COMPUTER AIDED LAND SUB-DIVISION PLANNING

A DISSERTATION

submitted in partial fulfilment of the
requirements for the award of the degree
of
MASTER OF URBAN AND RURAL PLANNING

By

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आ नो भद्राः क्रतवो यन्तु विश्वतः

Let noble thoughts come to us from every side — Rig. Veda. 1-89-i

DEDICATED TO MY PARENTS

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled "COMPUTER AIDED LAND SUB-DIVISION PLANNING' in partial fulfilment of the requirement for the award of the Degree of 'Master of Urban and Rural Planning', submitted in the Department of Architecture and Planning of the University of Roorkee, Roorkee is an authentic record of my own work carried out during a period from August 1986 to April 1987 under the supervision of Mr. R.K.Jain, Lecturer, Department of Architecture and Planning, University of Roorkee, Roorkee and Dr. N.Puri, Reader, Department of Civil Engineering, University of Roorkee, Roorkee.

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

Date: 30.4.87

(M.K.HATWAL)

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

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CHAPTER - I

INTRODUCTION

1.1 GENERAL :

Compared to any other time, today there is an increasing awareness amongst the physical planners engaged in the field of land sub-division planning to provide optimal solutions.

The increasing concern for providing the optimal solutions has resulted due to the problems, that are growing both in complexity and magnitude in developing country like India as one stage of development succeeds another. Also, today man's activities have become more diversified in nature. So, the available limited resources are being depleted at a faster rate. Simultaneously a growing awareness of the environment around us had resulted in an expanding body of information without recourse to which it is difficult to attempt any comprehensive solution to the land sub-division problem.

1.2 THE NEED OF MODERN APPROACH :

The traditional methods of land sub-division planning are of limited help to arrive at adjusted solutions. These methods have certain inherent draw backs, as seen in the light of present conditions. They have failed to give optimal solutions on the following counts:

(a) Piece meal nature of solutions has proved inadequate to tackle the multifaceted problems of present day.

(b) Today there are limitations on money, material and man-power. But this approach does not ensure optimum utilization of resources.

(c) Inadequate to evaluate all alternatives and to select best possible solutions.

(d) It is very slow and uncertain. The time one may take to reach a reasonably good solution can not be predicted.

(e) This method banks on intuitive thinking.

(f) Individualistic and implict approach discourages team work i.e. distribution of sub- jobs to respective specialists.

(g) It becomes practically impossible to keep note of all constraints at a time, because the present day problems are more complicated and dynamic in nature.

This necessitates replacement of traditional approach by an approach which -

(a) is capable of tackling the problem in its entirety.
(b) is systematic, logical and explicit.
(c) makes decision making easier.
(d) generates all possible solutions.
(e) identifies optimum results.

f) is based on a common language to facilitate multidisciplinary approach.

g) takes least time at less cost and at a higher efficiency level.

This is possible through the use of computers. With the help of computers, the complex problem of land sub-division planning can be solved more systematically. It should be noted that computer based land sub-division is not a mechanical process but it demands more understanding of the system and is a process of mutual interaction. Computers do not generate decisions, but they help in understanding the consequences of the set of decisions. They do not solve the problem. They are a means of exploration rather than a production line. They are only tools to help planners to solve the problem.

1.3 SYSTEMS APPROACH AND MODEL BUILDING: [Bijlani, H.U., 1981; Bijlani, H.U., 1982; Chadwick, G. 1971; Joglekar, M.N., 1984; Reif, B., 1973; HUDCO, 1985]

A system implies a complex whole or a set of related parts Also a system can be defined as a group of related objects interacting to form unity or it is an entity either physical or conceptual of related parts.

Now, to study the behaviour of the system, it is not always possible to carry out experiments in real life due to several practical limitations. So, it becomes necessary to analyse reality by observation and abstraction and an adequate means by which the characteristics of the system can be suitably studied has to be developed. Such a means is called as a 'Model'. So, the model provides a simplified **version** of reality in order to understand it better.

Models are of the following types:

(A) Physical: In these models, analogy in physical property is generally used. e.g. gravity model used by transportation engineers.

These are further classified as :

(a) Iconic - where the properties are represented by means of change in scale viz. drawings, sketches or **photo**graphs and

(b) Analogue - where the properties are represented by a different set of properties viz. maps, plans, graphs etc.

(B) Conceptual Models :

These models are those where there are no possible material analogies and are derived arbitrarily since there exists no further justification in assuming that the real world will be like the model.

These models can be either -

(a) Verbal - where description of reality is given in logical terms using words and

(b) Symbolic - where certain symbols are used to describe the system and the operations performed on the symbols express the relationship contained within the system. Mathematical models are of this type. Mathematical models can be further classified as follows :

(1) Equation System - Where the inter-relationship between various components of the model can be expressed in an equation form between the variables.

(2) Simulation Method - Where by some of the unknown variables and hence their relationship is defined in terms of values of a defined and fixed range and results obtained iteratively by exhausting the range.

(3) Computer Algorithms - Where all the rules of processing are not defined by equations but rather by hypothesis. Help of computer becomes necessary for these methods.

Land sub-division can be thought of as a system consisting of various components pertaining to the analyses of the physical properties i.e., the physical parameters and the infrastructure design. Again, each of these components is a subsystem containing various design elements which are inter-related to one another by certain relationship. Any change in one of the elements will have a definite impact on the behaviour of the others and on the larger system as well.

So, to study the behaviour of land subdivision systems, models can be built up accordingly.

1.4 OBJECTIVES AND SCOPE OF STUDY :

Computer based land sub-division planning aims at the following :

(a) To develop a scientific and flexible approach.

(b) To develop a process which furnishes the required design parameters for the physical and infrastructural design.

(c) To develop an approach which furnishes the cost implications of the design components as well as the total development cost implication for varying standards and specifications.

(d) To develop a process which generates an exhaustive list of alternatives.

(e) To develop a process which can select optimum result(s) in the context of land utility and cost.

(f) To get feed- back at various levels.

So, considering the above broad guidelines, this dissertation specifically aims at the following :

(i) To develop a mathematical model and computer program that could be used for land sub-division project formulations and for many key decisions in scheme preparation, site and utility- network design.

(ii) To introduce the concept of cost effectiveness as a principal measure of evaluating diverse planning alternatives.

(iii) To study the sensitivity of various design parameters of land sub-division using a module layout [Ref.Item No.3.3].

(iv) To study the applicability of this model in an industrial project design, a case study has been undertaken. The design of a proposed electronics complex, near Roorkee has been done using this model. The detailed sensitivity analysis has been carried out for different physical parameters & cost parameters; Based on this, the optimum results were identified and the layout of the complex along with the design of utilities was prepared.

1.5 RELEVANCE TO PLANNING FIELD:

The use of computers in land sub-division planning would help the planners to do the sensitivity analysis for various design parameters of land sub-division planning and would also help them to arrive at optimal solutions. The present study is an attempt in this direction. The sensitivity analysis showed that least module area, least module ratio and higher plot ratio would give optimum results. Also it was found that higher module areas lead to higher development costs. So, in this way, the parameters which are more sensitive could, be identified in advance. This is vital information and would guide the planners to create more realistic and rational base for land sub-division planning.

1.6 THESIS ORGANIZATION :

Chapter II provides a general review of the models as practised in land sub-division planning. It also throws light on the field application of these models in India.

Chapter III discusses in detail the mathematical model and the computer program developed in the study. It gives the details of the various elements of the model along with their purposes. The computer program has been presented in details. The sample outputs have also been included in the Appendix-D. The various input parameters have been listed along with the outputs generated.

Chapter IV consists of detailed sensitivity analysis of the parameters for the land subdivision planning.

Chapter V presents the case study undertaken. It discusses the applicability of the model to a real life situation.

Chapter VI summarises the findings of the study and includes recommendations for further work.

CHAPTER - II

REVIEW OF PREMIER STUDIES

2.1 GENERAL :

The field of computer aided land sub-division planning is an emerging area of research. A few scientific models applied to the planning problems are available. However, the development of such models is of recent origin and the majority of professionals are still unaware of their existence. Even if they are aware, these are not being used at field level. The important models are briefly reviewed in the following sections.

2.2 BERTAUD-PADCO MODEL [World Bank, 1981] :

This model has been developed by Alain C. Bertaud of the World Bank. Bertaud approached the problem of land sub-division bysimulating design process and site layouts into mathematical models with emphasis on affordability and finance feasibility. This model attempts to analyse systematically the relations between financial parameters, cost parameters and land use parameters. The model can be used basically for policy analysis,project appraisal, project formulations and site design.

The present model is an excellent tool for the planners engaged in the field of land sub-division planning. But in this case proper emphasis is not given to site layout design.

2.3 CAMINOS - GOETHERT MODEL [Caminos, H. et. al., 1983] :

In this study Prof. Caminos approached the problem with model layouts. He selcted two extreme layouts of fixed dimensions - one with optimum solution and other a deficit solution and used these as a guide to develop a matrix of optimum design indices.

The adopted layout models are of specific size with fixed size of semi-public area and road widths. The model would have been more useful if these parameters would have been also of flexible nature.

2.4 HUDCO-MODEL [HUDCO,1982a, HUDCO, 1983] :

This model has been developed by Housing and Urban Development Corporation, New Delhi. In this model, different site layouts and design process has been simulated into mathematical models. It attempts to systematically analyse the inter-relationship between the planning and design parameters in an urban layout and gives some indication about the sensitivity of the land-use parameters and utility-cost parameters to the plot size and plot ratio which is a very useful guide for the planners and engineers. The model can be used mainly as a tool for design of affordable shelter projects, project analysis and appraisal. This model incorporates computer programmes for a limited number of planning modules (Ref. Fig. 2.1). Also using this model, HUDCO has prepared a Handbook Matrix [HUDCO,1982] giving ready solution in respect of land use parameters and cost parameters for a number of planning modules for specific standards in respect of road widths, open spaces, utility network etc. which also could be used as a ready planning tool.

The emphasis is on module planning. Sensitivity analysis would be more meaningful if it is done with a flexible module layout in which all layout variables can be controlled.

Further, the model has been extended to sector level. In this way an attempt has been made to also include the services that are not considered at module level [HUDCO,1985].

2.5 OTHER STUDIES :

Besides these, studies by Allan Turner [Turner, A.,1968] and others are available as guide to physical planners. In addition there are number of national and local codes [CPWD,1981 ; IDUP, 1982; ISI, 1967; ISI, 1972; ISI, 1978; ISI, 1984; Kopardekar, H.D., 1966; MWH, 1976a; MWH, 1976b; PWD,1984; Swami, M.C.K., 1970; Saini, N.S., 1985] which help determine standards in physical planning.

Also, CBRI, Roorkee has done studies to analyse the sensitivity of density of different pattern of layouts. Datta and Garg [Datta, K.L. et.al, 1971] has taken different layouts with different block pattern and plot sizes and studied how best the density can be maximised. The emphasis is on high rise structures.

In a research study by HUDCO, optimisation of density in residential settlements is attempted [HUDCO,1980]. It has been shown that there is a large range of difference in the dwelling density, depending on different types of development and the value of other physical parameters selected. The emphasis is on multistoryed dwellings.

The study by T.S.S. Reddy* is the extension of Bertaud Model. Reddy has developed a project system which consists of a few mathematical models. It helps in the process of decision making in different cycles of project formulations. This tool also helps the planner to test the impact of such decisions on project cost, land use, layout efficiency and infrastructure.

2.6 FIELD APPLICATION :

In India a few projects are being designed through the use of computers.

HUDCO has designed a township at Sodala-Sangner, near Jaipur [HUDCO,1985] in Rajasthan. The computer programs were developed which selected the optimum planning modules, which served the purpose best. The layout plan is shown in Figure 2.2.

Also, Bombay Metropolitan Region Development Authority has been using computers in every phase of Bombay Urban Development Project [Reddy, T.S.S.,1984]. The Gorai site layout is being completely designed on the computer, using Bertaud

* : [Reddy,T.S.S., 1984]

Model [World Bank, 1981]. Two of the many alternative designs of a cluster of the Gorai Layout drawn by computer are shown in Figure 2.3.

In addition to these, HUDCO is also doing computer aided projects at Kalol, Ahmedabad and Lucknow [HUDCO,1985; Joglekar, M.N.,1984].

2.7 DISCUSSION :

In the foregoing discussion, the salient features of important models available in the field of land sub-division planning have been discussed. The three important studies are the Bertaud-Padco Model [The World Bank,1981], Camimos-Goethert Model [Caminos, H. et. al,1983] and HUDCO-MODEL [HUDCO,1982 a, HUDCO,1983]. The first one approaches the problem with the help of mathematical models, the second one with the help of model layouts and the last one is an extension of the Bertaud-Padco-Model [The World Bank, 1981]. The other studies available are of minor significance.

All the available models have been applied only to residential areas. So, in the present dissertation, the HUDCO-MODEL has been extended and applied to industrial area planning.

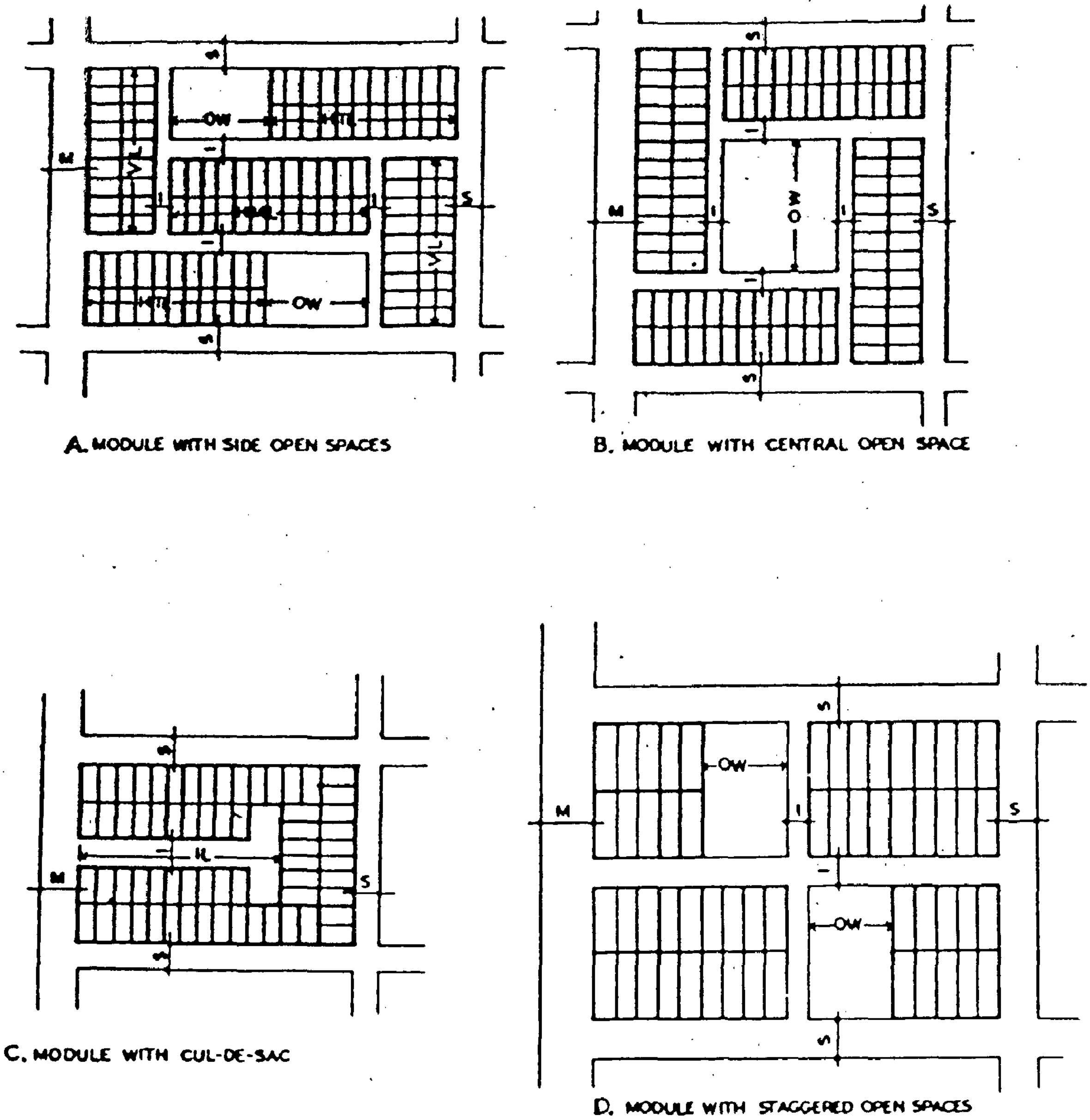
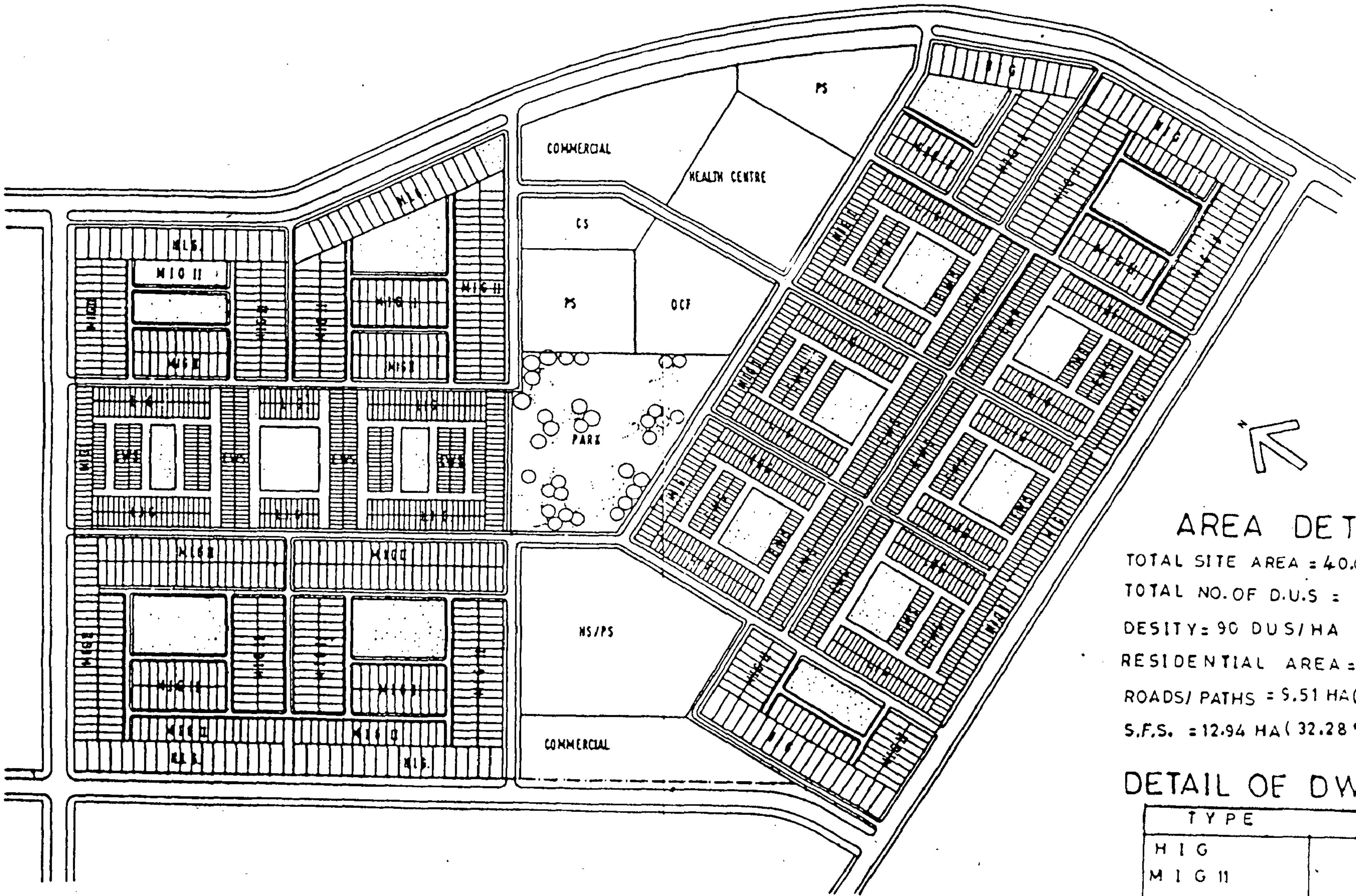


FIG. 2.1 · TYPOLOGY OF PLANNING MODULES (HUDCO, 1982 a)



AREA DETAILS

TOTAL SITE AREA = 40.08 HA

TOTAL NO. OF D.U.S = 3589

DESITY = 90 DUS/HA

RESIDENTIAL AREA = 17.63 HA (43.98%)

ROADS/ PATHS = 5.51 HA (23.73%)

S.F.S. = 12.94 HA (32.28 %) @ 7.2sqm/ CAPITA.

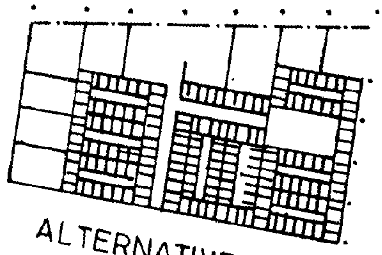
DETAIL OF DWELLING UNITS

TYPE	NO.
HIG	242
MIG II	674
MIG Ia	674
MIG Ib	192
LIG	748
EWS	1057
TOTAL —	3589

LAYOUT PLAN OF PROPOSED TOWNSHIP AT SODALA- SANGER, RAJASTHAN (HUDCO, 1985)

SCALE 1:4 50

FIG. 2.2



ALTERNATIVE- 1

TOTAL NO. OF PLOTS = 291

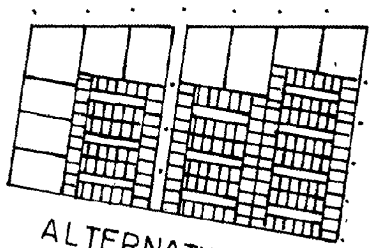
LAND USE:-

RESIDENTIAL AREA = 72 %

PARK AND PLAY GROUND AREA = 4.32 %

CIRCULATION AREA = 23 . 68 %

TOTAL = 100.00



ALTERNATIVE-2

TOTAL NO. OF PLOTS = .334

LAND USE

RESIDENTIAL AREA = 76. 28 %

TOTAL CIRCULATION = 23.72 %

FIG. 2. 3 GORAI LAYOUT PLAN [Reddy, T.S.S, 1984]

C H A P T E R - III

ELEMENTS OF THE CALSD - MODEL AND THEIR PURPOSES :

3.1 GENERAL :

A mathematical model called as CALSD-MODEL [Computer Aided Land Sub- Division Model] has been developed for the physical planners engaged in the field of land sub-division planning. It is intended to be a working tool for them. Specifically it deals with physical design and costing questions that should be addressed in formulating feasible land sub-division projects. The model developed has been presented in the form of a computer program along with the mathematical model of the same. This model is the extension of the HUDCO-MODEL [HUDCO,1982 a, HUDCO,1983].

3.2 BASIC STRUCTURE :

The present model is made up of two parts (Ref. Fig. 3.1) :

(a) Module Analysis and Design - PART A

(b) Module Selection - PART B

Module Analysis and Design - PART A :

The PART- A deals with the module analysis and design.

It derives the total number of module options available for a given module geometry.

This part has a number of sub-models. These include the following:

i) Physical Parameters Design-Sub-Model-I
ii) Circulation Network Costing-Sub-Model-II
iii) Water supply Network Design and Costing-Sub-Model-III
iv) Sewerage Network Design and Costing-Sub-Model-IV
v) Drainage Network Design and Costing-Sub-Model-V
vi) Land and Land Development Cost-Sub-Model-VI.

These sub-models determine the physical parameters of the module configuration, design the utility networks through seperate models each for water supply, drainage, sewerage, roads and land cost together with electrification, arboriculture. and levelling and dressing.

Module Selection PART -B :

This part of the CALSD-MODEL deals with the optimum module selection process. It applies the selection-test to the total module options generated. It consists of the following sub-model.

(i) Optimum Module Selection Sub Model- VII

Each of these sub-models consist of a set of mathematical equations, or equations, representing relationships amongst the particular project variables to which it refers. The mathematical model has been outlined in the following sections and further detailed equations have been presented in Appendix A-1, A-2, A-3, A-4, A-5 and A-6.

To make it possible to use these equations and relationships easily and to quickly identify the consequences of changes in values of selected variables, sub-programs have been written in Fortran - IV and the detailed sensitivity analysis has been carried out for the project considered under the case study. There is a sub-program for each sub model.

3.3 MODULE LAYOUT :

A grouping pattern of plots affect the land utilization pattern and design of utility networks. For a given geometrical pattern, there could be several alternative arrangements, some of which are more helpful in optimum design of utility network, than others. Design of basic grouping pattern or 'Module' is entirely in the hands of the planner. He has to develop a module which fulfills the needs of group for which it is needed.

The geometrical pattern of the the module is selected keeping in view the objective of the dissertation. Since, the model is to be applied to an industrial layout, so the module developed is such that it can cater to the requirements of such a layout.

The module geometry accomodates three types of plots, each having different areas (Ref. Fig. 3.2). Type 'A' plot is the biggest of three and is located along the approach roads (sector roads) and are the roads of highest order in the hierarchy of roads. Type 'B' plots are of next lower category and are located along the main approach road of the module (S2) or secondary peripheral module road (S2) in block of back to back plots. Type 'C' plots are the smallest and are located in the interior of the module and have access from lower hierarchy of roads (S1). An open space, called as social facility space is planned in the heart of the module and can grow in either direction.

3.4 PHYSICAL PARAMETERS DESIGN-SUB-MODEL - I :

3.4.1 General :

This sub-model studies the relationship of different basic physical parameters with the land utilization pattern for the module conceived. The mathematical model and the computer program developed for this sub-model has been presented in the following sections.

3.4.2 Design Standards :

The local planning standards govern the parameters like road widths, minimum plot dimensions, open space area etc. [ISI, 1984; IDUP, 1982 ; U.O.R., 1985]. So, these values have been structured in the program as per the requirements and planning regulations.

3.4.3 Mathematical Model :

The relationships between different physical parameters are expressed in the form of mathematical equations(Ref. Appendix A-1). These equations compute the number of plots, saleable area, open space area, circulation area etc.

There are checks for controlling length on road widths-

MAX. of $\sqrt{\frac{SA}{R}} - 4\,DB - 2S1 - S2$, $\sqrt{SA.R} - 4\cdot DC - DA - 2S1 - S2$

and 2 DC for S1 R.O.W.

MAX. of $\sqrt{SAR} - DC - S2$ and 2.DB for S2 R.O.W.

The open space dimension are checked for positive values -
$\sqrt{\frac{SA}{R}}$ should be $> 4DB + 2S1 + S2$ and $\sqrt{SA.R}$ should be $> 5DC + DA + 2S1 + S2$

Each plot has been assigned a value of load coefficient which has been taken as equivalent population load on that particular plot.

Further, the detailed mathematical model has been listed in Appendix - A-1.

3.4.4 Computer Program :

The description of the program is given below. A graphical representation in the form of flow chart is shown in Fig. 3.3.

Stage I :

The input variable values are read. These include the variables listed below :

SA	:	A single subscripted variable representing the module area in sq.m.
R	:	A single subscripted variable representing the module ratio.
PA, PB, PC	:	Single subscripted variable representing the plot area A, B and C in sq.m.
X	:	A single subscripted variable representing the plot ratio.
S1, S2	:	A single subscripted variable representing the road widths in m.
FA, FB, FC	:	Variable name representing the load coefficients for plot type A, B and C.
RL1, RL2	:	A single subscripted variable representing the permissible road lengths in m.

Stage II :

The program operates the different module areas, plot areas for varying module and plot ratios for a set of plots with areas PA, PB, PC and proceeds to calculate the plot dimensions like WA, DA, WB etc. and the module dimensions SB and SL.

State III :

The permissible road lengths are compared with the computed road lengths S21 and MS1. In case, the value of S21 and MS1 is greater than RL2 and RL1 respectively, the next cycle is taken up, otherwise the control proceeds further.

Stage IV :

The intermediate variables A2, A3 and A4 are computed. They are checked for positive open spaces and in case, the open space values are not positive, the operation for that particular set of module geometry is terminated.

Stage V:

The open space dimensions are computed.

The Stage VI :

The number of plots in each category that is type A, B and C is calculated and their sum total NP is also found.

The Stage VII :

The program computes the equivalent population PM with the help of load coefficients for the module geometry under consideration.

The Stage VIII :

The land use pattern is determined, the program calculates the saleable area, open space area, circulation area and their respective percentages. Also, total circulation length per unit of saleable area is found out.

Stage IX :

In this concluding stage, the various outputs generated are printed. The outputs are listed as follows. Also a sample output has been shown in Plate -1 (Ref. Appendix - D).

WA, WB, WC	:	Width of plot type A, B and C in m.
DA, DB, DC	:	Depth of plot type A, B, and C in m.
SL, SB	:	Module length, Module breadth in m.
NPA, NPB, NPC	:	Number of plots of type A, B and C
NP	:	Total numbers of plots.
CLA	:	Circulation Area in sq.m.
PCL	:	% Circulation Area.
SLA	:	Saleable Area in sq.m.
PSL	:	% Saleable area.

OPA	:	Open Space Area in sq.m.
POP	:	% Open Space Area
PM	:	Equivalent Module Population
BSFS, LSFS	:	Social facility space dimensions (M.)
TCLS	:	Total circulation Length per unit of saleable area.
PS1, PS2	:	The road widths selected for the particular module geometry in m.

3.5 CIRCULATION NETWORK COSTING-SUB-MODEL-II :

3.5.1 General :

This sub-model evaluates the total cost of circulation network in the module. The mathematical model and the computer program developed for this sub-model have been discussed in the following sections.

3.5.2 Criterion :

The circulation network forms a basic planning element for land utilization, land sub-division and the layout of utility services. The circulation system comprising of lines of circulation and lines of access, must take into consideration:

- the forms of circulation - existing or proposed in and around the site.
- the modes of circulation - i.e. users circulation (pedestrian/ vehicular).

- the limiting length of segments as per regulations [ISI, 1984]

3.5.3 Data :

The local planning requirements for sections and item specifications for various road widths (right of way) are to be furnished in the program. Unit costs in terms of per metre length of roads are to be worked out on local specifications and schedule of rates [CPWD, 1981, PWD, 1984].

3.5.4 Network :

The module includes two kinds of roads :

(i) Primary streets of width 'S2' Right of way

(ii) Secondary streets of width 'S1' right of way.

The circulation network has been shown in Fig. 3.4

3.5.5 Mathematical Model :

The equation system used for this model computes the total circulation cost in rupees. The equation system can be refered in the Appendix - A - 2.

3.5.6 Computer Program :

The description of the computer program is given below. A graphical representation is shown in Fig. 3.5.

First Step :

The input variable values are read. These include the variables discussed below :

SA	:	Module Area in sq.m.
R	:	Module Ratio.
DA, DB, DC	:	Depth of plot A, B and C in m. It is determined in sub-program - I.
CRMS1, CRMS2	:	It is a single subscripted variable giving the unit cost of road per metre length.
PS1, PS2	:	Road widths of type S1 and S2 in m. Determined by sub- program - I for the module geometry under consideration.
S1, S2	:	List of road widths of type S1 and S2 (in M.)
SC	:	Factor for accounting contengencies.

Second Step:

The value of PS1 is checked against the list of road widths S1 to arrive at the corresponding unit cost from the list of unit costs.

Third Step :

The road width PS2 is checked against list of road widths S2 to determine the corresponding unit costs.

Fourth Step :

The program computes the total cost of circulation 'C2' in rupees. Also, costs per sq.m. of saleable area is found and is represented by 'C2S'.

Fifth Step :

The length of the two type of roads i.e.'S1'and 'S2'is computed separately.

Sixth Step :

The outputs generated by the program are listed below. Also the sample out put is shown in Plate 2 A, 5 (Ref. Appendix - D).

C2 : Cost of circulation network (Rs.)

C2S : Cost of circulation network per sq.m. of saleable area.

LR1 : Length of 'S1' road (m.)

LR2 : Length of 'S2' road (m.)

3.6 WATER SUPPLY NETWORK DESIGN AND COSTING SUB-MODEL -III :

3.6.1 General :

This sub-model does the design of water supply network for the module and further evaluates the total cost of the water supply network. The mathematical model and the program developed is discussed in the following sections :

3.6.2 Criterion:

The water supply scheme should not only be economical but also meet the following requirements :

- Supply the anticipated peak demand of the proposed area.
- Meet the terminal head requirements.
- Satisfy all design requirements in respect of maximum velocity of flow generated, hydraulic gradient and design discharge for various pipes considered.
- The network must be easy to operate and maintain.

3.6.3 Layout :

The basic distribution network layout is shown in Fig. 3.6. The service connections for each plot would be made from the network lines running infront of the plots.

The network consists of two sizes of lines - (i) Primary line with internal diameter DW2 by which the supply is taken from trunk line on the module boundary and (ii) secondary line with internal diameter DW1 forming rest part of the circuit and laterals. A tapping is made on peripheral line at point (1) for primary line with a sluice valve on it and on the other end of the circuit i.e. at point 13 the secondary line is connected to the adjacent module (Refer Fig. 3.6). The primary line not only serves the module but also the 'B' type plots falling on each side of it. In case, there is no other module adjacent to a module, a secondary line 12 - 13 may be added to serve the 'B' type of plots.

3.6.4 Data :

The following data was used for the design of water supply network:

(i)	Average water demand [MWH, 1976a]	=	40 gallons/day/value of load coefficient
(ii)	Peak factor [MWH, 1976 a]	=	2.25
(iii)	Peak Consumption	=	Average demand X Peak factor
		=	40 X 2.25
		=	90 gallons/day/value of load coefficient
(iv)	Terminal head	=	7.32 m.

(v) The sizing of pipes must be adequate enough to carry the peak demand which depends on supply position and local municipal norms [MWH, 1976a ; MWH, 1976 b].

3.6.5 Mathematical Model :

The mathematical model developed for this sub-model is based on the Hazen William's Formula [MWH, 1976a ; Modi, P.N. et. al., 1970 ; Steel, E.W., 1979 ; Fair, G.M. et al., 1968].

$$V = 0.849 \times C \times [R]^{0.63} \times [S]^{0.54}$$

Where C = Roughness Coefficient. Taken as 100

R = Hydraulic radius (M)

S = Hydraulic gradient

V = Flow Velocity through pipes (M/S)

This basic equation can be restructured in following equations [Ref. appendix - B-1]:

$$V = 4.567 \times 10^{-3} \times C \times [D]^{0.63} \times [S]^{0.54} \quad ---- (1)$$

$$S = 2.158 \times 10^{4} \times [V]^{1.85} \times [D]^{-1.17} \times [C]^{-1.85} \quad -- (ii)$$

$$Q = 6.817 \times 10^{-2} \times C \times [D]^{2.63} \times [S]^{0.54} \quad ----- (111)$$

Now the velocities should be non- scouring. So, range of velocities is considered is 0.61 - 1.52 m/s.

The value of hydraulic gradient 'S' is found with the help of equation (ii). This value represents the head loss in pipe in unit length. For a given value of total pressure head available at supply point, the terminal head pressure can be worked out at various points using these values of hydraulic gradients.

The value of design discharge 'Q' can be found out from equation (iii). The derived value of 'Q' in gallons/d/per value of load coefficient is programmed in the form of αw values in the program. It is defined as

$$\alpha w = \left[\frac{Q}{\text{Avg.demand} \times \text{Peak factor}} \right]$$

The other water supply, components like sluice valves and fire-hydrants are worked out according to the load carried by 2 - 3 - 4 for primary line. The other lines 4 - 5 and 4 - 6 are checked for loads to get the number of these components for secondary line. The detailed equations of the model have been listed in Appendix - A - 3.

3.6.6 Computer Program :

The description of the computer program is given below. The graphical representation of the program in the form of a block diagram has been given in Fig. 3.7.

Ist Step :

The following input variable values are read in the program :

SA	:	Module Area in sq.m.
R	:	Module Ratio
NPB, NPC	:	Number of type B and C plots
PS1, PS2	:	Road widths selected, for roads S1 and S2(in m)
WC	:	Width of type- C plot (m)
FB, FC	:	Load coefficients for type B, C plots.
A2	:	Intermediate variable computed in sub-program- I
PM	:	Equivalent module population determined in sub-program I

LW1, LW2	:	Marketable length of pipe size DW1 and DW2 in m. The variable is single subscripted storing the value for a number of pipe ranges.
CW1, CW2	:	Single subscripted variable representing the unit costs of pipe size DW1 and DW2 respectively (Rs.)
CW1J, CW2J	:	Single subscripted variable representing the unit-cost of joints on pipe size DW1 and DW2. (Rs.)
CW1T	:	Single subscripted variable representing unit cost of T-Junction (DW1 X DW1) including jointing (Rs.)
CW12T	:	Single subscripted variable name for unit cost of a T-Junction including jointing in Rs.(DW2xD
CW1B, CW2B	:	Single subscripted variable name for unit cost of bend size on size DW1 and DW2 (Rs.).
CW12R	:	Single subscripted variable name for unit cost of reducer (DW2XDW1) including jointing (Rs.)
CW1P	:	Single subscripted variable representing unit cost of plug size DW1 including jointing (Rs.)
CW1V, CW2V	:	Single subscripted variable representing unit cost of of sluice valve on pipe size DW1, DW2 (Rs.)
CW1F	:	Single subscripted variable representing unit cost of fire hydrant with accessories (Rs.)
SC	:	Factor for accounting for contengencies.

2nd Step :

The load carried by line 4 - 5 'SV1' is computed in terms of αw values. Further the loads carried by line 4 - 6 'SV2' is computed in terms of αw values.

3rd Step :

The value of intermediate variable P1 is determined according as SV1 is greater or lesser than SV2.

4th Step :

The values of P1 are, compared with in built values of αw to get the number of sluice valves [Refer Appendix- C-1]

5th Step :

The two route lengths along network are computed as FH1 and FH2.

6th Step :

The values of FH1 and FH2 are checked for the criterion that maximum centr to centre distance between fire hydrants be 152 M.(Ref. Appendix- C1] .

7th Step :

The program computes the pipe lengths LWP1, A7 for size DW1 and DW2 respectively for general modules and LWPC1 , A7 for corner modules.

8th Step :

The values of P1 are again compared with in built values of αw and corresponding values of DW1 to select the required value of DW1 [Ref. Appendix - C1].

9th Step :

The values of PM are compared with inbuilt values of the αw and corresponding values of DW2 to select the required DW2 values.

10th Step :

The unit cost coefficients are selected for the selected pipe sizes and the total cost of water supply scheme is computed as per the cost equation given in appendix - A - 3. Also, the cost in Rs.per sq.mtr. of saleable area is calculated.

11th Step :

The program generates the following list of outputs. A sample output is given in Plate - 2A, 3, 5 in Appendix -D.

DW1, DW2	:	Internal diameters of selected pipe sizes DW1, DW2 (mm.)
NWF	:	Number of fire hydrants
NWV1, NWV2	:	Number of sluice valves of size 1 and 2 respectively.
CW(1), CWK(1)	:	Scheme of water supply scheme in Rs. for general and corner module
CW1S, CWK1S	:	Cost of water supply scheme in Rs. per sq.m. of saleable area for general and corner module
LWP1.	:	Length of pipe-line size DW1 (m) for general module.

A7 : Length of pipe line size DW2 for general and corner module (m.)

LWPC1 : Pipe lengths for size DW1 and DW2 in m.(corner module).

3.7 SEWERAGE NETWORK DESIGN AND COSTING SUB-MODEL- IV :

3.7.1 General :

The sub-model developed does the design of sewerage network of the module and computes the necessary cost. In the following sections, the mathematical model and computer program developed for this sub-model has been presented.

3.7.2 Criterion :

The main factors that go into making of a good sewer system are :

- the design velocity in all pipes should be non-silting and non scouring.
- the capacity of the sewer line must be of sufficient capacity to carry the discharge.
- no connections should be made at an acute angle towards the direction of flow or opposing the direction of flow.
- the system should be economic but adequate, simple and easy to maintain.
- system is basically for gravitational sewage flow.

3.7.3 Network :

A network layout is prepared for the module. It consists of two sizes of sewer lines. The line size of internal diameter DS1 collects mainly the discharge from the interior of module. The line size DS2 carries the entire combined collection from the module to the trunk line. In case, the module is at the corner, a seperate line L11 is to be added. The network is drawn in Figure No. 3.8.

It is assumed that the two plots are connected to each street manhole from either side of the sewer line. Apart from junction manholes as shown in the diagram, each segment lengths of sewer line would have intermediate manholes for serving plots on either side. In case of inner module the primary line in addition to the discharge carried from the module also carries discharge from one quarter of 'B' type plots of adjacent module.

3.7.4 Data :

The design of sewer system is programmed for anticipated sewage flow from the module which is based on :

(i) Average Sewage Discharge [MWH, 1976 b] = 30 gallons/day/value of load coefficient

(ii) Peak Factor [MWH,1976 b] = 3.0

(iii) The starting Manhole is of depth 'D1' (90 cm.) which is the required as per regulations.[MWH, 1976 b].

3.7.5 Mathematical Model :

The mathematical model is based on the Manning's Formula [MWH, 1976 b ; Steel, E.W, 1979 ; Fair, G.M. et. al., 1968 , Garg, S.K., 1982 b] given below :

$$V = \frac{1}{n} X R^{2/3} X S^{1/2}$$

Where,

n = Manning's rugocity coefficient, taken as 0.015

R = Hydraulic Mean depth (M)

S = Hydraulic gradient (Pipe line slope)

V = Velocity of flow (M/S)

This formula can be restructured as follows [Ref. Appendix B-2]

$$V = \frac{1}{n} X 0.397 X [D]^{0.67} X [S]^{0.50} \text{ ------- } (I)$$

$$Q = 0.156 X \frac{1}{n} X [D]^{2.67} X [S]^{0.50} \text{ -------- } (II)$$

The optimum velocity generated in sewers for gravitational flow of sewage is a very important design component. The design velocity should not fall below the self cleaning velocity i.e. 0.75 m/sec. Also, the velocity should be non scouring.So must not be higher than 3.0 - 3.5 m/s for asbestos cement pipes. The minimum velocity generated not only helps in keeping sewer size under control, but also prevents sewage from getting stale and decomposed by moving it faster .

Based on Manning's formula, the program operates such slopes for various sizes of pipes that would result the design velocity of 0.75 m/s in them.

The value of design discharge 'Q' depends on design velocity, crossectional area of flow and the material and slope of pipe. The maximum discharge carrying capacity is computed in form of sewerage flow factor 'αs'. It is defined as :

$$\alpha s = \frac{Q}{\text{Peak Factor X Avg. Discharge}}$$

The input values to the program are listed in Appendix - C - 2.

The sewerage components as the number of manholes, their sizes, number of drop connections etc. are calculated [ISI, 1983 ; ISI, 1967 ; ISI, 1984, MWH, 1976 b].

Mathematical model is given in Appendix - A - 4 in detail.

3.7.6 Computer Program :

The computer program developed for the sub-model is discussed in the following section. Also, the graphical representation given in the form of a block diagram is given in Fig. 3.9 and Fig. 3.10.

Stage I

The following input variables are read by the computer:

SA	:	Module Area (sq.m.)
R	:	Module Ratio
DA, DB, DC	:	Depth of type A, B, C plot (m). It is determined by sub-program - I.
PS1, PS2	:	Road widths of roads S1 and S2 for the module under consideration.
P1	:	This is an intermediate variable computed in sub program - III.
PM	:	Equivalent population determined by sub-program- I.
DS	:	Single subscripted variable representing pipe sizes (mm).
KKK	:	Single subscripted variable representing pipe slopes.
SCOF	:	Discharge factor
D1, D2, D3, D4	:	Standard depth of manhole sizes 1, 2, 3 and 4 (m)
G	:	Ground slope
CSVS	:	Unit cost of vent shaft (Rs.)
CSDC	:	Unit cost of drop connection (Rs.)
CMH1, CMH2 CMH3, CMH4	:	Unit cost of manhole chamber sizes -1, 2, 3 and 4 corresponding to manholes D1, D2, D3, D4 (Rs.)
CSE1, CSE2 CSE3, CSE4	:	Unit cost of extra depth over manhole sizes D1, D2, D3, and D4 (Rs/m)
COS	:	Unit cost of pipe material (Rs./m)
SC	:	Factor for accounting contengencies.

Stage II:

The length of sewer line segments L1 - L11 is computed. The value of L11 is computed only in case of corner module.

Stage III:

The program calculates the total number of manholes in each segment length i.e. M1-M11 including the junction manholes. The value of M11 is calculated only in case of corner module.

Stage IV :

The program at this stage calculates the pipe line lengths. The value of A8 and A81 represent pipe size -1 length and A9 and A91 represents length of pipe size - 2 in case of general and corner module respectively.

Stage V :

The program checks the value of P1 with the αs values programmed as SCOF to select the pipe size DS1 with their respective slope and cost of pipe material.

Stage VI :

The program compares the value of PM with the αs values programmed as SCOF to select the pipe size DS2 with their respective slopes and cost of pipe material.

Stage VII :

The program calls the sub-routine SAN. This calculates the value of L1N1 to L10N1 i.e. the total number of type D1 manholes in line L1 to L10. Similarly, the number of type D2, D3 and D4 manholes are found in each line separately and thus L1N2 - L10N2 ; L1N3 - L10N3 ; L1N4 - L10N4 is calculated. Further, the extra depths over manhole chamber of size 1,2,3 & 4. is found seperately for each line. So, the values of L1EN1 - L10EN1, L1EN2 - L10EN2 ; L1EN3 - L10EN3 , L1EN4 - L10EN4 are calculated. In the next step, the total number of manholes in each category i.e. N1, N2, N3, N4 is computed. Further, the total extra depths over manhole size 1,2,3,4 are computed i.e. values of EN1, EN2, EN3, EN4 is calculated. Similarly calculations are done for corner module. Lastly, the number of drop connections and ventshafts is calculated.

Stage VIII :

Finally, the program calculates the value of sewerage network in Rupees. Also, the cost is found in Rs. per sq.m. of saleable area. The calculation is done both for the general and corner module.

Stage IX :

The outputs generated by the program are listed as follows. Also, a sample output is given in plate No. 2A, 4 and 5 in Appendix - D.

DS1, DS2	:	Internal diameters of primary and secondary pipes (mm)
K1, K2	:	Longitudinal slopes of pipe size 1 and size 2 respectively.
N1, N2, N3, N4	:	Total number of manholes of size 1,2,3 4 for general module.
EN1, EN2, EN3, EN4	:	Total extra depth over manhole size of 1,2, 3,4, for general module (m.)
NSDC	:	Number of drop connections.
NSVS	:	Number of vent shafts
CS	:	Cost of sewerage for general module (Rs.)
A8, A81	:	Length of sewer line of size DS1 and DS2 respectively (m) for general module.
X1 - X11	:	Depths at ends of sewer line segments L1 to L11 respectively.
N11, N21, N31, N41	:	Total number of manhole sizes 1,2,3 and 4 respectively for corner modules.
EN11, EN21 EN31, EN41	:	Total extra depth over manhole size 1,2,3,4 respectively for corner modules (m.)
CSS	:	Cost of sewerage for general module per sq.m. of saleable area.
CCS	:	Cost of sewerage for corner module (Rs.)
A9, A91	:	Length of sewer line for corner module (m.)

3.8 DRAINAGE NETWORK DESIGN AND COSTING SUB MODEL V :

3.8.1 General :

The sub model is intended to design the storm water drainage system and evaluates the necessary cost. The mathematical model and the computer program developed for this sub-model is presented in the following sections.

3.8.2 Criterion :

The basic criterion followed are as follows :

- System is designed to carry the surface runoff developed after a storm.
- The minimum self cleansing velocity must be ensured in the drains.
- The drains are trapezoidal in section with side slopes of 1/2 : 1 with brick pitching, pointing on surface throughout all length and cement plastering at bends and junctions.
- be simple for cleaning and maintenance.

3.8.3 Network :

The program develops a storm water drainage network comprising of section 'D1' and 'D2' running along one side of road. While drain 'D1' collects storm runoff from the interior of module, 'D2' drain size carries it away from the module and disposes on to the peripheral drain. The junctions are provided with culverts. The network is given in Fig. No. 3.11.

3.8.4 Mathematical Model :

The design of drain sizes and sections depends upon maximum rainfall intensity, time of concentration and the runoff coefficient.

The trapezoidal drain sections are worked out on the basis of Manning's formula for flow in open channels [HUDCO,1985]

$$V = \frac{1}{n} \times \frac{[AD]^{0.67}}{P^{0.67}} \times [S]^{0.50}$$

Where:

V = Flow Velocity (m/s)

AD = Cross sectional area of flow (Sq.M.)

P = Wetted perimeter (m)

S = Longitudinal slope of drain

n = Manning's coefficient taken as 0.017

and $Q = AD.V$

Or $$Q = \frac{1}{n} \times \frac{[AD]^{1.67}}{[P]^{0.67}} \times [S]^{0.50}$$

Where Q = Flow Discharge (m^3/S)

The design velocities are considered between 0.61 to 1.52 m/s The drain sections are inclusive of a free board depth of 80mm above maximum flow level.

The design discharges are converted into αD values. It is defined as follows :

$$\alpha D = \frac{\text{Maximum Catchment Area Served}}{4047}$$

The input value of 'αD' are tabulated in Appendix - C - 3.

Further, details of the mathematical model are presented in Appendix- A-5.

3.8.5 Computer Program :

The program is outlined in the following paragraphs. A graphical representation of the program is shown in Fig. 3.12.

Step I :

The following input variables are read by the program.

SA	:	Module Area(sq.m.)
R	:	Module Ratio
DA, DB, DC	:	Depth of type A,B,C plots (M.) Determined in sub-programe-I.
PS1, PS2	:	Road widths of S1 and S2 roads determined, by sub-program - I
ALF	:	Drain discharge factor.Single subscripted variable.
DOD1, DOD2	:	Drain sizes (m) single subscripted variable.
KD	:	Corresponding slope of drains. Single subscripted variable .
CD1, CD2	:	Unit cost of drain sections. Single subscripted variable.
CDP	:	Cost of parapets on both ends of culvert(Rs.)
CD1C	:	Cost of R.C.C. pipe culvert (Rs./M.)

STEP-II :

The program calculates the drain lengths of size 1 and 2, namely the values of A12 and A13.

Step-III :

The catchment areas 'A14' and 'A15' served by the drain D1 is calculated.

Step - IV :

The value of ALF1 is calculated and is compared with the values of αD programmed as ALF. The drain section D1 is selected with design values of the respective longitudinal slope and velocity based on Manning's formula. Also, the corresponding slope and unit cost value is selected.

Step- V :

The value of ALF2 is calculated and is compared with the values of αD programmed as ALF. Thus the drain section D2 is decided along with the corresponding slope and unit costs.

Step - VI :

In this step, the drainage system costs are evaluated considering the unit costs of drain sections, unit costs of culverts and parapets.

Step - VII :

The output generated by the program is listed in the following paragraph. Also, a sample output is listed in Plate No. 2A, 3 and 5 in Appendix - D.

DD11, DD22	:	Drain Sections for drains D1 and D2 (M.)
KD1, KD2	:	Corresponding slopes
CD	:	Total cost of drainage system (Rs.)
CDS	:	Cost per sq.m. of the saleable area for the drainage system.
A12, A13	:	Length of drains of size D1 and D2 (M.)

3.9 LAND AND LAND DEVELOPMENT COST-SUB-MODEL- VI :

3.9.1 General :

sub - model evaluates the total cost of raw land and its development costs. The mathematical model and the computer program has been discussed in the following sections:

3.9.2 Mathematical Model :

The model computes the total land and land development costs. The equation system is given as follows :

CLD = (CLVL + CA + CE) X SA

CLAND = AL X SA

Where,

CLD	:	Cost of land development (Rs. per sq.m.)
CLVL	:	Unit cost of levelling and dressing(Rs. per sq.m.)
CA	:	Unit cost of arboriculture (Rs. per sq.m.)
CE	:	Unit cost of electrification (Rs. per sq.m.)
CLAND	:	Cost of land (Rs. per sq.m.)
AL	:	Unit cost of land acquisition (Rs. per sq.m.)
SA	:	Module Area (sq.m.)

Further, the mathematical model has been given in Appendix A-6 in detail.

3.9.3 Computer Program :

The description of the computer program is given in the following paragraphs. Also, a detailed flow chart of the program is given in Fig. 3.13.

Ist Step :

The following input variables are read :

CLVL	:	Unit cost of levelling and dressing (Rs. per sq. m.)
CA	:	Unit cost of arboriculture (Rs. per sq.m.)
CE	:	Unit cost of electrification (Rs. per sq.m.)
SA	:	Module Area (sq.m.)
SLA	:	Saleable Area (sq.m.) determined in sub-program - I

C2S	:	Cost of sewerage in Rs. per sq.m. of saleable land (from sub-program - IV) in Rs.
CW1S	:	Cost of water supply per sq.m. of saleable land (from sub-program - III) in Rs.
CSS	:	Cost of circulation in Rs. per sq.m. of saleable land (from sub- program - II)
CDS	:	Cost of drains per sq.m of saleable land in Rs. (from sub-program - V)

Second Step :

The total land development cost CLD and land development cost per unit area of saleable land is calculated (CLDS.)

Third Step :

The absolute cost of raw land (CLAND) and cost per unit area of saleable land is found (CLANDS).

Fourth Step :

The value of TCOS is found which is sum total of CLANDS, CLDS, C2S, CW1S, CSS and CDS.

Fifth Step :

Finally, the percentage of different infrastructure component costs is calculated. The percentage of land development costs (PLD), percentage of sewerage costs (PC2S), percentage of circulation costs (PCSS) and percentage of drainage costs (PCDS) and percentage of water supply cost (PCW1S) is calulcated.

Sixth Step :

The outputs generated have been listed in the following lines. A sample output is shown in Plate - 2 B (Ref. Appendix - D)

CLD	:	Cost of Land Development (Rs.)
CLDS	:	Cost of Land Development per sq.m. of saleable land in Rs.
TCOS	:	Total cost (Rs.)
CLAND	:	Cost of land (Rs.)
CLANDS	:	Cost of land per sq. saleable area (Rs./ sq.m.)
PLD, PC2S, PCW1S, PCSS, PCDS	:	Percentage of land development, sewerage, water supply, circulation and drain cost respectively.

3.10 OPTIMUM MODULE SELECTION- SUB-MODEL- VII:

3.10.1 General :

The module design process was detailed in the previous sub models. By varying the input parameters, the computer can be made to generate an exhaustive list of alternatives. However, all the alternatives provide results which are not of practical use. Some of the module options will exhibit partial results as certain variables become overstrained again. Again, some of the options will provide impractical geometrical configurations.

So a selection process becomes inevitable to ensure functional spaces of desired quality. So this sub-model helps in optimum module selection process. It offers a technique which enables the planners to take into account the consideration of both qualitative and quantitative aspects.

3.10.2 Selection Process :

The various selection criterion are to be decided by the planners. Some of the criterion may be used on the following:

i) The social facility space in the module.

ii) Total development cost.

iii) The distribution of various category plots etc.

The specific criterion are to be decided as per the requirements of the project.

The system scans all the alternatives and rejects those which do not fulfil the criterion laid down. So, the sub model operates on the principle of elimination. Thus it helps to bring down the range of alternatives within manageable proportions, thus achieving economy in manual work. Thus the program assures of results which are useful and acceptable to the planner.

3.10.3 Computer Program :

The program reads the input variables, module dimensions, plot widths, plot size, SFS dimensions and area, development costs and module area. First it prepares a list of module options having any side greater than 230 m. Scans this list for module options having smaller side of SFS greater than or equal to depth of smallest plot size. Further this list is short listed for module options with social facility space less than 4 % of the total module area. Next further checks for plot widths and cost are applied to finally arrive at the optimum module option. The block diagram of the program is given in Fig. No. 3.14.

3.11 Discussion :

The model (CALSD - MODEL) and the computer program developed in this study and discussed in the preceding sections would prove to be a working tool for the physical planners. The seven sub - models contained in this model, namely, the physical parameters design ; circulation network costing; water supply, sewerage and drainage network design and module selection model would greatly facilitate the analysis, design and selection of the optimum module. A module layout was selected and the CALSD - MODEL was applied to it. The computer generated an exhaustive list of alternatives. The results have been analysed and the sensitivity of various design parameters have been ascertained in the following chapter.

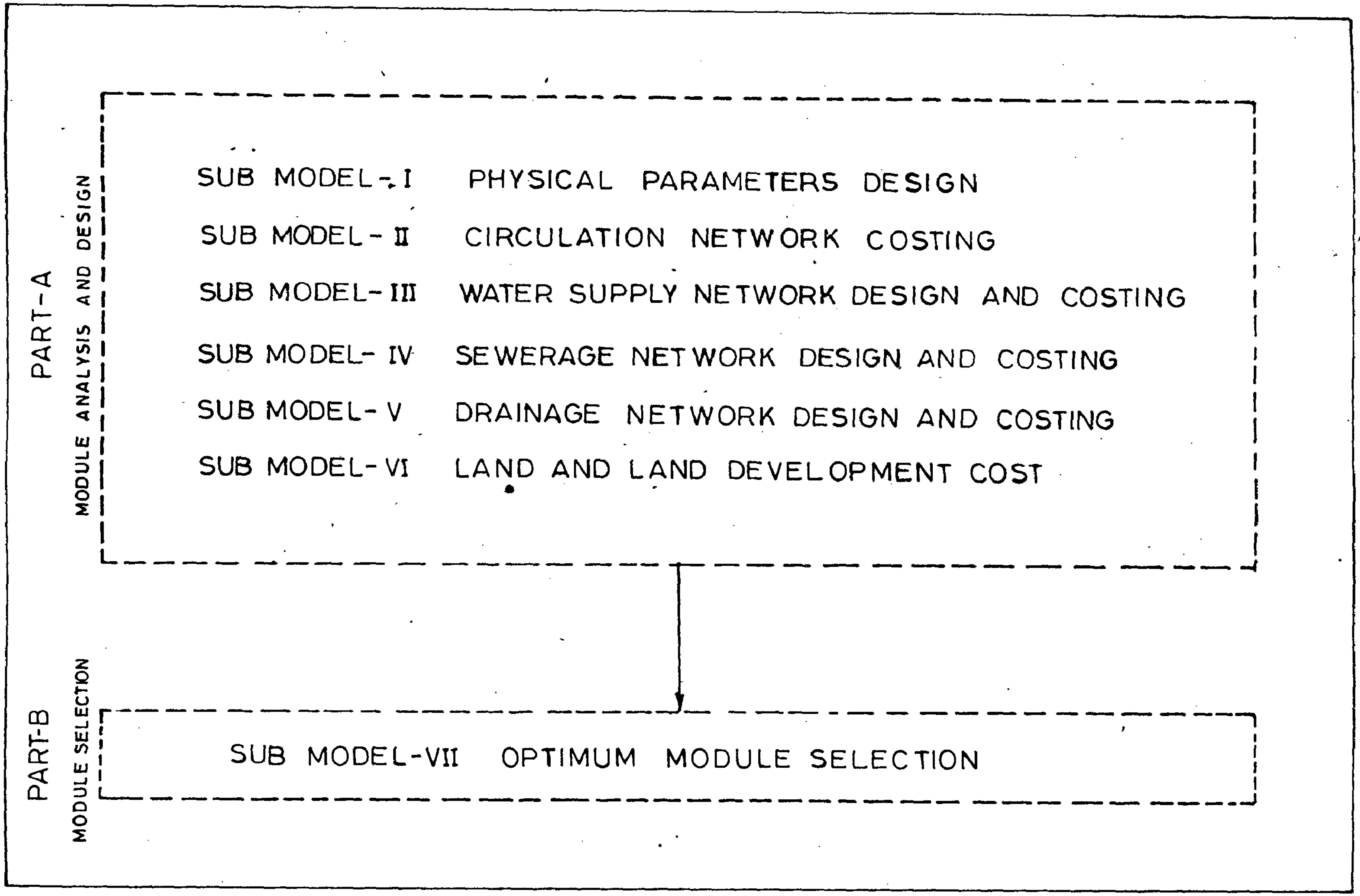
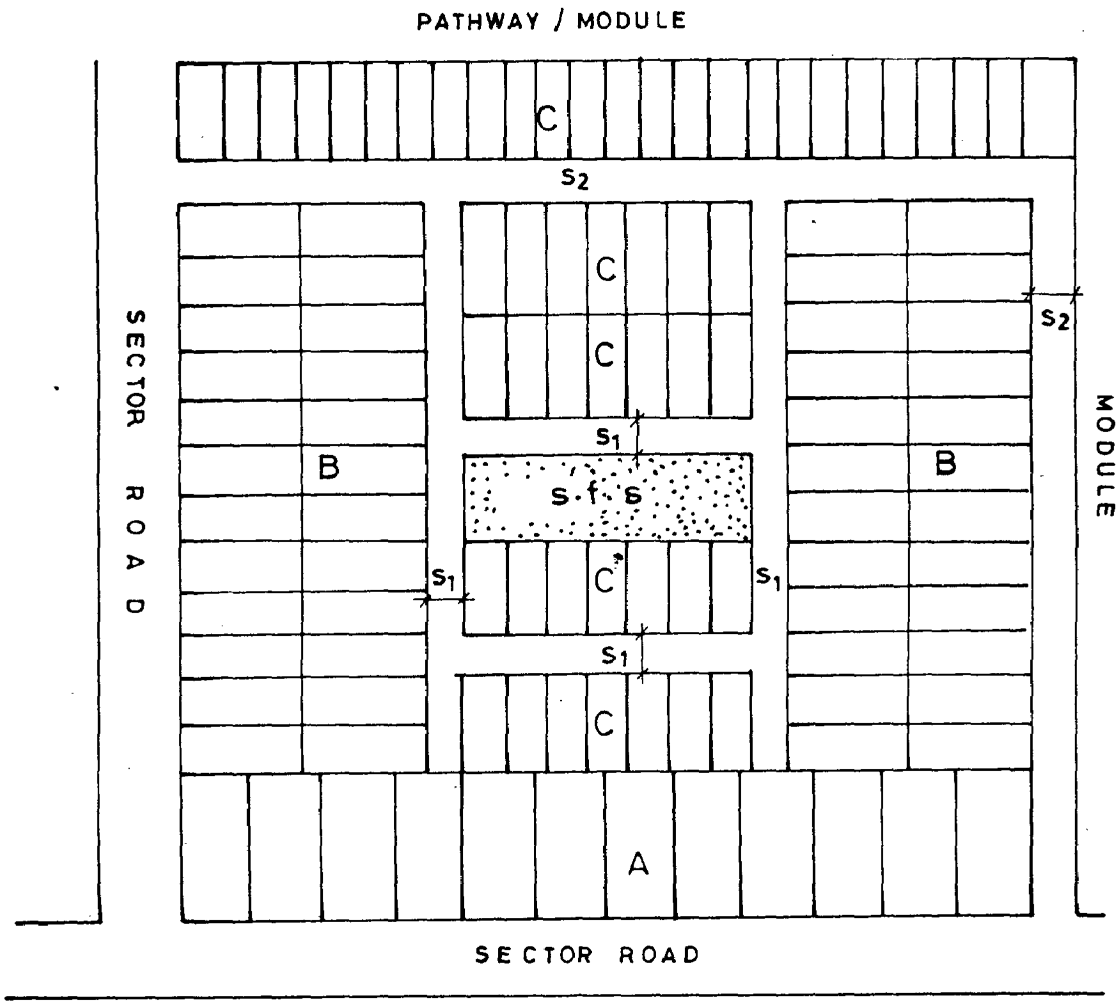


FIG.3.1 STRUCTURE OF THE CALSD-MODEL



INDEX :—

S. F. S – SOCIAL FACILITY SPACE

PLOT TYPES – A, B & C

ROAD WIDTHS – S_1, S_2

FIG. 3.2 MODULE GEOMETRY

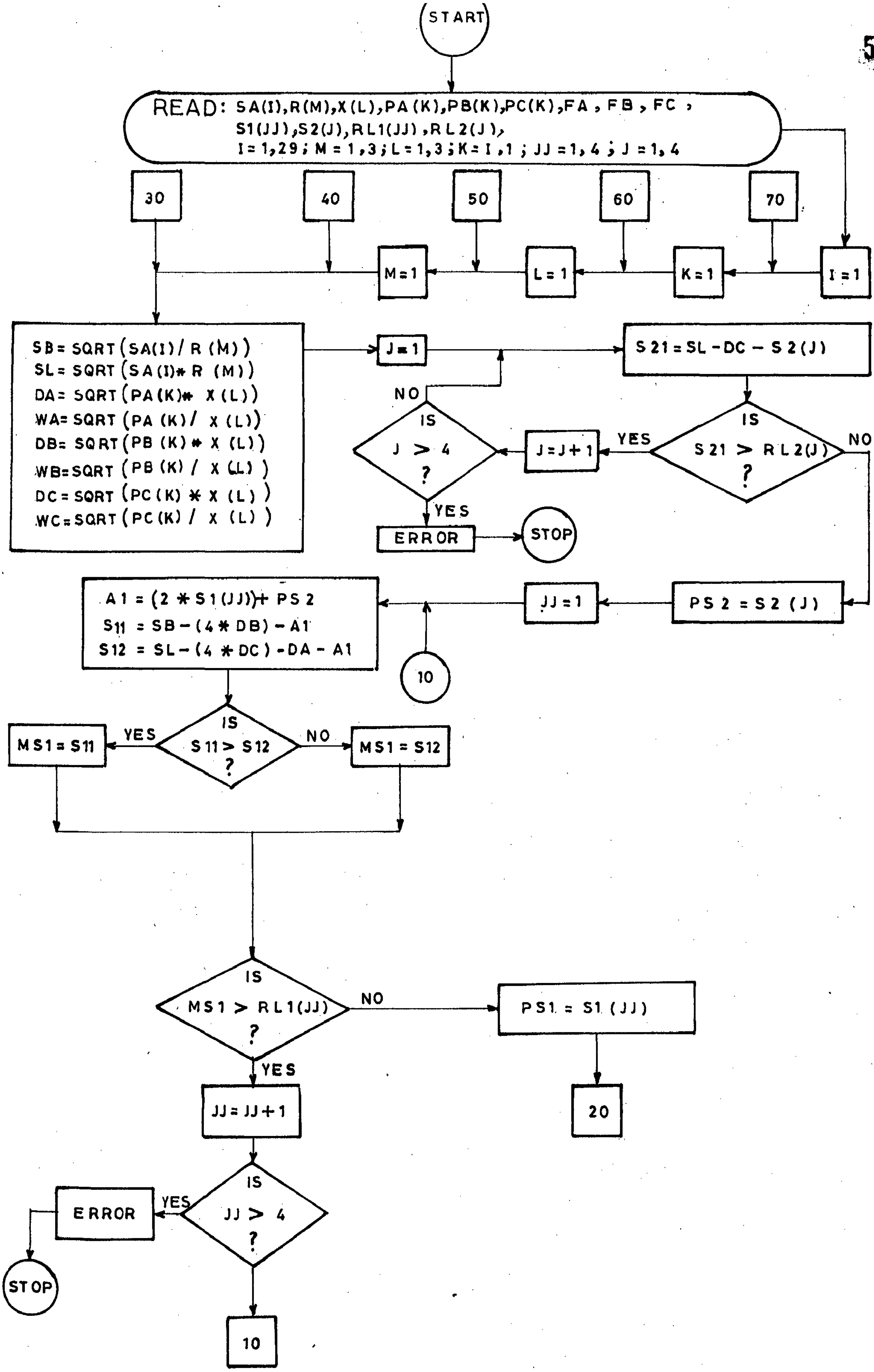
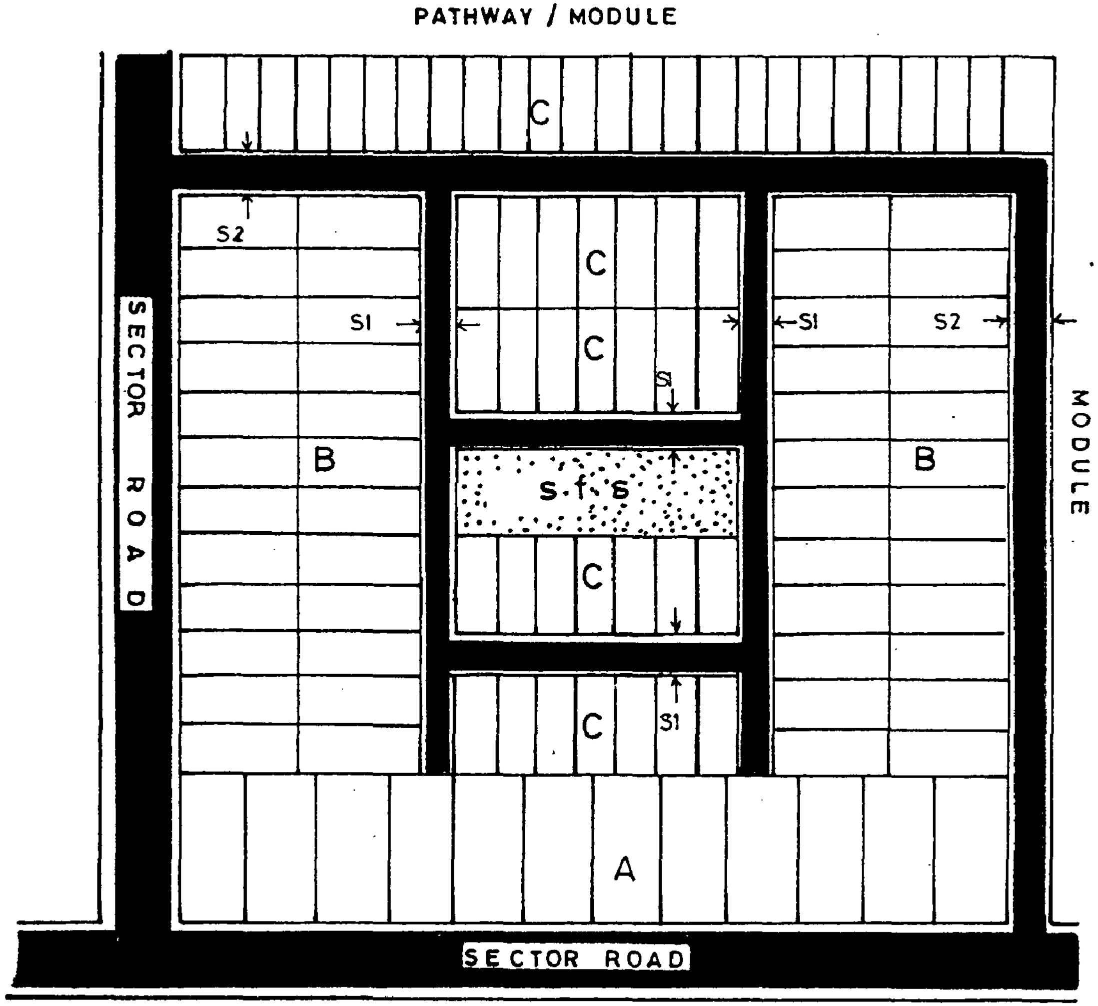


FIG. 3.3 FLOW CHART OF SUBPROGRAM-I



INDEX :—

S. F. S — SOCIAL FACILITY SPACE

PLOT TYPES — A, B & C

ROAD WIDTHS — S_1, S_2

FIG. 3.4 MODULE ROAD NETWORK

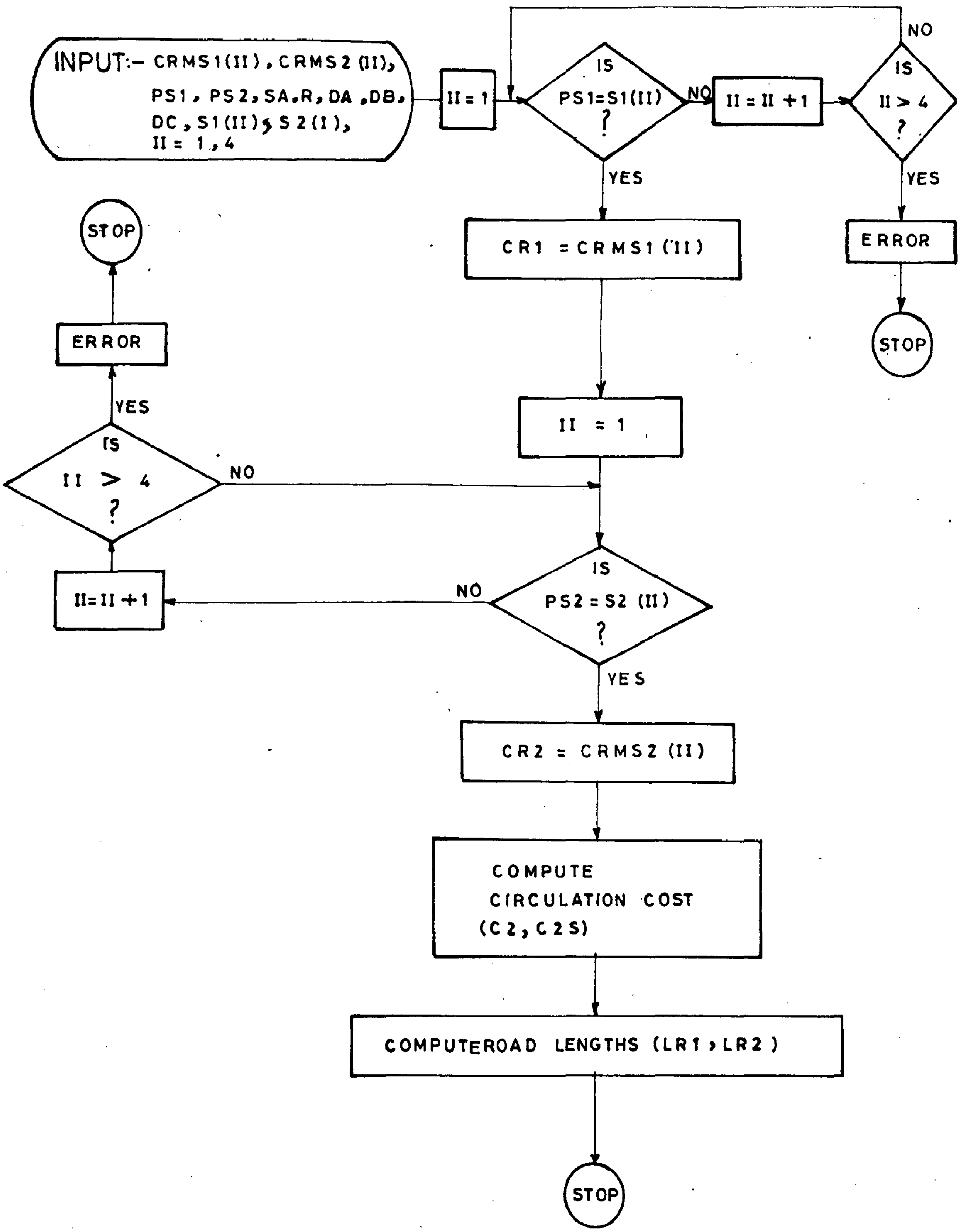


FIG. 3.5 BLOCK DIAGRAM OF SUB-PROGRAM-II

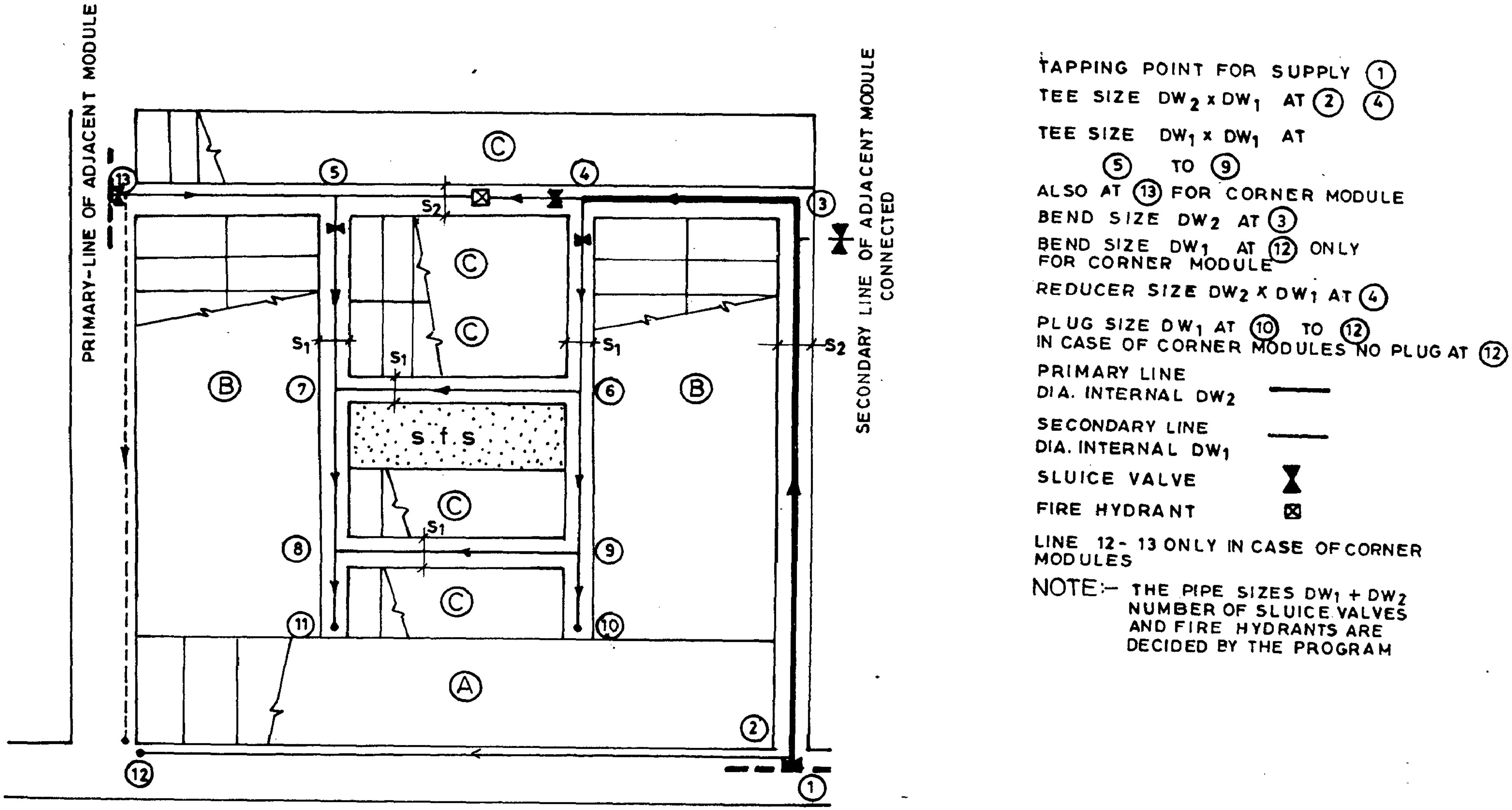
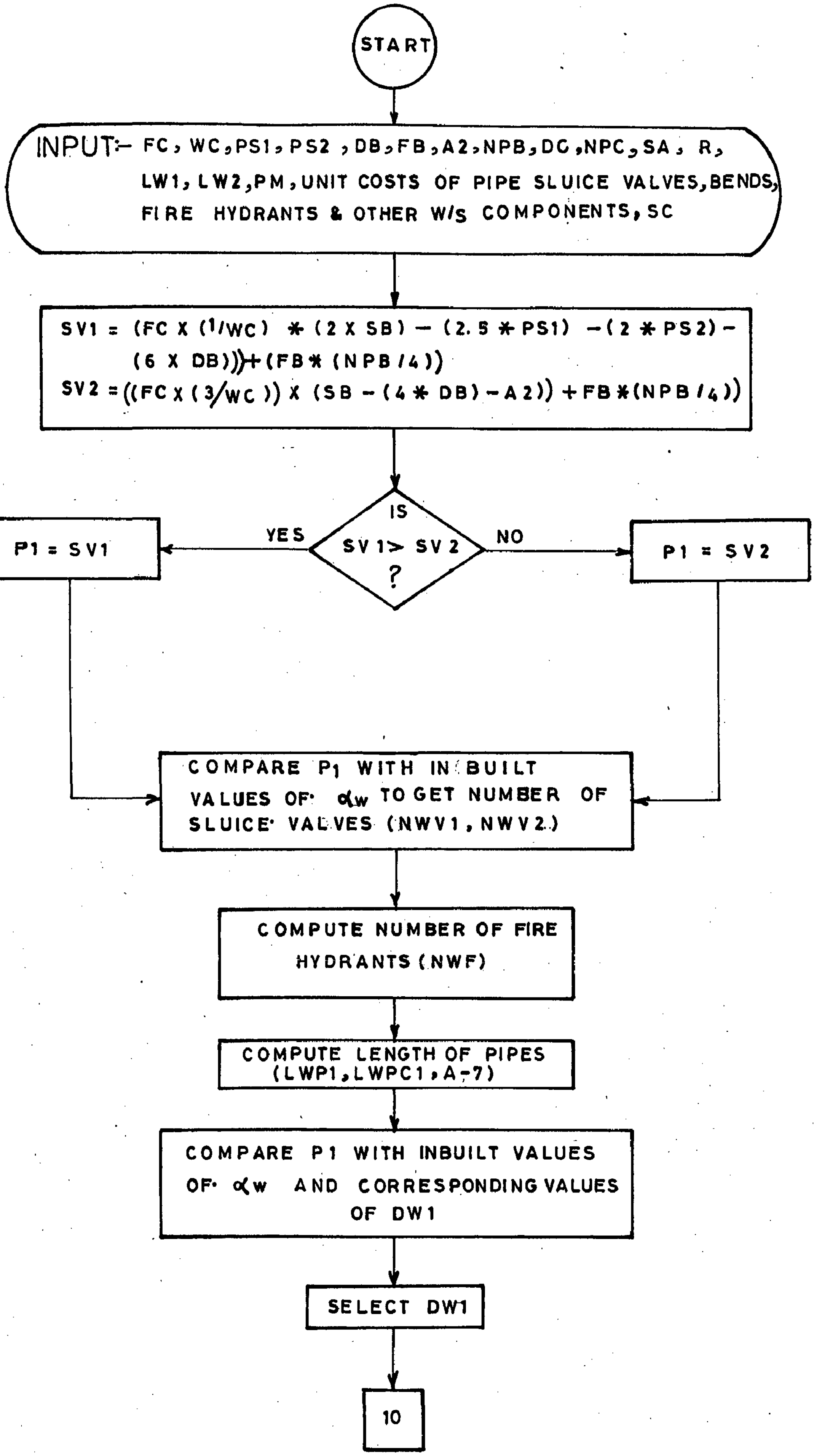


FIG. 3. 6 WATER SUPPLY NETWORK


START
INPUT:- FC, WC, PS1, PS2, DB, FB, A2, NPB, DC, NPC, SA, R,
LW1, LW2, PM, UNIT COSTS OF PIPE SLUICE VALVES, BENDS,
FIRE HYDRANTS & OTHER W/S COMPONENTS, SC
SV1 = (FC X (1/WC) * (2 X SB) – (2.5 * PS1) – (2 * PS2) –
(6 X DB))+(FB * (NPB /4))
SV2 = ((FC X (3/WC)) X (SB – (4 * DB) – A2)) + FB *(NPB /4))
IS
SV1 > SV2
?
YES
NO
P1 = SV1
P1 = SV2
COMPARE P1 WITH INBUILT
VALUES OF αw TO GET NUMBER OF
SLUICE VALVES (NWV1, NWV2)
COMPUTE NUMBER OF FIRE
HYDRANTS (NWF)
COMPUTE LENGTH OF PIPES
(LWP1, LWPC1, A-7)
COMPARE P1 WITH INBUILT VALUES
OF αw AND CORRESPONDING VALUES
OF DW1
SELECT DW1
10

CONTD.

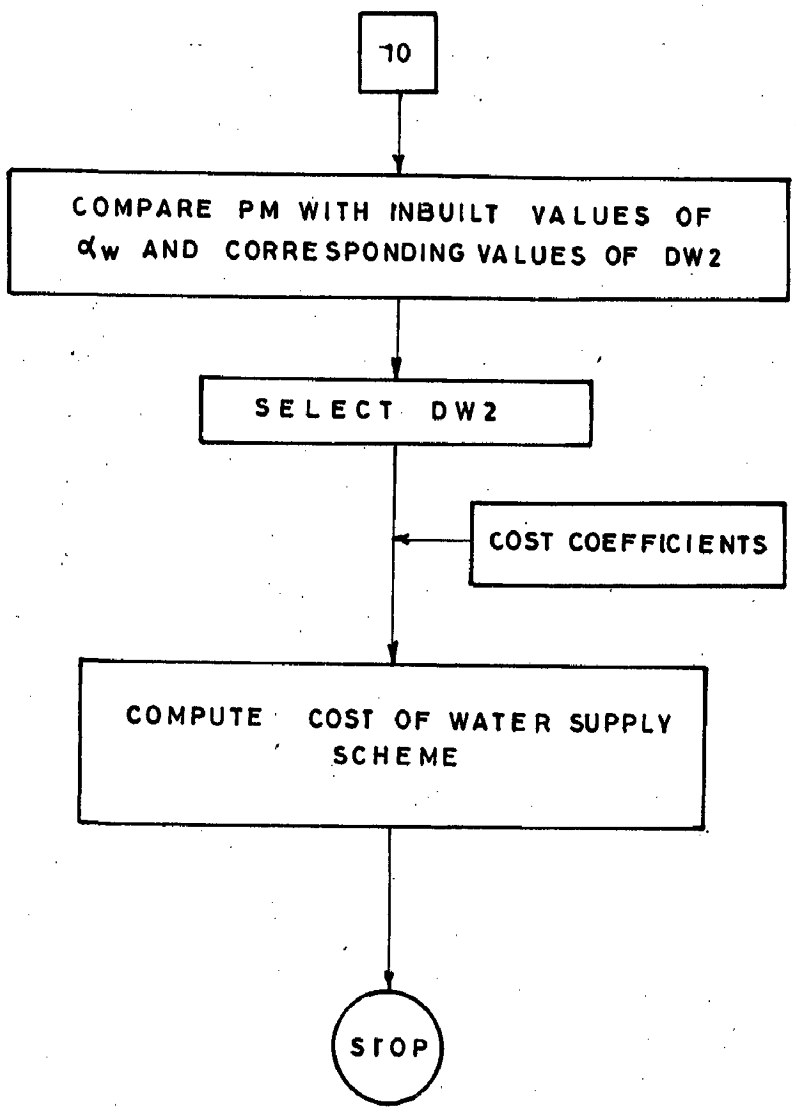


FIG. 3.7 BLOCK DIAGRAM OF SUB PROGRAM-III

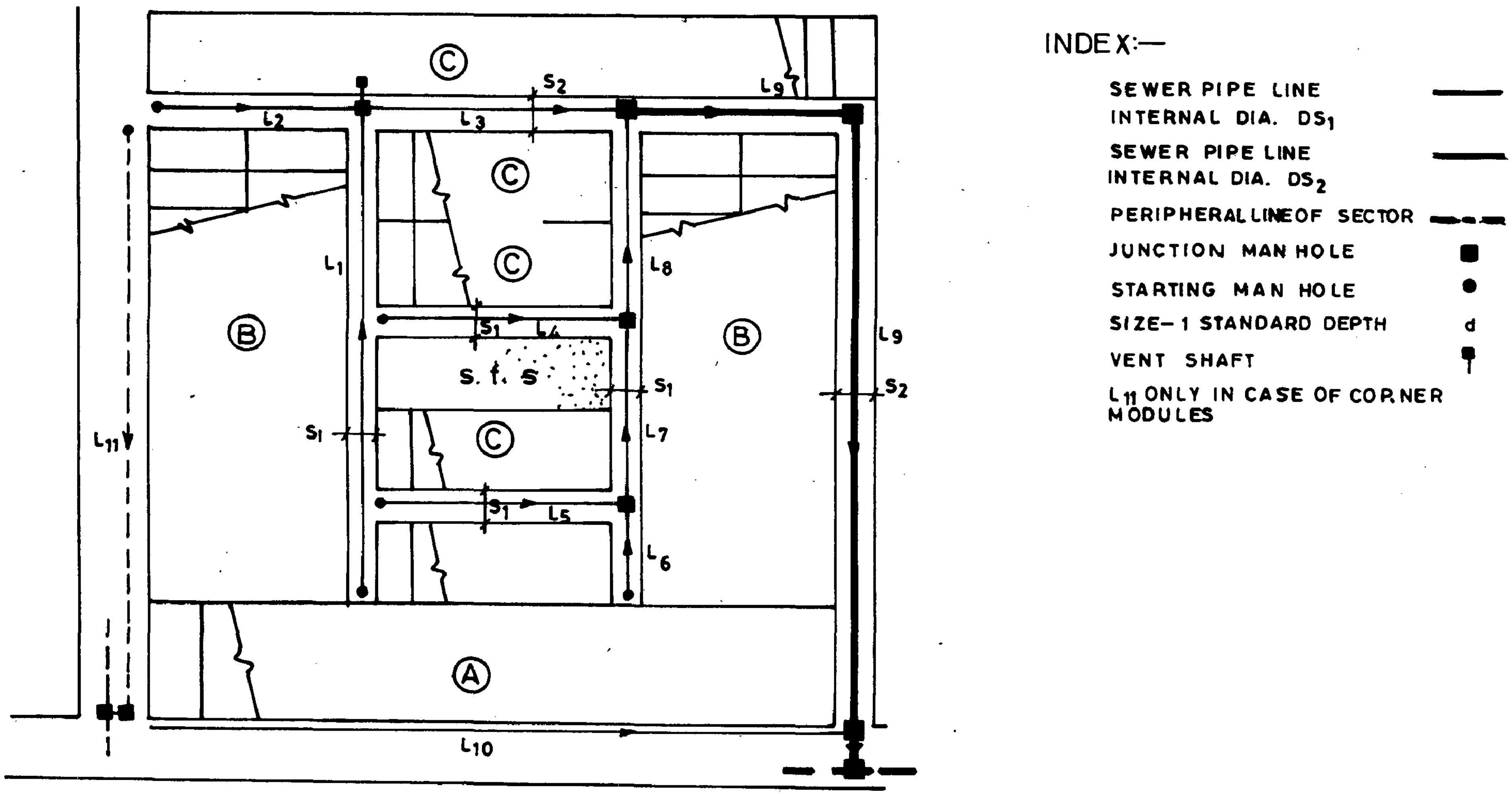


FIG. 3.8 SEWERAGE NET-WORK

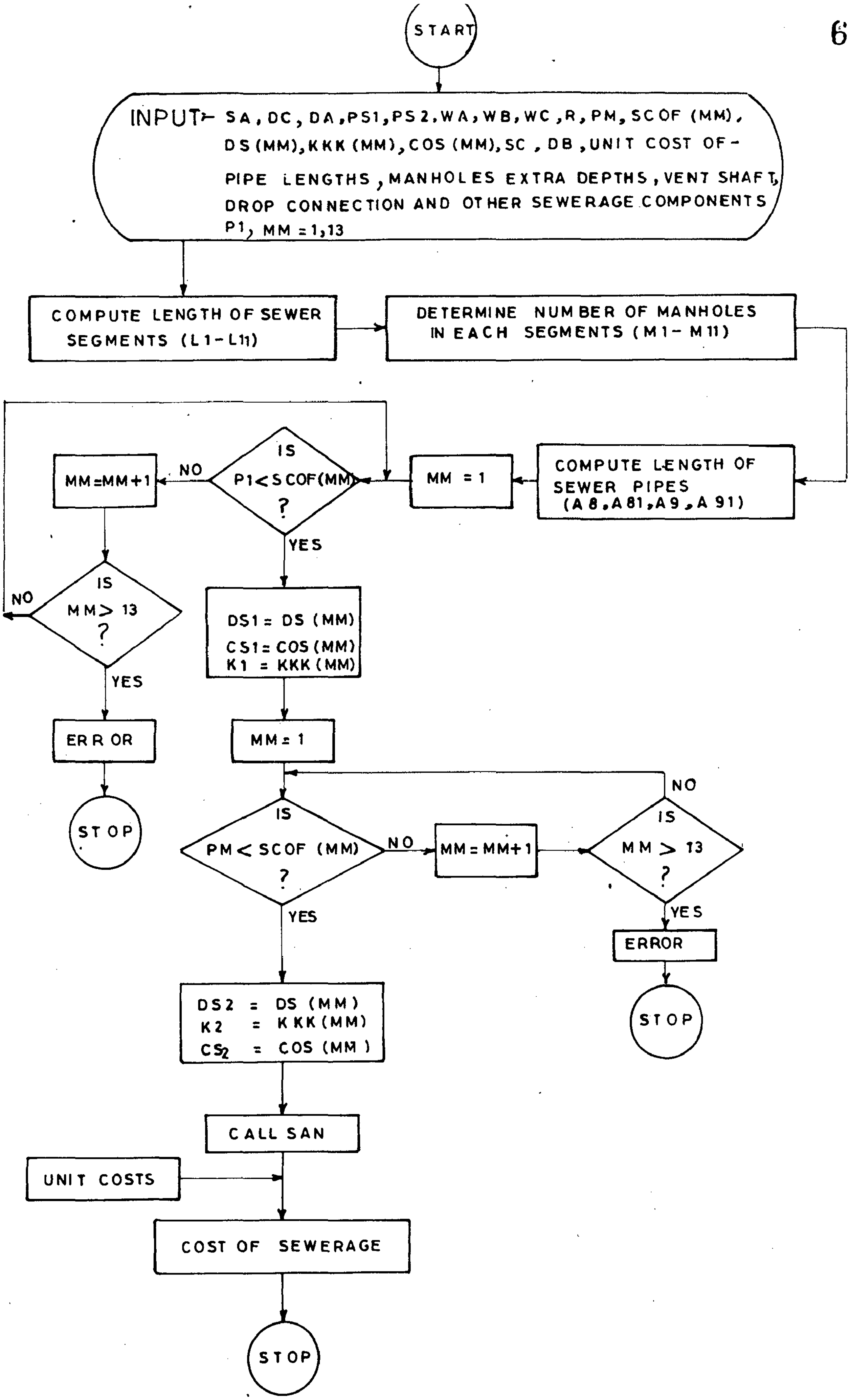


FIG. 3.9 BLOCK DIAGRAM OF SUB PROGRAM - IV

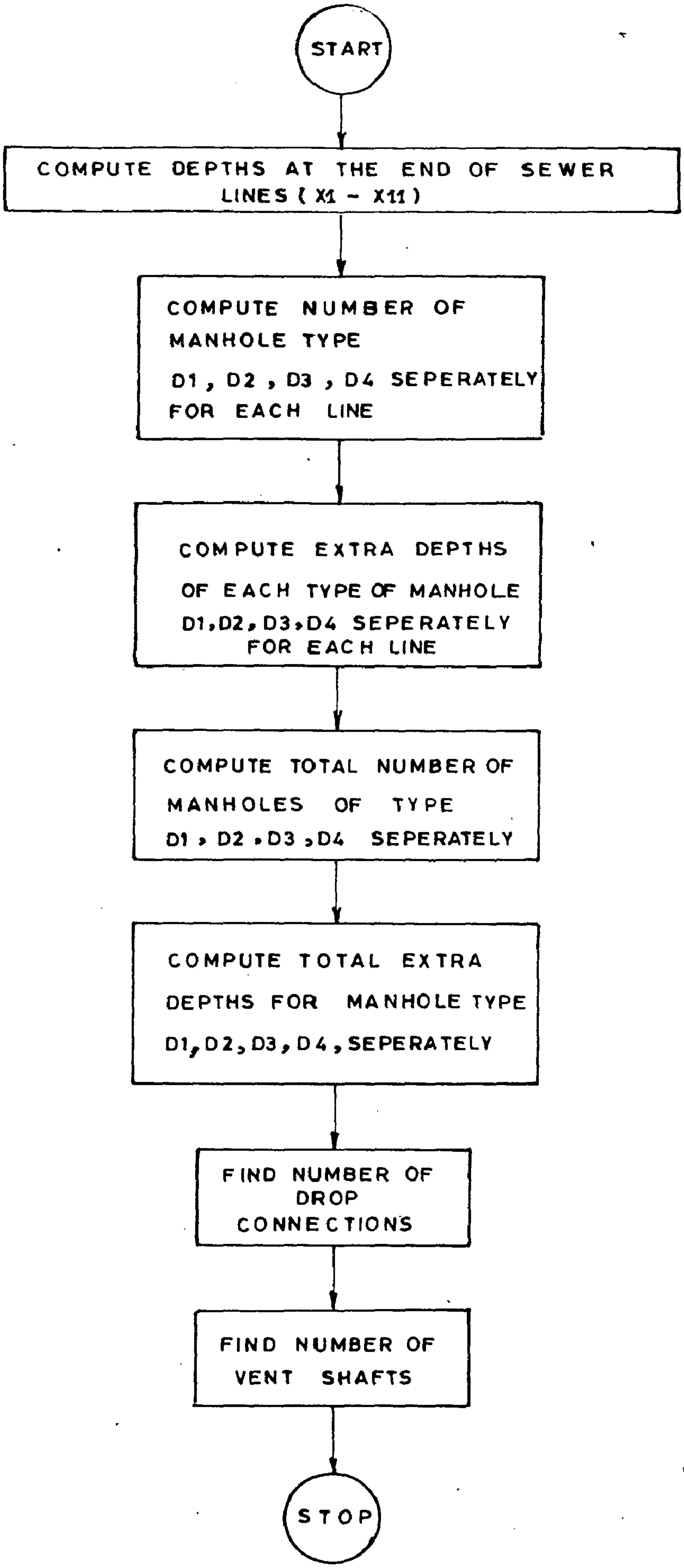


FIG. 3. 10 BLOCK DIAGRAM OF SUB-ROUTINE SAN

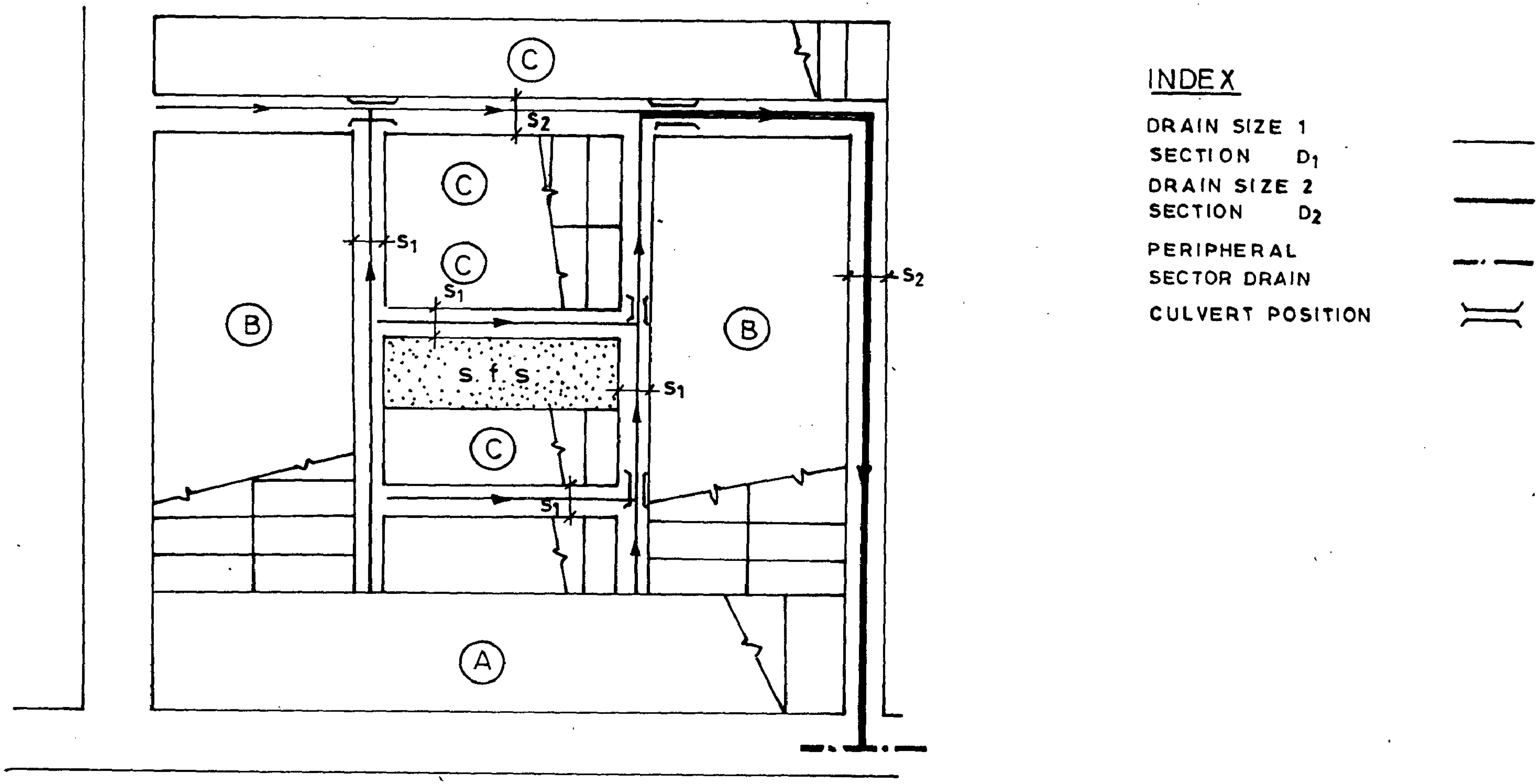


FIG. 3.11 STORM WATER DRAINAGE NETWORK

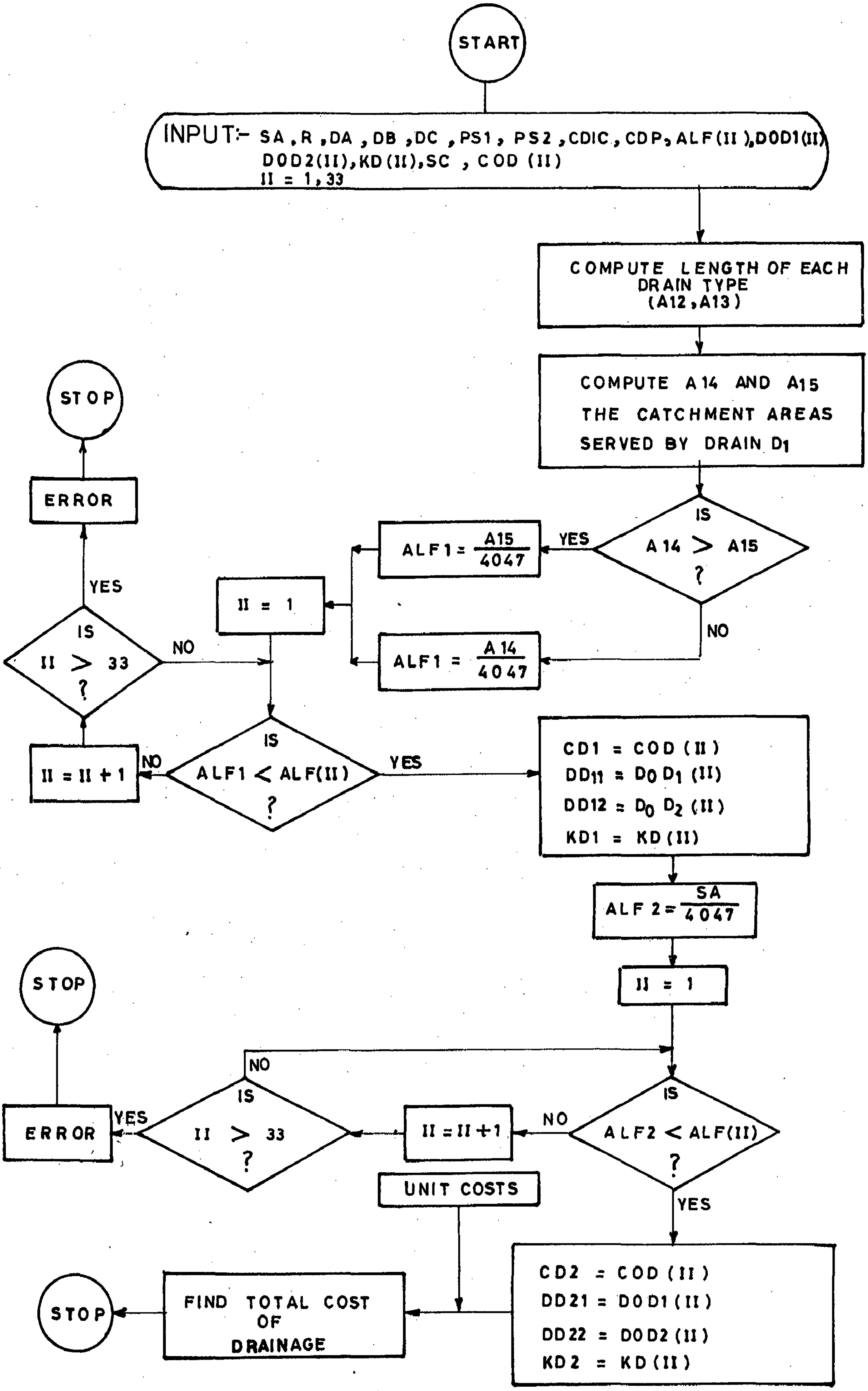


FIG. 3.12 BLOCK DIAGRAM OF SUB-PROGRAM - V

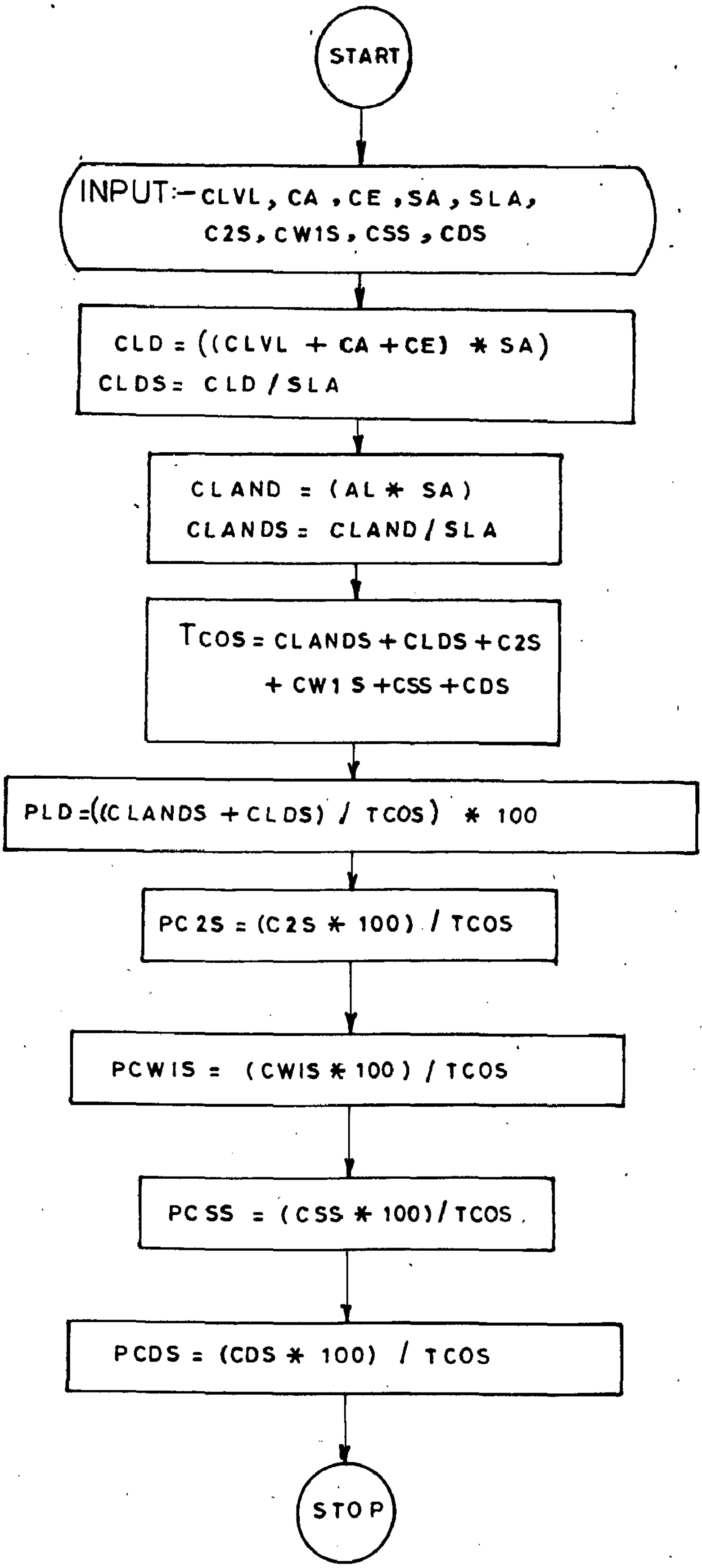


FIG. 3.13 BLOCK DIAGRAM OF SUB-PROGRAM - VI

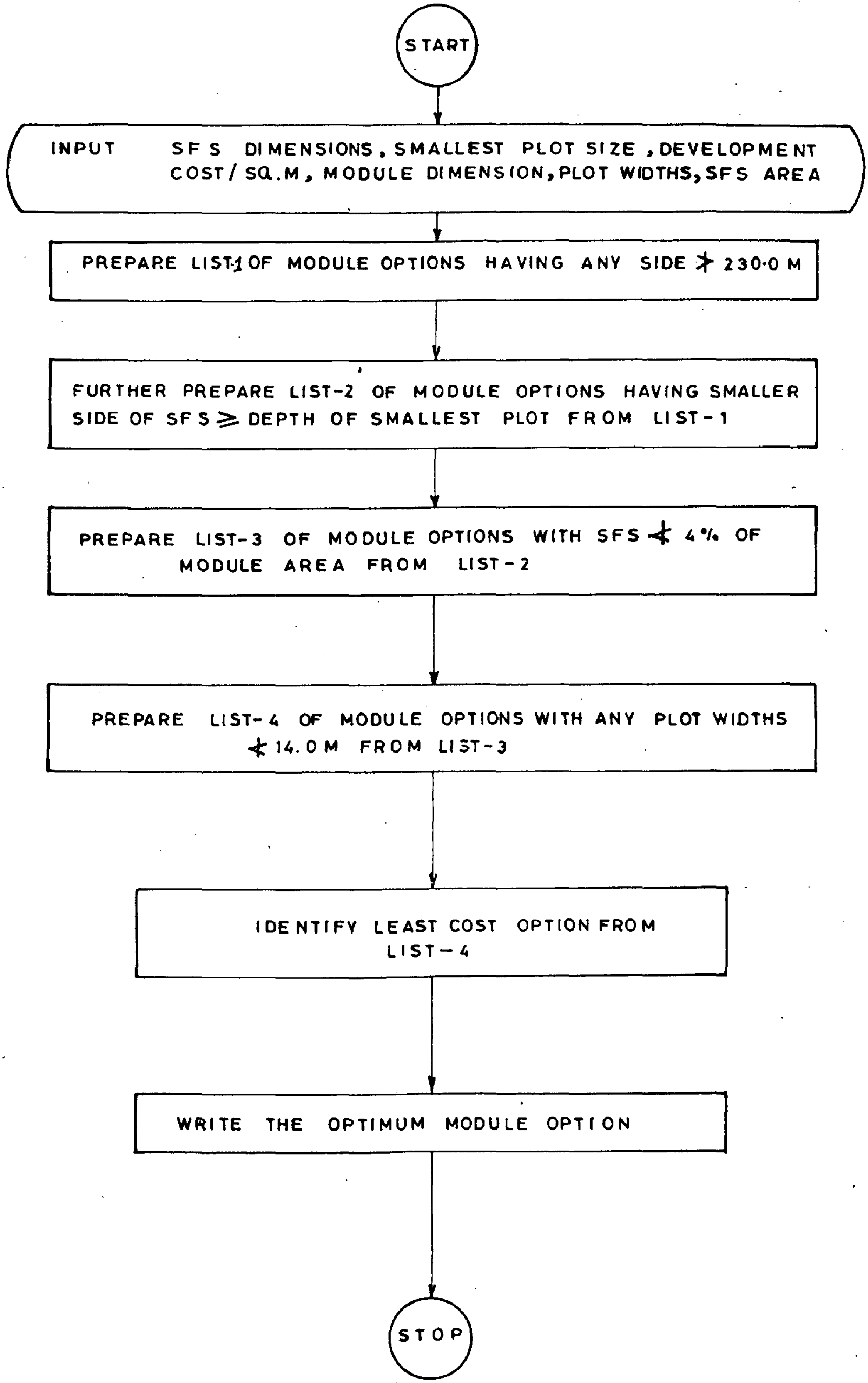


FIG. 3.14 BLOCK DIAGRAM OF SUB-PROGRAM-VII

C H A P T E R - IV

SENSITIVITY ANALYSIS

4.1 GENERAL:

The efficiency of a land sub-divison plan is generally ascertained in terms of various land use indicators such as saleable land, circulation area, social facility space etc. and in terms of cost indicators such as, length of various utility network per unit area, cost per unit of saleable area etc. Within the given constraints of standards, regulations etc., the planner generally tries to maximise the saleable land, minimise the circulation area and finally tries to reduce the cost per unit of saleable area.

Sometimes it is believed that all the above objectives could be achieved simultaneously and the fact that some of the above objectives have conflicting requirements, is ignored. In view of the above incompatibility of different planning objectives, it is essential that, the interaction of all variables which contribute to the efficiency parameters of a layout, should be clearly ascertained, in a given situation. This shall facilitate to achieve the desired set of planning objectives in a given situation.

4.2 SENSITIVITY OF PHYSICAL LAYOUT PARAMETERS :

The proportion of saleable land, the circulation area and the social facility space are the main physical parameters in a layout. The sensitivity of these physical layout parameters is judged for the selected module with the plot area combinations of 275, 325 and 375 sq.mts. The analysis is done by varying the plot ratio, module ratio and module area respectively.

4.2.1 Impact of Plot Ratio Variation :

The variation in plot ratio was studied for ratios of 1.0, 1.4 and 1.7 for a module of fixed area and module ratio of 1.4. Impact of varying plot ratio on various physical parameters was observed as follows [Ref. Fig. 4.1]:

(i) The area available under plots i.e. the saleable area increases with increase in plot ratio.

(ii) Total open space available decreases with increase in plot ratio.

(iii) Area under circulation decreases with increase in plot ratio.

(iv) If we consider the 31,000 sq.m. module, it will be seen that the saleable land increases from 64.09 % to 70.11 % when plot ratio is increased from 1.0 to 1.4. So the range of variation of saleable land is 1.09 [70.11/ 64.09]. The open space decreases from 7.73 %.

to 3.38 %. by increasing plot ratio from 1.0 to 1.4. So range in variation is 2.29 [7.73 / 64.09]. The circulation area decreases from 28.18 % to 26.51 % on increasing plot ratio from 1.0 to 1.4. So range of variation is 1.06 [28.18/26.51].

This means that sensitivity of open space area parameter to the variation in the plot ratio is more than other layout parameters [saleable area and circulation area] .

The foregoing analysis leads us to the conclusion that a higher plot ratio would lead to more economic solution.

4.2.2 Impact of Module Ratio Variation :

Module ratio variation was studied for ratios of 1.0, 1.4 and 1.7 for a fixed area module with plot ratio of 1.4. Impact of varying module ratios on other physical parameters was observed as follows [Ref. Fig. 4.2] :

(i) The circulation area increases with increase in module ratio.

(ii) The saleable area decreases with increasing module ratio. The variation is substantial when module ratio is increased from 1.0 to 1.4(3.4 %) upward. But when module ratio is increased from 1.4 to 1.7, the variation is not much pronounced (only of the order of 1.2 %).

(iii) The variation of open space is quite interesting. The total open space area increases when the module ratio is increased from 1.0 to 1.4 But on further increasing the module ratio to1.7, the open space area again decreases.

Hence, for higher module ratios, there is net increase in saleable area and reduction in open space area, the gains are offset by substantial increase in circulation area.

4.2.3 Impact of Module Area Variation :

The module area was varied from 31,000 sq.mtr. to 59,000 sq.mtr.. The study was done with plot ratio and module ratio 1.0 and 1.4 respectively. The results were as follows [Ref Fig. 4.3] :

(i) The saleable area decreases with increasing module area. The rate of decrease is sharper when the module area is increased from 37,000 sq.mtr. to 39,000 sq.mtr 3.34 %.)

(ii) Increase in module area generally leads to decrease in circulation area. However there are pockets of sharp increase. The circulation area increases sharply between the module area 37,000 sq.mtr. and 39,000 sq.mtr..

(iii) The open space also increases with increasing module area. This rate is slowed down in those modules that show sudden increase in circulation area.

The range of variation in open space area is 1.05 when module area is increased from 31,000 to 37,000 sq.m. But the range in variation is only 1.03 when module area increased from 37,000 sq.mtr. to 39,000 sq.mtr. as in this range, the circulation area increases sharply.

4.2.4 Conclusion:

The above analysis shows that to obtain optimum solutions, following must be attempted:

(a) Module Area must be least.

(b) Module Ratio must be least.

(c) Plot Ratio must be higher.

Combining these three situations will generally lead to optimum results.

4.3 SENSITIVITY OF INFRASTRUCTURE COSTS :

The total infrastructure cost of a scheme is largely dependent on the adopted level of services and optimal design of utility services. The cost of infrastructure in a deficient layout can be as high as almost double the cost incurred in an optimal layout. So, the subject of infrastructure cost relational studies is of utmost importance.

The cost of infrastructure services namely water supply, sewerage, storm water drains etc. can be studied for varying plot ratio, module area and module ratio. This would help to judge the cost efficiency of the layout.

4.3.1 Analysis of Cost Implications of Water Supply System :

The sensitivity of the cost of water supply system is studied for the following cases :

4.3.1.1 Varying Plot Ratio :

Variation in cost of water supply was studied for plot ratios of 1.0, 1.4 and 1.7 for a fixed module area and module ratio of 1.4 Sample studies showed that the cost of water supply reduces with the increasing plot ratio (Ref. Fig. 4.4A). With the plot area comination of 275, 325, 375 sq.mtr., the cost of water supply works out to be Rs. 11.0 per sq.mtr. of saleable area for a module area of 31,000 sq.m. with plot ratio of 1.0 and for the same module it works out to be Rs. 9.18 per sq.mtr. of saleable area for a plot ratio of 1.7. So reduction in cost is 16.5 %. The same trend was observed with module areas of 37,000; 45,000; 51,000 and 59,000 sq.mtr. where cost was reduced near by 18.7 %, 19.8 % , 19.9 % and 20.1 % respectively. So in case of bigger modules, greater cost reduction could be achieved.

4.3.1.2 Varying Module Ratio :

Variation in water supply cost was studied for module ratios of 1.0, 1.4, 1.7 for a fixed module area and plot ratios of 1.4. The plot area combination was 275, 325 and 375 sq.mtr. But in this case a definite trend was not noticed in the water supply costs (Ref. Fig. 4.5 A). The water supply costs were reduced by nearly 5.6 % when the module ratio was increased from 1.0 to 1.7 for a 31,000 sq.mtr. module. Whereas in case of a 45,000 sq.mtr. module, the cost increased by nearly 8.71 % .

4.3.1.3 Varying Module Area :

The study was done with plot ratio as 1.0, module ratio as 1.4 and plot ratio combinations of 275, 325, 375 sq.mtr. [Refer Fig. 4.6 A]. The cost of water supply per sq.m. of saleable area decreases as the module area is increased from 31,000 to 35,000 sq.mtr. But as the module area increases to 37,000 sq.mtr., there is a steep rise in cost by nearly 13 % . Thereafter for the higher module areas, no definite trend is seen.

4.3.2 Analysis of Cost Implications of Sewerage System :

The sensitivity of the cost of the sewerage system is judged for the plot area combination of 275, 325, 375 sq.mtr. The study was done for the following cases:

4.3.2.1 Plot Ratio Effect :

Variation in cost of sewerage system was studied for plot ratios of 1.0, 1.4, 1.7 and module ratio 1.4 for a fixed area module. The variation in plot ratio did not indicate a definite trend (Ref. Fig. 4.4 A). The cost of sewerage reduced by nearly 11.9 % when the plot ratio was increased from 1.0 to 1.7 for the 45,000 sq.mtr. module. The trend was reversed in the 51,000 sq.mtr. module, with the sewerage cost increasing nearly by 6.1 % for the same case. So, the sewerage system cost is less sensitive to the plot ratio changes.

4.3.2.2 Module Ratio Effect :

Variation in the cost of sewerage system is judged for module ratios of 1.0, 1.4 and 1.7 with plot ratio 1.4 for a fixed area module. The variation of module ratio did not indicate a definite trend (Ref. Fig.45 A). But in general, higher module ratio lead to increased sewerage costs. The sewerage costs went up by nearly 7 % by increasing module ratio from 1.0 to 1.7 for the 31,000 sq.mtr. module, these costs dropped by nearly 11.8 % for the same case.

4.3.2.3 Module Area Effect :

The variation of cost of sewerage was studied for various module areas ranging from 31,000 - 59,000 sq.mtr. for plot ratio of 1.0 and module ratio of 1.4. The cost of sewerage per sq.m. of saleable area goes on decreasing for module areas 31,000 to 39,000 sq.mtr. As the module size is increased to 41,000 sq.mtr., the cost shoots up by nearly 18.4 % with respect to the cost of 39,000 sq.mtr. module (Ref: Fig. 4.6 A). But again cost drops by nearly 12.5 % for 43,000 sq.mtr module with respect to cost of 41,000 sq.mtr. module. Again the cost shoots up by nearly 12.2 % for the 45,000 sq.mtr. module with respect to cost of 43,000 sq.mtr. module. Thereafter for higher modules no definite trend is noticed.

4.3.3 Analysis of Cost Implications of Drainage System :

The sensitivity analysis of storm water drainage system is done for the following cases mentioned below. The plot area combinations are 275, 325, 375 sq.mtr.

4.3.3.1 Plot Ratio :

The plot ratios considered are 1.0, 1.4, 1.7 and costs of storm water drainage is judged for this variation. (Ref. Fig. 4.4 B). The module ratio is 1.4 and the module area is kept constant. The general trend observed is that the drainage costs are decreased with increasing plot ratios. These costs get reduced nearly by 17.6 % , 19.5 %. and 20.6 %

for the modules having an area of 31,000; 45,000, 51,000 sq.mtr. respectively for the increase in plot ratio from 1.0 to 1.7. For the higher module area, the percentage reduction is higher with the increase in plot ratio.

4.3.3.2 Module Ratio :

The module ratios considered are 1.0, 1.4 and 1.7 and costs of storm water drainage per sq.m. of saleable area is judged for this variation (Ref. Fig. 4.5 B). The plot ratio is 1.4 and the module area is kept constant. No consistent trend was observed when the module ratio was increased from 1.0 to 1.7, the costs increased by nearly 10 % for the 31,000 sq.mtr. module. But in case of 37,000 sq.m module cost remains unchanged for the same case.

4.3.3.3 Module Area :

The analysis is done with the module areas varying from 31,000 sq.mtr. to 59,000 sq.mtr. and module ratios and plot ratios being 1.0 and 1.4 respectively(Ref. Fig. 4.6B). The analysis showed that though no clear cut trend is seen in the costs per sq.mtr. of saleable area of drainage costs, there are some sharp pockets of increase in the cost. When the module area is raised from 35,000 to 37,000 sq.mtr.,the costs go up by nearly 9.96 % . Same is the case by changing the module area from 49,000 to 51,000 sq.mtr. as the increase is nearly 6.9 %.

4.3.4 Analysis of Cost Implications of Circulation Network :

The sensitivity of circulation network costs per sq.m. of saleable area is done for the plot area combinations of 275, 325, 375 sq.mtr. The study is done for the following cases :

4.3.4.1 Plot Ratio :

The plot ratios considered were 1.0, 1.4, 1.7 and costs of circulation network studied for this variation The module ratio is 1.4 and module area is kept constant. The circulation network costs reduce with the increase in plot ratio (Ref. Fig. 4.4A). The reduction is about 20.8 %, 21.5 %, 17.4 %. in case of modules having an area of 31,000, 45,000, 59,000 sq.mtr respectively for the increase of plot ratio from 1.0 to 1.7. So, in the smaller modules percentage reduction in costs is higher.

4.3.4.2 Module Ratio :

Variation in road system costs was studied for module ratios of 1.0, 1.4, 1.7 with plot ratio as 1.4 for a fixed area module. The circulation network costs increase with the increase in module ratio (Ref. Fig. 4.5 A). The increase is about 25.56 %, 15.1 % 8.1% in case of modules having an area of 31,000; 45,000; 59,000 sq.mtr.respectively for the increase in plot ratio from 1.0 to 1.7. So the increase of cost is lesser in case of modules of higher areas.

4.3.4.3 <u>Module Area</u> :

The study is done by varying module area from 31,000 to 59,000 sq.mtr. for plot ratio 1.0 and module ratio 1.4. In general it was observed that the costs of roads follow an increasing trend with increasing module areas (Fig. 4.6 C). The costs variation is sharpest when the module area is increased from 37,000 to 39,000 sq.mtr. In this case costs increase nearly by 7.0 %.

4.3.5 <u>Analysis of Cost Implications of Land And other Costs</u> :

This study analyses the cost of (i) Land acquisition (ii) External electrification (iii) Site levelling and dressing and (iv) Arboriculture taken together and called as land and other costs per sq.m of saleable area. The plot area combinations are kept as 275, 325, 375 sq.m. and following cases are studied:

4.3.5.1 <u>Plot Ratio</u> :

Variation in the costs are studied for plot ratios of 1.0, 1.4, 1.7 with module ratio of 1.4 for a fixed area module. The trend observed is that the increasing plot ratios lead to lower land and other costs (Ref. Fig. 4.4B). The cost reductions are nearly by 12.2 %, 15.2 % and 16.7 % for the modules with areas of 31,000, 45,000, 59,000 sq.m. respectively for the increase of plot ratio from 1.0 to 1.7.

4.3.5.2 Module Ratio :

Variation in costs are studied for module ratios of 1.0, 1.4 and 1.7 with plot ratio of 1.4 for a fixed area module (Ref. Fig. 4.5 B). The increase in module ratio leads to higher land and other costs. The rise in costs is nearly by 4.0 % , 5.5 % and 3.4 % for the modules with areas of 31,000, 45,000, 59,000 sq.m. respectively for increase of module ratio from 1.0 to 1.4. Also, it is seen that for the module areas 41,000 sq.mtr. and above, there is no appreciable rise in cost of land and land development by changing the module ratio from 1.4 to 1.7 .

4.3.5.3 Module Area

The study is done for module area variation from 31,000 to 59,000 sq.mtr. for plot ratio of 1.0 and module ratio of 1.4 (Ref. Fig. 4.6 D). The general pattern is that higher module areas lead to higher land and other costs. The rise is sharpest when module area is raised from 37,000 to

39,000 sq.mtr., The costs jump up by nearly 3.4 % in this case.

4.3.6 Analysis of Total Infrastructural Costs :

The study is done for plot area combinations of 275, 325 and 375 sq.mtr. The total infrastructural costs are arrived at by summing (i) Water Supply Costs (ii) Sewerage Costs (iii) Drainage Costs (iv) Road Costs and (v) Land Development Costs.

The analysis for fixed module ratio of 1.4 and varying plot ratios of 1.0, 1.4, 1.7 for a fixed area module revealed that in general, higher plot ratios lead to increasing infrastructural costs (Ref. Fig. 4.7 A).

The analysis for fixed plot ratio of 1.4 and varying module ratio of 1.0, 1.4, 1.7 for a fixed area module showed that increasing module ratios lead to higher infrastructural costs. (Ref. Fig. 4.7 B).

The analysis for fixed plot ratio of 1.0 and fixed module ratio of 1.4 with varying module areas from 31,000 - 59,000 sq.mtr. showed that no definite trend was followed. However, the increase in infrastructural costs was sharpest when module area was increased from 39,000 - 41,000 sq.mtr. (Ref. Fig. 4.7 C).

4.4 DISCUSSION :

The present study is capable of identifying and indicating the relative importance of any design parameter of the land sub - division planningThe study concluded that to obtain optimum results ; module area and ratio must be least and plot ratio must be higher. The sensitivity analysis of water supply, drainage, circulation and land and land development costs indicated that higher plot ratios lead to reduction in their respective costs. Also, higher module ratios lead to higher circulation and land and land development costs. The sewerage costs did not indicate a definite trend. Also, the analysis of total infrastructural costs showed that, in general, higher plot ratios, module ratios and module areas lead to increased costs. So, in this way, the sensitivity analysis would help in identifying the optimal solutions which could be used for preparing the layout plan.

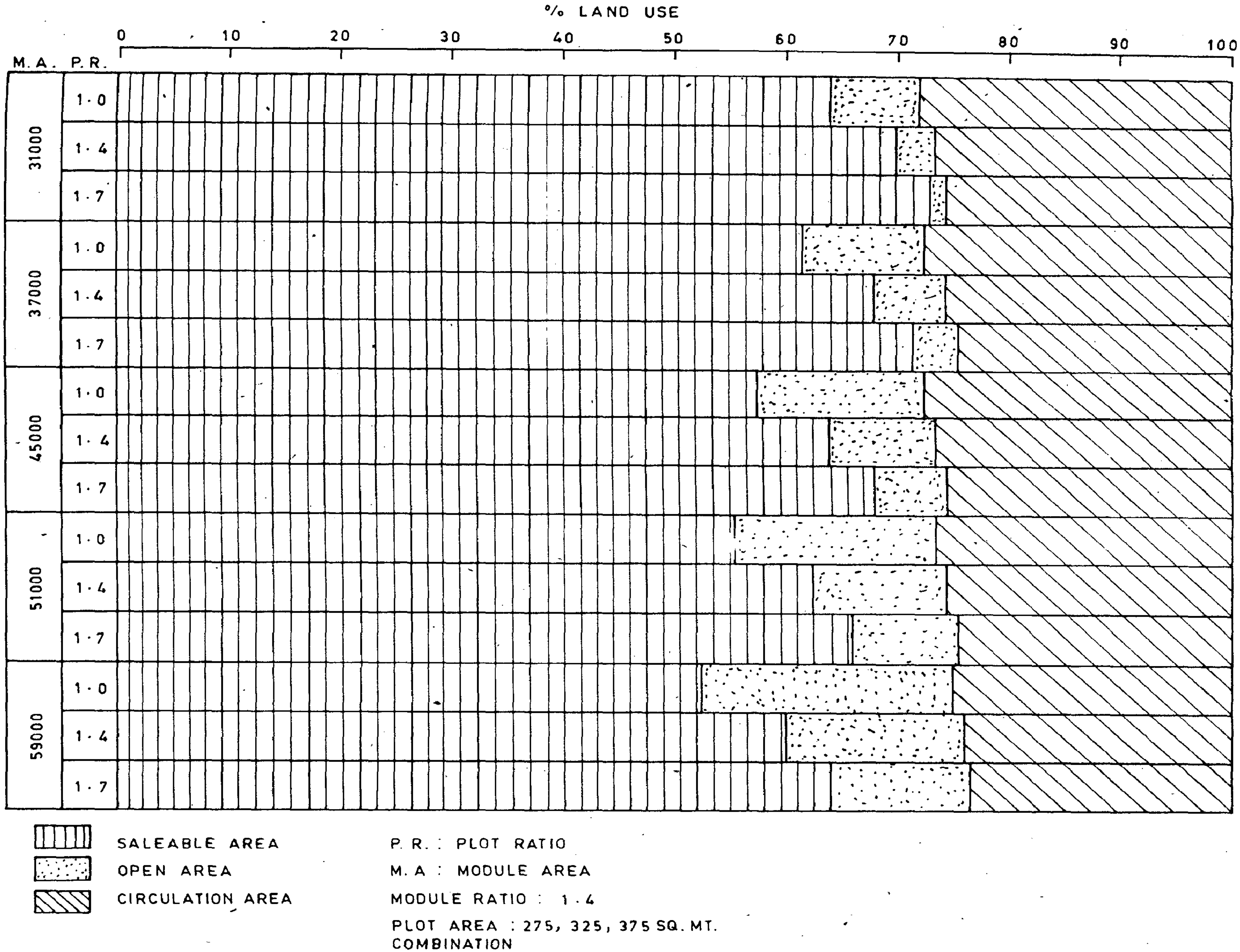


FIG. 4.1 IMPACT OF VARYING PLOT RATIO ON PHYSICAL PARAMETERS

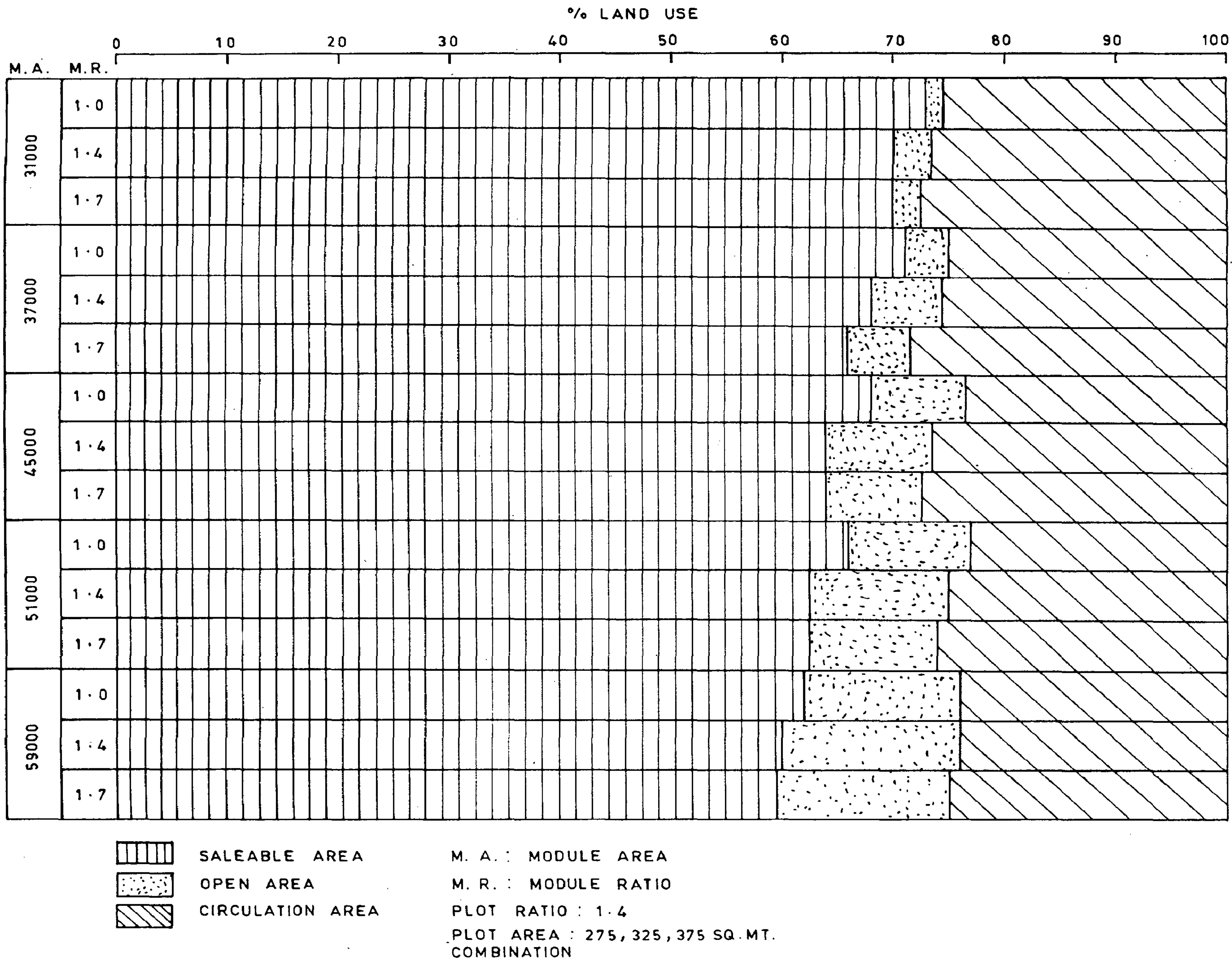
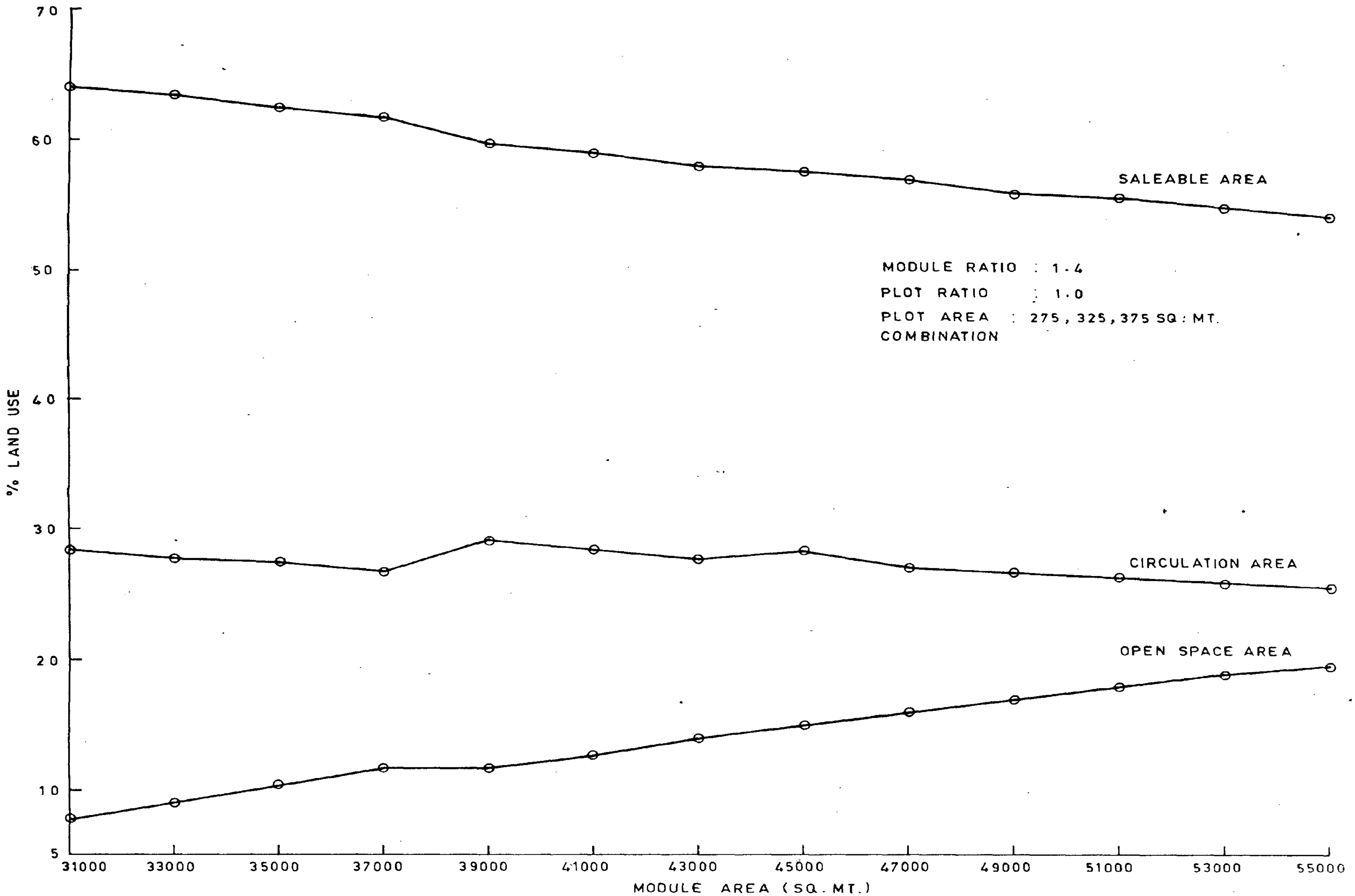


FIG. 4.2 IMPACT OF VARYING MODULE RATIO ON PHYSICAL PARAMETERS



70
60
50
40
30
20
10
5
% LAND USE
SALEABLE AREA
CIRCULATION AREA
OPEN SPACE AREA
MODULE RATIO : 1.4
PLOT RATIO : 1.0
PLOT AREA : 275, 325, 375 SQ: MT.
COMBINATION
31000
33000
35000
37000
39000
41000
43000
45000
47000
49000
51000
53000
55000
MODULE AREA (SQ. MT.)

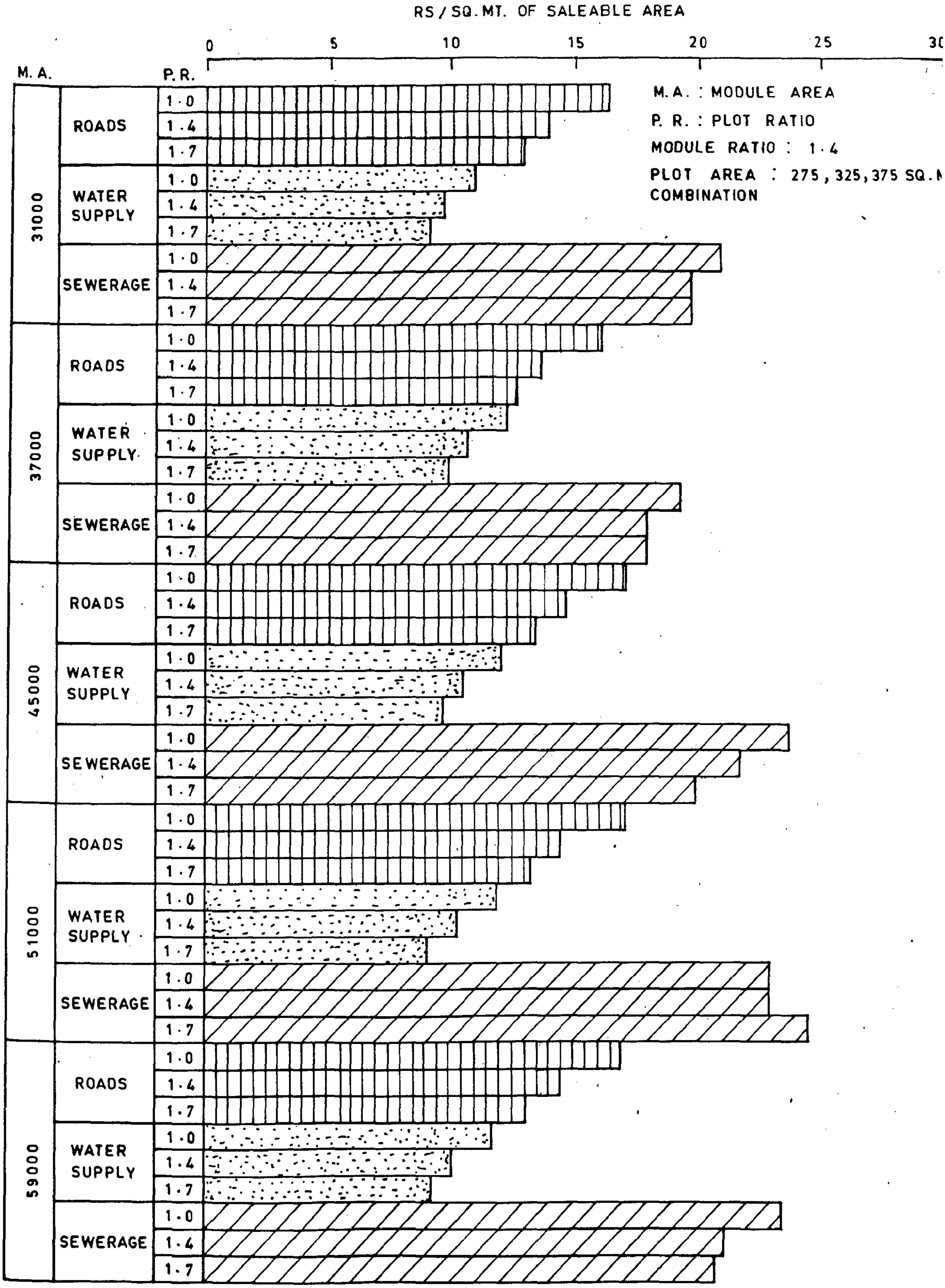


FIG. 4·4A IMPACT OF PLOT RATIO VARIATION ON INFRASTRUCTURE COSTS (ROADS, WATER SUPPLY, SEWERAGE)

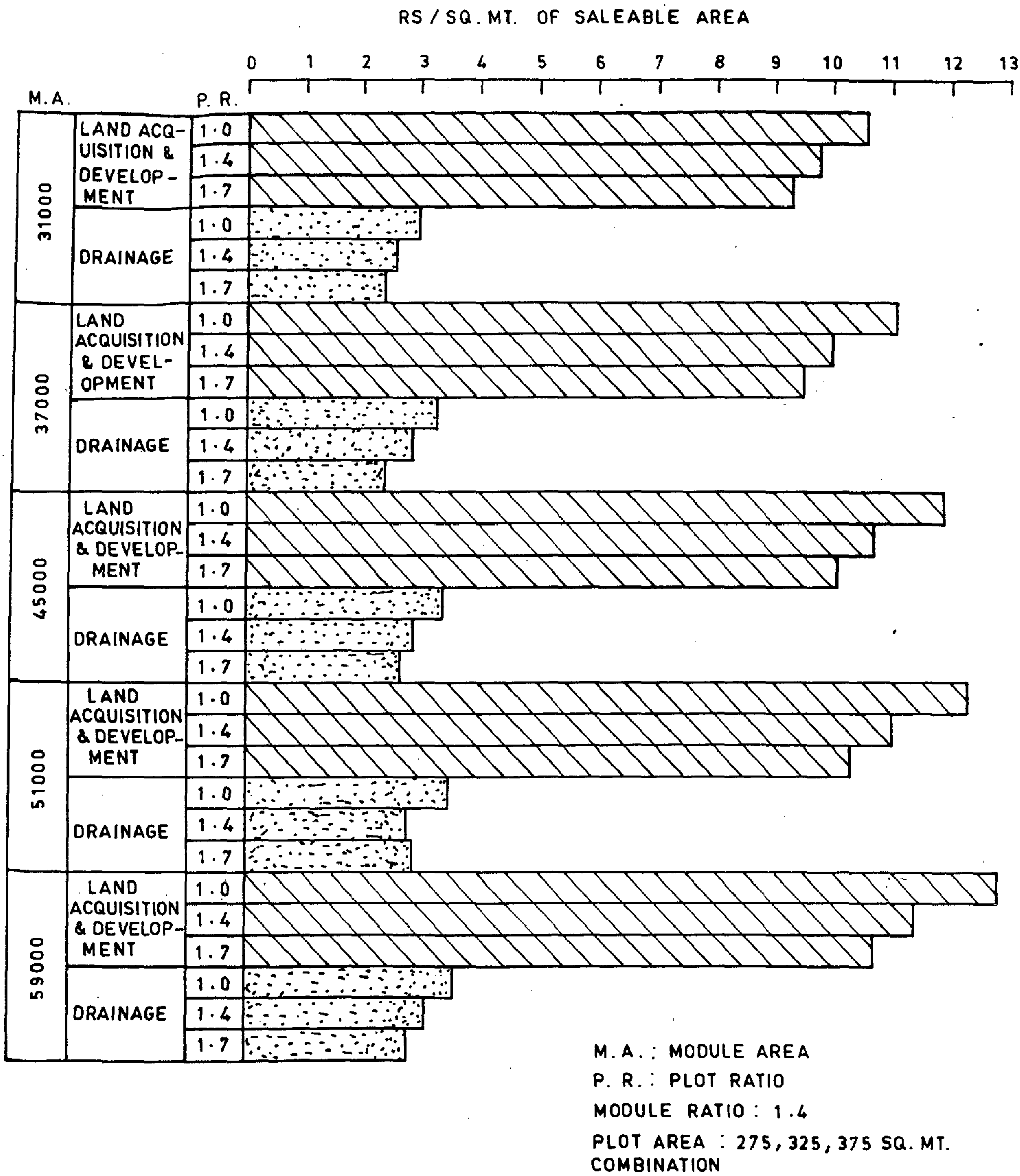


FIG. 4.4B IMPACT OF PLOT RATIO VARIATION ON INFRASTRUCTURE COSTS (LAND & LAND DEVELOPMENT, DRAINAGE)

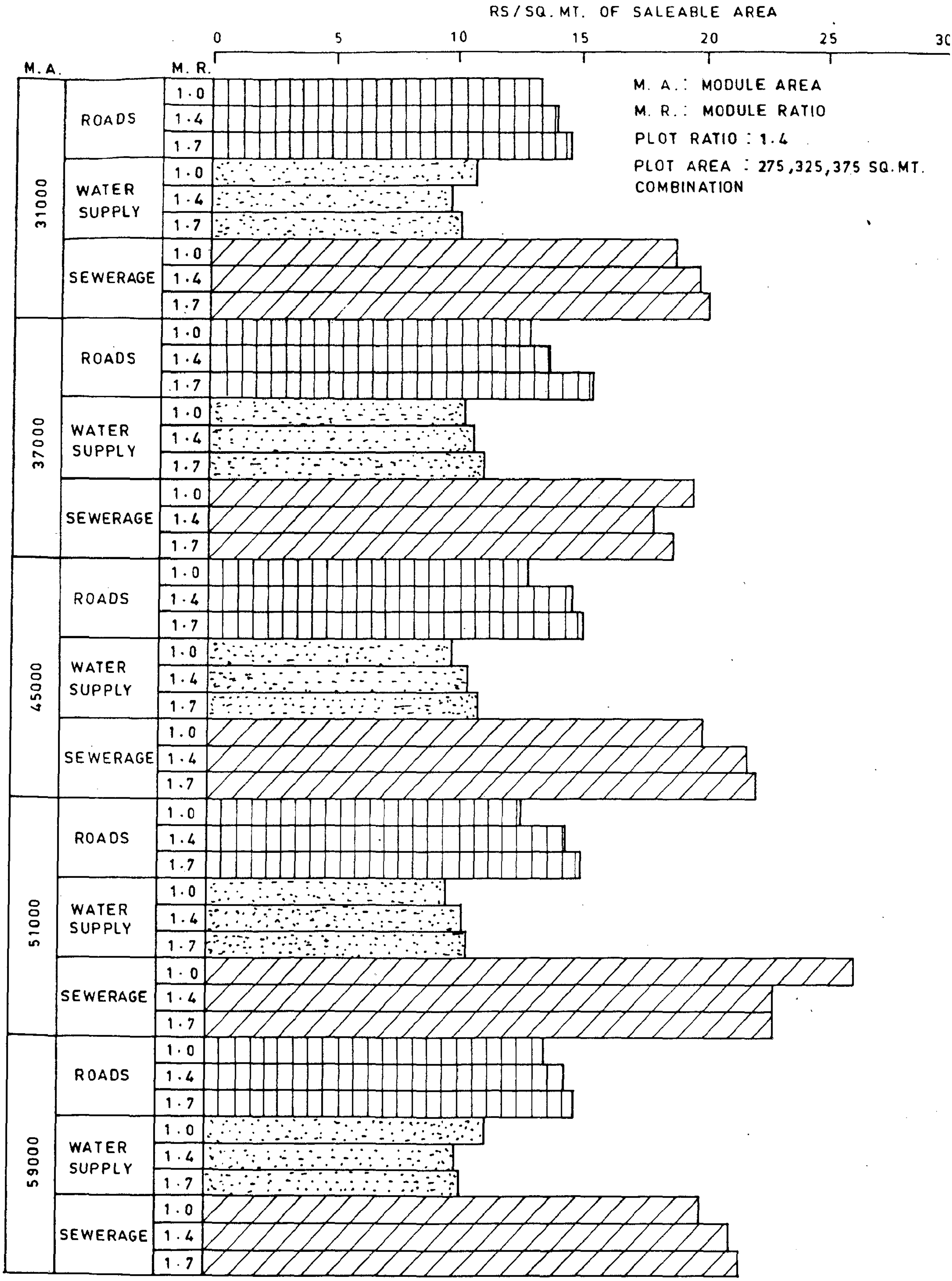


FIG. 4·5A IMPACT OF MODULE RATIO VARIATION ON INFRASTRUCTURE COSTS (ROADS, WATER SUPPLY, SEWERAGE)

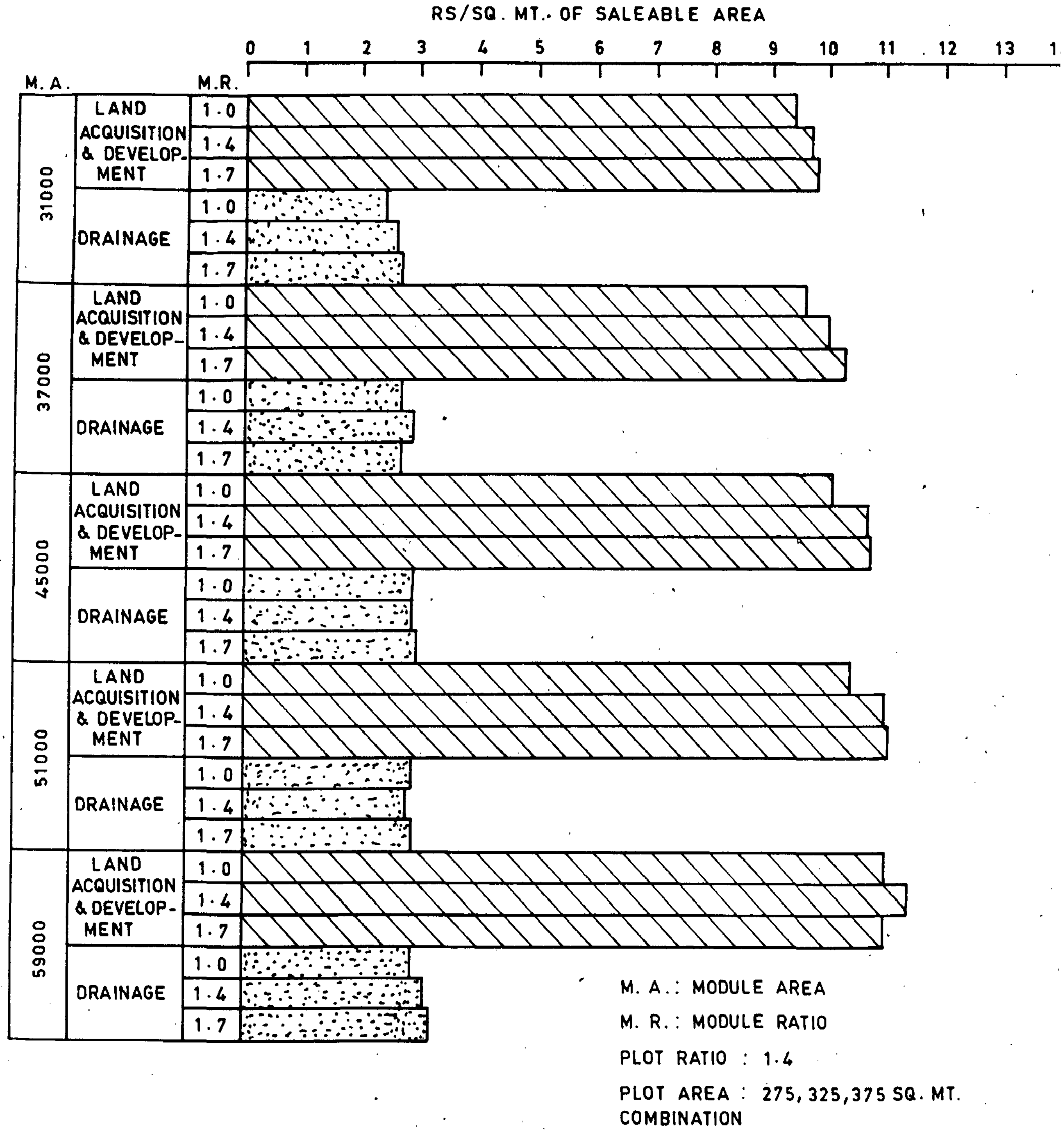


FIG. 4·5B IMPACT OF MODULE RATIO VARIATION ON INFRASTRUCTURE COSTS (LAND & LAND DEVELOPMENT DRAINAGE)

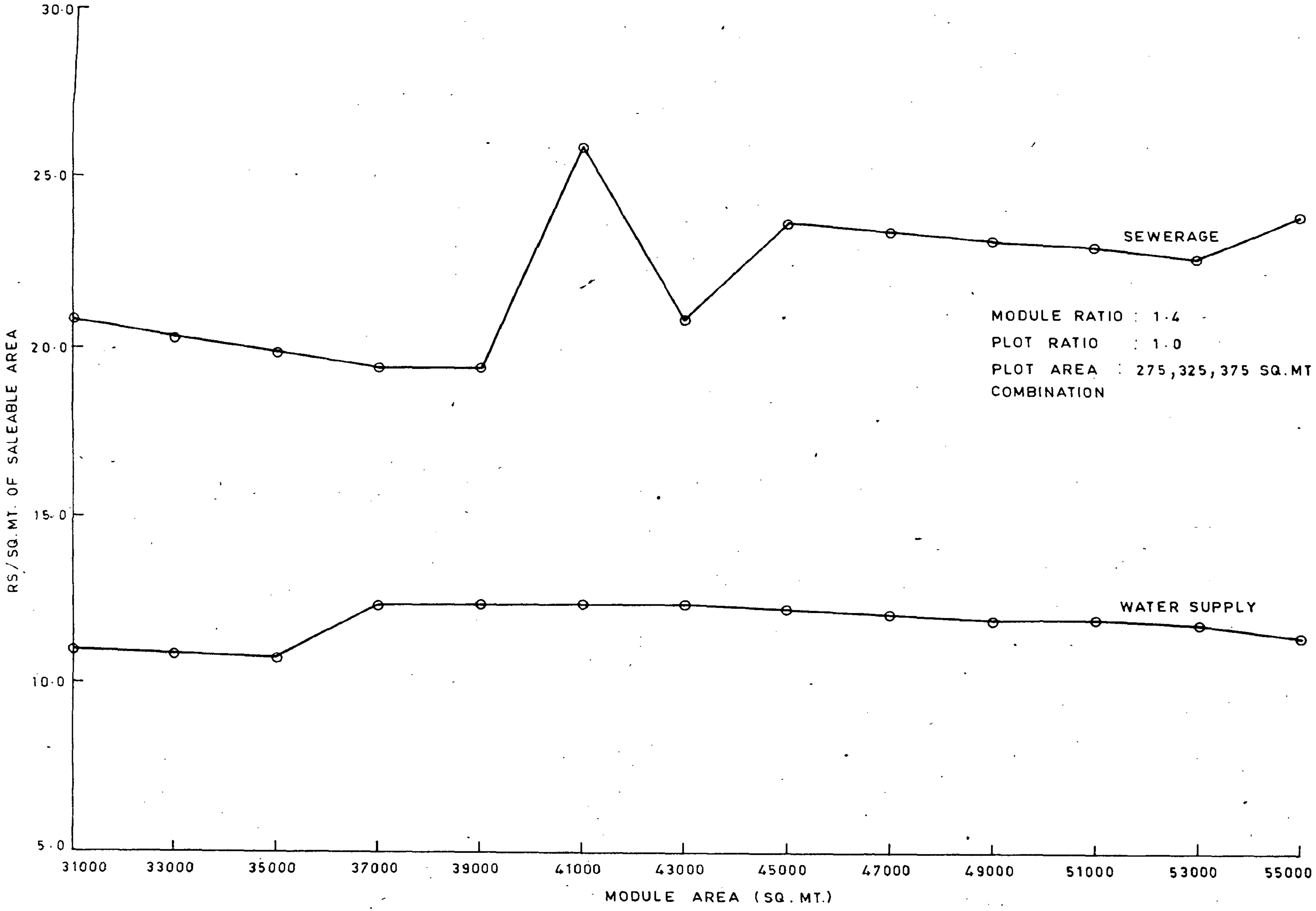


FIG.4.6A WATER SUPPLY & SEWERAGE COSTS PER SQ.MTR. OF SALEABLE AREA FOR MODULE AREA VARIATON

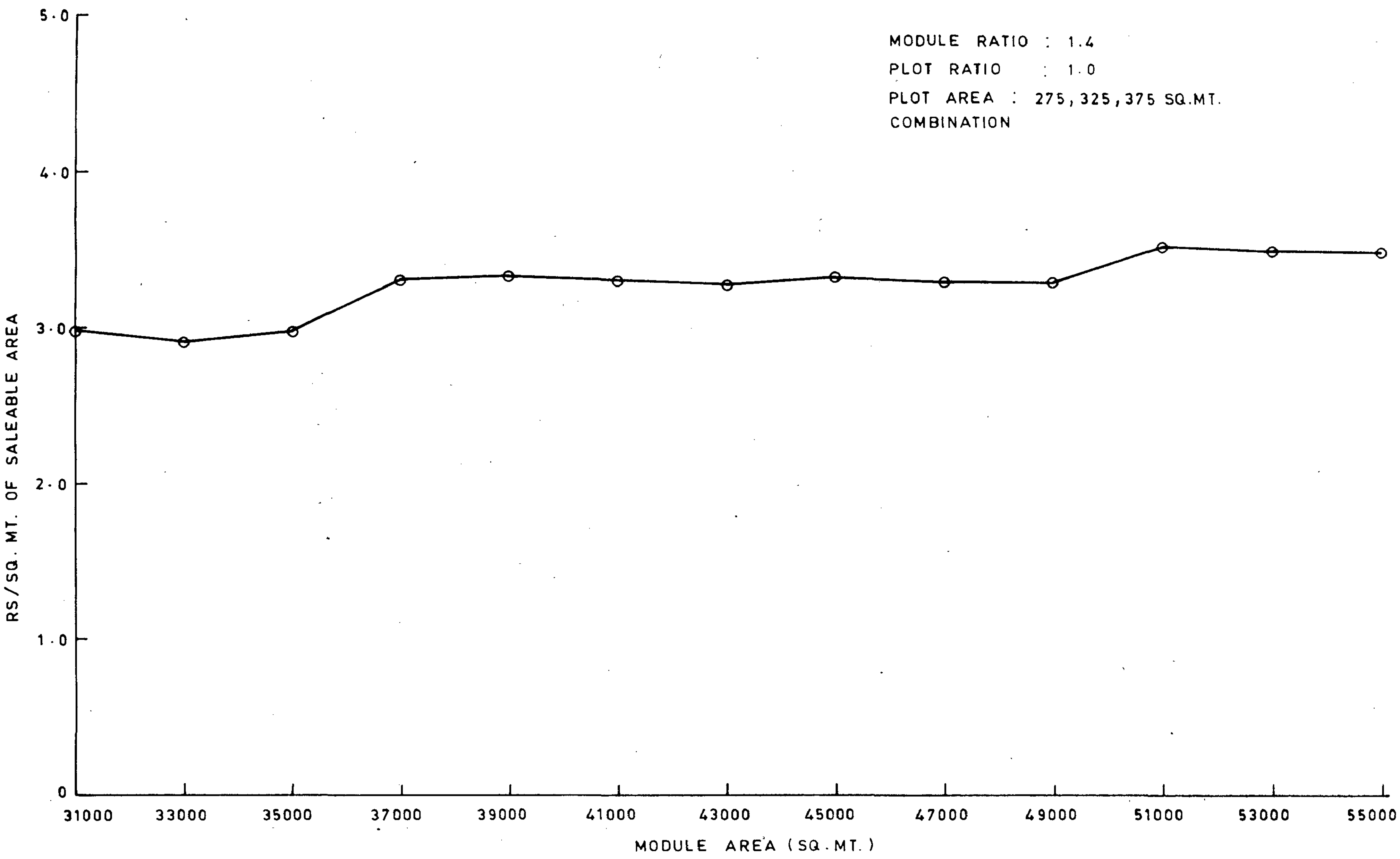


FIG.4·6B DRAINAGE COSTS PER SQ. MTR. OF SALEABLE AREA FOR MODULE AREA VARIATION

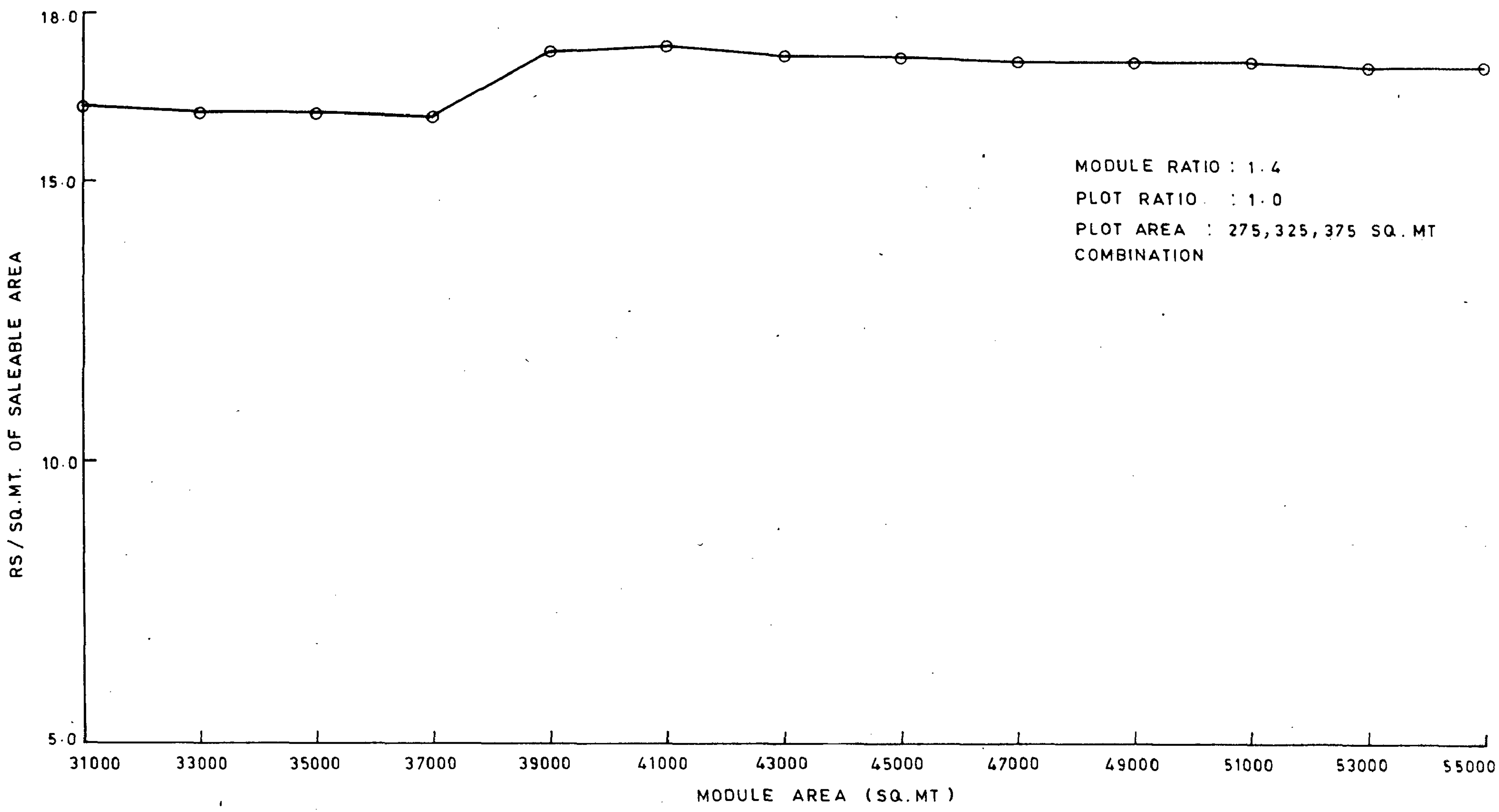


FIG. 4.6C ROAD COSTS PER SQ. MTR. OF SALEABLE AREA FOR MODULE AREA VARIATION

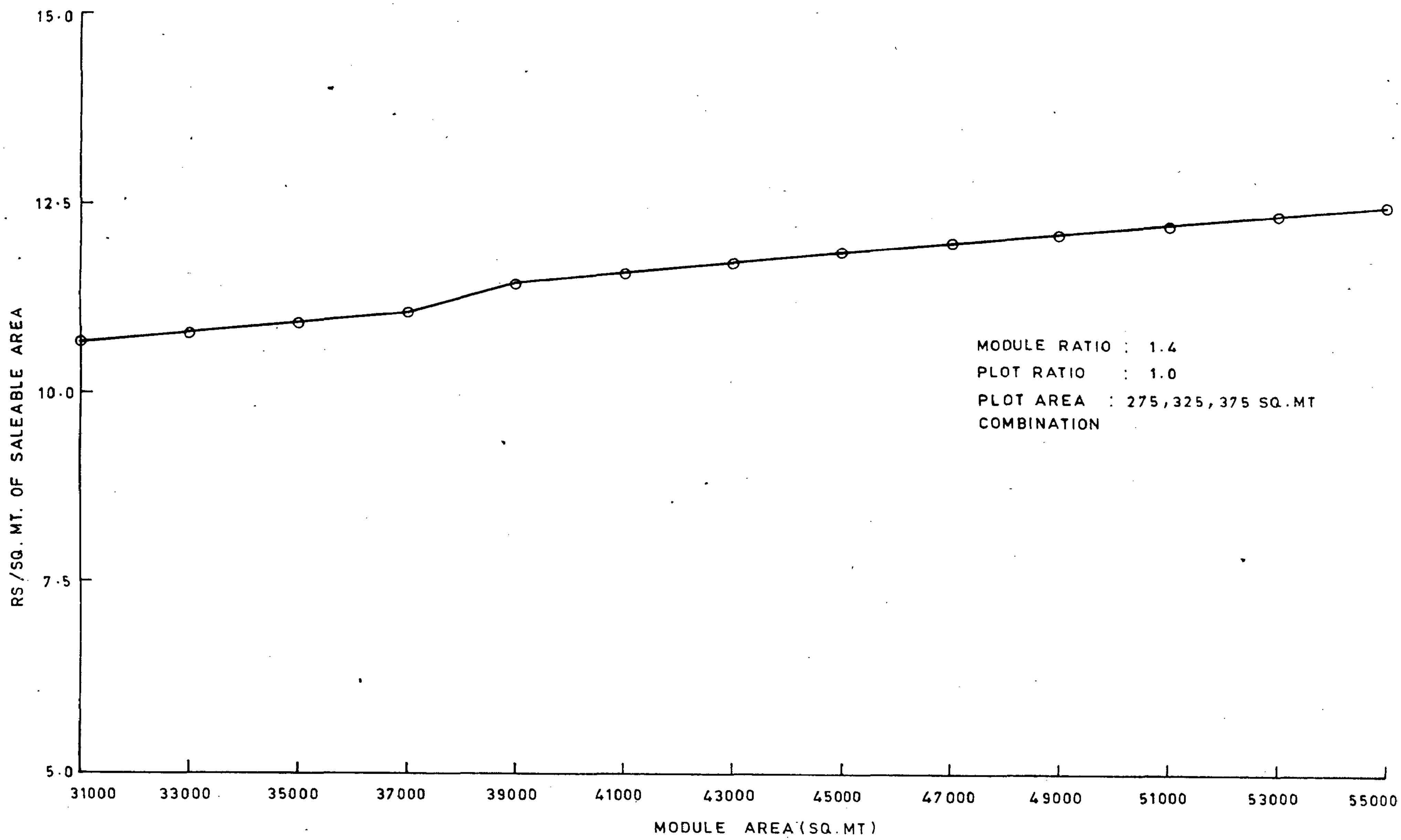


FIG.4.6D LAND & LAND DEVELOPMENT COSTS PER SQ. MT. OF SALEABLE AREA FOR MODULE AREA VARIATION

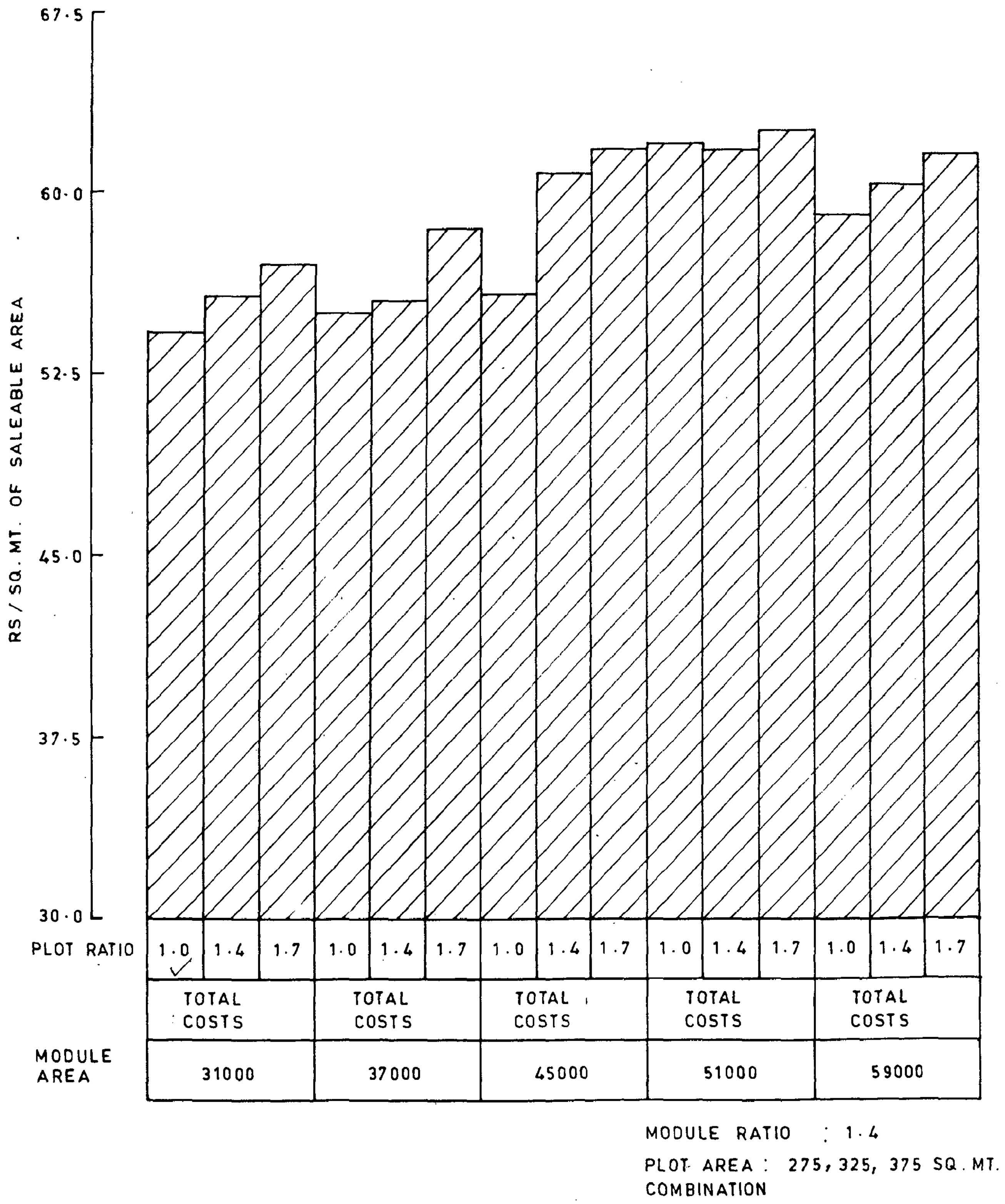


FIG. 4·7A IMPACT OF PLOT RATIO VARIATION ON TOTAL INFRASTRUCTURAL COSTS

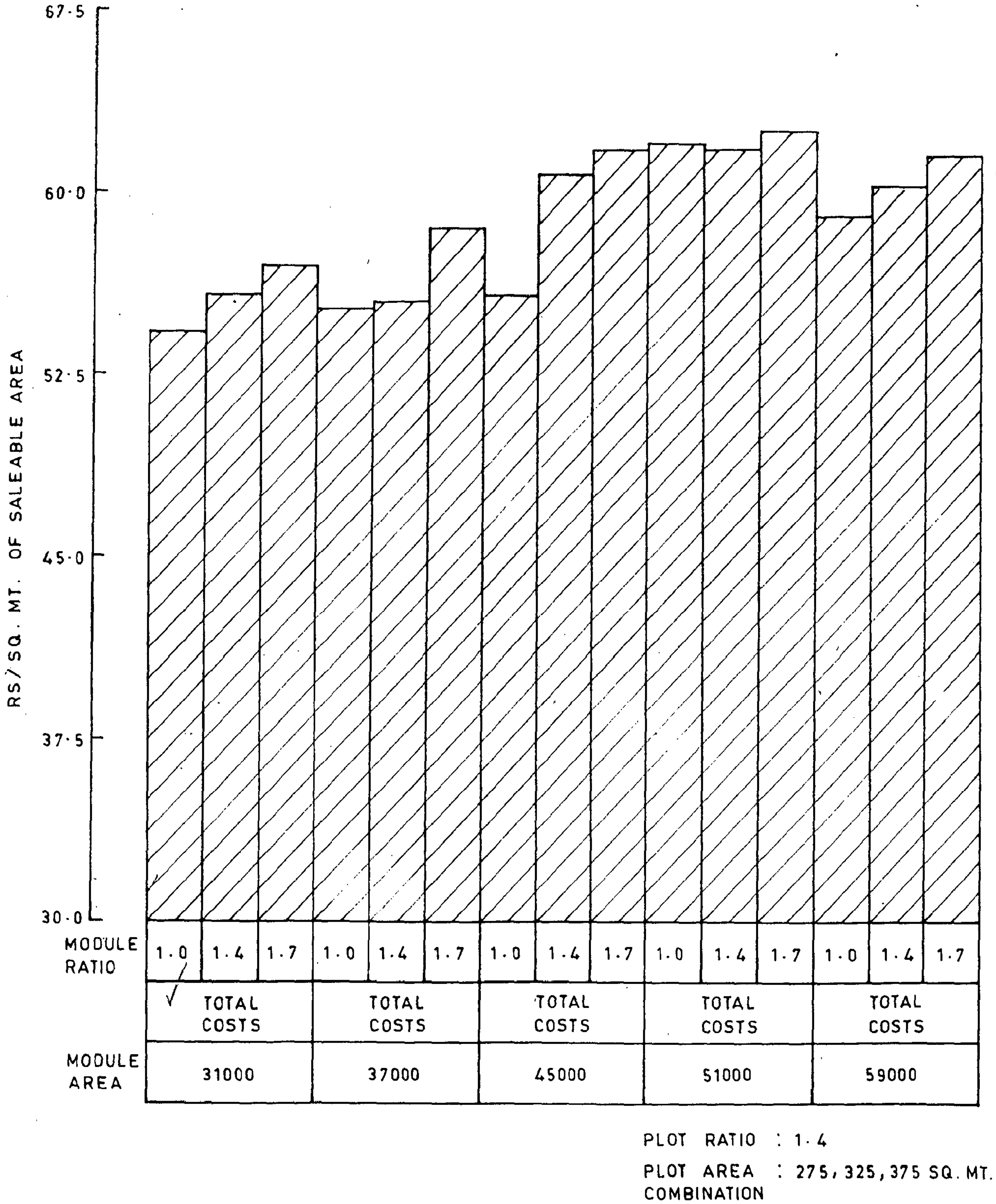


FIG. 4·7B IMPACT OF MODULE RATIO VARIATION ON TOTAL INFRASTRUCTURAL COSTS

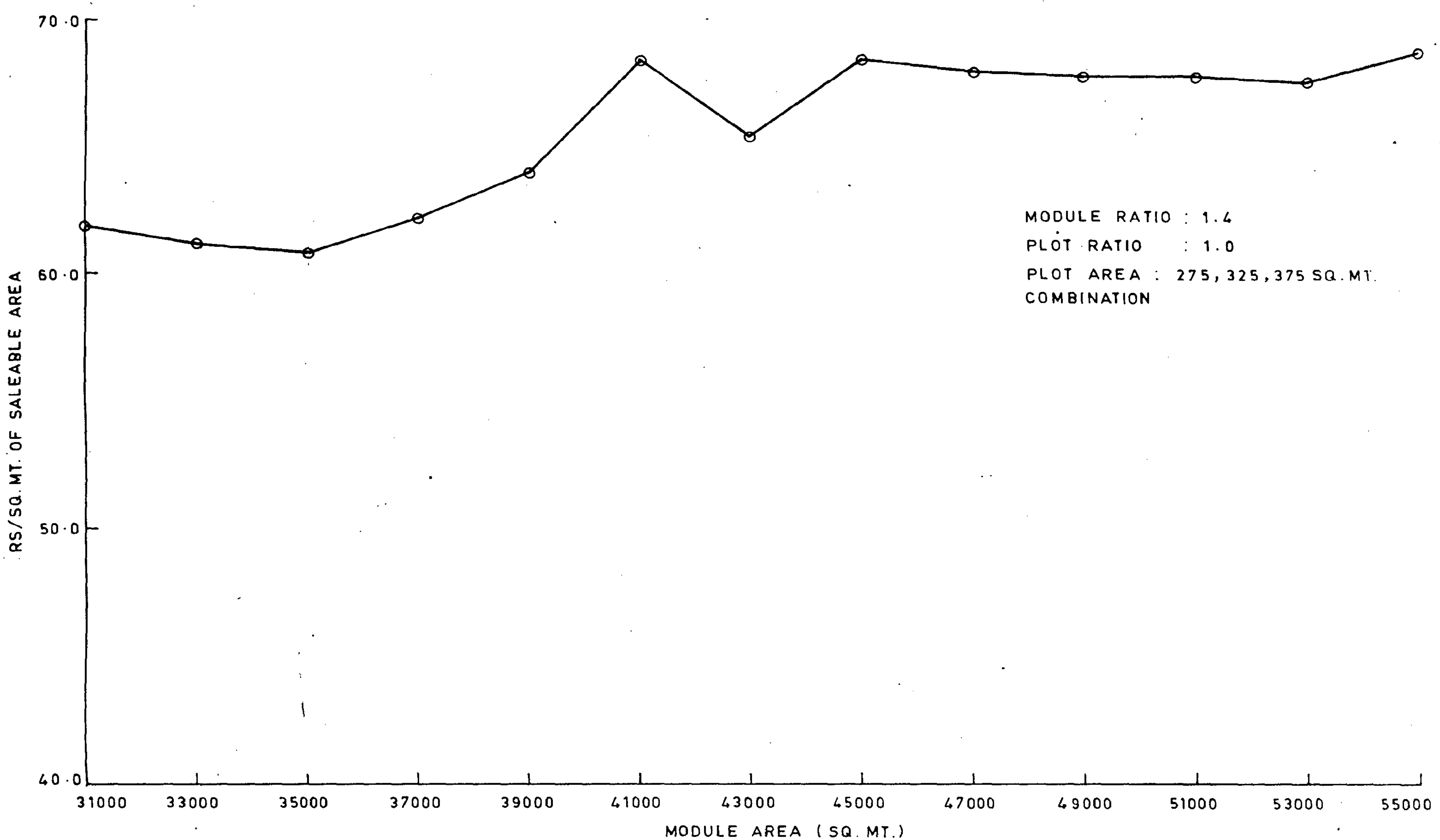


FIG.4.7C TOTAL INFRASTRUCTURAL COSTS PER SQ. MTR. OF SALEABLE AREA FOR MODULE AREA VARIATION

CHAPTER - V

PROJECT DESIGN STUDY

5.1 GENERAL :

Now, to test the model developed, a project design study was undertaken. It will thus not only help to establish the importance and credibility of the model developed but also furnish important results or observations which will act as feed back to further improve the methodology.

5.2 BACKGROUND HISTORY :

The Department of Science and Technology (DST), Government of India has requested different states to come forward with the establishment of ELECTRONICS COMPLEXES (ECs) by bringing educational, research, training, banking, management and government institutions together. In this regard, Roorkee University has been identified by DST to set up a ELECTRONICS COMPLEX for northern region. The objective of ECs is to develop a down to earth culture and environment for innovation and entrepreneurship on the basis of active interaction between academic institution and industries by sharing ideas, experience and facilities.

So, it was decided to take up the design of this complex as the project design study.

5.3 DESIGN OBJECTIVES :

The objective of the study is to workout a number of module options using the CALSD-MODEL and to identify the optimal module options. Then to work out a sub-division plan for the project using these optimal modules.

5.4 METHODOLOGY :

Once the mathematical model and the computer programs based on them are ready, the methodology followed is as follows :

i) Analyse the existing site layout.

ii) Develop a concept.

iii) Run the computer programs to evolve the planning modules.

iv) Identify the optimal solution and use it in planning the land sub-division plan.

5.5 SITE ANALYSIS

The site for the proposed complex is located about 10 Kms away from Roorkee on the Landhaura - Laksar Road. The total site area measures 40.47 hectares (100 acres), out of which 8.09 hectares (20 %) is earmarked for an industrial park (STEP) and the rest 32.38 hectares is reserved for the industrial sheds. The site is predominantly flat in nature. There are few spots in the area on the eastern boundary and in the central area having undulations with a level difference to the tune of 6 - 9 meters. It is surrounded by the villages Shikarpur, Khempur and Landhaura on the north - eastern, southern and western directions respectively. The location plan and site plan of the complex is given in Fig. No. 5.1(A) and Fig. No. 5.1(B) respectively.

5.6 THE CONCEPT :

Physical conditions of the site, grouping of industrial units, common facilities and optimum land-use are some of the important factors influencing the sub-division plan of an industrial layout. Essentially a layout should be such that it grows in response to the requirements. So, to meet the planning needs a concept should be worked out in the very beginning.

The site is bounded on the southern side by a road. It was decided to have two approach roads from it. They would serve as the main spines of the area. Also, one lateral road joining these spines was planned. The common facilities were located along this central spine. The administrative office was planned near the entrance and water tank and electric sub-station at the far end of the site. Also, along the lateral spine, one test laboratory was proposed.

The remaining area was detailed with modules where each one has its own social facility space.

Further more, to check the industries onto the nearby residential/agricultural areas and to keep the much needed distance between them, a buffer zone was introduced between them.

5.7 DATA INPUT :

The module developed in the CALSD - MODEL was used in this study. The plot area combinations were taken as 275, 325, 375 sq.mtrs. This was done keeping in view the code provisions [ISI, 1984] and the specific needs of the complex [U.O.R., 1985]. Three values of plot ratios 1.0, 1.4 and 1.7 and values of 1.0, 1.4 and 1.7 were specified for the module ratio. The module area variable was given a range of 29 values starting from 31000 sq.m. to 59000 sq.m. with increments of 1000 sq.m. The values of road widths were taken as per National Building Code, 1983 which provides relation between road widths and road lengths. The roads were metalled and brick paved for pathways. The water supply network was developed with C.I. pipes and sewerage system using asbestos cement pipes. Unit costs of different components were worked out with the help of CPWD rate lists [CPWD, 1981 ; PWD, 1984]. Also the load coefficients for the design of water supply network and sewerage network is considered as 55, 60, 65 for the three plots type - A, type- B and type - C respectively. The factor for accounting contengencies was taken as 10 %. The manholes considered were of size 90, 150, 225 and 315 cms. The ground was taken as to have a slope of 0.001.

The computer program was run with the above input data which consisted of 890 vaues and the output gave a result for a total of 25,776 information values in all.

5.8 THE SELECTION PROCESS :

After the programs were run, the computer generated an exhaustive list of alternatives. To find out which of the module option were optimal , the selection process was operated The criterion for the selection were identified as follows:

5.8.1 Open Space :

5.8.1.1 Dimensions :

The open space provided in the module must be of practical configuration so as to be useable and to enhance the quality of grouping of plots. Hence impractical configurations like strip forms were to be avoided. In order to have useable forms of open space, the criterion adopted was that the smaller side of open space should be equal to or greater than depth of smaller plot. This would render the open space area more effective and also it becomes possible to interchange portions of plotted area with social facility space.

5.8.1.2 Area :

The open space area in the module should not be less than 4.0 % . This is fixed keeping in view the code provisions [ISI, 1984].

5.8.2 Plots :

The width of the plots should be equal to or greater than 14.0 m. Plots with widths less than this were rejected. This criterion is decided as per the requirements of the industry that is to be set up [U.O.R., 1985; ISI, 1984].

5.8.3 Module :

The site available presented difficulty in fitting in of larger modules. So, it was decided to reject all modules having any side greater than 230 m.

5.8.4 Development Cost :

The modules which passed the fore mentioned criterion were subjected to further analysis. The module having the minimum development cost out of the shortlisted modules was taken as the optimal solution.

Functional criteria?

5.8.5 The Optimum Module :

The selection process identified the 37,000 sq.m. module with plot ratio of 1.4 and module ratio of 1.4 as the optimum solution [Ref. Fig. 5.2].

The sub-program- I determined the land utilization pattern of the module. The Table No. 5.1 summarises the land use analysis of the module.

TABLE 5.1

LAND UTILIZATION PATTERN AT MODULE LEVEL

TYPE	AREA(SQ.M.)	PERCENTAGE
Saleable	25227	68.18
Circulation	9209	24.89
Social Facility Space	2564	6.93

Further, the sub-program - I also gave the plot details along with the width of roads in the module. The plot type- B are in maximum number. The sub-program - II gave further information on the road network. The optimum plot details and circulation network details have been listed in Table No. 5.2 and Table No. 5.3 respectively

TABLE NO. 5.2

DETAILS OF PLOTS AT MODULE LEVEL

TYPE	AREA(SQ.M.)	NUMBER
A	275	12
B	325	44
C	375	22
TOTAL		78

TABLE NO. 5.3

DETAILS OF CIRCULATION NETWORK AT MODULE LEVEL

ROAD TYPE	WIDTH(M.)	LENGTH(M.)
S1	12.0	428.62
S2	12.0	355.25

The infrastructure costs were computed by sub-programs-II, III, IV, V, VI respectively for different infrastructural components. It was found that the sewerage costs had the lion's share in the net development cost of the module whereas the drainage system accounted for the least share. The infrastructure cost analysis is presented in Table No. 5.4

T A B L E N O. 5.4

INFRASTRUCTURE COSTS ANALYSIS AT MODULE LEVEL :

ITEM	COST(Rs.)	PERCENTAGE OF TOTAL COS
Land Acquisition	73,260	5.26
Land Development	1,79,000	12.78
Roads	3,48,000	24.87
Water Supply	2,72,000	19.39
Sewerage	4,55,000	32.50
Storm Water Drains	72,980	5.20
TOTAL	14,00,240	100.00

Net Development Cost = Rs. 55.53/sq.m. of saleable area

The subprograms - III, IV, V do the necessary design of the water supply network, sewerage network and the drainage network. The details of the water supply components have been presented in the following table (Ref. Table No. 5.5)

T A B L E N O. 5.5

DETAILS OF WATER SUPPLY NETWORK AT MODULE LEVEL :

PIPE LENGTHS(M)		SIZE(M.M.)		NO. OF SLUICE VALVES		NO.OF FIRE HYDRANTS
DW1	DW2	DW1	DW2	V1	V2	-
723.09	253.09	125	200	4	1	4

The details of the sewerage network viz. the pipe lengths, number of manholes etc. have been listed in Table No.5.6

TABLE NO. 5.6

SEWERAGE NETWORK DETAILS AT MODULE LEVEL

PIPE LENGTHS(M)		Size(M.M.)		SLOPE		NO. OF MANHOLES				EXTRA DEPTH OF MANHOLES(M.)			
DS1	DS2	DS1	DS2	DS1	DS2	N1	N2	N3	N4	EN1	EN2	EN3	EN4
759.75	218.10	200	300	0.001	0.004	10.8	10.9	14.6	-	4.10	3.73	4.8	-

The drains for carrying away the storm water have been designed. The various details viz. size of drains, slopes etc. is given in Table No. 5.7

TABLE NO. 5.7

DRAINAGE DETAILS AT MODULE LEVEL

LENGTH (M)		SIZE(MXM)		SLOPE	
D1	D2	D1	D2	D1	D2
616.05	218.10	0.30 X 0.46	0.30 X 0.53	0.0014	0.0025

In this way, the optimum module selection is completed. It is then used to prepare the sub-division plan of the electronic complex.

5. 9 SITE LAYOUT :

The site was worked out as per the concept plan with the optimum modules. Certain areas of the site were detailed manually due to their shape (which did not confer with those of the modules). Also some modifications were done in the modules to arrive at better ciruclation system. The table No. 5.8 gives the land - use analysis of the complex. The total type of units are A,B,C, M1, M2, M3, M4, M5 and M6. Their details are given in Table No. 5.9. The circulation plan was conceived with three types of roads. The roads of first order are the approach roads. The next ones are subsidiary roads and the third order roads are the pathways. The larger plots are generally placed on the approach roads. The road details are given in Table No. 5.10. The Fig. No. 5.3 gives the circulation plan. The layout plan is given in Fig. No. 5.4.

The water supply system was designed with the overhead tank placed at the far end of the complex. The fig. No. 5.5 gives the water supply network. The arterial lines from the water tank are spread over the site. The feeder lines of the modules are connected to it.

The sewerage supply network is shown in the figure No. 5.6. The sewage collected from the modules is discharged into the trunk sewer which takes the waste to the nearby sewage treatment plant.

5.10 LIMITATIONS AND GENERAL RECOMMENDATIONS :

The work was carried out in absence of topographical maps. The approximate values for the slopes, levels etc. were assumed. The design for water supply and sewerage has to be readjusted with the help or actual levels. But this was not done due to absence of topographical maps.

The approach road to the site, namely the Roorkee - Laksar Road must be also upgraded to a 24 m. road. And the Landhaura - Mangalore - Delhi road must be also upgraded accordingly. This is very essential as the setting up of an industrial area would demand better linkages due to increased traffic loads.

5.11 CONCLUSION :

The project design study undertaken attempts at devising and implementing CALSD - MODEL. This study will show that computerized land sub-division planning allows for a unified approach to the complex problem of layout design and reduces the time period drastically.

TABLE NO. 5.8

LANDUSE ANALYSIS OF THE LAYOUT

TYPE	PERCENTAGE
Plotted	56.75
Roads	28.00
Organized Open Space	7.75
Buffer Zone	1.75
Institution And Services	5.75
TOTAL	100.00

TABLE NO. 5.9

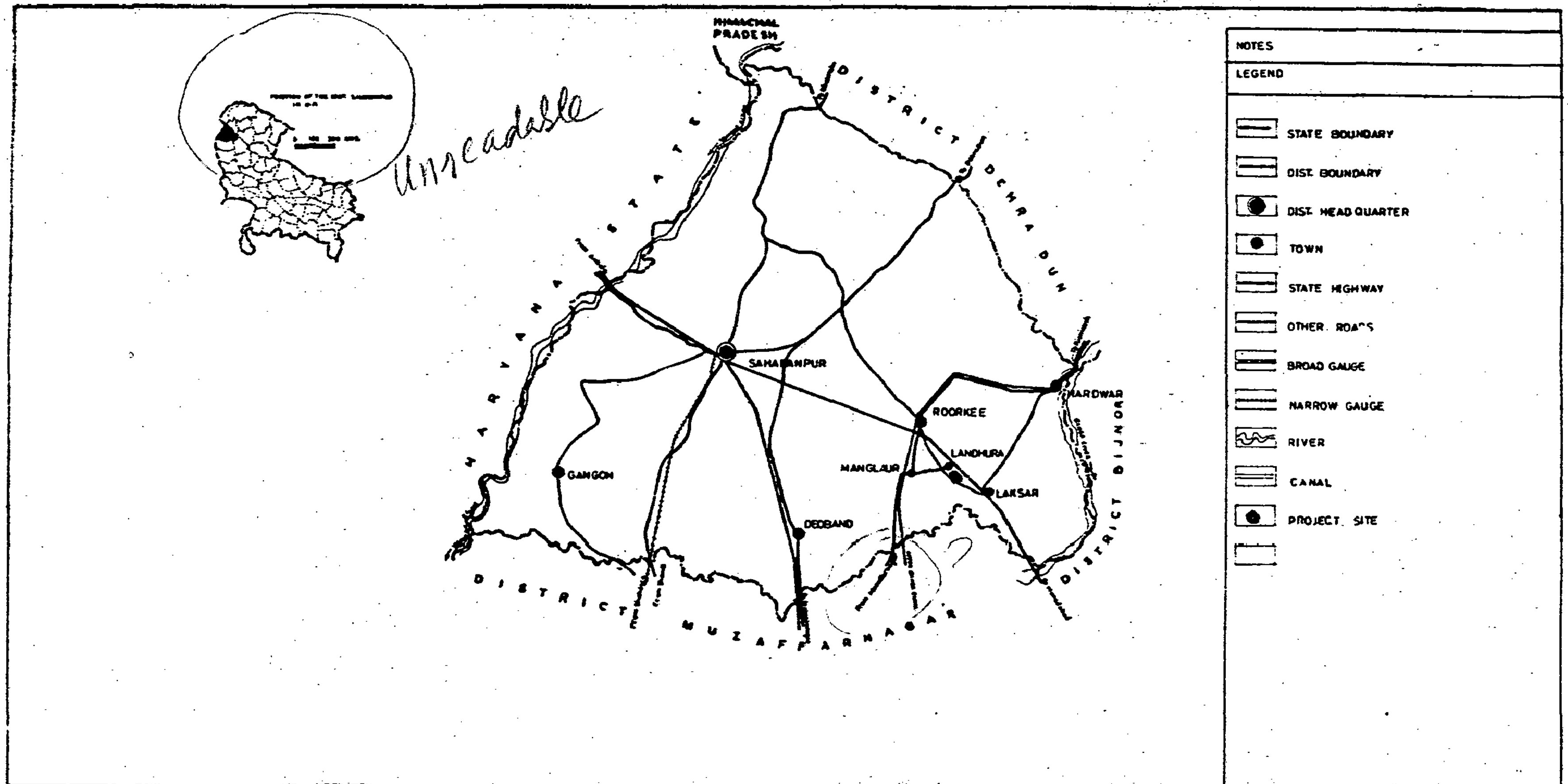
PLOT DETAILS OF THE LAYOUT

TYPE	AREA(Sq.M.)	NOS.
A	275	108
B	325	322
C	375	195
M1	1250	9
M2	562	6
M3	305	21
M4	975	5
M5	937	3
M6	687	3
TOTAL		672

TABLE NO. 5.10

ROAD DETAILS OF THE LAYOUT

TYPE	WIDTH(M)
Approach	24.0
Module(Both S1 and S2)	12.0
Pathways	5.0



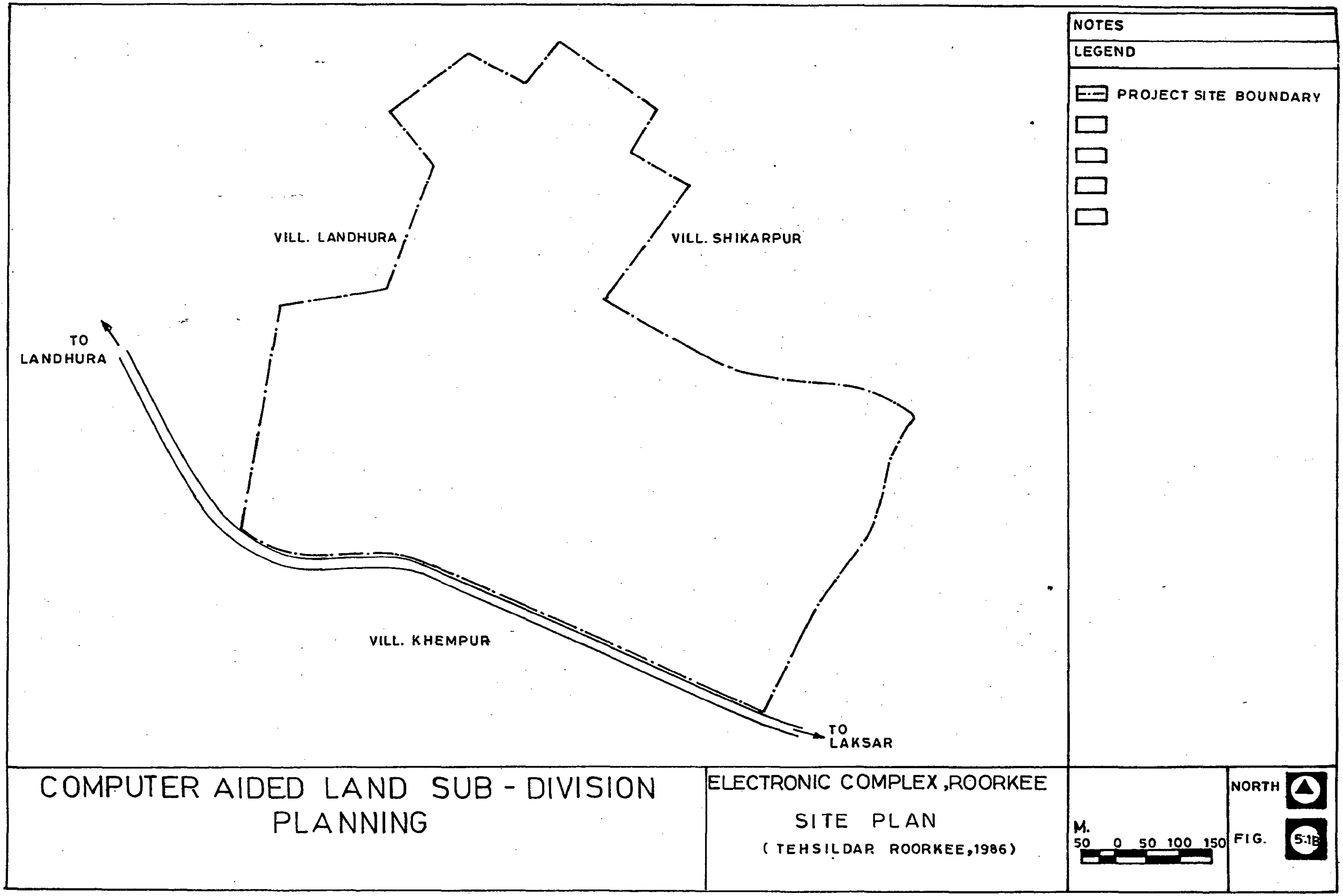
COMPUTER AIDED LAND SUB_DIVISION PLANNING

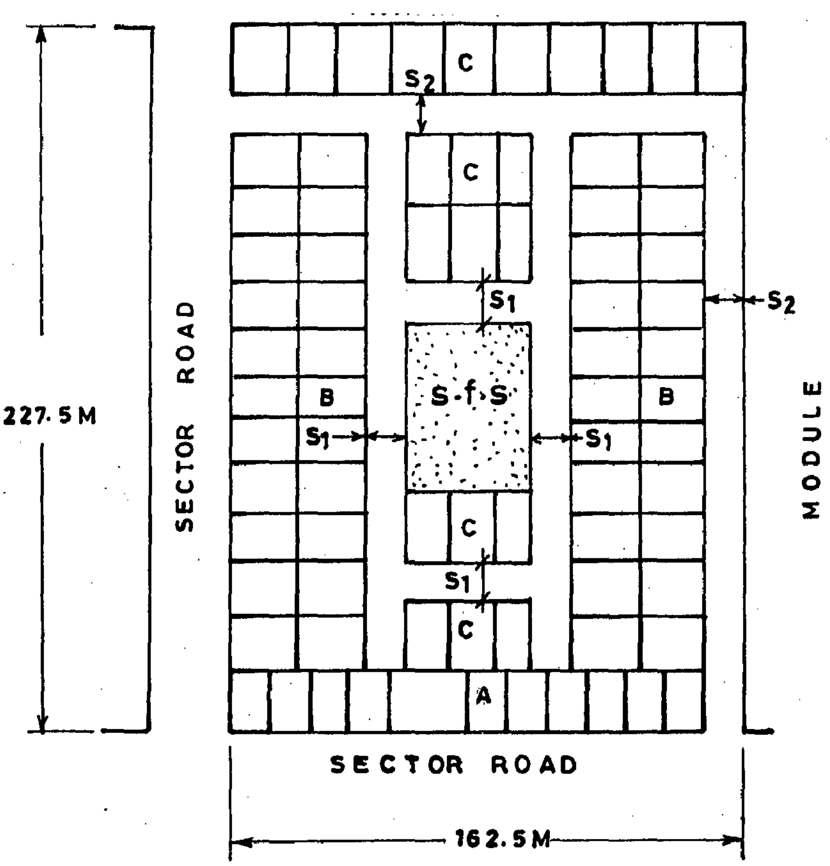
ELECTRONICS COMPLEX
ROORKEE
LOCATION PLAN
[D.C.O 1971]

M.K. HATWAL
M.U.R.P. THESIS 1985-87
DEPT. OF ARCH. AND PLNG.
U. O. R. ROORKEE U.P.
SCALE 1:33333
KMS. 5 0 5 10 15 20 K.

NORTH

FIG. 5.1A


NOTES
LEGEND
PROJECT SITE BOUNDARY
VILL. LANDHURA
VILL. SHIKARPUR
VILL. KHEMPUR
TO LANDHURA
TO LAKSAR
COMPUTER AIDED LAND SUB - DIVISION PLANNING
ELECTRONIC COMPLEX, ROORKEE
SITE PLAN
(TEHSILDAR ROORKEE, 1986)
M.
50 0 50 100 150
NORTH
FIG.
5.1B



MODULE AREA = 37000 SQ.M

MODULE RATIO = 1.4

PLOT RATIO = 1.4

PLOT AREA COMBINATION 275 SQ.M, 325 SQ.M, 375 SQ.M

S_2 = 12 M

S_1 = 12 M

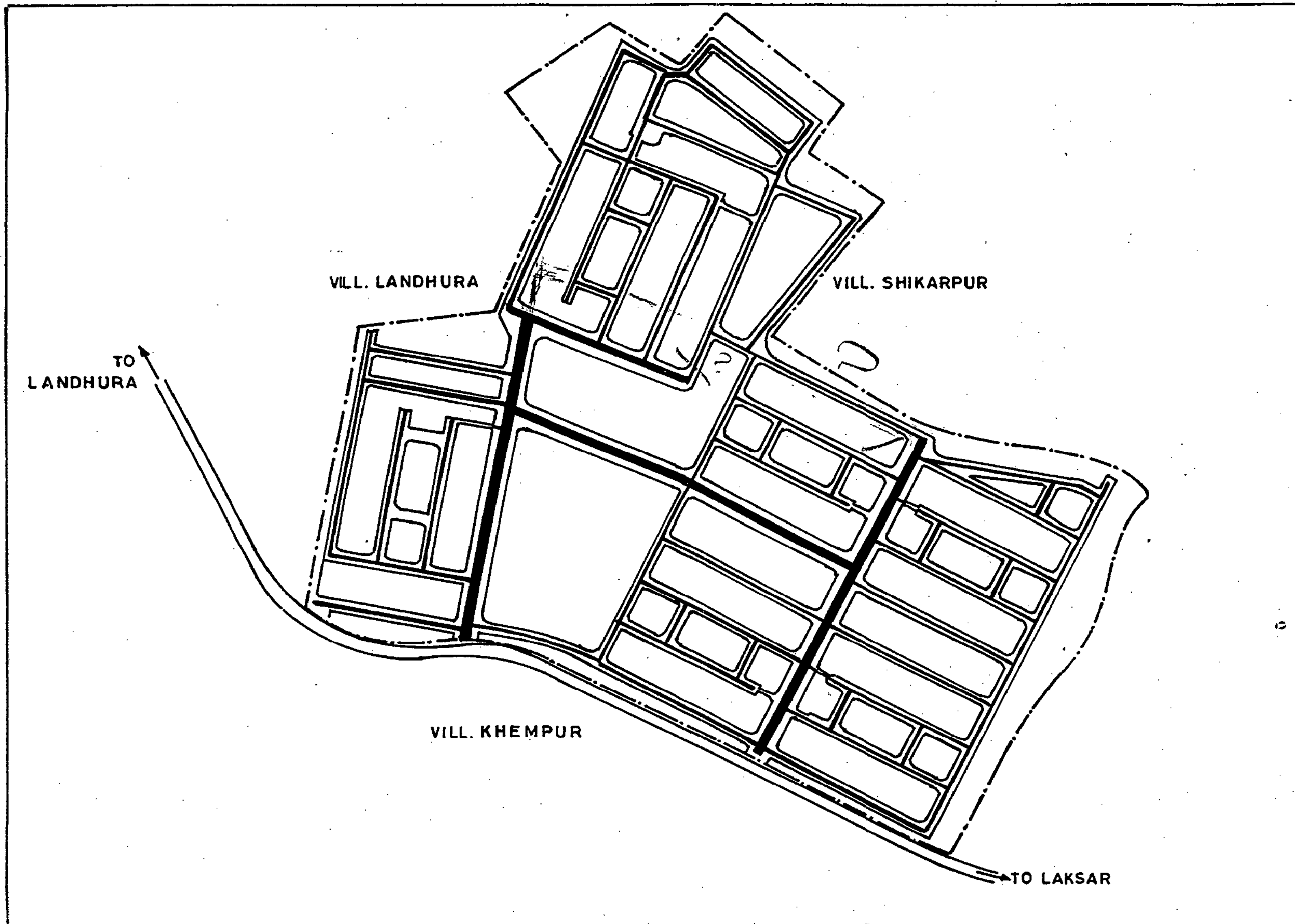
LAND UTILIZATION

TYPE	AREA (SQ.m)	%
SALEABLE	25227	68.18
CIRCULATION	9209	24.89
SOCIAL FACILITY SPACE	2564	6.93

PLOT DETAILS

TYPE	NOS.
A	12
B	44
C	22
TOTAL	78

FIG. 5.2 OPTIMUM MODULE LAYOUT



NOTES

LEGEND

- PROJECT BOUNDARY
- 1st ORDER
- 2nd ORDER
- 3rd ORDER

DETAILS

1st. ORDER ROADS = 24.0 M

2nd ORDER ROADS = 12.0 M

3rd ORDER ROADS = 5.0 M

COMPUTER AIDED LAND SUB-DIVISION PLANNING

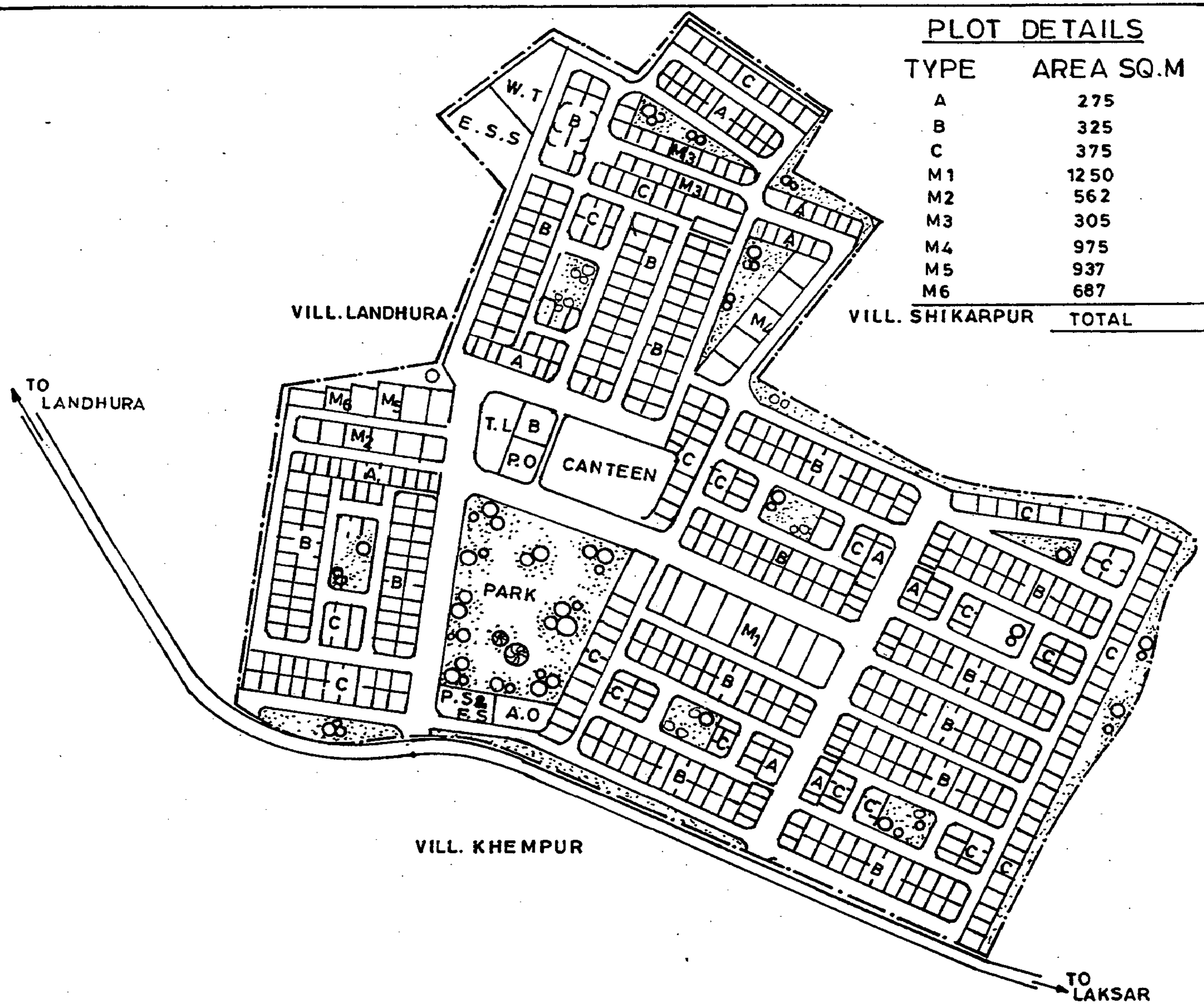
ELECTRONICS COMPLEX, ROORKEE

HIERARCHY OF ROADS

M 50 0 50 100 150

NORTH

FIG. 5.3



PLOT DETAILS

TYPE	AREA SQ.M	NUMBER
A	275	108
B	325	322
C	375	195
M1	1250	9
M2	562	6
M3	305	21
M4	975	5
M5	937	3
M6	687	3
TOTAL		672

NOTES

LEGEND

- PROJECT BOUNDARY
- ESS ELECTRIC SUB STATION
- WT WATER TANK
- TL TEST LAB
- b BANK
- PO POST OFFICE
- PS POLICE STATION
- FS FIRE STATION
- AO ADMINISTRATIVE OFFICE
- BUFFER ZONE
- ORGANISED OPEN SPACE

AREA DETAILS

1.	PLOTTED AREA	56.75 %
2.	ROADS	28.00 %
3.	ORGANISED OPEN SPACE	7.75 %
4.	BUFFER ZONE	1.75 %
5.	INSTITUTIONS SERVICES ETC.	5.75 %

M. 50 0 50 100 150

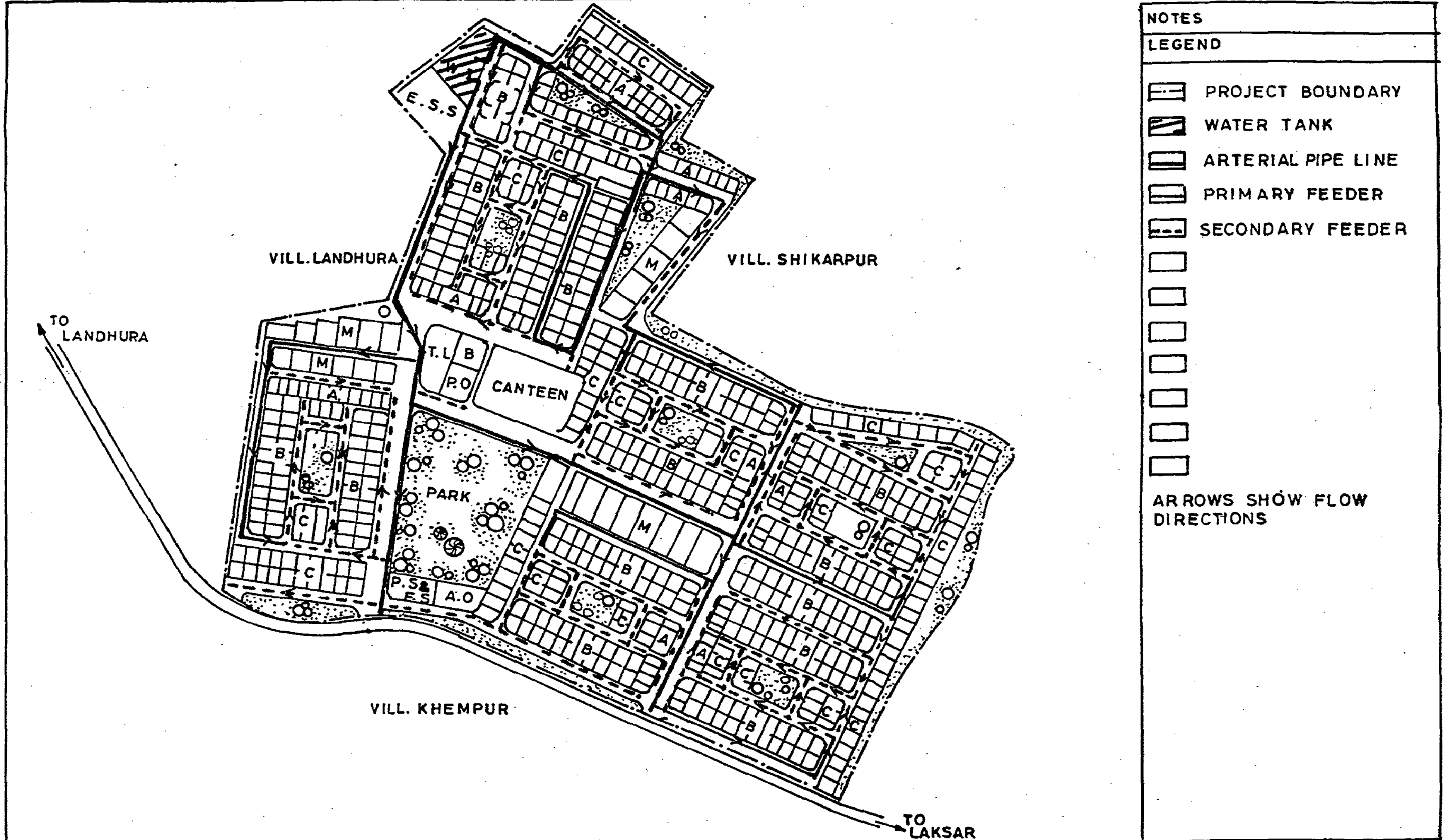
NORTH

FIG. 5.4

COMPUTER AIDED LAND SUB-DIVISION PLANNING

ELECTRONICS COMPLEX, ROORKEE

LAND UTILIZATION PATTERN



COMPUTER AIDED LAND SUB-DIVISION PLANNING

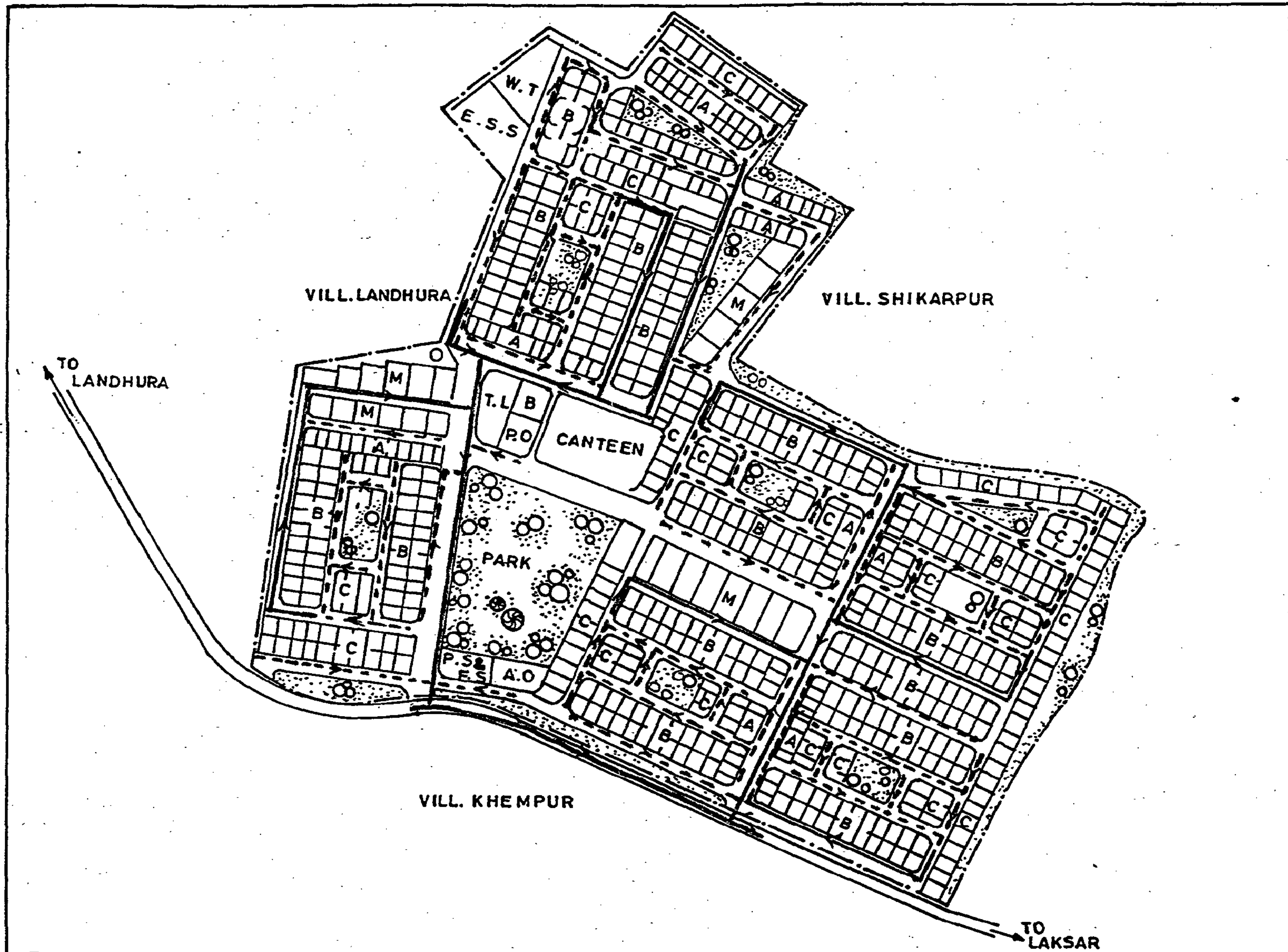
ELECTRONICS COMPLEX, ROORKEE

WATER SUPPLY NETWORK

M. 50 0 50 100 150

NORTH

FIG. 5.5



NOTES

LEGEND

- PROJECT BOUNDARY
- TRUNK SEWER
- PRIMARY LINE
- SECONDARY LINE

ARROWS INDICATE FLOW DIRECTION

COMPUTER AIDED LAND SUB-DIVISION PLANNING	ELECTRONICS COMPLEX, ROORKEE SEWERAGE-NETWORK	M. 50 0 50 100 150	NORTH FIG. 5.6

CHAPTER - VI

STUDY IMPLICATIONS AND REFLECTIONS

6.1 CONCLUSION :

The foregoing analyses and discussions lead us to the following conclusions:

(i) The mathematical model developed has greatly facilitated the decision making in different stages of project design. The sub-models have made it possible to design the different components of the sub-division layouts with a full understanding of the variables involved. The computer program generates a large number of options which could be analysed to select the optimum result(s).

(ii) The sensitivity analysis was carried out for the different design parameters of the layout. It showed that least module area, least module ratio and higher plot ratio would give optimum result(s). Also, it was found that the higher module areas lead to higher development costs and the sewerage system accounted for the major share of the development costs. In this way, the sensitivity analysis helped us to identify the parameters that were more sensitive. The planners after carrying out the sensitivity analysis could fix up their own criterion to decide upon the values of the design parameters.

(iii) The project design study showed that the land sub-division planning could be done more easily and quickly with the help of computer methods. Feed back of informations and the necessary changes during the various stages of planning become easy through this computer program.

So, in brief it could be summarised that computer aided land sub-division planning gives a rational and realistic base for systematic step by step sub-division of the land and over all planning.

6.2 LIMITATIONS :

The CALSD-MODEL has following limitations:

(i) Land sub-division is a complex system consisting of a very large number of interacting variables many of which are quantifiable and some defy quantification. In the present model a large number of variables have been quantified, but still it can not tell the social impact of the land forms nor it will indicate whether the solutions generated are functionally feasible on the sites involved. Hence, the design of layouts remain very much an art.

(ii) The model caters to layouts which are essentially rectangular in pattern.

(iii) The open spaces in the module are only centrally located.

(iv) The model has no provision for affordability, finance analyses etc.

6.3 FUTURE RESEARCH :

The study is a beginning in the emerging field of research and there is need for further efforts. Some areas of future research could include the following :

(i) Module layouts, that can account for multistoreyed development, could be designed.

(ii) Model could include the affordability criterion.

(iii) Computer graphics programs could be developed.

(iv) The present study is for small level land sub-division. Models could be developed that would cater to large scale land sub-division layouts like design of a township etc. Hence, they would also consider the higher level of services required in a large scale land sub-division.

B I B L I O G R A P H Y

1. Bijlani, H.U. (1981) : ' System Approach to Land Sub-Division, Utility Network and Affordability', Shelter, HUDCO Publication, New Delhi.

2. Bijlani, H.U. (1982): 'Shelter, Land Sub- Division, Circulation and Utility Network', Proceedings of 30th Annual Town and Country Planning Seminar and Development of Metropolitan Areas, March 13 - 16.

3. Bijlani, H.U.(1983) : Layout Design and Analysis, HUDCO Publication, New Delhi.

4. Caminos, H. and Geothert, R. (1983) : Urbanization Primer M.I.T. Press, U.S.A.

5. C.P.W.D. (1981) : Delhi Schedule of Rates - 1981, Vol I-II, C.P.W.D., New Delhi.

6. Chadwick, G.(1971) : Systems View of Planning, Pergamon Press, London.

7. Chiara, J.D. (1982) : Urban Planning and Design Criterion, Van Nostrand Reinhold Publication.

8. Datta, K.L., Garg, B.B. (1971): 'Layout Pattern Densities Of Housing Development ' , Indian Architect, April

9. D,C.O. (1971): District Census Hand Book - District Saharanpur - 1971, Part X - B, D.C.O., U.P.

10. Fair, G.M. et.al. (1968) : Water and Waste Water Engineering Vol I - II.

11. Garg, S.K. (1982 a) : Water Supply Engineering, Khanna Publishing Company, New Delhi.

12 Garg, S.K. (1982 b) : Sewage And Waste Disposal Engineering, Khanna Publishing Company, New Delhi.

13. HUDCO (1980) : Design and Research Series, Vol No. 5 and 7, HUDCO, New Delhi.

14. HUDCO (1982 a) : ' HUDCO Model, Computer Based Design and Analysis of Affordable Shelter, HUDCO, New Delhi.

15. HUDCO (1982 b) : User's Hand Book Matrix, HUDCO, New Delhi

16. HUDCO (1983) : HUDCO's Computer Based Model for Design and Analysis of Shelter Projects, HUDCO, New Delhi

17. HUDCO (1985) : Sector Model, HUDCO, New Delhi.

18. I.D.U.P. (1982) : Guidelines for Industrial Layouts, I.D., U.P.

19. I.S.I. (1967) : Code of Practice for Ancilliary Structure on Sewerage System, I.S. 4111 - 1967, Part I - Manhole, I.S.I., New Delhi.

20. I.S.I. (1972) : Code for Planning and Design of Surface Drains, I.S. 8835 - 1972, I.S.I., New Delhi.

21. I.S.I. (1978) : Guide for Requirements of Low Income Housing, IS : 8888 - 1978, I.S.I., New Delhi

22. I.S.I. (1983) : Code of Basic Requirements for Water Supply, Drainage and Sanitation , IS : 1172 - 1983 , ISI, New Delhi

23. I.S.I. (1984) : National Building Code of India - 1983, SP : 7 - 1983, I.S.I., New Delhi

24. Jain, A.K. et.al (1984) : Fortran Programming, Nem Chand and Bros., Roorkee.

25. Joglekar, M.N. (1983) : ' Computer Aided Design', Urban Development Planning Strategies and Techniques , ed., Saini, N.S. And Mahavir, SPA, New Delhi, pp. 155- 156.

26. Joglekar, M.N. (1984) : ' Land Use and Cost Optimisation in Neighbourhood Planning', Proceedings of International Conference on Low Cost Housing for Developing Countries, Nov. 12 - 17, C.B.R.I., Roorkee, pp. 277 - 287.

27. Kopardekar, H.D. (1966) : ' Land Requirement for Industry in Urban Area', Urban and Rural Planning Thought, SPA, No. 3-4, p.p. 65 - 95.

28. Mclouglin, J.B. (1970) : Urban and Regional Planning - A System Approach, Faber and Faber, London.

29. MWH (1976 a) : Mannual on Water Supply and Treatment, MWH, Govt. of India.

30. MWH (1976 b) : Mannual on Sewerage and Sewage Treatment, MWH, Govt. of India.

31. Modi, P.N. and Seth, S.M. (1982) : Hydraulics and Fluid Mechanics , Standard Book House Delhi.

32. PWD (1984) : Schedule of Rates for District Saharanpur- PWD, Saharanpur

33. Rajaraman, V. (1982) : Computer Programming in Fortran IV, Prentice Hall Pub. Company, New Delhi.

34. Reddy, T.S.S. (1984) : Computer Based Housing Design and Analysis, M.U.R.P. Thesis Submitted to School of Planning, Ahmedabad.

35. Reif, B. (1973) : Models in Urban and Regional Planning, Intertext Educational Pub.,. London.

36. Saini, N.S. et.al (1985) : Site Planning ed. saini, N.S. and others , SPA, New Delhi.

37. Steel, E.W. et. al (1979) : Water Supply and Sewerage, Mc grawhill Company, Tokyo.

38. Swami, M.C.K. (1970) : 'Costs of Urban Infrastructure for Industry as Related to City Size in Developing Countries,' Urban and Rural Planning Thought, No. 4, New Delhi.

39. Turner, Allan (1968) : Cities of The Urban Poor.

40. U.O.R. (1985) : Requirements for Proposed Electronics Complex and Industrial Nursery of UOR at Roorkee, August, University of Roorkee, Roorkee.

41. World Bank (1981) : Bertaud Model, World Bank, Washington D.C.

ABBREVIATIONS

(i)	CPWD	:	Central Public Works Department
(ii)	DCO	:	Director of Census Operations
(iii)	HUDCO	:	Housing and Urban Development Corporation Limited
(iv)	IDUP	:	Industries Department, Uttar Pradesh
(v)	ISI	:	Indian Standard Institution
(vi)	MWH	:	Ministry of Works and Housing
(vii)	PWD	:	Public Works Department
(viii)	SPA	:	School of Planning and Architecture
(ix)	UOR	:	University of Roorkee

APPENDIX A - 1

MATHEMATICAL MODEL : PHYSICAL PARAMETERS- SM - I

(i)	SA	=	Module Area
(ii)	R	=	Module Ratio
(iii)	S1, S2		Road Widths
(iv)	DA, DB, DC	=	Depth of type - 'A', 'B', 'C' plots respectively
(v)	WA, WB, WC	=	Width of type - 'A', 'B', 'C' plots respectively
(vi)	NPA, NPB, NPC	=	No. of type - 'A', 'B', 'C' plots respectively
(vii)	PSL	=	Percentage Area Under plots
(viii)	PCL	=	Percentage Circulation
(ix)	POP	=	Percentage open Space
(x)	PM	=	Equivalent Population of Module
(xi)	FA, FB, FC	=	Load Coefficients for plot type 'A', 'B', 'C'
(xii)	TCLS	=	Total Circulation length per sq.m. of module area.

The equations are as follows :

1. Check for controlling length on road widths:

Max. of $[\sqrt{\frac{SA}{R}} - 4DB - 2S1 - S2]$, $[\sqrt{SA.R} - 4DC - DA - 2S1 - S2$ and $[2DC]$ for S1 R.O.W.

Max. of $[\sqrt{SA.R} - DC - S2]$ and $[2DB]$ for S2 R.O.W.

2. $$NPA = \frac{1}{WA}\left[\sqrt{\frac{SA}{R}} - S2\right]$$

$$NPB = \frac{4}{WB}\left[\sqrt{SA.R} - DC - DA - S2\right]$$

$$NPC = \frac{1}{WC}\left[5\sqrt{\frac{SA}{R}} - 4(4DB - 2S1 - S2)\right]$$

3. $$PSL = \frac{100}{SA}\left[\sqrt{\frac{SA}{R}}(DA + 5DC + 4R.DB) - DA.S2 - 4DB(DA + DC + S2) - 4DC(4DB + 2S1 + S2)\right]$$

4. $$POP = \frac{100}{SA}\left[\sqrt{\frac{SA}{R}} - 4DB - 2S1 - S2\right]\left[\sqrt{SA.R} - 5DC - DA - 2S1 - S2\right]$$

5. $$PCL = \frac{100}{SA}\left[(2S1 + s2)\left\{\sqrt{\frac{SA}{R}}(1+R) - 2S1 - S2 - DC\right\} - 2S1(DA + 4DB)\right]$$

6. $PM = \frac{FA}{WA}\left(\sqrt{\frac{SA}{R}} - S2\right) + \frac{4FB}{WB}\left(\sqrt{SA.R} - DC - DA - S2\right)$

$$+ \frac{FC}{WC}\left\{5\sqrt{\frac{SA}{R}} - 4\left(DB + 2S1 - S2\right)\right\}$$

7 $TCLS = \frac{1}{A}\left[3\sqrt{\frac{SA}{R}}\left(1+R\right) - \left(4S1 + 5S2 + 2DA\right.\right.$

$$\left.\left. + 8DB + 2DC\right)\right]$$

APPENDIX A - 2

MATHEMATICAL MODEL : CIRCULATION NETWORK COSTING - SM-II

Total Cost

$$2CRMS1 \left\{ \sqrt{\frac{SA}{R}} \; (1+R) - (2S1 + 2S2 + DA + 4DB + DC) \right.$$

$$\left. + \; CRMS2 \left\{ \sqrt{\frac{SA}{R}} \; (1+R) - DC - S2 \right\} \right.$$

APPENDIX A - 3

MATHEMATICAL MODEL : WATER SUPPLY - SM - III

1. SIZING OF NETWORK PIPES

- $NC + NB$ ---------- For Size DW1 (line 2-3-4)
- $\frac{1}{WC}\left(2\sqrt{\frac{SA}{R}} - 2.5\,S1 - 2S2 - 6\,DB\right) + \frac{NB}{4}$ ----- for size DW2 (Line 4 - 5)
- $\frac{3}{WC}\left(\sqrt{\frac{SA}{R}} - 4DB - 2S1 - S2\right) + \frac{NB}{4}$ -------- for size DW2(Line 4-6)

2. NUMBER OF FIRE HYDRANTS

- $\sqrt{SA.R} - 0.5\sqrt{\frac{A}{R}} - DC$
- $\sqrt{\frac{SA}{R}}\,(1+R) - 1.5\,(S1+S2) - DA - 4DB - 2DC$

3. NUMBER OF SLUICE VALVES

- $\frac{1}{WC}\left(2\sqrt{\frac{SA}{R}} - 2.5S1 - 2S2 - 6\,DB\right) + \frac{NB}{4}$
- $\frac{3}{WC}\left(\sqrt{\frac{SA}{R}} - 4DB - 2S1 - S2\right) + \frac{NB}{4}$

4. TOTAL COST OF WATER SUPPLY SCHEME

- INNER MODULE

$$\left(CW1 + \frac{CW1J}{LW1} \right) \left\{ \sqrt{\frac{SA}{R}} \left(4 + 2R \right) - \left(2DA + 10\ DB + 2DC + 2.5\ S1 + 4.5\ S2 \right) \right\}$$

$$+ \left(CW2 + \frac{CW2J}{LW2} \right) \left(\sqrt{SA.R} - DC + 2DB + 0.5S1 \right) CW2B + 2CW12T$$

$$+ 5CW1T + 3CW1P + CW12R + NWV.CW1V + CW2V + NWF.CW1F$$

- CORNER MODULE

$$\left(CW1 + \frac{CW1J}{LW1} \right) \left\{ \sqrt{\frac{SA}{R}} \left(4 + 3R \right) - \left(2DA + 10\ DB + 3DC + 2.5S1 \right. \right.$$

$$\left. \left. 4.5S2 \right) \right\} + \left(CW2 + \frac{CW2J}{LW2} \right) \left(\sqrt{SAR} - DC + 2DB + 0.5S1 \right)$$

$$+ CW1B + CW2B + 2CW12T + 6\ CW1T + 2\ CW1P + CW12R$$

$$+ NWV.CW1V + CW2V + NWF.CW1F$$

APPENDIX A - 4

MATHEMATICAL MODEL : SEWERAGE NETWORK - SM - IV

1. SIZING OF PIPES

- $NC + NB$ ------- For Size DS2
- $\frac{1}{WC} \left(\sqrt{\frac{SA}{R}} - 6DB - 2.5S1 - 2S2 \right) + \frac{NB}{4}$ --- for size DS1
- $\frac{3}{WC} \left(\sqrt{\frac{SA}{R}} - 4DB - 2S1 - S2 \right) + \frac{NB}{4}$ --- for size DS1

2. LENGTH OF SEWER LINE SEGMENTS AND TOTAL NUMBER OF MANHOLE CHAMBERS IN EACH

- $L1 = \sqrt{SA.R} - DA - DC - 0.5S2$
- $L2 = 2DB + 0.5S1$
- $L3 = \sqrt{\frac{SA}{R}} - 4DB - S1 - S2$
- $L4, = L5 = L3 - 0.5S1$
- $L6 = DC + 0.5S1$
- $L7 = 2DC + S1$
- $L8 = L1 - L6 - L7$
- $L9 = \sqrt{SA.R} + 2DB - DC + 0.5S1$
- $L10 = \sqrt{\frac{SA}{R}} - 0.5S2$
- $L11 = L1$

- $M1 = \frac{1}{2WB}(L1 - 0.5S2) + 1$
- $M2 = \frac{L2}{2WC}$
- $M3 = \frac{L3}{2WC}$
- $M4 = M5 = \frac{L3 - S1}{2WC} + 1$
- $M6 = \frac{L6}{2WB}$
- $M7 = \frac{L7}{2WB}$
- $M8 = M1 - M6 - M7$
- $M9 = \frac{1}{2WC}(L9 + 0.5S2) - {} + \frac{1}{2WB}(L1 - 0.5S2) + 1$
- $M10 = \frac{1}{2WA}(L10 - 0.5S2) + 1$
- $M11 = M1$

3. DEPTH AT ENDS

- $X1 = D1 + (K1 - G)\,L1$
- $X2 = D1 + (K1 - G)\,L2$
- $X3 = X1 + (K1 - G)\,L3$
- $X4 = D1 + (K1 - G)\,L4$
- $X5 = D1 + (K1 - G)\,L5$
- $X6 = D1 + (K1 - G)\,L6$

- $X7 = X5 + (K1 - G)\ L7$
- $X8 = X7 + (K1 - G)\ L8$
- $X9 =$ Bigger of $(X3$ and $X8) + (K2 - G)\ L9$
- $X10 = D1 + (K1 - G)\ L10$
- $X11 = X1$

4. MANHOLE CHAMBERS AND EXTRA DEPTHS IN EACH CATEGORY

<u>LINE - L1</u>

If $X1 < D2$ Then: $N1 = M1$ and $EN1 = \frac{M1}{2}(X1 - D1)$

If $D2 \leqslant X1 < D3$ then : $N1 = \frac{M1}{L1} \cdot \frac{D2 - D1}{K1 - G}$, $EN1 = \frac{N1}{2}(D2 - D1)$,

$N2 = M1 - N1$, $EN2 = \frac{N2}{2}(D3 - D2)$

If $D3 \leqslant X1 < D4$ Then : $N1 = \frac{D2 - D1}{K1 - G} \cdot \frac{M1}{L1}$, $EN1 = \frac{N1}{2}(D2 - D1)$

$N2 = \frac{D3 - D2}{K1 - G} \cdot \frac{M1}{L1}$, $EN2 = \frac{N2}{2}(D3 - D2)$

$N3 = M1 - N1 - N2$, $EN3 = \frac{N3}{2}(X1 - D3)$

<u>LINE - L2</u>

If $X2 < D2$ then : $N1 = M2$, $EN1 = \frac{M2}{2}(X^2 - D1)$

$D2 \leqslant X2 < D3$ then : $N1 = \frac{M2}{L2} \cdot \frac{D2 - D1}{K1 - G}$, $EN1 = \frac{N1}{2}(D2 - D1)$

$$N2 = M2 - N1 \quad , \quad EN2 = \frac{N2}{2}(X2 - D2)$$

<u>LINE - L3</u>

- If $X3 < D2$ Then : $N1 = M3$, $EN1 = \frac{M3}{2}(X1 + X3 - 2D1)$

- $D2 \leqslant X3 < D3$ and $X1 < D2$ then :

$$N1 = \frac{M3}{L3} \cdot \frac{D2 - X1}{K1 - G} \quad , \quad EN1 = \frac{N1}{2}(D2 + X1 - 2D1)$$

$$N2 = M3 - N1 \quad , \quad EN2 = \frac{N2}{2}(X3 - D2)$$

- If $D2 \leqslant$ Each of $X1$ and $X3 < D3$ then : $N1 = 0$ $EN1 = 0$

$$N2 = M3 \quad , \quad EN2 = \frac{N2}{2}(X3 + X1 - 2D2)$$

- If $D3 \leqslant X3 < D4$ and $X1 < D2$ then :

$$N1 = \frac{M3}{L3} \cdot \frac{D2 - X1}{K1 - G} ,$$

$$EN1 = \frac{N1}{2}(D2 + X1 - 2D1)$$

$$N2 = \frac{M3}{L3} \cdot \frac{D3 - D2}{K1 - G} \quad , \quad EN2 = \frac{N2}{2}(D3 - D2)$$

$$N3 = M3 - N1 - N2 \quad , \quad EN3 = \frac{N3}{2}(X3 - D3)$$

- If $D3 \leqslant X3 < D4$ and $D2 \leqslant X1 < D3$

then : $N1 = 0$, $EN1 = 0$

$$N2 = \frac{M3}{L3} \cdot \frac{D3 - X1}{K1 - G}, \quad EN2 = \frac{N2}{2}(D3 + X1 - 2D2)$$

$$N3 = M3 - N2, \quad EN3 = \frac{N3}{2}(X3 - D3)$$

LINE - L4

- If $X4 < D2$ then : $N1 = M4$, $EN1 = \frac{M4}{2}(X4 - D1)$
- If $D2 \leqslant X4 < D3$ then : $N1 = \frac{M4}{L4} \cdot \frac{D2 - D1}{K1 - G}$

$$EN1 = \frac{M4}{2}(D2 - D1)$$

- $N2 = M4 - N1$, $EN2 = \frac{N2}{2}(X4 - D2)$

LINE - L5

- If $X5 < D2$ then : $N1 = M5$, $EN1 = \frac{N5}{2}(X5 - D1)$
- If $D2 \leqslant X5 < D3$ then : $N1 = \frac{M5}{L5} \cdot \frac{D2 - D1}{K1 - G}$

$$EN1 = \frac{N1}{2}(D2 - D1)$$

$$N2 = M5 - N1, \quad EN2 = \frac{N2}{2}(X5 - D2)$$

LINE - L-6

- If $X6 < D2$ then : $N1 = M6$, $EN1 = \frac{M6}{2}(X6 - D1)$
- If $D2 \leqslant X6 < D3$ then : $N1 = \frac{M6}{L6} \cdot \frac{D2 - D1}{K1 - G}$

$$EN1 = \frac{N1}{2}(D2 - D1)$$

$$N2 = M6 - N1 \text{ , } EN2 = \frac{N2}{2}(X6 - D2)$$

LINE - L - 7

- If $X7 < D2$ then : $N1 = M7$, $EN1 = \frac{M7}{2}(X7 + X5 - 2D1)$
- If $D2 \leqslant X7 < D3$ and $X5 < D2$

then : $N1 = \frac{M7}{L7} \cdot \frac{D2 - X5}{K1 - G}$

$$EN1 = \frac{N1}{2}(D2 + X5 - 2D1)$$

$$N2 = M7 - N1 \text{ , } EN2 = \frac{N2}{2}(X7 - D2)$$

- If $D2 \leqslant$ Each of $X5$ and $X7 < D3$

then : $N1 = 0$, $EN1 = 0$

$$N2 = M7 \text{ , } EN2 = \frac{M7}{2}(X5 + X7 - 2D2)$$

If D3 $\leq$ X7 $<$ D4 and X5 $<$ D2

$$\text{then: } N1 = \frac{M7}{L7}\cdot\frac{D2 - X5}{K1 - G}, \quad EN1 = \frac{N1}{2}(D2 + X5 - 2D1)$$

$$N2 = \frac{M7}{L7}\cdot\frac{D3 - D2}{K1 - G}, \quad EN2 = \frac{N2}{2}(D3 - D2)$$

$$N3 = M7 - N1 - N2, \quad EN3 = \frac{N3}{2}(X7 - D3)$$

If D3 $\leq$ X7 $<$ D4 and D2 $<$ X5 $<$ D3

$$\text{Then: } N1 = 0, \quad EN1 = 0$$

$$N2 = \frac{M7}{L7}\cdot\frac{D3 - X5}{K1 - G}, \quad EN2 = \frac{N2}{2}(D3 + X5 - 2D2)$$

$$N3 = M7 - N2, \quad EN3 = \frac{N3}{2}(X7 - D3)$$

<u>LINE - L-8</u>

- If X8 $<$ D2 then: $N1 = M8$, $EN1 = \frac{M8}{2}(X7 + X8 - 2D1)$
- If D2 $\leq$ X8 $<$ D3 and X7 $<$ D2 then: $N1 = \frac{M8}{L8}\cdot\frac{D2 - X7}{K1 - G}$

$$EN1 = \frac{N1}{2}(D2 + X7 - 2D1)$$

$$N2 = M8 - N1, \quad EN2 = \frac{N2}{2}(X8 - D2)$$

. If $D2 \leqslant$ Each of X_8 and $X7 < D3$

Then : $N1 = 0, \quad EN1 = 0$

$$N2 = M8 \,, \quad EN2 = \frac{N2}{2}(X7 + X8 - 2D2)$$

. If $D3 \leqslant X8 < D7$ and $X7 < D2$

$$\text{Then : } N1 = \frac{M8}{L8} \cdot \frac{D2 - X7}{K1 - G} \,, \quad EN1 = \frac{N1}{2}(D2 + X7 - 2D1)$$

$$N2 = \frac{M8}{L8} \cdot \frac{D3 - D2}{K1 - G} \,, \quad EN2 = \frac{N2}{2}(D3 - D2)$$

$$N3 = M8 - N1 - N2 \,, \quad EN3 = \frac{N3}{2}(X8 - D3)$$

. If $D3 \leqslant X8 < D4$ and $D2 \leqslant X7 < D3$

Then : $N1 = 0 \quad , \; EN1 \quad = 0$

$$N2 = \frac{M8}{L8} \cdot \frac{D3 - X7}{K1 - G} \,, \quad EN2 = \frac{N2}{2}(D3 + X7 - 2D2)$$

$$N3 = M8 - N2 \,, \quad EN3 = \frac{N3}{2}(X8 - D3)$$

. If $D3 \leqslant$ Each of $X7$ and $X8 < D4$

Then : $N1 = N2 = 0 \,, \quad EN1 = EN2 = 0$

$$N3 = M8 \quad , \quad EN3 = \frac{N3}{2}(X8 + X7 - 2D3)$$

LINE - L - 9

. If $X9 < D2$ then : $N1 = M9$,

$$EN1 = \frac{M9}{2}\{(\text{Bigger of } X3 \text{ and } X8) + X9 - 2D1\}$$

. If $D2 < X9 < D3$ and (Bigger of X3 and X8) $< D2$

$$\text{then: } N1 = \frac{M9}{L9} \cdot \frac{D2 - (\text{Bigger of } X3 \text{ and } X8)}{K2 - G}$$

$$EN1 = \frac{N1}{2}\{ D2 + (\text{Bigger of } X3 \text{ and } X8) - 2D1\}$$

$$N2 = M9 - N1 \quad , \quad EN2 = \frac{N2}{2} (X9 - D2)$$

. If $D2 \leq X9$. (Bigger of X3 and X8) $< D3$

then : $N1 = 0$, $EN1 = 0$

$N2 = M9$

$$EN2 = \frac{N2}{2} \{ X9 + (\text{Bigger of } X3 \text{ and } X8) - 2D2\}$$

. If $D3 \leq X9 < D4$ and (Bigger of X3 and X8) $< D2$

$$\text{then : } N1 = \frac{M9}{L9} \cdot \frac{D2 - (\text{Bigger of } X3 \text{ and } X8)}{K2 - G}$$

$$EN1 = \frac{N1}{2} \{ D2 + (\text{Bigger of } X3 \text{ and } X8) - 2D1\}$$

$$N2 = \frac{M9}{L9} \cdot \frac{D3 - D2}{K2 - G} \quad , \quad EN2 = \frac{N2}{2}(D3 - D2)$$

$$N3 = M9 - N1 - N2 \quad , \quad EN3 = \frac{N3}{2}(X9 - D3)$$

- If $D3 \leqslant X9 < D4$ and $D2 \leqslant$ (Bigger of X3 and X8) $< D3$

  then : $N1 = 0 \quad , \quad EN1 = 0$

$$N2 = \frac{M9}{L9} \cdot \frac{D3 - (\text{Bigger of X3 and X8})}{K2 - G}$$

$$EN2 = \frac{N2}{2}\{D3 + (\text{Bigger of X3 and X8}) - 2D2\}$$

$$N3 = M9 - N2 \quad , \quad EN3 = \frac{N3}{2}(X9 - D3)$$

- If $D3 \leqslant$ Each of X9 and (Bigger of X3 and X8) $< D4$

  then : $N1 = N2 = 0 \quad , \quad EN1 = EN2 = 0$

$$N3 = M9$$

$$EN3 = \frac{N3}{2}\{X9 + (\text{Bigger of X3 and X8}) - 2D3\}$$

- If $X9 \geqslant D4$ and $D2 \leqslant$ (Bigger of X3 and X8) $< D3$

  then : $N1 = 0 \quad , \quad EN1 = 0$

$$N2 = \frac{M9}{L9} \cdot \frac{D3 - (\text{Bigger of X3 and X8})}{K2 - G}$$

$$EN2 = \frac{N2}{2}\{ D3 + (\text{Bigger of } X3 \text{ and } X8) - 2D2\},$$

$$N3 = \frac{M9}{L9} \cdot \frac{D4 - D3}{K2 - G}, \quad EN3 = \frac{N3}{2}(D4 - D3),$$

$$N4 = M9 - M2 - M3, \quad EN4 = \frac{N4}{2}(X9 - D4)$$

LINE - L - 10

- If $X10 < D2$ then : $N1 = M10$, $EN1 = \frac{M10}{2}(X10 - D1)$
- If $D2 \leq X10 < D3$ then : $N1 = \frac{M10}{L10} \cdot \frac{D2 - D1}{K-G}$

$$EN1 = \frac{N1}{2}(D2 - D1)$$

$$N2 = M10 - N1, \quad EN2 = \frac{N2}{2}(X10 - D2)$$

LINE - L - 11

OPERATIONS AND RESULTS SAME AS IN LINE - 1

INNER MODULE : $\Sigma N1 = \sum_{L1}^{L10} N1$, $\Sigma N2 = \sum_{L1}^{L10} N2$

$$\Sigma N3 = \sum_{L1}^{L10} N3, \quad \Sigma N4 = \sum_{L1}^{L10} N4$$

$$\Sigma EN1 = \sum_{L1}^{L10} EN1 \quad , \quad \Sigma EN2 = \sum_{L1}^{L10} EN2$$

$$\Sigma EN3 = \sum_{L1}^{L10} EN3 \quad , \quad EN4 = \sum_{L1}^{L10} EN4$$

CORNER MODULE :

All above summations for Line L1 toL11

5. TOTOAL COST OF SEWERAGE SCHEME :

INNER MODULE :

$$CS1 \left\{ \sqrt{\frac{SA}{R}} (4+2R) - (3.5S1 + 4.5S2 + 2DA + 10DB + 2DC) \right\}$$

$$+ \; CS2 \left(\sqrt{SAR} + 2DB - DC + 0.5S1 \right) + CSDC.NSDC + CSVS.NSVS$$

$$+ \; CMH1.\Sigma N1 + CMH2.\Sigma N2 + CMH3.\Sigma N3 + CMH4.\Sigma N4$$

$$+ \; CSE1.\Sigma EN1 + CSE2.\Sigma EN2 + CSE3.\Sigma EN3 + CSE4.\Sigma EN4.$$

CORNER MODULE :

$$CS1 \left\{ \sqrt{\frac{SA}{R}} (4+3R) - (3.5S1 + 5S2 + 3DA + 10DB + 3DC) \right\}$$

$$+ \; CS2 \left(\sqrt{SAR} + 2DB - DC + 0.5S1 \right) + CSDC.NSDC + CSVS.NSVS$$

$$+ \; CMH1.\Sigma N1 + CMH2.\Sigma N2 + CMH3.\Sigma N3 + CMH4.\Sigma N4 + CSE1.\Sigma EN1$$

$$+ \; CSE2.\Sigma EN2 + CSE3.\Sigma EN3 + CSE4.\Sigma EN4$$

APPENDIX A - 5

MATHEMATICAL MODEL : DRAINAGE NETWORK - SM - V

SIZING OF DRAIN SECTIONS

- SA ----- For Section D2

- $\sqrt{SAR}(2DB + S1) + \left(\sqrt{\frac{SA}{R}} - 4DB - 2S1 - S2\right) X$

  $(2Dc + S2)$ --- For Section D1

- $\sqrt{SAR}(2DB + S1) + \left(\sqrt{\frac{SA}{R}} - 4DB - 2S1 - S2\right) X$

  $(SAR - 2DC - S2)$ -- For Section D1

TOTAL COST :

- $CD1\left\{\sqrt{\frac{SA}{R}}(3 + 2R) - (3.5S1 + 4S2 + 2DA + 8DB + 2DC)\right\}$

  $+ CD2(\sqrt{SAR} + 0.5S1 + 2DB - DC) + 4(CD1C \cdot S1 + CDP)$

APPENDIX A - 6

MATHEMATICAL MODEL : LAND AND OTHER COSTS - SM - VI

- $$CLD = [(CLVL + CA + CE) \times SA]$$

- $$CLDS = \left[\frac{CLD}{SLA} \right]$$

- $$CLAND = [AL \times SA]$$

$$CLANDS = \left[\frac{CLAND}{SLA} \right]$$

- $$TCOS = [CLANDS + CLDS + C2S + CW1S + CSS + CDS]$$

- $$PLD = \left[\frac{CLANDS + CLDS}{TCOS} \right] \times 100$$

- $$PC2S = \left[\frac{C2S \times 100}{TCOS} \right]$$

- $$PCW1S = \left[\frac{CW1S \times 100}{TCOS} \right]$$

- $$PCSS = \left[\frac{CSS \times 100}{TCOS} \right]$$

- $$PCDS = \left[\frac{CDS \times 100}{TCOS} \right]$$

APPENDIX - B1

WATER SUPPLY SYSTEM : BASIC EQUATIONS

The Hazen Williams Equation [MWH, 1976 a ; Modi, P.N. et.al. 1970, Steel, E.W. et.al., 1979 ; Fair, G.M. et.al., 1968

$$V = 0.849 \times C \times [R]^{0.63} \times [S]^{0.54}$$

Where C = Roughness Coefficient

S = Hydraulic Gradient

V = Flow Velocity Through Pipes (M/S)

Now, for circular conduits running full,

$$R = \frac{D}{4000}$$ Where, D = Internal Diameter of Pipe in mm

So, the basic equation can be restructured as follows:

$$V = 0.849 \times C \times \left[\frac{D}{4000} \right]^{0.63} \times [S]^{0.54}$$

$$V = 4.567 \times 10^{-3} \times C \times [D]^{0.63} \times [S]^{0.54}$$

If ' Q' is the flow discharge in gallon/ day,

Q = A.V. Where, A = Crossection area of pipe in sq.mm.

$$= \frac{\pi D^2}{4}$$

$$Q = \frac{\pi D^2}{4} X\ 4.56 \ X\ 10^{-3} C \ X \quad [D]^{0.63} X\ [S]^{0.54} X\ 10^{-6}$$

$$Q = 3.59\ X\ 10^{-9}\ X\ C\ X\ [D]^{2.63}\ X\ [S]^{0.54}$$

It gives the discharge in M^3/S. Now, restructuring the above equation to get 'Q' value in gallon/ day :

$$Q = 3.59\ X\ 10^{-9}\ X\ C\ X\ [D]^{2.63}\ X\ [S]^{0.54}\ X\ 219.975$$

$$\boxed{Q = 6.817\ X\ 10^{-2} X\ C\ X\ [D]^{2.65}\ X\ [S]^{0.54}}$$

APPENDIX - B 2

SEWERAGE SYSTEM : BASIC EQUATIONS

The Manning's Equation [MWH, 1976 b; Steel, E.W., 1979;, Fair, G.M. et. al., 1968, Garg, S.K., 1982 b] is :

$$V = \frac{1}{n} \times R^{2/3} \times S^{1/2}$$

Where,

n = Manning's rugocity Coefficient

R = Hydraulic Mean depth (M.)

S = Hydraulic gradient(Pipe line Slope)

V = Velocity of Flow (M/s)

Now, $R = \frac{A}{P}$ Where A = Crossectional area of flow (m^2)

P = Wetted Perimeter (M.)

For Circular Sewers,

Running half full with internal diameter 'D' (in M.)

$$R = \frac{\pi D^2/2X4}{\pi D/2} = \frac{D}{4}$$

So, the Manning's formula can be restructured as :

$$V = \frac{1}{n} \times \left[\frac{D}{4}\right]^{2/3} \times [S]^{1/2}$$

or

$$V = \frac{1}{n} \times 0.397 \times [D]^{0.67} \times [S]^{0.50}$$

Further, discharge or capacity of pipe in cubic meter/second is given as :

$$Q = A \times V$$

$$= \frac{\pi D^2}{4} \times \frac{1}{n} \times 0.397 \times [D]^{0.67} \times [S]^{0.50}$$

$$Q = 0.156 \times \frac{1}{n} \times [D]^{2.67} \times [S]^{0.50}$$

APPENDIX_C1

'α_w' VALUES

```
C
C      WATER SUPPLY INFRASTRUCTURE COST ANALYSIS-
C.     ('CW(1)')
       SV1=((FC*(1/WC))*((2*SB)-(2.5*PS1)-(2*PS2)-(6*DB)))+(FB*(NPB/4)
       SV2=((FC*(3/WC))*(SB-(4*DB)-A2))+(FB*(NPB/4))

       IF(SV1.GE.SV2)GO TO 5016
       P1=SV2
       GO TO 260
 5016  P1=SV1
  260  IF(P1.GE.400.0)GO TO 26000
       NWV1=1
       NWV2=1
       GO TO 26001
26000  NWV1=4
       NWV2=1
26001  FH1=SL-DC+(0.5*SB)
       FH2=(SB*(1+R(M)))-(1.5*(PS1+PS2))-DA-(4*DB)-(2*DC)
       IF(FH1.GT.(304.0))GO TO 273
       IF(FH2.GT.(228.0))GO TO 274
       NWF=4
       GO TO 277
  274  IF(FH2.GT.(380.0))GO TO 13
       NWF=5
       GO TO 277
  273  IF(FH1.GT.(860.0))GO TO 13
       IF(FH2.GT.(228.0))GO TO 275
       NWF=6
       GO TO 277
  275  IF(FH2.GT.(380.0))GO TO 276
       NWF=8
       GO TO 277
  276  IF(FH2.GT.(860.0))GO TO 13
         NWF=10
C
C      ESTIMATION OF LENGTH OF PIPE LINES (WATER SUPPLY)
C      LENGTH FOR PIPE SIZE-1 FOR GENERAL AND CORNER MODULES
```

```
  277 LWP1=((SB*(4+(2*R(M))))-
     1((2*DA)+(10*DB)+(2*DC)+(2.5*PS1)+(4.5*PS2)))
      LWPC1=((SB*(4+(3*R(M))))-
     1((2*DA)+(10*DB)+(3*DC)+(2.5*PS1)+(4.5*PS2)))
      A7=SL-DC+(2*DB)+(0.5*PS1)
C     A7 IS SAME AS LWP2 AND LWPC2(LENGTHS FOR PIPE SIZE-2
C     FOR GENERAL AND CORNER MODULES RESPECTIVELY)
      IF(P1.GT.648.0)GO TO 261
      DW1=80.0
      GO TO 266
  261 IF(P1.GT.1262.0) GO TO 262
       DW1=100.0
      GO TO 266
  262 IF(P1.GT.2362.0) GO TO 263
      DW1=125.0
      GO TO 266
  263 IF(P1.GT.4000.0) GO TO 264
      DW1=150.0
      GO TO 266
  264 IF(P1.GT.8196.0)GO TO 265
      DW1=200.0
      GO TO 266
  265 IF(P1.GT.14224.0) GO TO 1
        DW1=250.0
        GO TO 266
1       IF (P1.GT.22728.0) GO TO 2
        DW1=300.0
        GO TO 266
2       IF (P1.GT.30923.0) GO TO 3
        DW1=350.0
        GO TO 266
3       IF (P1.GT.40388.0) GO TO 4
        DW1=400.0
        GO TO 266
4       IF (P1.GT.51156.0) GO TO 13
        DW1=450.0
  266 IF(PM.GT.648.0)GO TO 267
      DW2=80.0
      GO TO 272
  267 IF(PM.GT.1262.0)GO TO 268
      DW2=100.0
      GO TO 272
  268 IF(PM.GT.2362.0)GO TO 269
      DW2=125.0
```

```
      GO TO 272
  269 IF(PM.GT.4000.0)GO TO 270
      DW2=150.0
       GO TO 272
  270 IF(PM.GT.8016.0)GO TO 271
      DW2=200.0
        GO TO 272
 271    IF(PM.GT.14224.0)GO TO 5
              DW2=250.0
        GO TO 272
5       IF(PM.GT.22728.0) GO TO 6
        DW2=300.0
        GO TO 272
6       IF (PM.GT.30923.0) GO TO 7
        DW2=350.0
        GO TO 272
7       IF (PM.GT.40388.0) GO TO 8
        DW2=400.0
        GO TO 272
8       IF (PM.GT.51156;0) GO TO 13
        DW2=450.0
```

APPENDIX - C2

'αs' - VALUES

'αs' Range	Internal Diameter of Pipes (mm)	Longitudinal Slope (1 IN)
$\alpha s \leq 1479$	150	100
$1479 < \alpha s \leq 2570$	200	145
$2570 < \alpha s \leq 3873$	250	195
$2873 < \alpha s \leq 5985$	300	250
$5985 < \alpha s \leq 7710$	350	300
$7710 < \alpha s \leq 10083$	400	360
$10083 < \alpha s \leq 18442$	450	510
$18442 < \alpha s \leq 22900$	500	590
$22900 < \alpha s \leq 32975$	600	750
$32975 < \alpha s \leq 54038$	700	1230
$54038 < \alpha s \leq 70461$	800	1470
$70461 < \alpha s \leq 82931$	900	1720
$82931 < \alpha s \leq 121980$	1000	2150

APPENDIX - C 3

'αD - VALUES

'αD' Range	Drain Size (mxm)	Longitudinal Slope	'αD' Range	Drain Size (m x m)	Longitudinal Slope
αD ≤ 1.05	0.23 x 0.23	0.0033	9.80 < αD ≤ 10.95	0.30 x 0.61	0.0025
1.05 < αD ≤ 1.15	0.23 x 0.23	0.004	10.95 < αD ≤ 11.58	0.30 x 0.69	0.00167
1.15 < αD ≤ 1.82	0.23 x 0.23	0.0025	11.58 < αD ≤ 12.69	0.30 x 0.69	0.002
1.82 < αD ≤ 2.10	0.23 x 0.30	0.0033	12.69 < αD ≤ 14.18	0.30 x 0.69	0.0025
2.10 < αD ≤ 2.73	0.23 x 0.30	0.002	14.18 < αD ≤ 15.81	0.46 x 0.69	0.00167
2.73 < αD ≤ 3.05	0.23 x 0.38	0.0025	15.81 < αD ≤ 17.31	0.46 x 0.69	0.002
3.05 < αD ≤ 3.78	0.23 x 0.46	0.0017	17.31 < αD ≤ 19.41	0.46 x 0.69	0.0025
3.78 < αD ≤ 4.14	0.23 x 0.46	0.002	19.41 < αD ≤ 21.51	0.46 x 0.69	0.002
4.14 < αD ≤ 4.42	0.30 x 0.46	0.0014	21.51 < αD ≤ 23.9[illegible]	0.46 x 0.76	0.0025
4.42 < αD ≤ 4.78	0.30 x 0.46	0.00167	23.99 < αD ≤ 24.92	0.46 x 0.76	0.00125
4.78 < αD ≤ 5.23	0.30 x 0.46	0.002	24.92 < αD ≤ 26.66	0.46 x 0.91	0.00143
5.23 < αD ≤ 5.85	0.30 x 0.46	0.0025	26.66 < αD ≤ 28.80	0.46 x 0.91	0.00167
5.85 < αD ≤ 6.60	0.30 x 0.53	0.00167	28.80 < αD ≤ 31.56	0.46 x 0.91	0.002
6.60 < αD ≤ 7.32	0.30 x 0.53	0.002	31.56 < αD ≤ 33.45	0.46 x 0.91	0.00143
7.32 < αD ≤ 8.18	0.30 x 0.53	0.0025	33.45 < αD ≤ 36.28	0.61 x 0.91	0.00167
8.18 < αD ≤ 8.94	0.30 x 0.61	0.00167	36.28 < αD ≤ 39.58	0.61 x 0.91	0.002

A P P E N D I X - D

: COMPUTER RESULTS :

PLATE:I PHYSICAL LAYOUT PARAMETERS

ELECTRONICS COMPLEX SCHEME BY UNIVERSITY OF ROORKEE

FOR LAYOUT PLAN WITH DIFFERENT TYPES OF UNITS

* MODULE LEVEL ANALYSIS *

(PHYSICAL PARAMETRES)

R	PS1	PS2	NPA	NPB	NPC	NP	SLA	PSL	OPA	POP	CLA	PCL	TCLS

NOTES

R =MODULE RATIO
PS1 =PERMISSABLE ROAD WIDTH S1
PS2 =PERMISSABLE ROAD WIDTH S2
NPA =NUMBER OF PLOTS OF TYPE *A*
NPB =NUMBER OF PLOTS TYPE *B*
NPC =NUMBER OF PLOTS OF TYPE *C*
NP =TOTAL NUMBER OF PLOTS (NPA+NPB+NPC)
SLA =SALEABLE AREA
PSL =PERCENTAGE SALEABLE AREA
OPA =OPEN SPACE AREA
POP =PERCENTAGE OPEN SPACE AREA
CLA =CIRCULATION AREA
PCL =PERCENTAGE CIRCULATION AREA
TCLS =TOTAL CIRCULATION LENGTH PER SQ.M. SALEABLE AREA

MB =BREADTH OF THE MODULE
ML =LENGTH OF THE MODULE
DA =DEPTH OF PLOT TYPE *A*
WA =WIDTH OF PLOT TYPE *A*
DB =DEPTH OF PLOT TYPE *B*
WB =WIDTH OF PLOT TYPE *B*
DC =DEPTH OF PLOT TYPE *C*
WC =WIDTH OF PLOT TYPE *C*
BSFS AND LSFS =SOCIAL FACILITY SPACE DIM.

MODULE AREA= 31000.0

275.0 325.0 375.0

1.2

R	PS1	PS2	NPA	NPB	NPC	NP	SLA	PSL	OPA	POP	CLA	PCL	TCLS
1.0	12.0	12.0	9.9	28.4	23.1	61.5	20633.	66.56	1812.	5.84	8555.	27.60	0.0355
1.4	12.0	12.0	8.2	35.6	16.1	59.9	19867.	64.09	2398.	7.73	8735.	28.18	0.0376
1.7	12.0	12.0	7.4	40.3	12.5	60.3	19838.	63.99	2158.	6.96	9004.	29.04	0.0388

(R = 1.0): (MB= 176.07 ML= 176.07 DA= 16.58 WA= 16.58 DB= 18.03 WB= 18.03 DC= 19.36 WC= 19.36) BSFS= 67.96 LSFS= 26.66

(R = 1.4): (MB= 148.80 ML= 208.33 DA= 16.58 WA= 16.58 DB= 18.03 WB= 18.03 DC= 19.36 WC= 19.36) BSFS= 40.69 LSFS= 58.92

(R = 1.7): (MB= 135.24 ML= 229.56 DA= 16.58 WA= 16.58 DB= 18.03 WB= 18.03 DC= 19.36 WC= 19.36) BSFS= 26.93 LSFS= 80.16

1.4

R	PS1	PS2	NPA	NPB	NPC	NP	SLA	PSL	OPA	POP	CLA	PCL	TCLS
1.0	12.0	12.	11.7	31.9	24.1	67.8	22641.	73.03	322.	1.04	8037.	25.93	0.0306

(R = 1.0): (MB= 176.07 ML= 176.07 DA= 19.62 WA= 14.02 DB= 21.33 WB= 15.24 DC= 22.91 WC= 16.37) BSFS= 54.76 LSFS= 5.88

```
1.4  12.   12.     9.8   42.4  15.8      65.9  21735.  70.11    1048.   3.38   8217.   26.51   0.0326
           CFB=  148.80  ML= 208.33 DA= 19.62  WA=  14.02 DB=  21.33 WB= 15.24 DC=  22.91 WC= 16.37)
           RSFS=  27.48      LSFS=  38.14

1.7  12.   12.     8.8   46.0  11.6      66.3  21699.  70.00     814.   2.63   8486.   27.37   0.0336
           CFB=  135.04  ML= 229.56 DA= 19.62  WA=  14.02 DB=  21.33 WB= 15.24 DC=  22.91 WC= 16.37)
           RSFS=  13.72      LSFS=  59.38

           1.7
           ---
1.4  12.   12.     1.8   43.2  15.1      69.1  22664.  73.11     459.   1.48   7876.   25.41   0.0301
           CFB=  148.80  ML= 208.33 DA= 21.62  WA=  12.72 DB=  23.51 WB= 13.83 DC=  25.25 WC= 14.85)
           RSFS=  18.78      LSFS=  24.46

1.7  12.   12.     9.7   49.4  10.4      69.5  22625.  72.99     229.   0.74   8145.   26.28   0.0311
           CFB=  135.04  ML= 229.56 DA= 21.62  WA=  12.72 DB=  23.51 WB= 13.83 DC=  25.25 WC= 14.85)
           RSFS=   5. 2      LSFS=  45.70

               MODULE AREA= 32000.0
               -----------
275.0  325.0  375.0
-------------------
           1.0
           ---
1.0  12.0  12.    11.1   29.1  23.9      63.0  21156.  66.11    2086.   6.52   8758.   27.37   0.0354
           CFB=  178.89  ML= 178.89 DA= 16.58  WA=  16.58 DB=  18.03 WB= 18.03 DC=  19.36 WC= 19.36)
           RSFS=  76.77      LSFS=  29.48

1.4  12.   12.0    8.4   36.3  16.7      61.4  20378.  63.68    2682.   8.38   8941.   27.94   0.0375
           CFB=  151.19  ML= 211.66 DA= 16.58  WA=  16.58 DB=  18.03 WB= 18.03 DC=  19.36 WC= 19.36)
           RSFS=  43.67      LSFS=  62.25

1.7  12.   15.     7.4   46.4  12.5      60.3  19849.  62.03    2109.   6.59  10042.   31.38   0.0389
           CFB=  137.20  ML= 233.24 DA= 16.58  WA=  16.58 DB=  18.03 WB= 18.03 DC=  19.36 WC= 19.36)
           RSFS=  26.79      LSFS=  80.83

           1.4
           ---
1.0  12.   12.    11.9   32.6  25.0      69.6  23259.  72.68     501.   1.56   8240.   25.75   0.0305
           CFB=  178.89  ML= 178.89 DA= 19.62  WA=  14.02 DB=  21.33 WB= 15.24 DC=  22.91 WC= 16.37)
           RSFS=  57.56      LSFS=   8.70

1.4  12.   12.     9.9   41.3  16.5      67.7  22339.  69.81    1239.   3.87   8423.   26.32   0.0324
           CFB=  151.19  ML= 211.66 DA= 19.62  WA=  14.02 DB=  21.33 WB= 15.24 DC=  22.91 WC= 16.37)
           RSFS=  29.86      LSFS=  41.47

1.7  12.   12.     8.9   46.9  12.3      68.1  22303.  69.70    1001.   3.13   8696.   27.18   0.0335
           CFB=  137.20  ML= 233.24 DA= 19.62  WA=  14.02 DB=  21.33 WB= 15.24 DC=  22.91 WC= 16.37)
           RSFS=  15.88      LSFS=  63.05

           1.7
           ---
1.4  12.   12.    10.9   44.2  15.9      71.0  23330.  72.91     588.   1.84   8082.   25.26   0.0300
           CFB=  151.19  ML= 211.66 DA= 21.62  WA=  12.72 DB=  23.51 WB= 13.83 DC=  25.25 WC= 14.85)
           RSFS=  21.16      LSFS=  27.79

1.7  12.   12.     9.8   50.4  11.2      71.5  23290.  72.78     354.   1.11   8355.   26.11   0.0310
           CFB=  137.20  ML= 233.24 DA= 21.62  WA=  12.72 DB=  23.51 WB= 13.83 DC=  25.25 WC= 14.85)
           RSFS=   7.18      LSFS=  49.37

               MODULE AREA= 33000.0
               -----------
275.0  325.0  375.0
-------------------
           1.0
```

```
1.0  12.0   14.     11.2  29.7  24.6        64.5  21670.  65.67   2372.   7.19   8958.   27.14  0.0353
            (HB=   181.66 ML= 181.66 DA= 16.58  WA=  16.58 DB=  18.03 WB=  18.03 DC=  19.36 WC=  19.36)
            RSFS=  73.55       LSFS=  32.25

1.4  12.0   14.      8.5  37.1  17.3        62.9  20880.  63.27   2976.   9.02   9143.   27.71  0.0374
            (HB=   153.53 ML= 214.94 DA= 16.58  WA=  16.58 DB=  18.03 WB=  18.03 DC=  19.36 WC=  19.36)
            RSFS=  45.42       LSFS=  65.53

1.7  12.0   15.      7.5  41.2  13.0        61.8  20351.  61.67   2383.   7.22  10266.   31.11  0.0388
            (HB=   139.33 ML= 236.85 DA= 16.58  WA=  16.58 DB=  18.03 WB=  18.03 DC=  19.36 WC=  19.36)
            RSFS=  28.22       LSFS=  84.45

            1.4
            ---
1.0  12.0   14.     12.1  33.4  25.8        71.3  23868.  72.33    692.   2.10   8440.   25.58  0.0304
            (HB=   181.66 ML= 181.66 DA= 19.62  WA=  14.02 DB=  21.33 WB=  15.24 DC=  22.91 WC=  16.37)
            RSFS=  67.34       LSFS=  11.47

1.4  12.0   12.     11.1  42.1  17.3        69.5  22933.  69.49   1441.   4.37   8625.   26.14  0.0323
            (HB=   153.53 ML= 214.94 DA= 19.62  WA=  14.02 DB=  21.33 WB=  15.24 DC=  22.91 WC=  16.37)
            RSFS=  32.21       LSFS=  44.76

1.7  12.0   15.      8.9  47.1  12.2        68.1  22307.  67.60    955.   2.89   9738.   29.51  0.0336
            (HB=   139.33 ML= 236.85 DA= 19.62  WA=  14.02 DB=  21.33 WB=  15.24 DC=  22.91 WC=  16.37)
            RSFS=  15.00       LSFS=  63.67

            1.7
            ---
1.4  12.0   12.     11.1  45.2  16.7        72.9  23985.  72.68    731.   2.21   8285.   25.10  0.0298
            (HB=   153.53 ML= 214.94 DA= 21.62  WA=  12.72 DB=  23.51 WB=  13.83 DC=  25.25 WC=  14.85)
            RSFS=  23.51       LSFS=  31.08

1.7  12.    12.     11.0  51.5  11.9        73.4  23945.  72.56    493.   1.49   8562.   25.95  0.0309
            (HB=   139.33 ML= 236.85 DA= 21.62  WA=  12.72 DB=  23.51 WB=  13.83 DC=  25.25 WC=  14.85)
            RSFS=   9.30       LSFS=  52.99

                 MODULE AREA= 34000.0
                 -----------

275.0  325.0  375.0
-------------------

            1.0
            ---
1.0  12.0   14.     12.4  30.3  25.3        65.9  22177.  65.23   2669.   7.85   9154.   26.92  0.0353
            (HB=   184.39 ML= 184.39 DA= 16.58  WA=  16.58 DB=  18.03 WB=  18.03 DC=  19.36 WC=  19.36)
            RSFS=  76.28       LSFS=  34.98

1.4  12.    14.      8.7  37.8  17.9        64.3  21375.  62.87   3282.   9.65   9343.   27.48  0.0373
            (HB=   155.84 ML= 218.17 DA= 16.58  WA=  16.58 DB=  18.03 WB=  18.03 DC=  19.36 WC=  19.36)
            RSFS=  47.73       LSFS=  68.77

1.7  12.0   15.      7.6  42.0  13.6        63.2  20846.  61.31   2668.   7.85  10487.   30.84  0.0387
            (HB=   141.42 ML= 240.42 DA= 16.58  WA=  16.58 DB=  18.03 WB=  18.03 DC=  19.36 WC=  19.36)
            RSFS=  30.31       LSFS=  88.01

            1.4
            ---
1.0  12.0   12.     12.3  34.1  26.7        73.1  24467.  71.96    896.   2.63   8637.   25.40  0.0304
            (HB=   184.39 ML= 184.39 DA= 19.62  WA=  14.02 DB=  21.33 WB=  15.24 DC=  22.91 WC=  16.37)
            RSFS=  63.17       LSFS=  14.21

1.4  12.0   12.     10.3  43.0  18.0        71.2  23519.  69.17   1656.   4.87   8825.   25.96  0.0322
            (HB=   155.84 ML= 218.17 DA= 19.62  WA=  14.02 DB=  21.33 WB=  15.24 DC=  22.91 WC=  16.37)
            RSFS=  34.52       LSFS=  47.99

1.7  12.0   15.      9.0  48.0  12.8        69.9  22892.  67.33   1150.   3.38   9958.   29.29  0.0335
            (HB=   141.42 ML= 240.42 DA= 19.62  WA=  14.02 DB=  21.33 WB=  15.24 DC=  22.91 WC=  16.37)
            RSFS=  17.10       LSFS=  67.23
```

```
                1.7
                ---
1.0   12.       12.0      13.6    30.3    27.1         76.9   25676.   75.52       29.      0.08     8296.   24.40     0.0279
                (CB=     184.39  ML= 184.39  DA=  21.62   WA=   12.72  DB=    23.51  WB=   13.83  DC=    25.25  WC=   14.85)
                RSFS=     54.37        LSFS=    0.53

1.4   12.0      12.0      11.3    46.1    17.4         74.8   24630.   72.44      886.      2.61     8484.   24.95     0.0297
                (CB=     155.84  ML= 218.17  DA=  21.62   WA=   12.72  DB=    23.51  WB=   13.83  DC=    25.25  WC=   14.85)
                RSFS=     25.82        LSFS=   34.31

1.7   12.0      15.0       9.9    51.7    11.8         73.4   23940.   70.41      450.      1.32     9611.   28.27     0.0309
                (CB=     141.42  ML= 240.42  DA=  21.62   WA=   12.72  DB=    23.51  WB=   13.83  DC=    25.25  WC=   14.85)
                RSFS=      8.40        LSFS=   53.55

                     MODULE AREA= 35000.0
                     -----------

275.0  325.0  375.0
-------------------

                1.0
                ---
1.0   12.0      12.0      10.6    30.9    26.0         67.4   22677.   64.79     2975.      8.50     9348.   26.71     0.0352
                (CB=     187.08  ML= 187.08  DA=  16.58   WA=   16.58  DB=    18.03  WB=   18.03  DC=    19.36  WC=   19.36)
                RSFS=     78.97        LSFS=   37.68

1.4   12.0      12.0       8.8    38.5    18.5         65.8   21863.   62.47     3598.     10.28     9539.   27.25     0.0372
                (CB=     158.11  ML= 221.36  DA=  16.58   WA=   16.58  DB=    18.03  WB=   18.03  DC=    19.36  WC=   19.36)
                RSFS=     50.10        LSFS=   71.95

1.7   12.0      15.0       7.7    42.0    14.1         64.7   21333.   60.95     2963.      8.47    10704.   30.58     0.0386
                (CB=     143.49  ML= 243.93  DA=  16.58   WA=   16.58  DB=    18.03  WB=   18.03  DC=    19.36  WC=   19.36)
                RSFS=     32.37        LSFS=   91.52

                1.4
                ---
1.0   12.0      12.0      12.5    34.8    27.5         74.8   25058.   71.60     1111.      3.17     8830.   25.23     0.0303
                (CB=     187.08  ML= 187.08  DA=  19.62   WA=   14.02  DB=    21.33  WB=   15.24  DC=    22.91  WC=   16.37)
                RSFS=     65.76        LSFS=   16.90

1.4   12.0      12.0      10.4    43.8    18.7         72.9   24096.   68.85     1883.      5.38     9022.   25.78     0.0322
                (CB=     158.11  ML= 221.36  DA=  19.62   WA=   14.02  DB=    21.33  WB=   15.24  DC=    22.91  WC=   16.37)
                RSFS=     36.79        LSFS=   51.17

1.7   12.0      15.0       9.2    48.9    13.5         71.6   23469.   67.05     1356.      3.87    10176.   29.07     0.0334
                (CB=     143.49  ML= 243.93  DA=  19.62   WA=   14.02  DB=    21.33  WB=   15.24  DC=    22.91  WC=   16.37)
                RSFS=     19.16        LSFS=   70.74

                1.7
                ---
1.0   12.0      12.0      13.8    37.1    28.0         78.8   26327.   75.22      184.      0.52     8490.   24.26     0.0278
                (CB=     187.08  ML= 187.08  DA=  21.62   WA=   12.72  DB=    23.51  WB=   13.83  DC=    25.25  WC=   14.85)
                RSFS=     57.76        LSFS=    3.22

1.4   12.0      12.0      11.5    47.0    18.2         76.7   25266.   72.19     1053.      3.01     8681.   24.80     0.0296
                (CB=     158.11  ML= 221.36  DA=  21.62   WA=   12.72  DB=    23.51  WB=   13.83  DC=    25.25  WC=   14.85)
                RSFS=     28.09        LSFS=   37.49

1.7   12.0      15.0      10.1    52.7    12.5         75.2   24575.   70.21      597.      1.71     9828.   28.08     0.0308
                (CB=     143.49  ML= 243.93  DA=  21.62   WA=   12.72  DB=    23.51  WB=   13.83  DC=    25.25  WC=   14.85)
                RSFS=     10.46        LSFS=   57.06

                     MODULE AREA= 36000.0
                     -----------

275.0  325.0  375.0
-------------------
```

ELECTRONICS COMPLEX SCHEME BY UNIVERSITY OF ROORKEE
FOR LAYOUT PLAN WITH DIFFERENT TYPES OF UNITS
* MODULE LEVEL ANALYSIS *

PLATE: 2A INFRASTRUCTURE COSTS

INFRASTRUCTURE COSTS ANALYSIS

```
R         CLAND                 CLD                C2        CW1(1)          CS          CD
                                           CWK(2)        CCS
```

NOTES

CLAND=COST OF LAND ACQUISITION
CLD=COST OF LAND DEVELOPMENT EXCLUDING COST OF LAND ACQUISITION
C2=COST OF ROAD
CW(1)=COST OF WATER SUPPLY OF GENERAL MODULE (CI PIPE)
CS=COST OF SEWERAGE OF GENERAL MODULE
CD=COST OF STORM WATER DRAINAGE
CWK(1)= COST OF WATER SUPPLY OF CORNER MODULE (CI PIPE)
CCS=COST OF SEWERAGE OF CORNER MODULE

MODULE AREA= 31000.0

```
275.0  325.0  375.0

             1.0

                        COST IN ABSOLUTE FIGURES =IN RUPEES
  1.000       0.6138E+05   0.150E+06 0.317E+06 0.251E+06 0.394E+06    0.6456E+05
                                               .2862E+06 .4401E+06

                           COST PER SALEABLE AREA= IN RUPEES
                       2.97        7.29       15.4       12.2       19.1       3.13
                                                 13.9       21.3

                        TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                                  60.03

                        PERCENTAGES OF SALEABLE COSTS
                                  17.09       25.58       20.27       31.85       5.212


                        COST IN ABSOLUTE FIGURES =IN RUPEES
  1.400       0.6138E+05   0.150E+06 0.323E+06 0.219E+06 0.416E+06    0.5859E+05
                                               .2524E+06 .4723E+06

                           COST PER SALEABLE AREA= IN RUPEES
                       3.09        7.57       16.3       11.0       20.9       2.95
                                                 12.7       23.8

                        TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                                  61.85

                        PERCENTAGES OF SALEABLE COSTS
                                  17.23       26.32       17.85       33.83       4.768
```

```
                       COST IN ABSOLUTE FIGURES =IN RUPEES
                      -----------------------------------
1.700    0.6138E+05      0.150E+06 0.333E+06 0.225E+06 0.425E+06    0.6042E+05
                                            .2616E+06 .4892E+06
                         COST PER SALEABLE AREA= IN RUPEES
                         *********************************
                     3.09       7.58       16.8      11.3     21.4      3.05
                                              13.2      24.7
                       TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                       ::::::::::::::::::::::::::::::::::::::::
                                 63.30
                       PERCENTAGES OF SALEABLE COSTS
                       =============================
                                16.86      26.55      17.91      33.86      4.811

              1.4
              ---
                       COST IN ABSOLUTE FIGURES =IN RUPEES
                      -----------------------------------
1.000    0.6138E+05      0.150E+06 0.298E+06 0.242E+06 0.423E+06    0.5483E+05
                                            .2764E+06 .4679E+06
                         COST PER SALEABLE AREA= IN RUPEES
                         *********************************
                     2.71       6.64       13.1      10.7     18.7      2.42
                                              12.2      20.7
                       TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                       ::::::::::::::::::::::::::::::::::::::::
                                 54.31
                       PERCENTAGES OF SALEABLE COSTS
                       =============================
                                17.22      24.21      19.68      34.44      4.459

                       COST IN ABSOLUTE FIGURES =IN RUPEES
                      -----------------------------------
1.400    0.6138E+05      0.150E+06 0.304E+06 0.213E+06 0.429E+06    0.5645E+05
                                            .2450E+06 .4853E+06
                         COST PER SALEABLE AREA= IN RUPEES
                         *********************************
                     2.82       6.92       14.0      9.78     19.8      2.60
                                              11.3      22.3
                       TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                       ::::::::::::::::::::::::::::::::::::::::
                                 55.87
                       PERCENTAGES OF SALEABLE COSTS
                       =============================
                                17.44      25.06      17.50      35.35      4.649

                       COST IN ABSOLUTE FIGURES =IN RUPEES
                      -----------------------------------
1.700    0.6138E+05      0.150E+06 0.314E+06 0.218E+06 0.437E+06    0.5827E+05
                                            .2542E+06 .5003E+06
                         COST PER SALEABLE AREA= IN RUPEES
                         *********************************
                     2.83       6.93       14.5      10.1     20.1      2.69
                                              11.7      23.1
                       TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                       ::::::::::::::::::::::::::::::::::::::::
                                 57.11
                       PERCENTAGES OF SALEABLE COSTS
                       =============================
                                17.09      25.36      17.60      35.25      4.702
```

```
                               COST IN ABSOLUTE FIGURES =IN RUPEES
1.400      0.6138E+05          0.150E+06 0.292E+06 0.208E+06 0.448E+06    0.5504E+05
                                                   .2401E+06 .5037E+06
                               COST PER SALEABLE AREA= IN RUPEES
                               *********************************
                           2.71       6.63      12.9      9.18      19.8      2.43
                                                10.6      22.2
                               TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                               :::::::::::::::::::::::::::::::::::::::
                                         53.60
                               PERCENTAGES OF SALEABLE COSTS
                               =============================
                                     17.43      24.01      17.13      36.90      4.531

                               COST IN ABSOLUTE FIGURES =IN RUPEES
1.700      0.6138E+05          0.150E+06 0.302E+06 0.214E+06 0.448E+06    0.5686E+05
                                                   .2493E+06 .5112E+06
                               COST PER SALEABLE AREA= IN RUPEES
                               *********************************
                           2.71       6.65      13.3      9.44      19.8      2.51
                                                11.0      22.6
                               TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                               :::::::::::::::::::::::::::::::::::::::
                                         54.45
                               PERCENTAGES OF SALEABLE COSTS
                               =============================
                                     17.19      24.48      17.34      36.37      4.616

                               MODULE AREA= 32000.0
                               -----------
275.0 325.0 375.0
-----------------
                 1.0
                 ---
                               COST IN ABSOLUTE FIGURES =IN RUPEES
1.000      0.6336E+05          0.155E+06 0.324E+06 0.256E+06 0.410E+06    0.6583E+05
                                                   .2916E+06 .4562E+06
                               COST PER SALEABLE AREA= IN RUPEES
                               *********************************
                           2.99       7.34      15.3      12.1      19.4      3.11
                                                13.8      21.6
                               TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                               :::::::::::::::::::::::::::::::::::::::
                                         60.22
                               PERCENTAGES OF SALEABLE COSTS
                               =============================
                                     17.15      25.46      20.07      32.15      5.167

                               COST IN ABSOLUTE FIGURES =IN RUPEES
1.400      0.6336E+05          0.155E+06 0.331E+06 0.223E+06 0.420E+06    0.5970E+05
                                                   .2569E+06 .4783E+06
                               COST PER SALEABLE AREA= IN RUPEES
                               *********************************
                           3.11       7.62      16.2      11.0      20.6      2.93
                                                12.6      23.5
                               TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                               :::::::::::::::::::::::::::::::::::::::
                                         61.50
```

ELECTRONICS COMPLEX SCHEME BY UNIVERSITY OF ROORKEE
FOR LAYOUT PLAN WITH DIFFERENT TYPES OF UNITS
* MODULE LEVEL ANALYSIS *

INFRASTRUCTURE COSTS ANALYSIS

PLATE:2B INFRASTRUCTURE COSTS(%)

CLAND	CLD	C2	CW1(1)	CS	CD

NOTES

CLAND=COST OF LAND ACQUISITION
CLD=COST OF LAND DEVELOPMENT EXCLUDING COST OF LAND ACQUISITION
C2=COST OF ROAD (METAL)
CW(1)=COST OF WATER SUPPLY OF GENERAL MODULE (CI PIPE)
CS=COST OF SEWERAGE OF GENERAL MODULE
CD=COST OF STORM WATER DRAINAGE

MODULE AREA= 31000.0

275.0 325.0 375.0

1.0

1.000 0.6138E+05

COST IN ABSOLUTE FIGURES =IN RUPEES
0.150E+06 0.317E+06 0.251E+06 0.394E+06 0.6456E+05

COST PER SALEABLE AREA= IN RUPEES
2.97 7.29 15.4 12.2 19.1 3.13

TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
60.03

PERCENTAGES OF SALEABLE COSTS
17.09 25.58 20.27 31.85 5.212

1.400 0.6138E+05

COST IN ABSOLUTE FIGURES =IN RUPEES
0.150E+06 0.323E+06 0.219E+06 0.416E+06 0.5859E+05

COST PER SALEABLE AREA= IN RUPEES
3.09 7.57 16.3 11.0 20.9 2.95

TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
61.85

PERCENTAGES OF SALEABLE COSTS
17.23 26.32 17.85 33.83 4.768

1.700 0.6138E+05

COST IN ABSOLUTE FIGURES =IN RUPEES
0.150E+06 0.333E+06 0.225E+06 0.425E+06 0.6042E+05

COST PER SALEABLE AREA= IN RUPEES
3.09 7.58 16.8 11.3 21.4 3.05

```
:::::::::::::::::::::::::::::::::::::::::::::
              63.30

PERCENTAGES OF SALEABLE COSTS
=============================
          16.86        26.55        17.91        33.86        4.811


      1.4
      ---

                        COST IN ABSOLUTE FIGURES =IN RUPEES
                        -----------------------------------
1.000      0.6138E+05     0.150E+06 0.298E+06 0.242E+06 0.423E+06     0.5483E+05
                          COST PER SALEABLE AREA= IN RUPEES
                          *********************************
                       2.71       6.64       13.1       10.7       18.7       2.42
                        TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                        :::::::::::::::::::::::::::::::::::::::::::::
                                      54.31
                        PERCENTAGES OF SALEABLE COSTS
                        =============================
                                  17.22        24.21        19.68        34.44        4.459


                        COST IN ABSOLUTE FIGURES =IN RUPEES
                        -----------------------------------
1.400      0.6138E+05     0.150E+06 0.304E+06 0.213E+06 0.429E+06     0.5645E+05
                          COST PER SALEABLE AREA= IN RUPEES
                          *********************************
                       2.82       6.92       14.0       9.78       19.8       2.60
                        TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                        :::::::::::::::::::::::::::::::::::::::::::::
                                      55.87
                        PERCENTAGES OF SALEABLE COSTS
                        =============================
                                  17.44        25.06        17.50        35.35        4.649


                        COST IN ABSOLUTE FIGURES =IN RUPEES
                        -----------------------------------
1.700      0.6138E+05     0.150E+06 0.314E+06 0.218E+06 0.437E+06     0.5827E+05
                          COST PER SALEABLE AREA= IN RUPEES
                          *********************************
                       2.83       6.93       14.5       10.1       20.1       2.69
                        TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                        :::::::::::::::::::::::::::::::::::::::::::::
                                      57.11
                        PERCENTAGES OF SALEABLE COSTS
                        =============================
                                  17.09        25.36        17.60        35.25        4.702


      1.7
      ---

                        COST IN ABSOLUTE FIGURES =IN RUPEES
                        -----------------------------------
1.400      0.6138E+05     0.150E+06 0.292E+06 0.208E+06 0.448E+06     0.5504E+05
                          COST PER SALEABLE AREA= IN RUPEES
                          *********************************
                       2.71       6.63       12.9       9.18       19.8       2.43
                        TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                        :::::::::::::::::::::::::::::::::::::::::::::
                                      53.60
                        PERCENTAGES OF SALEABLE COSTS
                        =============================
```

```
                          COST IN ABSOLUTE FIGURES =IN RUPEES
                          ------------------------------------
1.700      0.6138E+05       0.150E+06 0.307E+06 0.214E+06 0.448E+06    0.5686E+05
                            COST PER SALEABLE AREA= IN RUPEES
                            *********************************
                         2.71       6.65       13.3       9.44       19.8       2.51
                          TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                          ::::::::::::::::::::::::::::::::::::::::
                                     54.45
                          PERCENTAGES OF SALEABLE COSTS
                          =============================
                                 17.19       24.48       17.34       36.37       4.616

                         MODULE AREA= 32000.0
                         ------------

75.0  325.0  375.0
------------------

                1.0
                ---

                          COST IN ABSOLUTE FIGURES =IN RUPEES
                          ------------------------------------
1.000      0.6336E+05       0.155E+06 0.324E+06 0.256E+06 0.410E+06    0.6583E+05
                            COST PER SALEABLE AREA= IN RUPEES
                            *********************************
                         2.99       7.34       15.3       12.1       19.4       3.11
                          TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                          ::::::::::::::::::::::::::::::::::::::::
                                     60.22
                          PERCENTAGES OF SALEABLE COSTS
                          =============================
                                 17.15       25.46       20.07       32.15       5.167

                          COST IN ABSOLUTE FIGURES =IN RUPEES
                          ------------------------------------
1.400      0.6336E+05       0.155E+06 0.331E+06 0.223E+06 0.420E+06    0.5970E+05
                            COST PER SALEABLE AREA= IN RUPEES
                            *********************************
                         3.11       7.62       16.2       11.0       20.6       2.93
                          TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                          ::::::::::::::::::::::::::::::::::::::::
                                     61.50
                          PERCENTAGES OF SALEABLE COSTS
                          =============================
                                 17.44       26.42       17.82       33.55       4.764

                          COST IN ABSOLUTE FIGURES =IN RUPEES
                          ------------------------------------
1.700      0.6336E+05       0.155E+06 0.361E+06 0.227E+06 0.428E+06    0.6083E+05
                            COST PER SALEABLE AREA= IN RUPEES
                            *********************************
                         3.19       7.82       18.2       11.4       21.6       3.06
                          TOTAL COST=IN RS/SQ.M. OF SALEABLE AREA
                          ::::::::::::::::::::::::::::::::::::::::
                                     65.23
                          PERCENTAGES OF SALEABLE COSTS
                          =============================
                                 16.88       27.87       17.51       33.05       4.698
```

ELECTRONICS COMPLEX SCHEME BY UNIVERSITY OF ROORKEE

FOR LAYOUT PLAN WITH DIFFERENT TYPES OF UNITS

* MODULE LEVEL ANALYSIS *

(INFRASTRUCTURE COMPOMENTS-WATER SUPPLY AND STORM WATER DRAINAGE) PLATE:3 W/S & DRAINAGE DETAILS

R	WATER SUPPLY DW1	DW2	NWV1	NWV2	NWF	STORM WATER DRAINAGE D1	KD1	D2	KD2

NOTES

R =MODULE RATIO
DW1 =INTERNAL DIAMETER OF WATER PIPE SIZE=1
DW2 =INTERNAL DIAMETER OF WATER PIPE SIZE=2
NWV1 =NUMBER OF SLUICE VALVES OF SIZE=1
NWV2 =NUMBER OF SLUICE VALVES OF SIZE=2
NWF =NUMBER OF FIRE-HYDRANTS
D1 =SECTION FOR DRAIN SIZE=1(IN METRE*METRE)
KD1 =LONGITUDNAL SLOPE(1 IN) DRAIN SIZE=1
D2 =SECTION FOR DRAIN SIZE=2(IN METER * METER)
KD2 =LONGTUDINAL SLOPE (1 IN) DRAIN SIZE=2

MODULE AREA= 31000.0

275.0 325.0 375.0

R	DW1	DW2	NWV1	NWV2	NWF	D1	KD1	D2	KD2
1.0									
1.0	125.00	200.00	4	1	4	0.30 X 0.46	.00140	0.30 X 0.53	.00250
1.4	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.4									
1.0	125.00	200.00	4	1	4	0.23 X 0.46	.00200	0.30 X 0.53	.00250
1.4	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7									
1.4	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250

MODULE AREA= 32000.0

275.0 325.0 375.0

1.0	125.00	200.00	4	1	4	0.30 X 0.46	.00140	0.30 X 0.53	.00250
1.4	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.4									
1.0	125.00	200.00	4	1	4	0.23 X 0.46	.00200	0.30 X 0.53	.00250
1.4	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7									
1.4	125.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250

MODULE AREA= 33000.0

275.0 325.0 375.0

1.0									
1.0	125.00	200.00	4	1	4	0.30 X 0.46	.00167	0.30 X 0.53	.00250
1.4	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.4									
1.0	125.00	200.00	4	1	4	0.30 X 0.46	.00140	0.30 X 0.53	.00250
1.4	125.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7									
1.4	125.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250
1.7	125.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.53	.00250

MODULE AREA= 34000.0

275.0 325.0 375.0

1.0									
1.0	125.00	200.00	4	1	4	0.30 X 0.46	.00167	0.30 X 0.61	.00167
1.4	100.00	200.00	4	1	4	0.23 X 0.46	.00200	0.30 X 0.61	.00167
1.7	100.00	200.00	4	1	4	0.23 X 0.46	.00170	0.30 X 0.61	.00167

ELECTRONICS COMPLEX SCHEME BY UNIVERSITY OF ROORKEE
FOR LAYOUT PLAN WITH DIFFERENT TYPES OF UNITS
* MODULE LEVEL ANALYSIS *

PLATE:4 SEWERAGE NETWORK DETAILS

(INFRASTRUCTURE COMPONENTS-(SEWERAGE)

```
R       DS1     X1     DS2     X2     NSDC   X3    NSVS   X4    N1    X5    N2    X6    N3    X7    N4     X8    EN1    X9    EN2   X10   EN3   X11
 EN4     K1                   K2                                N11         N21               N31          N41          EN11               EN21         EN31           EN41
```

```
R          =MODULE RATIO
DS1        =INTERNAL DIA. OF SEWER PIPE SIZE-1
DS2        INTERNAL DIA. OF SEWER PIPE SIZE-2
NSDC       =NO. OF DROP CONNECTION
NSVS       =NO. OF VENT SHATS
N1,N2,N3,N4=TOTAL NO.OF MAN-HOLES  SIZES
                    1,2,3,4 RESPECTIVELY FOR GENERAL MODULES
EN1,EN2,EN3,EN4=TOTAL EXTRA DEPTHS FOR MAN-HOLE SIZES
                    1,2,3,4 RESPECTIVELY FOR GENERAL MODULES
X1 TO X11=    DEPTHS AT ENDS OF SEWER LINES SEGMENTS
                    L1 TO L11 RESPECTIVELY
K1 AND K2    =LONGITUDNAL SLOPES OF SEWER PIPES
                    SIZES 1 AND 2 RESPECTIVELY
N11,N21,N31 AND N41=TOTAL NO. OF MAN-HOLES OF SIZES
                    1,2,3 AND 4 RESPECTIVELY FOR CORNER MODULES
EN11,EN21,EN31,EN41=TOTAL EXRA DEPTHS FOR MAN-HOLES
                    SIZES 1,2,3,4 RESPECTIVELY FOR CORNER MODULES
```

MODULE AREA= 31000.0

275.0 325.0 375.0

1.0

```
1.   150.       300.       1.0  2.0   9.02        7.46        6.63        6.69              2.45        2.61              4.12
 12.3        2.11       1.28      2.83     1.57        1.57        1.13        2.02      2.54      3.42      2.43      2.11
0.1000000E-01   0.4000000E-02              11.3        9.75        6.63        6.69       3.13      3.31      4.12      12.3

1.4  150.       300.       1.0  2.0   11.0        10.1        6.06        9.12              2.80        3.78              3.59
 11.0        2.40       1.28      2.87     1.32        1.32        1.13        1.78      2.59      3.56      2.19      2.40
0.1000000E-01   0.4000000E-02              13.2        12.6        6.87        9.12       3.46      4.70      3.64      11.0

1.7  150.       300.       1.0  2.0   10.7        9.65        5.47        10.6              2.58        3.44              2.99
 9.73        2.59       1.28      2.94     1.20        1.20        1.13        1.65      2.66      3.70      2.06      2.59
0.1000000E-01   0.4000000E-02              12.8        12.1        6.95        10.6       3.22      4.35      3.24      9.73
```

1.4

```
1.   150.       300.       1.0  2.0   13.0        10.6        9.38        7.81              3.53        3.65              6.02
 37.6        2.05       1.34      2.65     1.45        1.45        1.16        1.97      2.33      3.25      2.43      2.05
0.1000000E-01   0.4000000E-02              15.6        12.9        9.38        7.81       4.32      4.30      6.02      37.6

1.4  150.       300.       1.0  2.0   12.5        11.9        8.67        10.7              3.07        4.43              5.62
 21.8        2.34       1.34      2.69     1.20        1.20        1.16        1.72      2.38      3.40      2.19      2.34
0.1000000E-01   0.4000000E-02              15.0        14.7        9.36        10.7       3.83      5.50      5.65      21.8

1.7  150.       300.       1.0  2.0   12.1        11.3        8.09        12.5              2.88        4.02              5.12
 16.5        2.53       1.34      2.76     1.08        1.08        1.16        1.60      2.45      3.53      2.06      2.53
```

/PL.4 CONTI
170

```
0.1000000 -01  0.4000000E-02          14.6      14.1      9.56      12.5      3.63      5.07      5.33      16.5

              1.7
              ---
1.4  150.        300.     1.0  2.0     13.4      13.1      10.6      11.7                3.29                4.84                6.96
  43.6       2.30    1.38       2.58       1.12      1.12      1.18      1.69      2.24      3.28      2.19      2.30
 0.1000000 -01  0.4000000E-02                 16.2      16.1      11.2      11.7      4.11      6.00      6.97      43.6

1.7  150.        300.     1.0  2.0     13.0      12.4      10.0      13.7                3.12                4.41                6.55
  25.8       2.49    1.38       2.64       .999      .999      1.18      1.56      2.31      3.42      2.06      2.49
 0.1000000 -01  0.4000000E-02                 15.7      15.5      11.4      13.7      3.93      5.55      6.72      25.8

                   MODULE AREA= 32000.0
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275.0  325.0  375.0
-------------------
              1.0
              ---
1.   150.        300.     1.0  2.0     12.0      10.4      6.08      6.77                3.34                3.44                3.71
  10.2       2.13    1.28       2.88       1.59      1.59      1.13      2.05      2.60      3.48      2.46      2.13
 0.1000000 -01  0.4000000E-02                 14.2      12.8      6.08      6.77      4.02      4.19      3.71      10.2

1.4  150.        300.     1.0  2.0     11.1      10.2      5.57      9.24                2.84                3.82                3.13
  9.70       2.43    1.28       2.92       1.34      1.34      1.13      1.80      2.64      3.63      2.21      2.43
 0.1000000 -01  0.4000000E-02                 13.2      12.6      6.48      9.24      3.49      4.74      3.21      9.70

1.7  150.        300.     1.0  2.0     10.6      9.60      5.32      10.8                2.56                3.43                2.87
  9.49       2.61    1.28       2.95       1.19      1.19      1.13      1.65      2.67      3.72      2.07      2.61
 0.1000000 -01  0.4000000E-02                 12.8      12.0      6.85      10.8      3.19      4.32      3.15      9.49

              1.4
              ---
1.   150.        300.     1.0  2.0     13.1      10.6      8.80      7.90                3.59                3.66                5.66
  24.2       2.07    1.34       2.70       1.47      1.47      1.16      1.99      2.39      3.31      2.46      2.07
 0.1000000 -01  0.4000000E-02                 15.7      13.0      8.80      7.90      4.37      4.38      5.66      24.2

1.4  150.        300.     1.0  2.0     12.5      11.9      8.14      10.8                3.11                4.48                5.21
  17.6       2.37    1.34       2.74       1.22      1.22      1.16      1.74      2.43      3.46      2.21      2.37
 0.1000000 -01  0.4000000E-02                 15.0      14.8      8.95      10.8      3.86      5.54      5.25      17.6

1.7  150.        300.     1.0  2.0     12.1      11.3      7.52      12.6                2.90                4.06                4.66
  14.3       2.56    1.34       2.81       1.10      1.10      1.16      1.62      2.50      3.59      2.08      2.56
 0.1000000 -01  0.4000000E-02                 14.6      14.1      9.12      12.6      3.65      5.10      4.91      14.3

              1.7
              ---
1.4  150.        300.     1.0  2.0     13.5      13.1      10.0      11.9                3.32                4.92                6.58
  30.3       2.33    1.38       2.63       1.14      1.14      1.18      1.71      2.29      3.35      2.21      2.33
 0.1000000 -01  0.4000000E-02                 16.2      16.2      10.7      11.9      4.14      6.08      6.61      30.3

1.7  150.        300.     1.0  2.0     13.0      12.4      9.41      13.9                3.14                4.45                6.12
  21.1       2.52    1.38       2.70       1.02      1.02      1.18      1.58      2.36      3.48      2.08      2.52
 0.1000000 -01  0.4000000E-02                 15.7      15.5      11.0      13.9      3.95      5.59      6.34      21.1

                   MODULE AREA= 33000.0
                   ------------
275.0  325.0  375.0
-------------------
              1.0
              ---
1.   150.        300.     1.0  2.0     11.9      10.7      5.53      6.84                3.32                3.53                3.28
  8.77       2.16    1.28       2.93       1.62      1.62      1.13      2.07      2.65      3.54      2.48      2.16
 0.1000000 -01  0.4000000E-02                 14.2      13.1      5.53      6.84      3.99      4.34      3.28      8.77

1.4  150.        300.     1.0  2.0     11.1      10.2      5.08      9.35                2.88                3.86                2.65
  8.72       2.46    1.28       2.97       1.36      1.36      1.13      1.82      2.69      3.69      2.23      2.46
 0.1000000 -01  0.4000000E-02                 13.3      12.6      6.10      9.35      3.53      4.78      2.76      8.72
```

[illegible] OF ROORKEE

FOR LAYOUT PLAN WITH DIFFERENT TYPES OF UNITS

* MODULE LEVEL ANALYSIS *

(LENGTHS OF PIPES AND ROADS)

PLATE:5 LENGTH OF PIPE, ROAD & DRAINS

(LENGTH IN METRES)

R	ROADS LR1	LR2	WATER SUPPLY LWP1 / LWPC1	LWP2 / LWPC2	SEWERAGE LSP1	LSP2 / LSPC1	LD1 / LSPC2	DRAINAGE LD2

NOTES

R =MODULE RATIO
LR1 =LENGTH OF S1 ROAD
LR2 =LENGTH OF S2 ROAD
LWP1 =LENGTH OF WATER PIPE SIZE-1 FOR GENERAL MODULE
LWP2 =LENGTH OF WATER PIPE SIZE-2 FOR GENERAL MODULE
LSP1 =LENGTH OF SEWER PIPE SIZE-1 FOR GENERAL MODULE
LSP2= LENGTH OF SEWER PIPE-2 FOR GENERAL MODULE
LD1 =LENGTH OF DRAIN SIZE-1
LD2 =LENGTH OF DRAIN SIZE-2
LWPC1 =LENGTH OF WATER PIPE SIZE-1 FOR CORNER MODULE
LWPC2 =LENGTH WATER PIPE SIZE-2 FOR CORNER MODULE
LSPC1 =LENGTH OF SEWER PIPE SIZE-1 FOR CORNER MODULE
LSPC2 =LENGTH OF SEWER PIPE SIZE-2 FOR CORNER MODULE

MODULE AREA= 31000.0

275.0 325.0 375.0

1.0

R	LR1	LR2	LWP1 / LWPC1	LWP2 / LWPC2	LSP1	LSP2 / LSPC1	LD1 / LSPC2	LD2
1.	392.15	320.77	720.24 876.94	198.76 198.76	708.24 842.36	198.76 198.76	574.22	198.76
1.4	402.14	325.77	675.70 864.66	231.02 231.02	663.70 830.08	231.02 231.02	556.95	231.02
1.7	417.09	333.24	663.11 873.31	252.26 252.26	651.11 838.73	252.26 252.26	558.13	252.26

1.4

R	LR1	LR2	LWP1 / LWPC1	LWP2 / LWPC2	LSP1	LSP2 / LSPC1	LD1 / LSPC2	LD2
1.	352.56	317.22	674.03 827.19	201.82 201.82	662.03 789.57	201.82 201.82	534.63	201.82
1.4	362.55	322.22	629.50 814.91	234.08 234.08	617.50 777.29	234.08 234.08	517.35	234.08
1.7	377.49	329.69	616.91 823.56	255.31 255.31	604.91 785.94	255.31 255.31	518.53	255.31

1.7

1.4	336.18	319.88	599.08 782.16	236.09 236.09	587.08 742.53	236.09 236.09	491.28	236.09
1.7	351.42	327.35	586.49 790.80	257.33 257.33	574.49 751.18	257.33 257.33	492.46	257.33

MODULE AREA= 32000.0

275.0 325.0 375.0

1.0

1.0	403.42	326.41	737.14 896.66	201.58 201.58	725.14 862.08	201.58 201.58	588.31	201.58
1.4	413.57	331.48	691.89 884.18	234.35 234.35	679.89 849.60	234.35 234.35	570.76	234.35
1.7	416.76	336.07	665.60 879.47	255.93 255.93	653.60 843.39	255.93 255.93	559.95	255.93

1.4

1.0	363.83	322.86	690.94 846.91	204.63 204.63	678.94 809.29	204.63 204.63	548.71	204.63
1.4	373.98	327.93	645.69 834.43	237.41 237.41	633.69 796.81	237.41 237.41	531.16	237.41
1.7	389.16	335.52	632.90 843.22	258.99 258.99	620.90 805.60	258.99 258.99	532.36	258.99

1.7

1.4	347.91	325.60	615.27 801.68	239.42 239.42	603.27 762.06	239.42 239.42	505.09	239.42
1.7	363.09	333.19	602.48 810.47	261.00 261.00	590.48 770.84	261.00 261.00	506.29	261.00

MODULE AREA= 33000.0

275.0 325.0 375.0

1.0

1.0	414.52	331.95	753.78 916.07	204.35 204.35	741.78 881.49	204.35 204.35	602.18	204.35
1.4	424.83	337.11	707.83 903.41	237.63 237.63	695.83 868.82	237.63 237.63	584.36	237.63
1.7	428.24	341.82	681.34 898.83	259.54 259.54	669.34 862.75	259.54 259.54	573.57	259.54

1.4

1.0	374.92	328.41	707.58 866.32	207.41 207.41	695.58 828.70	207.41 207.41	562.58	207.41
1.4	385.23	333.56	661.63 853.66	240.69 240.69	649.63 816.03	240.69 240.69	544.76	240.69
1.7	35	338.27	635.14	262.60	623.14	262.60	533.97	262.60