barra-2, World bank	74336
66.	Kaka dev ground, p-1 block & Shiv puri	13946
67.	Param purva, juhi	25466
68.	Naramau bangar/akbarpur	9911
69.	Dalal purwa	15852
70.	Babu purwa	17419
71.	Govind nagar, viddarthi market/ nirala nagar u	20289
72.	Patka pur	23809
73.	K block kidwai nagar	23001
74.	Geeta nagar/sharda nagar	19874
75.	Ajeet ganj	16803
76.	Harbansh mohal	22833
77.	Gandhi gram	25196
78.	Hiraman purwa	24545
79.	Prem nagar	19933
80.	Garariyan purva/fajal ganj	15841
81.	Babu purwa	15780
82.	Nirala nagar, ambedkar nagar	24863
83.	Lalhari , peeli labour coloney, juhi	22225

84.	Babu purwa(I. Colony)	18403
85.	Barra-3, 4, barra,5,6,7, ratan lal nagar	55456
86.	Govind nagar	14005
87.	Usman pur/usman pur goun/keshav nagar/ saket nagar	28038
88.	Becon ganj	32471
89.	Maheshwari mohal	22538
90.	Pashupati nagar	23391
91.	Dana khori	18861
92.	L- block,pblock,m block kaka dev & jay prakash nagar	16669
93.	Chandari	26882
94.	Parade	21413
95.	Chaman ganj	15973
96.	Kidwai nagar block-n	14531
97.	Krishna nagar block-11	14092
98.	Kaushalpuri	14266
99.	Chatai mohal	15871
100.	Begam purwa	22521
101.	Shastri nagar coloney 1/2,shastri nagar & p.w.d.colony	14244
102.	Collectorgunj	22586
103.	Colonel gunj	23224
104.	Vinayak pur/panchvati	21703
105.	Sita ram mohal	17217
106.	Talaq mohal	18890
107.	Site no.2 kidwai nagar	8480
108.	Chowk sarrafa	18070
109.	Govind nagar block a,b,c,d,e,peeli railway coloney	27530
110.	General gunj	20878
	Others	
	Police line	1380
	District jail	2426
	P.A.C	2516
	H.A.L	1580
	Panki power corporation	10102
	I.I.T	7924
	University	922
	Central railway	1462
	Rawat pur station yard	3021
	Cantonment area	204923
	Total population	**2772212**

Multiple Regression models for income and other variables

a) Regression model 1

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.985[a]	.971	.969	789.563

a. Predictors: (Constant), persons-diarrhoea, no of rooms in house, frequency of SW collection, qty of plastics in waste, exp education, qty of solid waste, exp clothes, persons-typhoid, exp petrol, exp recreation, no of pressure cooker, cooking gas, exp electricity, water cons(Jul-Oct), no of TV, exp telephone, expenditure, exp transportation, qty of petrol used, water cons(Nov-Feb), water cons(Mar-Jun)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.78E+09	21	275278116.7	441.568	.000[a]
	Residual	1.73E+08	278	623410.495		
	Total	5.95E+09	299			

a. Predictors: (Constant), persons-diarrhoea, no of rooms in house, frequency of SW collection, qty of plastics in waste, exp education, qty of solid waste, exp clothes, persons-typhoid, exp petrol, exp recreation, no of pressure cooker, cooking gas, exp electricity, water cons(Jul-Oct), no of TV, exp telephone, expenditure, exp transportation, qty of petrol used, water cons(Nov-Feb), water cons(Mar-Jun)

b. Dependent Variable: monthly income

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	184.337	212.871		.866	.387
	expenditure	1.048	.053	.372	19.679	.000
	exp education	.946	.043	.295	22.037	.000
	exp transportation	1.389	.141	.220	9.823	.000
	exp electricity	1.615	.319	.079	5.058	.000
	exp telephone	3.612E-02	.168	.004	.215	.830
	exp petrol	.514	.243	.072	2.109	.036
	exp clothes	1.162	.130	.141	8.924	.000
	exp recreation	1.549	.209	.105	7.423	.000
	cooking gas	1.253	.683	.029	1.834	.068
	no of rooms in house	32.795	91.795	.005	.357	.721
	qty of petrol used	38.523	33.645	.036	1.145	.253
	water cons(Nov-Feb)	.971	.733	.043	1.324	.186
	water cons(Mar-Jun)	-.245	.561	-.018	-.437	.662
	water cons(Jul-Oct)	-.688	.738	-.040	-.932	.352
	qty of solid waste	90.668	58.918	.020	1.539	.125
	frequency of SW collection	17.894	21.481	.010	.833	.406
	qty of plastics in waste	-68.995	68.553	-.012	-1.006	.315
	no of TV	-319.361	102.006	-.051	-3.131	.002
	no of pressure cooker	56.353	75.507	.013	.746	.456
	persons-typhoid	-109.864	113.080	-.013	-.972	.332
	persons-diarrhoea	18.517	39.804	.006	.465	.642

a. Dependent Variable: monthly income

b) Regression model 2

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.985[a]	.971	.969	785.581

a. Predictors: (Constant), no of pressure cooker, frequency of SW collection, qty of plastics in waste, exp education, exp recreation, qty of solid waste, exp transportation, exp clothes, exp electricity, cooking gas, no of TV, water cons(Jul-Oct), expenditure, qty of petrol used, water cons(Nov-Feb), exp petrol, water cons(Mar-Jun)

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.78E+09	17	340006819.5	550.942	.000[a]
	Residual	1.74E+08	282	617137.010		
	Total	5.95E+09	299			

a. Predictors: (Constant), no of pressure cooker, frequency of SW collection, qty of plastics in waste, exp education, exp recreation, qty of solid waste, exp transportation, exp clothes, exp electricity, cooking gas, no of TV, water cons(Jul-Oct), expenditure, qty of petrol used, water cons(Nov-Feb), exp petrol, water cons(Mar-Jun)

b. Dependent Variable: monthly income

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	225.092	201.027		1.120	.264
	expenditure	1.044	.051	.370	20.391	.000
	exp education	.948	.042	.295	22.793	.000
	exp transportation	1.372	.139	.217	9.900	.000
	exp electricity	1.659	.309	.081	5.368	.000
	exp petrol	.547	.238	.077	2.300	.022
	exp clothes	1.163	.128	.141	9.071	.000
	exp recreation	1.533	.202	.104	7.583	.000
	cooking gas	1.254	.674	.029	1.860	.064
	qty of petrol used	39.879	33.052	.037	1.207	.229
	water cons(Nov-Feb)	.852	.712	.038	1.197	.232
	water cons(Mar-Jun)	-.194	.555	-.014	-.349	.727
	water cons(Jul-Oct)	-.691	.730	-.040	-.947	.345
	qty of solid waste	96.065	57.917	.021	1.659	.098
	frequency of SW collection	19.360	21.065	.011	.919	.359
	qty of plastics in waste	-75.445	67.358	-.013	-1.120	.264
	no of TV	-312.488	99.063	-.050	-3.154	.002
	no of pressure cooker	56.239	72.550	.013	.775	.439

a. Dependent Variable: monthly income

c) Regression model 3

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.984[a]	.969	.968	800.591

a. Predictors: (Constant), no of pressure cooker, qty of plastics in waste, exp education, exp recreation, qty of solid waste, exp transportation, exp clothes, exp electricity, expenditure, exp petrol

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.77E+09	10	576891509.4	900.062	.000[a]
	Residual	1.85E+08	289	640946.280		
	Total	5.95E+09	299			

a. Predictors: (Constant), no of pressure cooker, qty of plastics in waste, exp education, exp recreation, qty of solid waste, exp transportation, exp clothes, exp electricity, expenditure, exp petrol

b. Dependent Variable: monthly income

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	367.098	155.893		2.355	.019
	expenditure	1.039	.049	.369	21.100	.000
	exp education	.931	.040	.290	23.239	.000
	exp transportation	1.384	.139	.219	9.964	.000
	exp electricity	1.738	.301	.085	5.766	.000
	exp petrol	.719	.154	.101	4.684	.000
	exp clothes	1.110	.111	.135	9.961	.000
	exp recreation	1.336	.189	.091	7.076	.000
	qty of solid waste	111.412	55.840	.025	1.995	.047
	qty of plastics in waste	-72.209	66.398	-.013	-1.088	.278
	no of pressure cooker	1.795	66.949	.000	.027	.979

a. Dependent Variable: monthly income

d) Regression Model 4

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.984[a]	.969	.968	799.466

a. Predictors: (Constant), qty of solid waste, exp recreation, exp petrol, exp education, exp clothes, exp electricity, expenditure, exp transportation

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	5.77E+09	8	721019630.4	1128.098	.000[a]
	Residual	1.86E+08	291	639146.137		
	Total	5.95E+09	299			

a. Predictors: (Constant), qty of solid waste, exp recreation, exp petrol, exp education, exp clothes, exp electricity, expenditure, exp transportation

b. Dependent Variable: monthly income

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	303.799	126.290		2.406	.017
	expenditure	1.038	.045	.368	23.237	.000
	exp education	.930	.040	.290	23.251	.000
	exp transportation	1.375	.138	.218	9.937	.000
	exp electricity	1.701	.296	.083	5.741	.000
	exp petrol	.735	.151	.104	4.857	.000
	exp clothes	1.111	.111	.135	10.019	.000
	exp recreation	1.328	.188	.090	7.049	.000
	qty of solid waste	94.408	53.070	.021	1.779	.076

a. Dependent Variable: monthly income

Multiple Regression model for quantity of generated solid waste

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.578[a]	.334	.323	.8157

a. Predictors: (Constant), exp food, frequency of SW collection, employed persons, family size, monthly income

ANOVA[b]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	98.130	5	19.626	29.493	.000[a]
	Residual	195.640	294	.665		
	Total	293.770	299			

a. Predictors: (Constant), exp food, frequency of SW collection, employed persons, family size, monthly income

b. Dependent Variable: qty of solid waste

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.758	.176		4.312	.000
	monthly income	9.508E-06	.000	.043	.461	.645
	family size	.243	.034	.455	7.186	.000
	employed persons	-.159	.092	-.108	-1.729	.085
	frequency of SW collection	-1.74E-02	.021	-.042	-.846	.398
	exp food	1.424E-04	.000	.227	2.402	.017

a. Dependent Variable: qty of solid waste

Variable Definitions

Population
INIT 2725207
+dt*In_migration_rate
-dt*Out_migration_Growthrate
-dt*Deathrategrowth
+dt*Birthrate Growth
SW_Market_Activity
INIT 86
+dt*Market_SW_GR
TONS/DAY
Area Growth Rate
= Area*AGF
Birthrate Growth
= Population*NBRF
Commercial_Unit_SW_GR
= Commercial_units*Com_Unit_SW_GRF
Deathrategrowth
= Population*NDRF
HBGR
= No_of_Hospial_Beds*HBGRF
In_migration_rate
= Population*IMF
IUGR
= Industrial_Units*IUGRF
Market_SW_GR
= SW_Market_Activity*Market_SW_GRF
Out_migration_Growthrate
= Population*OMF
PCGR
= HIGPer_capSWGEN*FPCGRF_1
PCGR_1
= MIGPer_capSWGEN*FPCGRF_1
PCGR_2
= LIGPer_capSWGEN*FPCGRF_1
PCGR_3
= EWSPer_capSWGEN*FPCGRF_1
PercievedArea Growth Rate
= PercievedArea*PAGF
CES
= ES1_R+ES2_R+ES3_R+ES4_R+ES5_R
Collection_efficiency
= GRAPH(gap_in_collection,0,0.2,[0.97,0.84,0.64,0.36,0.18,0.1"Min:0;Max:1"])
Com_Activity_SW
= Commercial_units*Per_Unit_SW_Gen
Com_Non_Recyclable_SW
= NHZComm_SW*CNRSWF

Com_Recyclable_SW
= NHZComm_SW*CRSWF
Composite_efficiency
= 0.4*Collection_efficiency+0.4*Treatment_efficiency+0.2*Disposal_efficiency
DensityofPopulation
= Population/Area
populatonper sq.km
DirectRecycling_from_Generation
= Total_SWGeneration*RCF
Disposal_efficiency
= GRAPH(Gap_Cllection_Disposal_R,0,0.2,[0.04,0.71,0.92,0.98,1,1"Min:0;Max:1"])
ES1_R
= ((TotalUncllected_SW+Untreated_SW)/Total_SWGeneration)*0.35
ES2_R
= (Total_SW_Collection/Total_SWGeneration)*.1
ES3_R
= (Total_SW_Treated/Total_SWGeneration)*0.2
ES4_R
= (Net_SW_Disposal/Total_SWGeneration)*0.25
ES5_R
= (DirectRecycling_from_Generation/Total_SWGeneration)*0.1
EWS
= Population*EWSF
Formal_sector_total_manpower_requirement
= Man_power_for_disposal+ManPow_for_collection+ManpowerReq_for_treatment
FPCGRF_1
= 0.0133*(1-AwarnessFraction*0.7-InvestmentFraction*0.3)
Gap_Cllection_Disposal_R
= (Total_SW_Collection-Net_SW_Disposal)/Total_SW_Collection
gap_in_collection
= (NetSW_Generatin-Total_SW_Collection)/NetSW_Generatin
gap_in_Treatment
= (Total_SW_Collection-Total_SW_Treated)/Total_SW_Collection
HIG
= Population*HIGF
HOS_NHZSW
= Net_HOSPITAL_SW*HOS_NHZF
HOS_Non_Recyclable_SW
= HOS_NHZSW*HOS_NRSWF
HOS_Recyclable_SW
= HOS_NHZSW*HOS_RSWF
HZComm_SW
= TotalSWfrom_All_Commercial_Acivities_Activity*Comm_HZF
HZHOS_SW
= TOTAL_HOSPITAL_SW*HZHOS_SWF

○ HZISW
— IndSW*IHZF
○ HZSW
= Total Household Solid Waste Generation*HZF
○ HZSW_SW_TREATMENT
— Net HZSWCollection*HZSWTRF
○ HZSWCF
= 0.48*(1+0.25*Awarenessf+0.5*Investmnentf+0.25*Organised_Sectorf)
○ HZSWTRF
— 0.02*(1+0.2*Awarenessf+0.5*Investmnentf+0.3*Organised_Sectorf)
○ Ind_Non_Recyclable_SW
— NHZISW*IndNRSWF
○ Ind_Recyclable_SW
— NHZISW*IRSWF
○ IndSW
— Industrial_Units*PerIndUnit GenSW
○ Informal_Man_power_req_for_recycling
— Direct Recycling_from_Generation*Informal_sector_Man_power_per_ton_for_recycling
○ Land_req_for_didposal
— Net_SW_Disposal*Land_per_ton
○ LIG
= Population*LIGF
○ Man_power_for_disposal
— Net_SW_Disposal*Manpower_per_tondisposal
○ ManPow_for_collection
= Total_SW_Collection*manpowerreq_per_ton
○ ManpowerReq_for_treatment
— Total_SW_Treated*Man_power_per_ton_treatment
○ Market_SW_GRF
= 0.0175*(1-0.4*Awarenessfraction-0.6*Investmentf)
○ MIG
— Population*MIGF
○ Net_HOSPITAL_SW
= TOTAL_HOSPITAL_SW*(1-Illegal_Recycling_Fraction-Inceneration_Fraction)
○ Net_SW_Disposal
— Total_SW_Collection-Total_SW_Treated
○ NetHZSWCollection
= Total_HZSW*(1-HZSWCF-HZSWF_Illegal_disposalduring_collection)
○ NetNHZSWCollection
— Total_NZSW*(NHZSWCF-NHZSWF_Illegal_disposalduring_collection)
○ NetSW_Generatin
= Total_SWGeneration-Direct Recycling_from_Generation
○ NHZ_SWTREATMENT
— NetNHZSWCollection*NHZSWTRF
○ NHZComm_SW
= TotalSWfrom_All_Commercial_Acivities_Activity*Comm_NHZF

○ NHZISW

— IndSW*INHZF

○ NHZSW

= TotalHouseholdSolidWasteGeneration*NHZF

○ NHZSWCF

— 0.48*(1+0.25*Awarenessf+0.5*Investmnentf+0.25*Organised_Sectorf)

○ NHZSWTRF

— 0.01*(1+0.2*Awarenessf+0.5*Investmnentf+0.3*Organised_Sectorf)

○ No_of_Trips_Required

— Total_SW_Collection/Av_Capacity_Collection_Vehicle

○ NonRecylableSW

— NHZSW*NRSWF

○ Number_of_Vehicle

= No_of_Trips_Required/Av_Number_tripsper_vehicle

○ Per_Unit_SW_Gen

— 0.020*(1-0.4*Awarenessfraction-0.6*Investmentf)

TONS/DAY

○ PerBedGenSW

= 0.00090*(1-0.5*Awarenessf2-0.5*Investmentf2)

TONS/DAY

○ Percieved_Density

— Population/PercievedArea

○ PerIndUnitGenSW

— 0.14*(1-0.3*Awarenessf1-0.7*Investmentf1)

TONS/DAY

○ RCF

= 0.17*(1+0.2*Awarenessf+0.6*Investmnentf+0.2*Organised_Sectorf)

○ RecyclableSW

— NHZSW*RSWF

○ SWfrom_HIG

— HIG*HIGPer_capSWGEN

○ SWfrom_LIG

— LIGPer_capSWGEN*LIG

○ SWfrom_MIG

— MIG*MIGPer_capSWGEN

○ SWfromEWS

= EWS*EWSPer_capSWGEN

○ TOTAL_HOSPITAL_SW

— No_of_Hospial_Beds*PerBedGenSW

○ Total_HZSW

= HZComm_SW+HZHOS_SW+HZISW+HZSW

○ Total_Non_Recyclable_SW

— Com_Non_Recyclable_SW+HOS_Non_Recyclable_SW+Ind_Non_Recyclable_SW+NonRecylableSW

○ Total_NZSW

= HOS_NHZSW+NHZComm_SW+NHZISW+NHZSW

◯ Total_Recycalble_SW
= Com_Recyclable_SW+HOS_Recyclable_SW+Ind_Recyclable_SW+Recyclable SW

◯ Total_SW_Collection
= Net HZSWCollection+Net NHZSWCollection

◯ Total_SW_Treated
= HZSW_SW_TREATMENT+NHZ_SWTREATMENT

◯ Total_SWGeneration
= Total_HZSW+Total_NZSW

◯ Total_Uncollected_SW
= Total_SWGeneration-Total_SW_Collection

◯ Total Household Solid Waste Generation
= SWfrom_HIG+SWfrom_MIG+SWfrom_LIG+SWfrom EWS

◯ Total SWfrom_All_Commercial_Acivities_Activity
= SW_Market_Activity+Com_Activity_SW

◯ Total Unclected_SW
= Total_SWGeneration-Total_SW_Collection

◯ Treatment_efficiency
= GRAPH(gap_in_Treatment,0,0.2,[0.95,0.81,0.57,0.31,0.14,0.05"Min:0;Max:1"])

◯ Untreated_SW
= Total_SWGeneration-Total_SW_Treated

◇ AGF
= 0.019

◇ Av_Capacity_Collection_Vehicle
= 8
tons

◇ Av_Number_tripsper_vehicle
= 5

◇ Awarenessf
= 0

◇ Awarenessf1
= 0

◇ Awarenessf2
= 0

◇ Awarenessfraction
= 0

◇ AwarnessFraction
= 0

◇ CNRSWF
= 0.52

◇ Com_Unit_SW_GRF
= 0.0175

◇ Comm_HZF
= 0.02

◇ Comm_NHZF
= 0.98

CRSWF
— 0.48
EWSF
= 0.25
HBGRF
— 0.036
HIGF
= 0.15
HOS_NHZF
— 0.25
HOS_NRSWF
— 0.50
HOS_RSWF
— 0.5
HZF
— 0.05
HZHOS_SWF
— 0.75
HZSWF_Illegal_disposalduring_collection
— 0.0528
IHZF
= 0.35
Illegal_Recycling_Fraction
— 0.503
IMF
= 0.0216
Inceneration_Fraction
— 0.20
IndNRSWF
= 0.23
Informal_sector_Man_power_per_ton_for_recycling
— 29
INHZF
= 0.65
Investmentf
— 0
Investmentf1
= 0
Investmentf2
— 0
Investment Fraction
= 0
Investmnentf
— 0
IRSWF
= 0.77

◇ IUGRF
— 0.045
◇ LIGF
= 0.40
◇ Lland_per_ton
— 0.143
sqm/ton
◇ Man_power_per_ton_treatment
= 0.5
◇ Manpower_per_tondisposal
— 1.0
◇ manpowerreq_per_ton
= 3.5
per ton
◇ MIGF
— 0.20
◇ NBRF
= 0.033
◇ NDRF
— 0.01
◇ NHZF
= 0.95
◇ NHZSWF_Illegal_disposalduring_collection
— 0.0628
◇ NRSWF
= 0.48
◇ OMF
— 0.011
◇ Organised_Sectorf
= 0
◇ PAGF
— 0.0069
◇ RSWF
= 0.52

BRIEF BIODATA OF RESEARCHER

Ms Hina Zia

Academics

2007 Presently a candidate for the degree of Doctor of Philosophy at IIT Roorkee, India
2002 Post-graduated from Indian Institute of Technology Roorkee, Roorkee with a Masters in Urban and Rural Planning with distinction and first rank
1999 Graduated from Aligarh Muslim University, Aligarh with a Bachelors in Architecture with Honours and first rank

Experience

- Worked for six months as a Project Assistant on 'Pilot Study of Roorkee and Ramnagar Towns', a Ministry of Urban Development & Poverty Alleviation, GOI project
- Worked as an Assistant Architect in 'M/s Sarkar Associates', Faizabad (for 10 months)
- Worked as a trainee in 'M/s Archi Technoconsult', Aligarh (for 6 months)

Awards and Achievements

- Selected for SRF (CSIR scholarship) during Ph.D (2005)
- MHRD scholarship during Ph.D (2003 onwards)
- MHRD scholarship during Master's Program (2000-2002)
- Merit Scholarship awarded by the Vice-Chancellor, A.M.U. to the rank holders (1996-1999)
- Merit scholarship awarded by Bharat Sewa Trust (1995-96)
- Ist rank in class at Master's level
- Ist rank in class at Bachelor's level
- 13th rank in State merit in High School
- Awarded by the Governor of Uttar Pradesh for achieving highest marks in Mathematics in High School

Membership/Affiliation

- Life member of Council of Architecture
- Associate member of the Institute of Planners

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LIST OF PUBLICATIONS

International journals

1. *Hina Zia and Devadas V., "**Municipal Solid Waste Management in Kanpur, India: Obstacles and prospects**", Management of Environmental quality: An International Journal, Vol. 18, No.1, 2007, pp. 89-108.*
2. *Zia H. and Devadas V., "**Impact of built environment on health in Kanpur City**", paper accepted for publication in June 2007 issue of* Journal of Design and the Built Environment, *University of Malaya, Kuala Lumpur, Malaysia.*
3. *Zia H. and Devadas V., "**Energy management in Lucknow city**", paper accepted for publication in* Energy Policy, *an international journal of Elsevier publications, U.K.*

National journals

4. *Zia H. and Devadas V., "**Management of solid wastes in urban settlements: case study Kanpur**"* ITPI Journal, July-Sep, 2006.
5. *Zia H. and Devadas V., "**Municipal Solid waste management in Kanpur city**", paper accepted for publication in Nagarlok, an IIPA Journal.*

Conference proceedings

6. *Zia H., Dr. Najamuddin, Devadas V. and Mathhew L., "**Participatory planning for optimal residential land utilization in Kochi city**",* paper published in 55th National Town and Country Planners Congress, Cochin, Jan 7-12, 2007.
7. *Zia H., Devadas V. and Dilip Das., "**Solid Waste Management in Kanpur City**",* paper accepted in National Conference on System Dynamics, Hubli, Karnataka, Dec 26-27, 2006.
8. *Zia H. and Devadas V, "**Integrated and Equitable provision of Infrastructure through JNNURM: a dream or reality**",* paper published in the proceedings of 54th National Town and Country Planners Congress, Amritsar, Jan 14-16, 2006, pp. 329-334.
9. *Zia H. and Devadas V., "**Sustainable Waste Management: Issues and Strategies**"* in UGC Seminar on Sustainable Human Settlements: Issues & Strategies, GNDU, Amritsar, 18th-19th Mar, 2005
10. *Zia H., Devadas V. and Shankar R., "**Issues and practices in Municipal Solid Waste management: an overview**"* in International Conference Prithvi 2005, Thiruananthpuram, 19-28 Feb, 2005
11. *Zia H., Devadas V. and Shankar R., "**Urban dynamics and Sustainable Solid Waste Management in India**"* in International Conference Prithvi 2005, Thiruananthpuram, 19-28 Feb, 2005

12. *Zia H., Devadas V. and Shankar R.,* ***"Role of Informal sector in Waste Recycling in India"*** in International Conference Prithvi 2005, Thiruananthpuram, 19-28 Feb, 2005
13. *Zia H. and Devadas V.,* ***"Biomass and Sustainable Energy",*** presented in National conference on Traditional Knowledge Systems of India, IIT Kharagpur, 9th to 11th Jan, 2004
14. *Zia H. and Devadas V.,* ***"Energy Management in an Urban System",*** presented in National conference on Indian Habitat and Infrastructure-Need for innovative approach, CBRI Roorkee, 25th to 26th Sep, 2003.