# STUDY OF WASTE MANAGEMENT ISSUES IN INDIAN HEALTHCARE SUPPLY CHAIN

**Ph.D. THESIS**

***by***

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**A THESIS**

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***by***

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# INDIAN INSTITUTE OF TECHNOLOGY ROORKEE
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## CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the thesis entitled **"STUDY OF WASTE MANAGEMENT ISSUES IN INDIAN HEALTHCARE SUPPLY CHAIN"** in partial fulfilment of the requirements for the award of the Degree of Doctor of Philosophy and submitted in the Department of Management Studies of the Indian Institute of Technology Roorkee, Roorkee is an authentic record of my own work carried out during a period of July 2013 to February 2016 under the supervision of Dr. A. Ramesh, Assistant Professor, Department of Management Studies, Indian Institute of Technology Roorkee, Roorkee.

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

(Vikas Thakur)

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

Dated:

(A. Ramesh)
Supervisor

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# ABSTRACT

Healthcare Waste Management (HCWM) is now the key focus in the national health polices in many of the countries. The hazardous Medical Waste (MW) has become the big threat for the Government and Healthcare Facilities (HCFs), as it adversely affects the public and environment health. With increase in population and growing HCFs, the quantity of per capita Healthcare Waste (HCW) being generated is escalating day by day. HCW today poses grave challenges to hospitals and medical institutions, especially in developing nations, where MW is very often mixed with municipal waste, threatening the health and safety of the handling staff, general public and the environment. Due to these reasons, World Health Organization (WHO) and researchers over the past few years, have turned their attention to find effective ways to manage HCW. Although, tremendous efforts have been made by the environmental regulatory authority and waste handlers, but still they have not been successful to protect the environment from the health hazards caused by HCW. In countries like India, where there is huge population burden and also the resources are limited, the HCWM system is full of challenges and threats. Hence, there is a need to resolve the problems related to HCWM in India and provide the recommendations to the Government and other HCFs in order to improve the existing ineffective and inefficient HCWM strategies and standards.

In this research work, a structured literature review has been conducted of all the articles published in eight related journals from 2005 to 2014, in order to identify the gaps in HCWM system in India. Also, the field surveys and brainstorming sessions were held with the experts, in order to finalize the objectives of the study. A model based on grey theory approach and Analytic Hierarchy Process (AHP) suggested that the HCFs in Uttarakhand, should go for outsourcing in order to lower the operational costs and meeting the environmental obligations. Another model based on, Analytic

Network Process (ANP) and TOPSIS under grey environment had been developed to select the outsourcing partner. Furthermore, the generation rates and patterns of MW were analyzed from the sample collected from various HCFs. The barriers for implementation of HCWM system were assessed using Interpretive Structural Modeling (ISM) and Fuzzy-MICMAC analysis. This resulted into defining the key areas which must be focused in order to implement the effective and robust HCWM system in India. Subsequently, some hypotheses were formulated and questionnaire survey was done to collect the perception of the respondents on various issues of HCWM system.

The main contributions of this research may be summarized as follows:

- A model has been developed based on grey theory and AHP to select the best HCWD strategy.
- A framework based on ANP and TOPSIS under grey environment has been developed to select the best outsourcing partner for disposing the HCW.
- The generation patterns and composition of MW have been analyzed through MLR and ANN modeling techniques.
- The barriers interrelationships have been analyzed through ISM methodology.
- The barriers of implementing HCWM system in India have been classified into four groups using Fuzzy-MICMAC analysis.
- The hypotheses related to: importance, objectives, enablers and barriers of implementing HCWM system in India have been tested empirically.

**Keywords:** Healthcare Waste, Medical Waste, Healthcare Waste Management, Analytic Hierarchy Process, Analytic Network Process, TOPSIS, Interpretive Structural Modeling.

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| | |
|---|---|
| AIDS | Acquired Immune Deficiency Syndrome |
| ANOVA | Analysis of Variance |
| AHP | Analytic Hierarchy Process |
| ANP | Analytic Network Process |
| ANN | Artificial Neural Network |
| BDRM | Binary Direct Relationship Matrix |
| BMW | Bio-medical Waste |
| BMWM | Biomedical Waste Management |
| CPCB | Central Pollution Control Board |
| CBWTF | Common Bio-medical Waste Treatment Facility |
| CI | Consistency Index |
| CR | Consistency Ratio |
| DEA | Data Envelopment Analysis |
| MD | Doctor of Medicine |
| ERP | Enterprise Resource Planning |
| FDRM | Fuzzy Direct Relationship Matrix |
| FIRM | Fuzzy Indirect Relationship Matrix |
| GIS | Graphic Information System |
| HCF | Health Care Facility |
| HCW | Health Care Waste |
| HCWD | Health Care Waste Disposal |
| HCWM | Health Care Waste Management |
| ISM | Interpretive Structural Modeling |
| JIT | Just-In-Time |
| MICMAC | Matrice d'Impacts Croisés - Multiplication Appliquée á un Classement |
| MATLAB | Matrix Laboratory |
| MAE | Mean Absolute Error |
| MSE | Mean Squared Error |

| | |
|---|---|
| MPCC | Medical Pollution Control Committee |
| MW | Medical Waste |
| MWM | Medical Waste Management |
| MoEF | Ministry of Environment, Forest and Climate Change |
| MCDM | Multi-Criteria Decision-Making |
| MLR | Multiple Linear Regression |
| MSW | Municipal Solid Waste |
| PROMETHEE | Preference Ranking Organization Method for Enrichment Evaluations |
| PPP | Public-Private Partnership |
| R & D | Research and Development |
| RMSE | Root Mean Squared Error |
| SAW | Simple Additive Weight |
| SPCB | State Pollution Control Boards |
| SPSS | Statistical Package for Social Sciences |
| SSIM | Structural Self-Interaction Matrix |
| SCM | Supply Chain Management |
| TOPSIS | Technique for Order of Preference by Similarity to Ideal Solution |
| TQM | Total Quality Management |
| WHO | World Health Organization |

# CHAPTER 1
# INTRODUCTION

## 1.1 INTRODUCTION

The concern for Medical Waste Management (MWM) is increasing rapidly due to awareness among the hospital administration and people about the harm caused by the infectious waste. With increase in population and growing Healthcare Facilities (HCFs), the quantity of per capita Healthcare Waste (HCW) being generated is escalating day by day. HCFs and other medical institutions are finding HCW as big threat to the environment and public. Hence, researchers are now focusing more on Healthcare Waste Management (HCWM) and handling practices (Askarian et al., 2004; Talebbeydokhti and Kherandmand, 2006). World Health Organization (WHO) has defined HCW as the byproduct generated while delivering the healthcare services and recommended that it should be treated as a special waste (Rushbrook et al., 2000). Government of India has also defined the HCW under Bio Medical Waste (Management & Handling) Rule, in 1998 as: any waste, which is generated during the diagnosis, treatment, or immunization of human beings or animal, or in research activities pertaining to or in the production or testing of biological and including prescribed categories.

Irrespective of the WHO guidelines and local Government rules and regulations, the HCW is poorly handled and managed by the HCFs and Common Biomedical Waste Treatment Facilities (CBWTFs). Hence, it is very important to study the current HCWM practices and make the policies and guidelines to improve the existing situation in order to ensure the public and environmental health safety.

## 1.2 HEALTHCARE WASTE (HCW)

Generally, the hospital waste includes all the wastes generated by HCFs and other minor & scattered sources (home dialysis, self-insulin, recuperative care etc.), that may be infectious or non-infectious waste, but the Medical Waste (MW) is particularly the sub-category, that represent the potentially dangerous waste, such as sharps and waste with infectious, hazardous, radioactive, and genotoxic properties that endanger human health and environment that is produced from the hospitals (Klangsin and Harding, 1998; Levendis et al., 2001). Table 1.1 shows various studies focused on defining the HCW.

**Table 1.1:** Definitions of HCW

| Sl. No. | Definition | Sources |
|---|---|---|
| 1. | HCW is the by-product generated in the hospitals and consists of sharps, blood, body parts, chemicals, pharmaceuticals, medical devices and radioactive materials. | WHO (1999) |
| 2. | HCW is generated from HCFs and is composed of two categories: general waste and MW. | Phengxay et al. (2005) |
| 3. | HCW consists of two categories: infectious waste (articles such as urine containers, body fluids, excreta, human tissue, sharp-edged and glass pieces) and non-infectious waste. | Gupta and Boojh (2006) |
| 4. | Classified the HCW into five categories: recyclable waste (black bags), common waste (blue bags), infectious regulated MW (red bag), hazardous waste and low-level radioactive waste. | Alagoz and Kocasoy (2007) |
| 5. | HCW includes all the waste materials generated from the treatment, diagnosis, or immunization of humans or animals at hospitals, veterinary and medical centers. | Mbongwe et al. (2008) |
| 6. | HCW composed of solid waste and waste water. Healthcare solid waste further consists of non-risk (75-90 %) and hazardous waste (10-25 %). | Mesdaghinia et al. (2009) |
| 7. | Classified HCW as follows: sharps, infectious waste, genotoxic waste, general waste, heavy metals, pathological waste, chemical waste, pharmaceutical waste, pressurized containers, and radioactive waste. | Al-Khatib et al. (2009) |
| 8. | Classified the waste generated from HCFs into following categories: MW, municipal waste, recyclables, sharps, liquid waste, hazardous waste. | Eker and Bilgili (2011) |
| 9. | Classified HCW into five categories: infectious, pathological, medical, pharmacy and chemical. | Longe (2012), Chen et al. (2013) |
| 10. | HCW comprises of general waste (plastics, textiles, glass, metals, paper) and infectious waste (sharps, pathological, infectious, absorbent cotton, discarded medical plastic). | Eleyan et al. (2013) |

| | | |
|---|---|---|
| 11. | HCW is composed of: general, infectious, sharps, pharmaceutical, pathological, and radioactive. | Tesfahun et al. (2014) |

### 1.2.1 HCW Classification

HCW can be classified as shown in Figure 1.1.

#### 1.2.1.1 Communal waste

It is general waste which is not hazardous or infectious to human beings, for example: packaging material and boxes, plastic and glass bottles, paper, wrappers etc. (Prüss et al., 1999; WHO, 1999; Jang et al., 2006; Alagoz and Kocasoy, 2007).

#### 1.2.1.2 Biomedical waste (BMW)

a) **Infectious waste:** This category of waste basically consists of pathogens, which may cause disease to the persons in contact, for example: waste from surgery, waste from infectious patients and equipment in contact, tissues etc. (Prüss et al., 1999; Alagoz and Kocasoy, 2007).

b) **Anatomical and pathological:** It mainly consists of body parts, tissue, organ, blood and body fluid, fetuses (Prüss et al., 1999; Jang et al., 2006).

c) **Sharps:** It consists of needles, knives, blades, scalpels etc. (Prüss et al., 1999).

d) **Pharmaceutical:** This category consists of medicines which are being not consumed timely and are no longer of use (Prüss et al., 1999).

e) **Genotoxic waste:** Waste of genotoxic chemicals and drugs, which are basically used in cancer therapy (Prüss et al., 1999).

f) **Chemical waste:** Wastes consisting of laboratory substances, film developer, solvents, expired or no longer needed disinfectants etc. (Prüss et al., 1999).

g) **Heavy-metal waste:** Wastes which consists of heavy metals like: blood pressure gauges, batteries, broken thermometer (Prüss et al., 1999).

h) **Pressurized containers:** Gas cylinders, aerosol cans, gas cartridges (Prüss et al., 1999).

i) **Radioactive waste:** This contains the radioactive substances like: wastes from patients treated with unsealed radio nuclides, unused liquids from radiotherapy (Prüss et al., 1999).

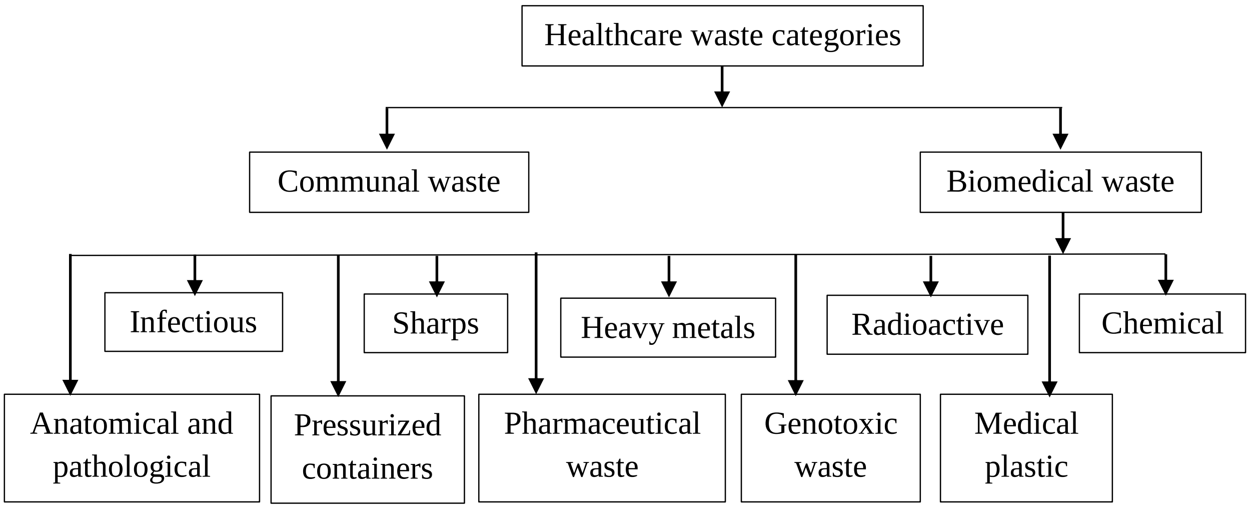


**Figure 1.1:** Classification of HCW

(Source: Prüss et al., 1999; WHO, 1999; Jang et al., 2006; Alagoz and Kocasoy, 2007)

### 1.2.2 HCW Composition

In order to find out the proper waste disposal techniques and methods, it is important to estimate the amount of generation of BMW and the composition of the waste. Figure 1.2 represents the composition of HCW in terms of volume of different components. As per the report of Central Pollution Control Board (CPCB) of India, 4,057 ton of HCW is generated by the registered HCFs per day, out of which 2,919 ton of waste is treated, while the rest goes without any treatment to the environment. Around 0.5 to 2 kg waste is generated per bed per day in India, and major part of this waste is composed of 'general waste' (70-80%), followed by 'infectious waste' (15-20%), 'pathological waste' (5-10%), and 'chemical and sharp wastes' (0.5-1%) (Katoch and Kumar, 2008).

As per the WHO survey, around 75-90% of the HCW is general non-hazardous waste and it comes from administrative activities, kitchen and housekeeping functions. The rest 10-25% of the waste generated from HCFs is hazardous waste and posing serious threats to the hospital environment and public health. Figure 1.3 is showing the latest results of WHO survey conducted at various HCFs in 2014.

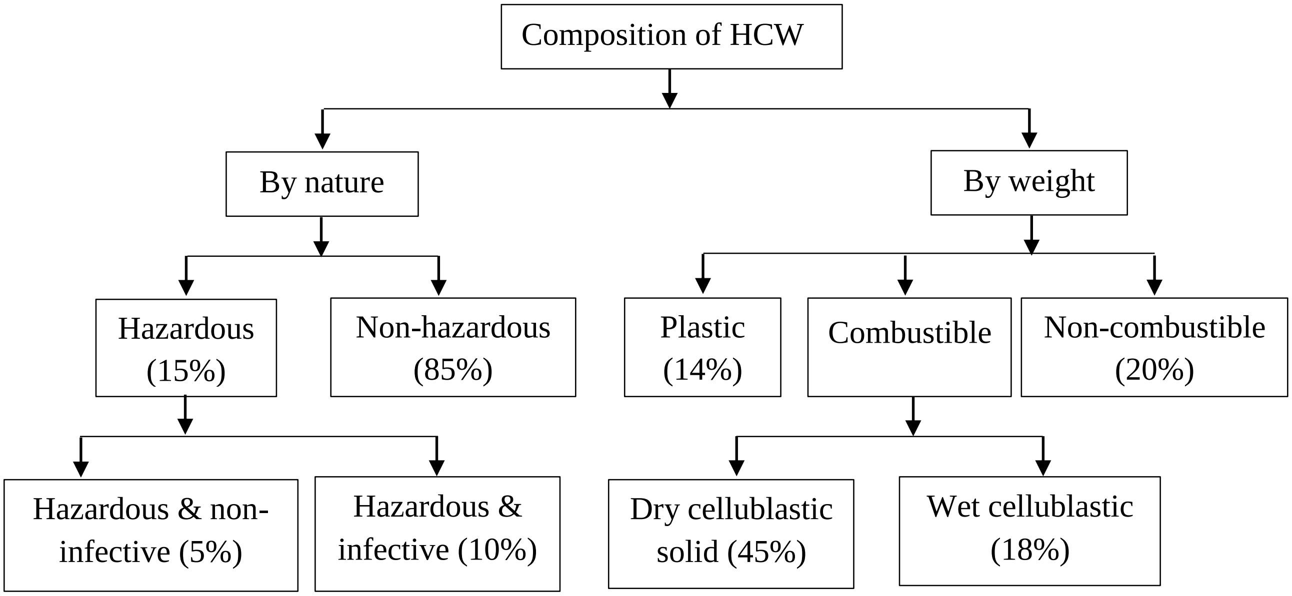


**Figure 1.2:** Composition of HCW

(Source: Chandra, 1999; WHO, 1999)

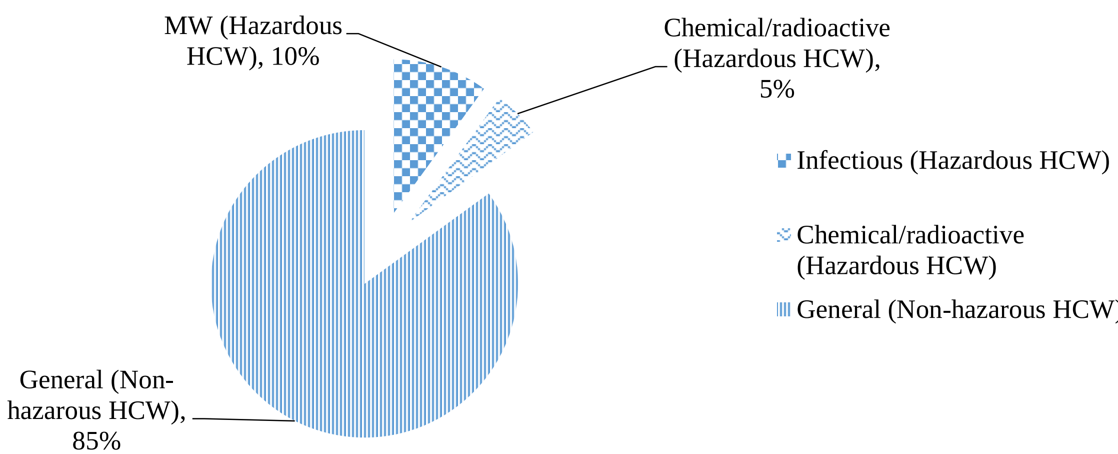


**Figure 1.3:** HCW Composition Generated from HCFs

(Adapted from WHO, 2014)

## 1.3 SOURCES OF HCW

The main sources of HCW include human and animal hospitals, medical research centers and colleges, laboratories etc. (Soares et al., 2013). As per the Gazette of India, 1998 the sources of BMW can be classified into two main categories: primary sources and other sources as shown in Figure 1.4. BMWs are mainly generated from wards, delivery rooms, emergency, operating theatres, laboratories, research centers, medical colleges, pharmaceutical & chemical stores etc. To ensure the implementation of strong HCWM system it is necessary to identify the point of generation of waste and then to implement the segregation practices at the source itself. To minimize the waste, it is important to identify and monitor the source of waste generation.

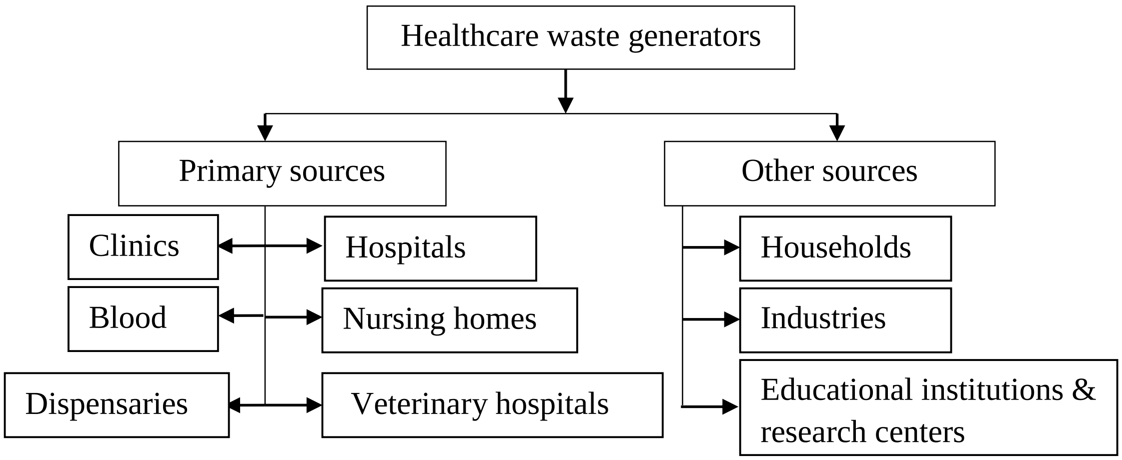


**Figure 1.4:** Sources of HCW

(Source: The Gazette of India, 1998)

## 1.4 RISKS ASSOCIATED WITH HCW

In order to ensure the implementation of proper HCWM system, it is important to identify the risk associated with the HCW and the persons, who may get infected. The general waste (75-85%), which is major part of the total HCW is not dangerous and can be mixed and treated with the other municipal waste. But, the small portion of the HCW (15-25%) is very hazardous in nature and should be treated as the special waste in order to protect the public and environmental health risks. As per WHO (2014), the main reasons for hazardous nature of the HCW are:

- Presence of radioactive material.
- Presence of hazardous chemicals and pharmaceuticals.
- Presence of infectious agents.
- Presence of infectious sharps.
- Composition of genotoxic elements.

The persons like: who are at generation points or handling the HCW are in the close proximity with infectious HCW and may get exposed to the hazardous HCW. The persons may get infected due to careless handling or lack of awareness among the waste handling workers about the harm may be caused by the hazardous HCW. The main community that may get infected includes (WHO, Basel Convention & UNEP 2005):

- Patients being treated at HCFs.
- Doctors and attending staff.
- Visitors to HCFs.
- Waste handling workers at HCFs.
- Waste handling staff and workers at CBWTF.
- Hospital premises and surrounding environment.

## 1.5 HEALTHCARE WASTE MANAGEMENT (HCWM)

The tremendous increase in the growth and industrial progress has resulted with huge amount of hazardous waste, which is being generated as the byproduct while delivering the products and services to the society. Similarly, in the healthcare industry, the service providers are competing with each other for providing better and advanced services to the increasing population and hence, are leading to the generation of large amount of infectious waste. Therefore, to establish effective and efficient hazardous waste management system is matter of international concern. World Health Organization (WHO) has also laid down robust regulatory waste management regimes to ensure the environment safety and sustainability. As per WHO, Basel Convention & UNEP (2005), a proper HCWM system should focus on the following objectives: establish legal and regulatory framework; rationalize HCWM practices with-in the HCFs; develop operational resources specifically to HCWM system; developing capacity and conduct training programs; setting up proper monitoring plan and minimize pollution while treating the waste. WHO also advocated that it's the responsibility of the producer to ensure the proper waste management which is produced while selling their services or products. WHO (2007) also stressed that HCWM plan should be implemented at national, regional and local level in order to achieve safe and sustainable implementation of HCWM system.

As per Moreira and Günther (2012), HCWM plan relates to recording all the activities done to manage HCW and analyzing the characteristics and risks associated with each type of waste generated in order to protect environment and public health. A strong HCWM system depends on robust legislation and planning, dedicated operational resources and trained staff, hospital waste management experts' commitment (WHO, 2005). Researchers and authors across the World have given different aspects to improve HCWM system: an internal management system and training program for waste handling staff and workers (DaSilva et al., 2005; Abdulla et al., 2008); national regulatory framework (Askarian et al., 2004; Shinee et al., 2008); estimating the amount and type of HCW generated (Tsakona et al., 2007) and selecting proper disposal techniques (Lee et al., 2004; Diaz et al., 2005). As HCWM is the evolving field, hence, proper plans and policies should be laid down for controlling the waste management process.

## 1.6 REGULATORY REGIME FOR BIOMEDICAL WASTE MANAGEMENT (BMWM) AND HANDLING

The Government regulatory authority has very important role to enforce the public and private HCFs to implement the HCWM policy. The Government guidelines will act as the blueprint for the State Pollution Control Boards and HCFs to make the decisions and allocate the operational resources to establish the HCWM system. Adopting international conventions and considering the problems and needs in the current system, the national policy should be framed in order to govern the public health and environment sustainability. There are so many international policies, guidelines and documents available for the reference, developed by: World Health Organization, United Nations Environment Program-Secretariat of the Basel Convention and several Non-Governmental Organizations (NGOs) (WHO, 2014). The WHO policy document (safe health-care waste management), suggested that individual nation should make the self-assessment before selecting the HCWM policy and laid down the core guidelines for attaining safe and sustainable HCWM system (WHO, 2007). The International Solid Waste Association (ISWA) advocated that segregation, storage, transportation, treatment and final disposal of the HCW are the main activities which need to be focused for sustainable development.

In India, the National Environment Policy, 2006 has laid down various controlling measures for protecting the environment and stressed on the collection and treatment of recycling waste and devising measures for environmentally safe disposal of final residual. In India, the waste management policies are governed by the sub-ordinate legislation and the Ministry of Environment, Forest and Climate Change (MoEF), Government of India in conjunct with State Pollution Control Boards of different states (SPCB) administer the gamut of waste management regulations.

### 1.6.1 BMW (Management & Handling) Rules, 1998

BMW rules help in regulating the infectious waste disposal process and provide the necessary framework for the effective disposal and treatment of HCW. As per BMW (Management & Handling) Rules, 1998 all the persons and organizations who deal with generation, collection, storage, transportation, treatment and disposal of BMW come under these rules. Some of the highlights of the guidelines are:

- Proper disposal of BMW is the responsibility of every organization, which generates it, like: nursing homes, dental clinics, hospitals, dispensary, veterinary institution, pathology, blood banks etc.
- BMW should be treated and disposed as per Schedule I (shown in Appendix I) and in compliance with standards listed in Schedule V (shown in Appendix V).
- Every producer of BMW should set up the treatment plant or should transport the BMW to Government approved CBWTF.
- BMW should not be mixed with each other and should be segregated as per Schedule II **(**shown in Appendix II**)** in different color coded bags and bags should be labeled as per Schedule III **(**shown in Appendix III**)**.
- The container carrying the BMW from the generation point to the treatment facility should be labeled with the information given in Schedule III (shown in Appendix III) and IV (shown in Appendix IV) and vehicle carrying the BMW should be authorized by the competent Government authority.
- The BMW should not be kept within the premises of HCF, more than 48 hours without any treatment.
- The non-hazardous general HCW and treated BMW, should be dumped at the municipal dump sites as defined in BMW (Handling & Management) Rules (Second Amendments), 2000.
- Each operator is supposed to send the complete report about the different types of wastes generated and treated, by 31 January of every year to the SPCBs and SPCBs are responsible for submitting the report to CPCB by 31 March every year.
- All the records maintained by the authorized persons are subject to inspection and verification by the regulatory authority at any time.

## 1.7 NEED FOR HCWM SYSTEM

Implementing proper HCWM system is very important due to the infectious nature of the HCW and harm caused to the public and environment (Muduli and Barve, 2012). The infectious HCW poses big threat to environment and needs the proper management before its final disposal (Hassan et al., 2008). This is coming as huge challenge to the developing nations, due to the exercise of inappropriate practices and poor handling of HCW and outdated disposal methods, which are leading to environmental and human health hazards (Hossain et al., 2011). The various inadequacies found in sorting and disposal practices of MW are: the absence of use of coded and colored bags, no proper tracking techniques (Oweis et al. 2005), ineffective segregation at source (Tsakona et al., 2007; Stanković et al., 2008; Farzadkia et al., 2009), inappropriate collection methods, unsafe storage of waste, insufficient financial and human resources for proper management, and poor control of waste treatment and disposal (Jang et al., 2006; El-Salam, 2010).

The exponential growth in HCFs and the level of healthcare services provided to the public, has led to the generation of massive amount of HCW. This creates an alarming situation for the Indian Government to deal with the pollutants coming out from the HCW and its treatment plants. The mixing of infectious BMW with the general waste and open burning of HCW leading to release of dioxin to the atmosphere (Gupta and Boojh, 2006). Hence, poorly managed HCW may lead to the generation of so many diseases like: gastroenteric infection, respiratory infection, ocular infection, genital infection, skin infection, anthrax, meningitis, AIDS, haemorrhagic fevers, septicaemia, bacteraemia, candidaemia, viral hepatitis A, B and C, avian influenza etc. (WHO, 2014).

The enforcement of BMW (Handling & Management) Rules, 1998 by Indian Government and increased level of awareness among the public about the infectious nature of HCW, the HCFs are forced to manage their waste more effectively. However, in countries like India, where there is huge population burden and also the resources are limited, the HCWM system is full of challenges and threats. Although, tremendous efforts have been made by the environmental regulatory authority and waste handlers, but still they have not been successful to protect the environment from the health hazards caused by HCW (Muduli and Barve, 2012). Hence, there is rising need of implementing better HCWM system and provide the training aids to waste handling staff and workers. Therefore, the existing HCWM system should be reviewed and recommendations should be provided to the

Government and HCFs, in order to improve the existing ineffective and inefficient HCWM strategies and standards.

## 1.8 CURRENT STATUS OF HCWM SYSTEM IN INDIA

As per the report of CPCB of India, 4,057 tons HCW is generated by the registered HCFs per day, out of which 2,919 tons of waste is treated, while the rest goes without any treatment to the environment daily. Table 1.2 explains the overall generation and treatment of MW and the number of HCFs, who are violating the MWM rules.

**Table 1.2:** MW Generation and Treatment in India

| BMW generation and disposal (kg/day) | | | | | | No. of HCFs violating BMW rules | | |
|---|---|---|---|---|---|---|---|---|
| 2007-08 | | 2008-09 | | 2009-10 | | 2007-08 | 2008-09 | 2009-10 |
| BMW generation | BMW disposal | BMW generation | BMW disposal | BMW generation | BMW disposal | | | |
| 506745 | 288203.8 | 409114.4 | 295271.9 | 405702 | 291983 | 19090 | 18140 | 13037 |

Source: www.investinindia.com/investmentindia.

Some of the studies conducted in Indian hospitals resulted into the following waste generation rates: Patil and Pokhrel (2005) calculated 2.31 kg/bed/day of BMW generation rate in their study conducted in a Hospital in Karnatka State; Gupta and Boojh (2006) computed 0.5 kg/bed/day of BMW generation rate in Balrampur hospital, Lucknow; and Katoch and Kumar (2008) calculated the 0.25 kg/occupied bed/day BMW rate in their study conducted at three hospitals in Shimla. Hence, the BMW generation rates differ as per region and climate conditions.

India is a developing nation and due to financial constraints and huge population, it is difficult to implement any policy throughout uniformly. But, still in past few years, Indian Government has initiated many efforts to fight against environment degradation and has laid certain policies for each industry to protect environment. As per WHO report, the waste generated by HCFs has led to 3-8 %

climate change in the developed nations. Hence, it is crucial decision to make about the proper disposal of BMW. As per the annual report 2011-12 prepared by CPCB, the present status of BMWM scenario in India is as below:

- Number of HCFs in the country: 1,39,594
- Number of beds: 14,20,563

- Number of HCFs using CBWTFs: 98,764
- Number of HCFs having treatment and disposal facilities: 20,228
- Number of on-site treatment equipment installed (excluding CBWTFs):
    - Number of Incinerators
      With air pollution control device: 419
      Without air pollution control device: 273
    - Number of Autoclaves: 2,710
    - Number of Microwaves: 179
    - Number of Hydroclave: 13
    - Number of Shredders: 4,250
- Total number of treatment equipment installed at CBWTFs:
    - Number of Incinerators: 177
    - Number of Autoclaves: 161
    - Number of Microwaves: 10
    - Number of Hydroclaves: 5
    - Number of Shredders: 170

### 1.9 CHALLENGES TO HCWM SYSTEM IN INDIA

Indian healthcare industry is wide spread, which includes varying sizes of HCFs and providing different kinds of healthcare services. As per the World Bank Database, 2010 around 63% of the total beds are covered by private HCFs, which also include the foreign players. Hence, the increased level of competition forcing the HCFs to provide better healthcare services on lesser cost, which is leading to the generation of large amount of HCW and poor handling of the waste which is generated as the byproduct. Due to the lack of budget, the HCFs are not focusing much on the HCWM system, which they think is not their core business.

The NGOs and Pollution Control Boards had highlighted various HCFs and treatment facilities, which are violating the HCW disposal rules every year in their reports. Hence, the biggest challenge for the regulatory authority is to enforce the HCFs and treatment facilities to implement the BMW (Handling & Management) Rules, 1998 in order to ensure the effective disposal. The second main challenge for implementing the HCWM system is that, in India most of the workers and staff, who are handling the infectious waste are not aware about the harm that may be done by the hazardous HCW. The rag pickers used to recycle the plastic syringes and other plastic materials without any chemical disinfection. In Delhi alone, more than 50 million Rupees per year business is done through this recycling (Patil and Pokhrel, 2005; Verma, 2010), without knowing its harmful effects. Hence, there is need to create the awareness and conduct the training programs for the employees, who are actually handling the waste and disposing it off.

In India, still the incineration is used as the main treatment method, which is outdated and produces large amount of harmful gases and ash after disposal. According to study conducted by Ferraz et al. (2000), the incineration of 3.8 kg/bed/day MW produces an ash of 0.3–0.4 kg/bed/day. Hence, replacing the existing outdated technology and importing advanced technique is big challenge for hospital administration (Muduli and Barve, 2012). People are more reluctant to change, even if the change is good for the organization and environment.

Other major challenge to HCWM system in India is the poor segregation of HCW at the point of generation, which results in more infectious waste (Gupta and Boojh, 2006) and even if the segregation is done properly at the generation point, then on the latter stage the waste handling workers used to mix it (Athavale and Dhumale, 2010). Hence, this improper segregation, increases the amount of infectious waste. Lack of proper operational strategy is also major drawback of current Indian HCWM system. As a result, the HCW is collected in mixed form and transported through open trucks/carts, which leads to the spread of infection (Patil and Pokhrel, 2005).

Lack of coordination among central regulatory authority and State Health Department is another limitation of the current HCWM system, which leads to poor implementation of HCWM system in India (Verma, 2010). Although, many countries and government agencies such as WHO, US Environmental Protection Agency, US Centers for Disease Control and Prevention, and Germany have established strict guidelines for hospitals and medical institutions regarding collection, transportation, storage and disposal of HCW (El-Salam, 2010), yet a little attention is paid to management of HCW, and rules remain largely unenforced. As per the survey done by WHO in 22 developing countries, about 18 to 64% of healthcare facilities are using inappropriate waste disposal methods (Zhang et al. 2013). Hence, in India a lot more needs to be done in order to establish a robust HCWM system and protect the environment from the hazardous waste.

## 1.10 MOTIVATION FOR THIS RESEARCH

As per CPCB (Annual report 2011-12), in India, there are more than 14,20,563 hospital beds, around 1,39,594 HCFs, thousands of registered and countless unregistered nursing homes, dispensaries, laboratories etc. and other institutions and research centers, which are generating approximately 4,057 tons of HCW every day. HCFs mainly focus only on providing better healthcare services, and except some big hospitals most of the small HCFs and clinics are not disposing their wastes properly. Some hospitals are doing the unauthorized recycling of HCW without any treatment. The HCWM field is the most neglected area in healthcare industry and hospital administration thinks that this is not their responsibility and minimum budget is allotted to dispose it off. Hence, India needs effective implementation of HCWM system in order to protect the public and environment health.

Due to rising healthcare concerns, the hazardous HCW is getting more attention from everyone around the World. So, now researchers, practitioners and academics are focusing more on safe treatment of the infectious waste and protect the environment. Moreover, Indian present Government is focusing more “Clean India” and so many campaigns have been initiated in this regard. Hence, the primary motivation of the present research is to explore the opportunities to implement the effective and efficient HCWM system. The study has been conducted to analyze the various elements of strong HCWM system and to develop the better HCWD operational strategy.

## 1.11 SCOPE OF THE PRESENT RESEARCH

The scope of the present research is limited to some selective issues on HCW supply chain management in India. Some issues have been addressed in perspective of the Indian HCWM industry and others are based on the data collected from HCFs and CBWTFs situated in Uttarakhand, Northern State of India. Figure 1.5 shows the scope of the research.

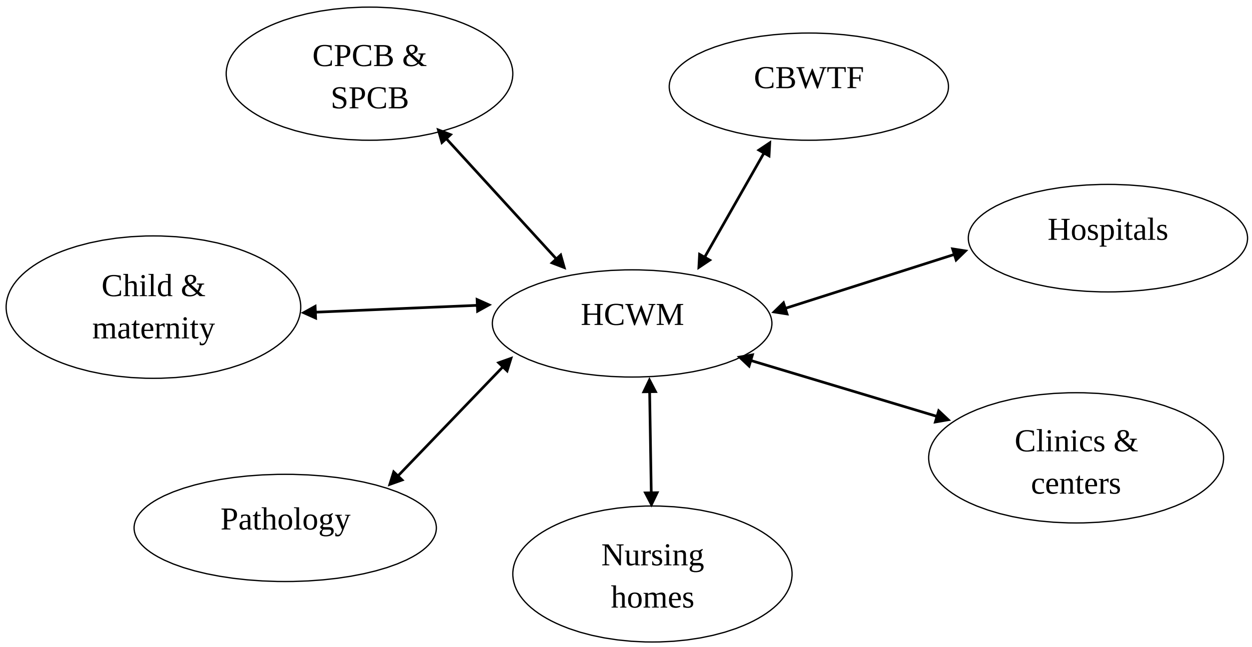


**Figure 1.5:** Scope of the Present Research

Uttrakhand, State of India is having varied kinds of HCFs, which are generating huge amount of infectious HCW. Hence, the HCW generation data has been analyzed from different types of HCFs and other treatment facilities in Uttarakhand and discussed the various strategic issues. The current status of the HCWM activities in Uttarakhand healthcare industry has been analyzed and associated issues have been addressed for the improvement in the existing system.

### 1.12 OBJECTIVES OF THE PRESENT RESEARCH

The present research aims at following objectives:

- To propose the model to prioritize the HCWD strategy and apply the model to select the appropriate HCWD strategy in Uttarakhand, a Northern State of India.
- To develop the framework for selecting the strategic outsourcing partner for disposing the infectious HCW.
- To analyze the composition and generations rates of the MW produced from various sources and find out the factors which are significantly contributing towards the amount of HCW generated. To analyze the seasonal variation in the amount of HCW generated from various HCFs.

- To establish and analyze the interrelationships among the barriers of HCWM practices in India and classify the barriers as per the operational, tactical and strategic issues in order to discuss managerial implications at different levels of management.
- To test the validity of some hypotheses related to: (a) importance of HCWM system (b) objectives of implementing HCWM system (c) barriers and enablers of HCWM system.

## 1.13 RESEARCH METHODOLOGY

The Figure 1.6 shows the schematic research design adopted in the present study. Based on the literature review, review of WHO objectives, discussion with academicians and experts in the related field and targeting the main aim of "Clean India" set by the present Indian Government, research directions have been identified. After finalizing the research objectives, the work done and theories developed in the same area were reviewed and past results have been compared. Then suitable research methodology has been identified. This is followed by the data collection through questionnaire survey, then analysis and results, and then conclusions were drawn to mitigate the research issue identified.

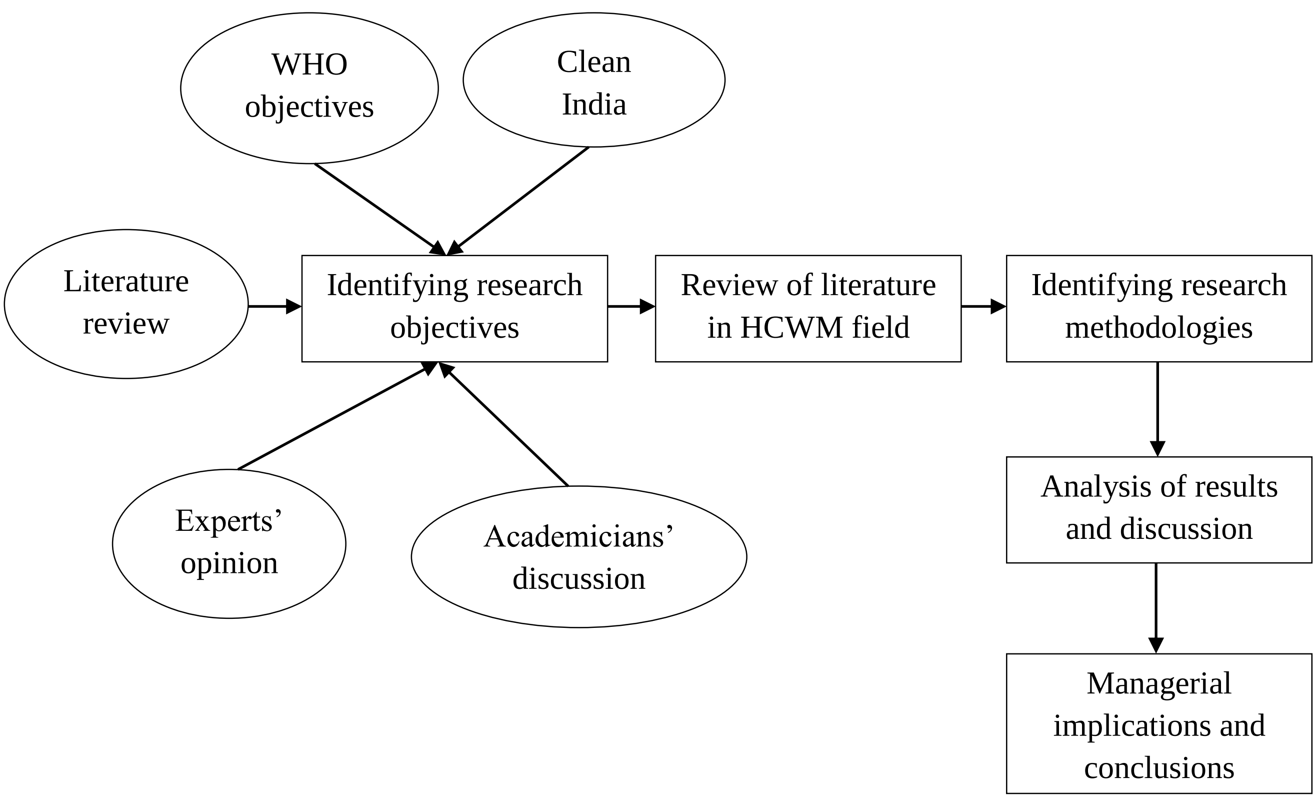


**Figure 1.6:** Overview of Research Design

The various tools/techniques used for achieving the above stated objectives are:

i) Grey Theory Approach: Grey theory has been used to collect the preferences from the experts on various issues. The responses have been collected in terms of grey numbers, which are converted into crisp values in order to prioritize the various elements under consideration.

ii) Analytical Hierarchy Process (AHP): AHP has been used to select the HCWD strategy. Two alternatives (outsourcing and in-house treatment) of treating the HCW have been evaluated with respect to various criteria by using AHP methodology.

iii) Analytic Network Process (ANP): ANP methodology has been used to select the best outsourcing partner to dispose the HCW. The selection of HCWD firm depends upon number of criteria and sub-criteria. Hence, the criteria weights and desirability indices of all the alternatives have been computed using ANP steps.

iv) TOPSIS: TOPSIS has been used with the combination of ANP in order to rank the various alternatives of HCWD firms. TOPSIS is a MCDM technique and give the best alternative, which is having the least distance from the best positive solution and farthest from the worst alternative. TOPSIS also considers the relative weighs of the selection criteria.

v) Questionnaire Survey: two different questionnaire surveys were conducted: first survey was targeted to collect the HCW generation data from various HCFs and second has been used to gain the broad insight into the various issues related to implementing HCWM system in India.

vi) Multiple Linear Regressions (MLR): MLR technique has been used to model the HCW generation data from various HCFs and identifying the various factors, which are significantly contributing towards the generation rates. Best fit models have been identified for the different types of HCW.

vii) Artificial Neural Networks (ANN): ANNs are statistical learning models which are inspired by the neural networks and are used to predict the function, which is depending upon various independent variables. The same analysis done by MLR technique has been replicated using ANN and it has been observed that better results have been observed using ANN. For our data, we have constructed the optimum neural network using MATLAB.

viii) Interpretive Structural Modeling (ISM): ISM methodology has been used to establish a hierarchy of barriers which are obstructing the implementation of HCWM system in India. The barriers have been categorized as per their driving power and dependence power using Fuzzy-MICMAC analysis.

## 1.14 RESEARCH OVERVIEW

Figure 1.7 represents the overview of the whole research. In order to identify the gaps in the area of HCWM field, an extensive literature review has been done and discussions were held between experts, practitioners, academicians and WHO policies & guidelines were reviewed. As there was lack of proper decision model to select the outsourcing partner for disposing the HCW, hence, first part of the study focused on strategically selecting the HCWD firm, who can treat the waste efficiently and effectively. To predict the generation rates of different types of HCW and the composition of HCW, the HCW data is collected from various HCFs and analyzed using modeling techniques. To understand the interrelationships among barriers of HCWM system, ISM framework is proposed, which helps in classifying all the barriers as per their driving and dependence power in the hierarchy. Then questionnaire survey was conducted to understand the various issues on implementing the HCWM system in India.

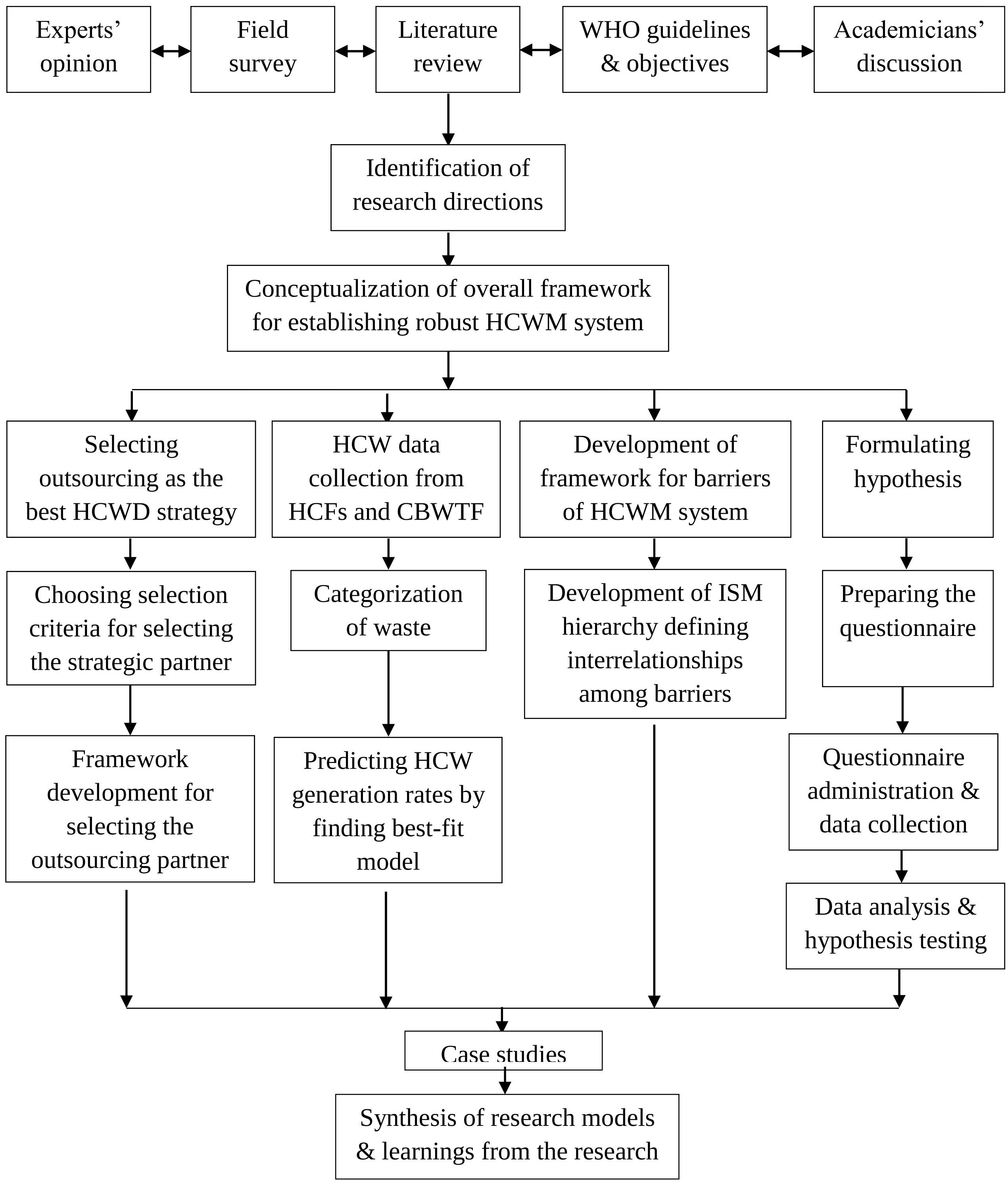


**Figure 1.7:** Research Overview

## 1.15 ORGANIZATION OF THE THESIS

The present thesis consists of eight chapters as shown in Figure 1.8. A brief description of all the chapters is as follows:

Chapter 1 comprises the introduction of the HCW definitions and its classification. It defines the sources of HCW and the risks associated with it. Chapter 1 also highlights the various issues related to HCWM and its importance in protecting the environment and human health. An overview of the WHO policies and guidelines and also the glimpse of Indian BMW (Management & Handling) Rules, 1998 had been reflected here. Various challenges and gaps in Indian HCWM system were identified, which provide the motivation for the present research. Objectives and the required methodologies have been explained here. In the last, the whole overview of the research has been presented.

Chapter 2 highlights the literature related to HCWM across the world. The attempt is made to discuss the conceptual frameworks, theories, empirical studies, experimental studies, models, waste handling practices and other issues related to HCWM. The whole literature has been classified into five broad categories: i) general HCWM practices, ii) hospital waste water management, iii) dental waste management, iv) HCWD techniques and methods and v) ash/residual treatment after disposal treatment. This chapter also highlights the review of the various research methodologies used in the present research. In the last, the research gaps identified from the literature and Indian HCWM industry have been reported in the end of the chapter.

In Chapter 3, grey theory and AHP based framework has been developed for identifying the best HCWD strategy. The proposed framework has been applied for evaluating HCWD strategies in Uttrarakhand, Northern State of India.

Chapter 4 presents the model based on ANP and TOPSIS under grey environment, to select the best HCWD outsourcing partner. This framework has been applied to select the outsourcing partner for disposing the infectious HCW in (Roorkee & Haridwar), Uttarakhand and could be useful for the hospital administration for choosing the strategic partner. The criteria and sub-criteria have been identified from the literature and experts' discussion and have been prioritized using ANP technique. TOPSIS methodology has been used to rank the various alternatives.

Chapter 5 analyzes the composition and generation rates of HCW generated at various HCFs. Here, HCW generation data has been collected from 75 HCFs situated in Uttarakhand and its composition has been analyzed. The HCW rates have been modeled using MLR and ANN modeling techniques. Predicting the HCW generation rates is useful for the HCFs and CBWTFs to handle the waste properly and plan the resources accordingly. The various factors, which are affecting the rate of MW generations have been identified.

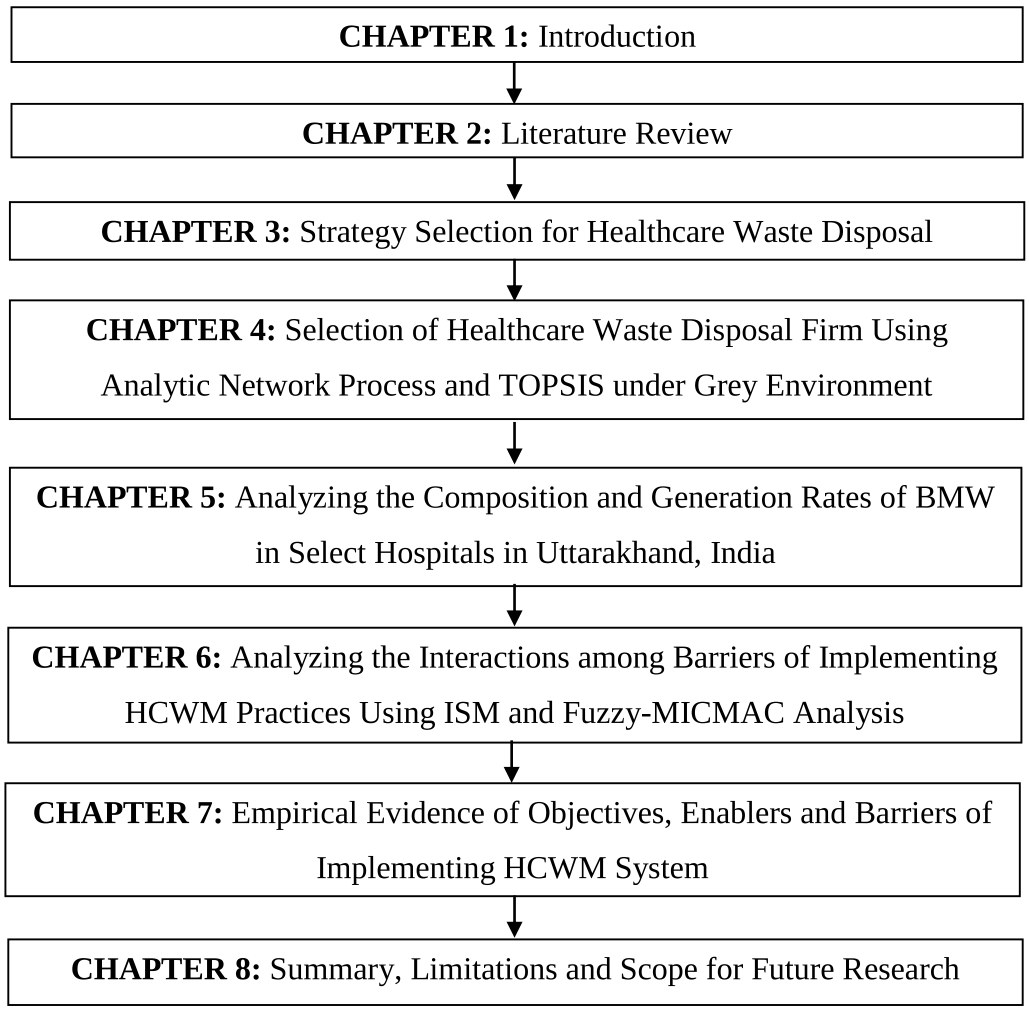


**Figure 1.8:** Outline of the Thesis

In Chapter 6, the various barriers of implementing HCWM practices in India have been identified from the literature and the survey of the HCFs and treatment facilities. The interrelationships among these barriers have been identified through the brainstorming sessions held with the experts in the field and academicians. Then, the barriers have been represented in the form of hierarchy, to provide the framework for the effective deployment of HCWM system in India. In the end, these barriers have been classified on the basis of driving and dependence power using Fuzzy-MICMAC analysis.

Chapter 7 consists of the survey methodology used in this research to test the various hypotheses. It comprises the development of the questionnaire and its testing through pilot survey. The questionnaire has been then circulated among various employees working at different levels in HCFs, treatment facilities and the regulatory authority. In the end, a total of 126 questionnaires were received and analyzed statistically.

Chapter 8 represents the summary of the research, findings and major implications of the research. This chapter concludes the whole study, with listing the main limitations of the study and the scope for future research in the end of this chapter.

### 1.16 CHAPTER SUMMARY

In this chapter, a brief introduction of the overall research has been given. The chapter defines the BMW (Handling and Management) Rules, 1998 and WHO policies and guidelines over HCWD. Here, the current status of the Indian HCWM industry and its related challenges has been highlighted. This chapter highlights the objectives of the whole research and also the brief description of the research design and methodology has been presented. In the end, the whole outline of the thesis has been highlighted. The next chapter reviews the significant work done in the related field and identifies the various gaps for the future research.

# CHAPTER 2
# LITERATURE REVIEW

## 2.1 INTRODUCTION

There has been a tremendous rise in the amount of Healthcare Waste (HCW) generated over the last few years due to increase in population, number and size of health care facilities, and use of disposable medical products (Mohee, 2005). HCW today poses grave challenges to hospitals and medical institutions (Naito, 1987), especially in developing nations, where Medical Waste (MW) is very often combined with municipal waste, which is threatening the health and safety of handling staff, general public and the environment. Due to these reasons, researchers have over the past few years, turned their attention to finding ways to manage HCW (Askarian et al., 2004; Talebbeydokhti and Kherandmand, 2006).

The authors, on the basis of the literature reviewed, found that 75-90% of the waste produced by Healthcare Facilities (HCFs) was non-hazardous (Prüss et al., 1999; Soliman and Ahmed, 2007; Chaerul et al., 2008a; Shinee et al., 2008). The remaining 10– 25% of MW was regarded hazardous and was a potential cause of a variety of health risks. If this relatively small amount of infectious MW is mixed with general waste, then the whole waste becomes hazardous (Chaerul et al., 2008b) and it is found in the study done by Bazrafshan and Mastafapoor (2011) in Iran that most of the hospitals are not segregating the MW properly at the point of generation. Thus, to prevent the spread of pathogens in the environment, it is important to segregate MW from general waste (Kgathi and Bolanee, 2001; Miyazaki and Une, 2005; Taru and Kuvarega, 2005). Miyazaki and Une (2005) stated that by adopting measures like sterilization and incineration, infectious waste material could be turned into non-infectious. After such treatment, infectious waste can be buried in a sanitary landfill.

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*Part of this chapter has been published as:*

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This chapter has used both quantitative and qualitative techniques (literature review, meta-analysis, historical analysis, bibliometric analysis and structured analysis) to analyze extant literature (e.g. Ngai et al., 2008; Irani et al., 2010; Dobrzykowski et al., 2014). The papers published in eight esteemed journals in the field of waste treatment and disposal and environment management during the years January 2005 to July 2014 were considered. The names of these journals (in alphabetical order) are: International Journal of Environmental Health Research (IJEHR); International Journal of Healthcare Quality Assurance (IJHQA); Journal of Environmental Management (JEM); Journal of Hazardous Material (JHM); Journal of Material Cycles and Waste Management (JMCWM); Resources, Conservations and Recycling (RCR); Waste Management (WM); and Waste Management & Research (WMR).

## 2.2 CLASSIFICATION OF THE LITERATURE

The whole literature has been classified into various areas with the consent of the experts. The topics and sub-topics identified are shown in Table 2.1 along with the corresponding frequency of papers targeted on each area. The broad areas are: Topic 1 - Hospital Waste Management Practices is the most written with 105 papers (59.66% of the total sample), followed by Topic 5 - Ash/Residual Management After Disposal Treatment (31 articles, 17.61%), Topic 4 - HCWD Techniques and Methods (21 studies, 11.93%), Topic 2 - Hospital Wastewater Management (11 papers, 6.25%) and Topic 3 - Dental Waste Management (8 articles, 4.55%).

**Table 2.1:** HCWM Topics Frequency Distribution

| Topic | Category description | Frequency | Percentage share |
|---|---|---|---|
| **Topic 1** | **General HCWM practices** | **105** | **59.66** |
| 1.1 | General waste management practices and current status | 53 | 30.11 |
| 1.2 | Scavenging and recycling of hospital waste | 5 | 2.84 |
| 1.3 | Generation and composition of hospital waste | 21 | 11.93 |
| 1.4 | Characterization of HCW | 8 | 4.55 |
| 1.5 | Assessment of awareness of HCWM practices among hospital staff and HCWD training program | 9 | 5.11 |
| 1.6 | Minimization of hospital wastes | 4 | 2.27 |

| Topic | Category description | Frequency | Percentage share |
|---|---|---|---|
| 1.7 | Measuring efficiency and effectiveness of HCWM system | 5 | 2.84 |
| **Topic 2** | **Hospital wastewater management** | **11** | **6.25** |
| 2.1 | Treatment options for hospital wastewater | 4 | 2.27 |
| 2.2 | Effects of untreated wastewater to environment and society | 2 | 1.13 |
| 2.3 | Composition and magnitude of hospital effluents in hospital wastewater | 5 | 2.84 |
| **Topic 3** | **Dental waste management** | **8** | **4.55** |
| 3.1 | Generation and composition of dental wastes | 5 | 2.84 |
| 3.2 | Dental waste management practices | 3 | 1.71 |
| **Topic 4** | **Healthcare waste disposal techniques and methods** | **21** | **11.93** |
| 4.1 | Alternatives for HCW treatment | 8 | 4.55 |
| 4.2 | Evaluation of HCW treatment options | 10 | 5.68 |
| 4.3 | Selection of HCW disposal firms | 3 | 1.71 |
| **Topic 5** | **Ash/residual management after disposal treatment** | **31** | **17.61** |
| 5.1 | Characterization, utilization and leachate analysis of HCW incinerator ash | 13 | 7.39 |
| 5.2 | Assessment of emission on environment from hospital waste incineration | 10 | 5.68 |
| 5.3 | Mixing HCW ash with cements for construction elements | 3 | 1.7 |
| 5.4 | Hospital waste incinerators investigation and evaluation | 5 | 2.84 |
| | **Total** | **176** | **100** |

## 2.3 COMPARISON OF METHODOLOGIES USED IN HCWM FIELD

This section seeks to determine which research methodology has been used most frequently over the time period and also try to identify the trends in the methodologies adopted. Table 2.2 shows that empirical studies are dominating the rest of the methodologies with a total of 49 papers (27.84%). Experimental study occupies second position, as it has been applied in 42 articles (23.86%), followed by case study/ethnographic study (33 papers, 18.75%). Theoretical/conceptual methods featured in 21 studies (11.93%), mathematical modelling in 20 articles (11.36%), reports in eight papers (4.55%) and literature reviews in three studies (1.71%).

**Table 2.2:** Frequency Distribution of Research Methodologies

| S. No. | Methodology | Frequency | Percentage |
|---|---|---|---|
| 1. | Empirical study | 49 | 27.84 |
| 2. | Experimental study | 42 | 23.86 |
| 3. | Case study/ethnographic study | 33 | 18.75 |
| 4. | Theoretical/conceptual | 21 | 11.93 |
| 5. | Mathematical modelling | 20 | 11.36 |
| 6. | Reports | 8 | 4.55 |
| 7. | Literature review | 3 | 1.71 |

## 2.4 PRIORITIZATION OF HCWM TOPICS BY FREQUENCY

Table 2.3 represents the frequency-wise distribution of all sub-topics in descending order, dividing them into three groups. It shows a total of 19 sub-topics divided such that the first group contains the most researched six sub-topics, the second group consists of seven moderately researched sub-topics, and the third group contains six least researched sub-topics.

**Table 2.3:** HCWM Sub-topics Rearranged by Frequency Group

| S. No. | Topic | Description | Frequency |
|---|---|---|---|
| | **Group A** | **Top 6 most researched sub-topics** | **116** |
| 1. | 1.1 | General waste management practices and current status | 53 |
| 2. | 1.3 | Generation and composition of hospital waste | 21 |

| S. No. | Topic | Description | Frequency |
|---|---|---|---|
| 3. | 5.1 | Characterization, utilization and leachate analysis of HCW incinerator ash | 13 |
| 4. | 4.2 | Evaluation of HCW treatment options | 10 |
| 5. | 5.2 | Assessment of emission on environment from hospital waste incineration | 10 |
| 6. | 1.5 | Assessment of awareness of HCWM practices among hospital staff and HCWD training program | 9 |
| | **Group B** | **Middle 7 moderately researched sub-topics** | **41** |
| 7. | 1.4 | Characterization of healthcare wastes | 8 |
| 8. | 4.1 | Alternatives for HCW treatment | 8 |
| 9. | 1.2 | Scavenging and recycling of hospital waste | 5 |
| 10. | 1.7 | Measuring efficiency and effectiveness of HCWM system | 5 |
| 11. | 2.3 | Composition and magnitude of hospital effluents in hospital wastewater | 5 |
| 12. | 3.1 | Generation and composition of dental wastes | 5 |
| 13. | 5.4 | Hospital waste incinerators investigation and evaluation | 5 |
| | **Group C** | **Bottom 6 least researched sub-topics** | **19** |
| 14. | 1.6 | Minimization of hospital wastes | 4 |
| 15. | 2.1 | Treatment options for hospital wastewater | 4 |
| 16. | 3.2 | Dental waste management practices | 3 |
| 17. | 4.3 | Selection of HCW disposal firms | 3 |
| 18. | 5.3 | Mixing HCW ash with cements for construction elements | 3 |
| 19. | 2.2 | Effects of untreated wastewater to environment and society | 2 |

## 2.5 REVIEW ON RESEARCH METHODOLOGIES USED IN THIS RESEARCH

### 2.5.1 Grey Theory Approach

In conventional Multi-Criteria Decision-Making (MCDM) methods, the weights and ratings of all the attributes are well known to the decision makers (Kaufmann and Gupta, 1991) and decision makers rate the alternatives by considering all the attributes/criteria. This method of prioritizing the alternatives depends on the subjective judgments given by various decision makers (Li et al., 2007). Since, to predict the exact numerical value for the attributes is difficult as it involves high degree of uncertainty. MCDM technique must be able to consider the vagueness and uncertainty of the situation, as these are the important characteristics of decision-making problems (Gumus, 2009). The grey theory can deal with this uncertain information by giving the opportunity to the decision makers to express their preferences in terms of linguistic variables (Deng, 1989) and this approach is advantageous over fuzzy theory, as it considers the condition of fuzziness (Li et al., 2007).

Deng discussed grey theory first time in 1982, which includes five major parts: grey prediction; grey relational analysis; grey decision; grey programming; and grey control. Figure 2.1 defines the concept of grey system as: if the full information is available with the decision maker, then the system is known as white system; if the information about the system is unknown then it is known as black system and system with partial information is known as grey system.

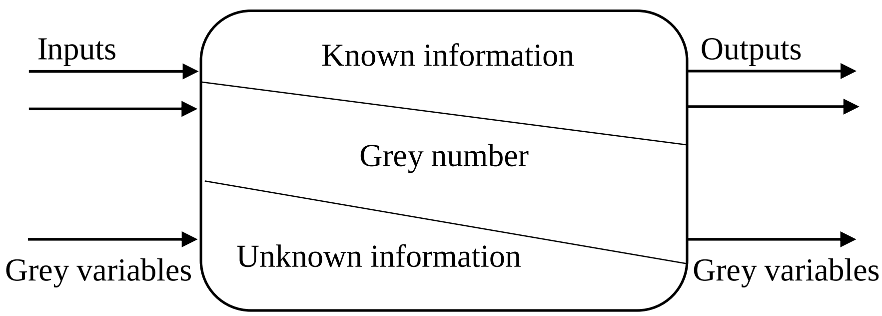


**Figure 2.1:** Concept of Grey System

(Source: Li et al., 2007)

Grey number is represented in numerical interval, which represents the uncertain information and is written as ⊗G. Grey number can be of three types:

i) Lower limit grey number: If only lower limit of the grey number can be predicted, then it is called lower limit grey number and is given by $[\underline{G}, \infty)$.

ii) Upper limit grey number: If only upper limit of grey number can be found, then it is known as upper limit grey number and is written as $(\infty, \overline{G}]$.

iii) Interval grey number: If both upper and lower limits can be estimated, then it is known as interval grey number and is written as $[\underline{G}, \overline{G}]$.

Grey theory has been used by various researchers as shown in Table 2.4.

**Table 2.4:** Grey Theory Applications by Previous Researchers

| Sl. No. | Applications | References |
|---|---|---|
| 1. | Analyzed information entropy of discrete grey numbers. | Zhang et al. (1994) |
| 2. | Evaluated the performance of airline. | Feng and Wang (2000) |
| 3. | Used for selecting the suppliers. | Wang et al. (2005) |
| 4. | Multi-criteria models for grey relationships. | Olson and Wu (2006) |
| 5. | For selecting the best supplier. | Li et al. (2007) |
| 6. | For selecting the best material. | Chan and Tong (2007) |
| 7. | Grey relational analysis in MCDM problems. | Kuo et al. (2008) |
| 8. | Ranking the knowledge management system. | Mehregan et al.(2012) |
| 9. | Addressed the problem of parts' supplier evaluation and selection for manufacturing industry and proposed an integrated genetic algorithm based on grey goal programming approach. | Sadeghieh et al. (2012) |
| 10. | Developed a grey-based carbon management model for green supplier selection. | Hashemi et al. (2013) |
| 11. | Used an integrated approach with ANP and improved grey relational analysis for green supplier selection. | Hashemi et al. (2015) |
| 13. | Supplier selection in banking industry. | Thakur and Ramesh (2015) |

### 2.5.2 Analytic Hierarchy Process (AHP)

AHP is structured MCDM method for organizing and analyzing complex decisions, developed by T. L. Saaty in 1970s. In AHP both qualitative as well as quantitative information can be used to make the decisions based on multi-criteria. AHP captures the priorities of each alternative with respect to criteria from the pair-wise comparisons. A salient feature of the AHP is to quantify decision makers' subjective judgments by assigning corresponding numerical values based on the relative importance of factors under consideration. Some of the applications using AHP methodology have been shown in Table 2.5.

**Table 2.5:** AHP Applications by Previous Researchers

| Sl. No. | Applications | References |
|---|---|---|
| 1. | Evaluation of casting suppliers with respect to 18 criteria by developing a web-based AHP system. | Akarte et al. (2001) |
| 2. | Used nine criteria for selecting the suppliers by using AHP model. | Muralidharan et al. (2002) |
| 3. | Developed an interactive selection model based on AHP. | Chan (2003) |
| 4. | AHP-GP (Goal programming) based approach for selecting the suppliers. | Çebi and Bayraktar (2003); Wang et al. (2005) |
| 5. | Used six criteria and 20 sub-criteria to evaluate suppliers based on AHP. | Chan and Chan (2004) |
| 6. | Applied AHP model to evaluate and select suppliers. | Liu and Hai (2005) |
| 7. | AHP-grey relational analysis model to combine qualitative and quantitative data for choosing the best supplier. | Yang and Chen (2006) |
| 8. | Used AHP based framework to select suppliers by using 14 selection criteria. | Chan and Kumar (2007) |
| 9. | Developed an integrated AHP and a multi-attribute negotiation framework for selecting the suppliers. | Chen and Huang (2007) |
| 10. | Solved supplier selection problem in a mass customization environment. | Hou and Su (2007) |
| 11. | Integrated AHP and DEA model was developed, wherein weights calculated by AHP has been used in DEA model. | Ramanathan (2007) |
| 12. | AHP–DEA based framework to select non-homogeneous suppliers. | Saen (2007); Sevkli et al. (2007) |
| 13. | Integrated AHP, DEA and ANN model to find out the efficiency index. | Ha and Krishnan (2008) |
| 14. | AHP- mixed integer non-linear programming model was developed to calculate the optimal order quantity. | Mendoza and Ventura (2008) |
| 15. | Integrated cluster analysis and AHP to rank alternatives. | Bottani and Rizzi (2008) |

| Sl. No. | Applications | References |
|---|---|---|
| 16. | Fuzzy-AHP approach for selecting the flexible manufacturing system. | Avinash and Sridharan (2009) |
| 17. | AHP model for apparel industry. | Chan and Chan (2010) |
| 18. | Used Delphi-AHP-TOPSIS based benchmarking framework for performance improvement of a cold chain. | Joshi et al. (2011) |
| 19. | AHP-based sorting approach. | Ishizaka et al. (2012) |
| 20. | D-numbers and AHP based methodology to select the suppliers. | Deng et al. (2014) |
| 21. | AHP model for evaluating sustainable manufacturing processes in Indian electrical panel industries. | Gupta et al. (2015) |

### 2.5.3 Analytic Network Process (ANP)

ANP process is more advanced than AHP in a complex MCDM situation (Meade and Sarkis, 1998; Lee and Kim, 2000; Yurdakul, 2003; Ravi et al., 2005). The main reasons behind using ANP technique for the firm selection are:

i) Selecting the HCWD partners will depend on various criteria and sub-criteria, hence making the pair-wise comparison will be difficult in AHP. ANP can easily model the complex decision problems.

ii) ANP considers the interrelationship and feedback among various criteria and alternatives in its network structure. In addition to this, there exist dependencies among various elements in our problem of selecting the HCWD firm.

iii) ANP permits consideration of all the tangible as well as intangible factors, which are having impact on the decision-making process.

iv) ANP also considers the non-linear interrelationships among the various elements in the selection hierarchical process.

Some applications of ANP methodology are given in Table 2.6.

**Table 2.6:** ANP Applications by Previous Researchers

| Sl. No. | Applications | References |
|---|---|---|
| 1. | Used ANP approach in the interdependent information system project selection process. | Lee and Kim (2000) |
| 2. | Assessment of alternative research-development projects. | Meade and Presley (2002) |
| 3. | Model for strategic supplier selection. | Sarkis and Talluri (2002) |
| 4. | Evaluation of long-term performances of production systems. | Yurdakul (2003) |
| 5. | Analyzed the development process of a decision support system. | Mikhailov and Singh (2003) |
| 6. | Defined optimal production schedules. | Momoh and Zhu (2003) |
| 7. | Selection of the best among the competing system configurations. | Tesfamariam and Lindberg (2005) |
| 8. | Selection of product mix for efficient manufacturing in a semiconductor fabricator. | Chung et al. (2005) |
| 9. | Solved the facility location problem. | Partovi (2006) |
| 10. | To select knowledge management strategies. | Wu and Lee (2007) |
| 11. | Selection of logistics service provider. | Jharkharia and Shankar (2007) |
| 12. | Identification of core technologies. | Lee et al. (2009) |
| 13. | R&D project evaluation and selection. | Jung and Seo (2010) |
| 14. | Measuring the competition level and performance. | Dagdeviren and Yuksel (2010); Tsai et al. (2011) |
| 15. | Performance evaluation for hot spring hotels. | Chen et al. (2011) |
| 16. | Selection of non-traditional machining processes. | Das and Chakraborty (2011) |
| 17. | Evaluation of green suppliers. | Buyukozkan and Cifci (2012) |
| 18. | SWOT analysis for airline industry. | Sevkli et al. (2012) |

| Sl. No. | Applications | References |
|---|---|---|
| 19. | Assessment of green supplier development programs. | Dou et al. (2014) |
| 20. | Performance parameters selection for maintenance. | Horenbeek and Pintelon (2014) |
| 21. | Machine tool selection. | Nguyen et al. (2014) |
| 22. | Product development. | Zaim et al. (2014) |
| 23. | Selection of best ERP system for SMEs using ANP and PROMETHEE based integrated framework. | Kilic et al. (2015) |

### 2.5.4 TOPSIS

Hwang and Yoon (1981) developed TOPSIS as a MCDM technique. The main advantage of using TOPSIS after ANP is that it gives the best alternatives solution, which is having the least distance from the positive ideal solution and the farthest distance from the negative ideal solution (Abo-Sinna and Amer, 2005; Jahanshahloo et al., 2006; Shih et al., 2007; Gumus, 2009). TOPSIS can also consider the relative weights of the selection criteria (Zolfani and Antucheviciene, 2012). The various areas of application of TOPSIS methodology have been shown in Table 2.7.

**Table 2.7:** TOPSIS Applications by Previous Researchers

| Sl. No. | Applications | References |
|---|---|---|
| 1. | Ranking the performance of competing companies in the textile industry by entropy measure and modified TOPSIS approach. | Deng et al. (2000) |
| 2. | Prioritizing failures in failure mode, effects and criticality analysis using Fuzzy TOPSIS. | Braglia et al. (2003) |
| 3. | Evaluation and ranking of candidate robots. | Bhangale et al. (2004) |
| 4. | Evaluated vendor by suing nominal group technique, ANP and modified TOPSIS. | Shyur and Shih (2006) |
| 5. | Fuzzy-Simple Additive Weight (SAW) and fuzzy TOPSIS approach for selecting the location of an international distribution center in Pacific Asia. | Kuo et al. (2007) |

| Sl. No. | Applications | References |
|---|---|---|
| 6. | Identifying best new product idea using hierarchical fuzzy TOPSIS and fuzzy heuristic multi-attribute utility function. | Kahraman et al. (2007) |
| 7. | Integrated TOPSIS, ANN and simulation meta-modeling for determining the number of Kanbans and the container size for JIT manufacturing systems. | Araz et al. (2008) |
| 8. | Applied AHP, Taguchi method, and simulation for finding the most suitable dispatching rule for a flow shop with multiple processors. | Kuo et al. (2008) |
| 9. | Fuzzy-AHP and Fuzzy-TOPSIS for selecting the partner for a strategic alliance in a logistics value chain. | Buyukozkan et al. (2008) |
| 10. | Solid waste transshipment site selection problem by applying Fuzzy-AHP and Fuzzy-TOPSIS approach. | Önüt and Soner (2008) |
| 11. | AHP-TOPSIS hybrid model to evaluate the mobile phone options. | Mahdavi et al. (2008a) |
| 12. | Used TOPSIS with interval data for evaluating six sites for establishing data factory. | Jahanshahloo et al. (2009) |
| 13. | Applied Fuzzy TOPSIS and Interpretive Structural Modeling (ISM) selecting the best third-party reverse logistics provider. | Kannan et al. (2009) |
| 14. | Evaluating risk involved in hazardous activities of the production process using Fuzzy TOPSIS. | Grassi et al. (2009) |
| 15. | Ranking automobile seat comfort based on consumer preferences using AHP and entropy method approach. | Fazlollahtabar (2010) |
| 16. | Evaluating service providers using Fuzzy-TOPSIS and simulation. | Chamodrakas et al. (2011) |
| 17. | Used Fuzzy-TOPSIS and DEA for ranking suppliers of textile industry in Taiwan. | Chen (2011) |
| 18. | Developed framework using Fuzzy DEMATEL and fuzzy TOPSIS for selecting the supplier. | Dalalah et al. (2011) |

| Sl. No. | Applications | References |
|---|---|---|
| 19. | Applied AHP, multi-objective nonlinear programming and multiple linear regression models for selecting the suppliers in electronics industry. | Fazlollahtabar et al. (2011) |
| 20. | Applied Fuzzy-TOPSIS to locate the manufacturing facility. | Alimoradi et al. (2011) |
| 21. | Evaluating environmental supplier performance using Fuzzy-TOPSIS. | Awasthi et al. (2011) |
| 22. | Simulation based fuzzy TOPSIS approach for group multi-criteria supplier selection problem. | Zouggari and Benyoucef (2012) |
| 23. | Selecting green suppliers based on GSCM practices: Using fuzzy TOPSIS applied to a Brazilian electronics company | Kannan et al., (2014) |
| 24. | An Extended TOPSIS Method for Multiple Attribute Decision Making based on Interval Neutrosophic Uncertain Linguistic Variables. | Broumi et al. (2015) |

### 2.5.5 Questionnaire Survey

Questionnaire survey is the best method to analyze the current situation of HCWM practices and its related issues. In the literature, various researchers throughout the world have analyzed the status of HCWM in their nations and calculated the amount of infectious wastes to be generated. Academicians have also focused on assessing the waste handling practices at various HCFs and the awareness about the infectious nature of the waste among the waste handling workers and staff. Some of the surveys in the field of waste management have been shown in Table 2.8.

### 2.5.6 Multiple Linear Regression (MLR) Modeling

Mathematical modeling can be helpful for managing the waste, to formulate the policies and to evaluate the strategies. MLR attempts to model the relationship between two or more explanatory variables and a response variable by fitting a linear equation to the observed data. The MLR model is given as:

**Table 2.8:** Questionnaire Surveys by Previous Researchers in Waste Management Area

| Sl. No. | References | Focus of the survey | Sample size | Remarks (respondents/industry profile/outcome) |
|---|---|---|---|---|
| 1. | Christmann (2000) | To evaluate the performance of "Best Practices" of Environmental Management in protecting the environment and reducing the costs at the same time. | 88 | Results revealed that process innovation and implementation are the complementary assets that moderate the relationship between best practices and cost advantage, a significant factor in determining firm performance. |
| 2. | Poon et al. (2001) | Survey was conducted to check the feasibility of on-site waste sorting and the current status of waste generated in Hong Kong. | 150 | The study revealed that on-site sorting is very much time and labor consuming. Hence, participants resist for on-site segregation. |
| 3. | Askarian et al. (2004) | To find out the amount of different types of MW generated and their management practices. | 75 | Survey revealed the generation rate of 4.45 kg/day/bed and found that the waste segregation practices and training aids are poor at the HCFs. |
| 4. | Balram and Dragićević (2005) | Survey was conducted to elaborate the design and development of a valid and reliable scale to measure the dimensions of civilians' attitude toward urban green spaces in Canada. | 179 | The survey resulted that the citizens' attitude toward urban green spaces is a multi-dimensional concept. Two dimensions were supported through quantitative analysis: "behavior" and "usefulness". |

| Sl. No. | References | Focus of the survey | Sample size | Remarks (respondents/industry profile/outcome) |
|---|---|---|---|---|
| 5. | Sharholy et al. (2007) | Determining the quantitative and qualitative characteristics of Municipal Solid Waste (MSW) along with basic information and to create Graphic Information System (GIS) maps for Allahabad city. | 22 | Analyzed the current status of MSW management and highlighted that segregation and recycling of the waste reduces the total disposable waste. |
| 6. | Tam (2008) | To assess the effectiveness of waste management plan in construction industry in Hong Kong. | 250 | The results revealed that Government is the most willing stakeholder to minimize the waste, but cost-factor is the main obstruction for the construction players. They evaluated various methods of reusing and reducing the waste. |
| 7. | Hassan et al. (2008) | To document the MW handling practices like: collection, storage, transportation and disposal in Dhaka, Bangladesh. | 60 | The results showed that lack of awareness, appropriate policy and laws, and willingness are responsible for the improper management of MW in Dhaka City. |
| 8. | Osmani et al. (2008) | Focused on the sources of construction waste, waste minimization practices and barriers in architectural profession in UK. | 40 | Study resulted that waste management is not the priority in the design process. Study found the following barriers: attitudes towards waste minimization, lack of interest from clients, and training to sustainable |

| Sl. No. | References | Focus of the survey | Sample size | Remarks (respondents/industry profile/outcome) |
|---|---|---|---|---|
| | | | | implementation of waste reduction strategies during the design process. |
| 9. | Abdulla et al. (2008) | Analyzed MWM practices at various HCFs in Jordan. | 21 | Survey shown that more than 57 % of the HCFs are disposing their liquid waste into municipal sewer system. MW rates vary from 0.5 to 2.2 kg/bed/day, which comprises of 90% infectious waste and 10% sharps. |
| 10. | Marinkovic et al. (2008) | Analyzing the hazardous MW production and its management in Croatia. | 88 | The biggest producers of MW are hospitals and are not even implementing the waste handling rules. |
| 11. | Yong et al. (2009) | Assessment of MWM practices like: generation, segregation, collection, storage, training & education, transportation, disposal and public awareness about MW in China. | 164 | Results reveal that majority of the people lack in awareness about the infectious MW and they even don't know the difference between MW and recyclable waste and their proper disposal. The people were dissatisfied with the current waste management practices in China. |
| 12. | Coker et al. (2009) | Study targeted at analyzing MW management practice in Ibadan, Nigeria. | 52 | Survey resulted that secondary HCFs produce the largest amount of MW among all the HCFS and overall waste management practices are poor, putting staff, workers and waste handlers at health risks. |

| Sl. No. | References | Focus of the survey | Sample size | Remarks (respondents/industry profile/outcome) |
|---|---|---|---|---|
| 13. | Birpinar et al. (2009) | Assess the MWM practices in Turkey. | 192 | Computed a MW generation rate of 0.63 kg/bed/day. Segregation practices found to be ok, but in 25% of the HCFs the waste is collected in inappropriate containers. |
| 14. | Sawalem et al. (2009) | Assessment of current hospital waste management practices in Libya. | 14 | Waste generation rate was found to be 1.3 kg/patient/bed. Survey has shown that there no guidelines for waste collection, storage and disposal. |
| 15. | Debere et al. (2013) | Analyzing the HCW generation rates and its management in Ethiopia. | 6 | The survey revealed that public hospitals produce more HCW in comparison to private hospitals and calculated a generation rate of 0.361- 0.669 kg/patient/day. |
| 16. | Zhang et al. 2013 | Explored the current MWM practices in Western China. | 74 | The study calculated the generation rates of 0.79, 0.59 and 0.61 kg/bed/day in tertiary, secondary and primary hospitals, respectively. They concluded that inappropriate segregation results in higher waste. |

$$y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \cdots \ldots + \beta_n x_n \quad (2.1)$$

In eqn. (2.1), 'y' represents the dependent variable, which is to be predicted and $x_1, x_2, \ldots \ldots x_n$ are the independent variables which are affecting the dependent variable. $\beta_1, \beta_2, \ldots \ldots \beta_n$ are the coefficients of corresponding independent variables, which represents the variation in the dependent variable with each unit variation in the independent variable. $\beta_0$ is the constant term and when independent values are zero, it has no significance. The various applications of MLR technique in modeling the data and predicting the values have been shown in Table 2.9.

**Table 2.9:** MLR Modeling Applications by Previous Researchers

| Sl. No. | Applications | References |
|---|---|---|
| 1. | Regression modeling strategies for improved prognostic prediction. | Harrell et al. (1984) |
| 2. | MLR modeling for predicting the soil salinity. | Lesch et al. (1995) |
| 3. | Used multiple regression to predict the amount of waste generated at public and private hospitals. | Awad et al. (2004) |
| 4. | Prediction of generation and composition of hospital waste in Iran. | Sabour et al. (2007) |
| 5. | Predicting the performance and power for various applications executing on any microprocessor configuration in a large micro architectural design space by using regression modeling. | Lee and Brooks (2006) |
| 6. | Modeling the seasonal variation in the generation rates of BMW. | Katoch and Kumar (2008) |
| 7. | Applied multivariate regression analysis to predict the MW production at hospitals and its associated factors. | Cheng et al. (2009) |
| 8. | Used ANN and MLR to predict rate of MW generation. | Jahandideh et al. (2009) |
| 9. | Calculated linear regression correlations between waste produced and number of examined patients. | Graikos et al. (2010) |
| 10. | Applied simple linear regression for assessing the quantities of infectious waste generated. | Sanida et al. (2010) |
| 11. | Applying MLR and ANN techniques for modeling and prediction of surface roughness of steel in turning operations. | Asiltürk and ÇUnkaş (2011) |

| Sl. No. | Applications | References |
|---|---|---|
| 12. | Analyzing the composition and production rate of pharmaceutical and chemical waste from Xanthi General Hospital in Greece. | Voudrias et al. (2012) |

### 2.5.7 Artificial Neural Network (ANN)

ANNs are statistical learning models which are inspired by the neural networks and are used to predict the function, which is depending upon various independent variables. The ANNs are trained by providing certain set of data and then are used to estimate the dependent variable. The functioning of ANNs depends on the interconnected neurons, which exchange the information between each other. These linkages between neurons are assigned certain weights depending on the past data, so that mean square error (MSE) is minimized and then network becomes adaptive to inputs and capable of learning. ANN model consists of following three main elements: i) set of connections with certain weight on each connection, ii) an adder for getting the combined weight of all inputs and iii) an activation function for getting the amplitude of the output neuron. To start with, various networks are generated by varying the learning rates, iterations and number of hidden neurons and finally the optimum network is selected by applying different training algorithms, which produces the minimum MSE. Table 2.10 highlights the literature related to applications of ANN modeling technique in prediction and forecasting.

**Table 2.10:** ANN Modeling Applications by Previous Researchers

| Sl. No. | Applications | References |
|---|---|---|
| 1. | Automated generation of energy use predictors' demonstration using ANN networks. | Kreider (1991) |
| 2. | Developed a model for accurate short-term predictions of sulphur-dioxide concentrations in order to control the emissions from a coal-fired power station. | Boznar et al. (1993) |
| 3. | Prediction of rates of energy use in commercial buildings. | Kreider et al. (1995) |
| 4. | Applied for short-term load-forecasting in electric-power systems. | Mandal et al. (1995) |
| 5. | Modeled the combustion process of incineration plants with the objective of reducing toxic emissions. | Muller and Keller (1996) |
| 6. | Application for predictive control of a thermal plant. | Milanic and Karba (1996) |

| Sl. No. | Applications | References |
|---|---|---|
| 7. | Prediction of surface ozone concentrations in an industrial area of North America. | Yi and Prybutok (1996) |
| 8. | Forecasting the daily runoff for the Little Patuxent River watershed as a function of daily rainfall, temperature, and snowmelt in Maryland. | Tokar and Johnson (1999) |
| 9. | Applied ANN technique to rainfall-runoff modeling and flood forecasting. | Dawson and Wilby (2001) |
| 10. | Patterning and predicting aquatic insect species richness in running waters | Park et al. (2003) |
| 11. | ANN and MLR models for analyzing the pollution concentration in the air in Greece. | Grivas and Chaloulakou (2006) |
| 12. | Predicting the MSW generation rates by using ANN. | Jalili and Noori (2007) |
| 13. | Used ANN and MLR to predict rate of MW generation. | Jahandideh et al. (2009) |
| 14. | Analyzing the diesel engine performance and exhaust emission by using waste cooking biodiesel fuel. | Ghobadian et al. (2009) |
| 15. | Modeling the river water quality. | Singh et al. (2009) |
| 16. | Applying MLR and ANN techniques for modeling and prediction of surface roughness of steel in turning operations. | Asiltürk and ÇUnkaş (2011) |
| 17. | ANN based heuristic for flow shop scheduling problems. | Ramanan et al. (2011) |

### 2.5.8 Interpretive Structural Modeling (ISM)

ISM is a qualitative and interpretive method which helps to understand the complex and poorly articulated problems in terms of well-defined hierarchical structure (Pfohl et al., 2011). ISM methodology helps to impose order and direction on the complex relationship among elements of a given system (Warfield, 1974; Sage, 1977). Depending upon the pattern of interrelationships among various elements involved in the hierarchy, ISM helps the decision makers to identify the most critical elements in the defined problem and the direction of influence of these elements on the other elements involved in the structure. In ISM, different types of relationships like: definitive, comparative, influence and temporal can be defined among the elements (Bolanos et al., 2005). ISM methodology can be helpful for defining the complex problems like MWM, as it is very sensitive environmental and human health related issue. HCWM system is multifaceted and is influenced by number of variables. Hence, ISM technique can easily develop the hierarchy including all the elements and defining their inter-relationships. Table 2.11 shows the applications of the ISM methodology by the previous researchers.

**Table 2.11:** ISM Applications in Previous Studies

| Sl. No. | Applications | References |
|---|---|---|
| 1. | Energy conservation in cement industry | Saxena and Vrat (1992) |
| 2. | Vendor selection | Mandal and Deshmukh (1994) |
| 3. | Developed a hierarchy of actions required to achieve the objectives of waste management in India. | Sharma and Gupta (1995) |
| 4. | Knowledge management. | Singh et al. (2003) |
| 5. | Analyzing third party reverse logistics provider. | Ravi and Shankar (2005) |
| 6. | Applied in strategic decision making. | Bolanos et al. (2005) |
| 7. | Understanding the barriers of implementing IT in supply chains. | Jharkharia and Shankar (2005) |
| 8. | Integrated ISM and ANP approach to develop a balanced scorecard for a company. | Thakkar et al. (2006) |
| 9. | Modeling the enablers of supply chain mitigation. | Nishat et al. (2006) |
| 10. | Modeling agility of supply chain. | Agarwal et al. (2007) |
| 11. | Green supplier selection using ISM and AHP. | Kannan et al. (2008) |
| 12. | IT-enablers for Indian Manufacturing SMEs. | Thakkar et al. (2008) |
| 13. | Selection of reverse logistics providers using ISM and Fuzzy-TOPSIS. | Kannan et al. (2009) |
| 14. | Developing hierarchical structure of Public-Private Partnership (PPP) risks. | Iyer and Sagheer (2009) |
| 15. | Analyzed the barriers to corporate social responsibility in supply chains. | Faisal (2010) |
| 16. | Barriers to Total Quality Management (TQM) implementation. | Talib et al. (2011) |

| Sl. No. | Applications | References |
|---|---|---|
| 17. | Analyzing the barriers of developing the landfill communities. | Chandramowli et al. (2011) |
| 18. | Analyzing the supply chain risks. | Pfohl et al. (2011) |
| 19. | Analyzing the critical failure factors in ERP Implementation. | Jharkharia (2011) |
| 20. | Analysis of critical success factors of world-class manufacturing practices. | Haleem et al. (2012) |
| 21. | Assessing the reverse logistics providers. | Govindan et al. (2012) |
| 22. | Evaluating medical tourism enablers. | Ranjan et al. (2013) |
| 23. | Analyzing the drivers for implementing reverse logistic functions in Indian manufacturing industry. | Jindal and Sangwan (2013) |
| 24. | Green supply chain management. | Mathiyazhagan and Haq (2013) |
| 25. | Identifying flexible manufacturing system dimensions and their interrelationship. | Dubey and Ali (2014) |
| 26. | Multi-objective decision modeling for green supply chains. | Mangla et al. (2014) |
| 27. | Effects of lean, green and resilient practices on supply chain performances. | Govindan et al. (2015) |

## 2.6 STRENGTH OF CONTEMPORARY RESEARCH

Throughout the World, there are so many international regulatory bodies, who are continuously focusing on the infectious HCW and its proper handling and management, like: World Health Organization (WHO), United Nations Environment Program-Secretariat of the Basel Convention and several Non-Governmental Organizations (NGOs). WHO has released the policy document on “Safe Health-Care Waste Management” and International Solid Waste Association (ISWA) advocated that segregation, storage, transportation, treatment and final disposal of the HCW, are the main activities which need to be focused for sustainable development.

Many reputed journals like: International Journal of Environmental Health Research, International Journal of Healthcare Quality Assurance, Journal of Environmental Management, Journal of Hazardous Material, Journal of Material Cycles and Waste Management, Resources, Conservations and Recycling, Waste

Management, Waste Management & Research etc. have given considerable importance to the research on HCWM and its related issues. So many National and International conferences, workshops are being organized throughout the world targeting the themes like: environmental health and sustainability, waste management, recycling and waste minimization etc. Hence, infectious BMWM is catching the concern from researchers, academicians, environment protection and pollution control boards etc. in order to protect the environmental and human health.

## 2.7 IDENTIFIED GAPS IN LITERATURE

The following gaps have been identified from the literature:

- Still the HCWM industry unorganized and some HCFs are outsourcing the waste to strategic partners, while others are treating it in-house. Literature lacks the study related to prioritizing the HCWD strategies for improving the waste handling and management practices in India. The preference for HCWD strategies may vary with the location of the HCF. Hence, each HCF should evaluate the treatment options as per their evaluation criteria.
- In most of the HCFs in India, the outsourcing partner is selected just on the basis of qualitative assessment, which may result in biased selection. Hence, there is a need for a comprehensive model which can consider both qualitative as well as quantitative parameters in order to make the strategic selection of the HCWD firm.
- Indian literature lacks in the study on assessing the generation rates and composition of HCW coming out from various HCFs. For the proper management of the waste and allocation of the resources, it is necessary to predict the amount of HCW to be generated and handled every day. Analyzing the generation patterns will help the hospital administration and treatment facilities to plan their capacity and resources accordingly.
- In India, still the current status of HCWM is poor and few studies have been done to analyze the barriers which are obstructing the implementation of HCWM system properly.
- Indian literature lacks the comprehensive survey on analyzing the HCWM practices at various HCFs and the awareness among the staff, waste handling workers. Hence, it is important to collect the opinion from the healthcare industry on the various issues, which are affecting the establishment of effective HCWM system.

## 2.8 CHAPTER SUMMARY

Here, a structured review on HCWM practices has been presented from the eight esteemed journals. The journals have been searched for the selected keywords. This generated a total of 176 articles related to HCWM and all have been categorized into five topics and 19 sub-topics under five main topics. Subsequently, the literature about the various methodologies used in this research has been given. This structured study has led to certain gaps in the literature and some relevant issues related to HCWM have been identified, which have provided the future research directions.

# CHAPTER 3

# STRATEGY SELECTION FOR HEALTHCARE WASTE DISPOSAL (HCWD)

## 3.1 INTRODUCTION

Healthcare Waste Management (HCWM) is posing a grave challenge to the healthcare industry, especially in the developing nations (Alagoz and Kocasoy, 2008a; Gai et al., 2010; Manga et al, 2011). The generation rates of Healthcare Waste (HCW) have increased tremendously since last few decades due to increased Healthcare Facilities (HCFs), population and use of disposable products for treating the patients (Mohee, 2005). Generally, the hospital waste includes all the wastes generated by HCFs, that may be infectious or non-infectious waste, but the Medical Waste (MW) is particularly the sub-category, that represent the potentially dangerous waste, such as sharps and waste with infectious, hazardous, radioactive, and genotoxic properties that endanger human and environment health (Klangsin and Harding, 1998; Levendis et al., 2001). Hence, due to the hazardous nature of the MW, it is matter of concern for any Nation's environment regulatory agency and should be disposed of by using proper mechanism.

Due to the rising concerns about the MW, Ministry of Environment and Forests, India, drafted HCWM legislation and hospital wastes are being regulated under the Act of Bio-Medical Wastes (Management and Handling) Rules, 1998. Bio-Medical Wastes (Management and Handling) Rules, 1998 are mainly based on the process that includes following steps: separation of communal waste from Bio-Medical Waste (BMW), containment, treatment, and disposal of BMW in different categories. The Supreme Court of India, also initiated the first step by directing the Central Pollution Control Board (CPCB) to find out the alternatives and effective technologies for HCW treatment and set up the technology standards. States have been given the responsibility to handle the BMW with State Pollution Control Boards (SPCBs) in State and Pollution Control Committees in Union Territories, which are used to advise the State Government on various Bio-Medical Waste Management (BMWM) and handling issues.

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Due to improper disposal and treatment techniques, the infectious HCW is emerging as a great threat to the environment and the public (Liu et al., 2013a). Hence, the effective disposal of the HCW is of great importance due to the hazardous nature of the HCW. Like other developing countries, Indian Healthcare Waste Disposal (HCWD) industry is also fragmented, as some hospitals are having their own in-house waste treatment facilities and others are outsourcing the process to Government authorized Common Biomedical Waste Treatment Facilities (CBWTFs). Literature also lacks the quantitative studies targeting the selection of HCWD strategy and hence, this part of the chapter targets the following objectives:

- To identify and prioritize the factors, which affect the selection of HCWD strategy.
- To propose the model to select the HCWD strategy.
- To apply the proposed model to select the HCWD strategy in Uttarakhand, Northern State of India.

To achieve these objectives the rest of the chapter has been organized as follows: next section highlights the methodology for selecting the HCWD strategy, and then the proposed model has been applied to evaluate the alternatives in Uttarakhand, India. Discussion and managerial implications of the present study have been emphasized, which is followed by the chapter summary.

## 3.2 METHODOLOGY

The Figure 3.1 represents the various steps adopted in the present chapter in order to prioritize the HCWD strategies. This section of the chapter highlights the Multi Criteria Decision Making (MCDM) methodology adopted to select the appropriate strategy for disposing the HCW by considering various criterion. According to Gumus (2009), MCDM technique must be able to consider the vagueness and uncertainty of the situation, as these are the important characteristics of decision-making problems. Hence, Grey theory is the best approach to define the variables under uncertainty and many researchers have used this tool for decision making and evaluation: Feng and Wang (2000) evaluated the performance of airlines, Olson and Wu (2006) proposed multi-criteria model for grey relationships, Li et al. (2007) used for best supplier selection, Chan and Tong (2007) used grey theory for selecting the best material and Mehregan et al. (2012) used for ranking the knowledge management system.

The purpose of using grey numbers approach is to provide the weights to the selection criteria under uncertain information and it is advantageous over fuzzy theory, as it also considers the condition of fuzziness (Li et al., 2007). Preferences given by the experts in terms of grey numbers are further used by

Analytic Hierarchy Process (AHP) to solve the MCDM problem. AHP is structured MCDM method for organizing and analyzing complex decisions.

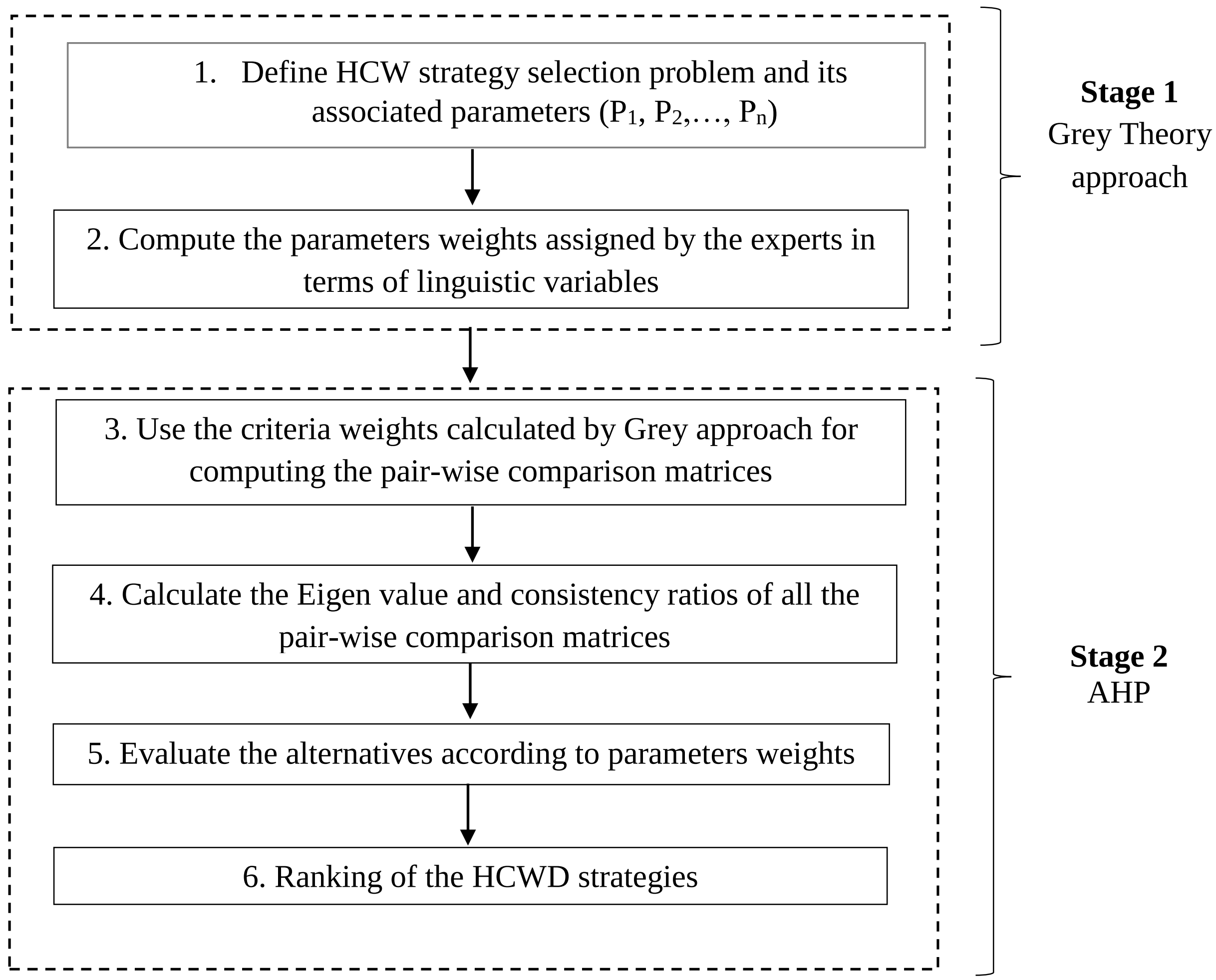


**Figure 3.1:** Methodology for Choosing the HCWD Strategy

In AHP, both qualitative as well as quantitative information can be used to make the decisions based on multi-criteria. AHP captures the priorities of each alternative with respect to certain criteria from the pair-wise comparisons. Various steps involved in the proposed methodology are:

**Step 1:** The first step identifies the problem of choosing the HCWD strategy and its associated parameters ($P_1$, $P_2$,…, $P_n$) for evaluating the various alternatives.

**Step 2:** Here, grey numbers have been used to assign weights to the selection criteria assigned by the expert's panel in terms of linguistic variables. These linguistic variables are converted into grey numbers by using the 1-7 scale as shown in Table 3.1. The attributes weights for various alternatives are assigned using scale given in Table 3.2.

**Table 3.1:** Scale of Criteria Weights

| **Sl. No.** | **Scale** | $\otimes \boldsymbol{W}$ |
|---|---|---|
| 1. | Very low (VL) | [0.0,0.1] |
| 2. | Low (L) | [0.1,0.3] |
| 3. | Medium low (ML) | [0.3,0.4] |
| 4. | Medium (M) | [0.4,0.5] |
| 5. | Medium high (MH) | [0.5,0.6] |
| 6. | High (H) | [0.6,0.9] |
| 7. | Very high (VH) | [0.9,1.0] |

**Table 3.2:** Scale of Attribute Weights

| **Sl. No.** | **Scale** | $\otimes \boldsymbol{W}$ | **Sl. No.** | **Scale** | $\otimes \boldsymbol{W}$ |
|---|---|---|---|---|---|
| 1. | Very poor (VP) | [0,1] | 5. | Medium good (MG) | [5,6] |
| 2. | Poor (P) | [1,3] | 6. | Good (G) | [6,9] |
| 3. | Medium poor (MP) | [3,4] | 7. | Very good (VG) | [9,10] |
| 4. | Fair (F) | [4,5] | | | |

Now, the expert's opinion regarding the weights of the evaluation parameters are collected and the final weights are converted from grey values to crisp values by applying 'De-graying' method, which includes the following 3-step procedure (Opricovic and Tzeng, 2003; Wu and Lee, 2007; Fu et al., 2012):

i) Normalization of the grey values:

$$\underline{\otimes} x_{ij}^{p} = \left(\underline{\otimes} x_{ij}^{p} - \min_{j} \underline{\otimes} x_{ij}^{p}\right) \Big/ \Delta_{\min}^{\max} \tag{3.1}$$

$$\overline{\otimes} x_{ij}^{p} = \left(\overline{\otimes} x_{ij}^{p} - \min_{j} \overline{\otimes} x_{ij}^{p}\right) \Big/ \Delta_{\min}^{\max} \tag{3.2}$$

$$\Delta_{\min}^{\max} = \max_{j} \overline{\otimes} x_{ij}^{p} - \min_{j} \underline{\otimes} x_{ij}^{p} \tag{3.3}$$

ii) Find out the total normalized crisp value:

$$Y_{ij}^{p} = \left(\underline{\otimes} x_{ij}^{p}(1-\underline{\otimes} x_{ij}^{p}) + (\overline{\otimes} x_{ij}^{p} \times \overline{\otimes} x_{ij}^{p})\right) \Big/ (1-\underline{\otimes} x_{ij}^{p} + \overline{\otimes} x_{ij}^{p}) \tag{3.4}$$

iii) Compute crisp value:

$$Z_{ij} = \frac{1}{p}(Z_{ij}^{1} + Z_{ij}^{p} + \ldots\ldots + Z_{ij}^{p}) \tag{3.5}$$

where,

$P$ : number of decision makers.

$\min_{j} \underline{\otimes} x_{ij}^{p}$ : minimum value for each column *j* for manager *i*.

$\max_{j} \underline{\otimes} x_{ij}^{p}$ : maximum value for each column *j* for manager *i*.

**Step 3:** The weights assigned to various parameters are used to make the pair-wise comparisons among all the elements. The pair-wise comparison matrix shows the preference of row element over the column element as shown below in equation 3.6:

$$A = \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} \\ 1/a_{12} & 1 & a_{23} & a_{24} \\ 1/a_{13} & 1/a_{23} & 1 & a_{34} \\ 1/a_{14} & 1/a_{24} & 1/a_{34} & 1 \end{bmatrix} \tag{3.6}$$

**Step 4:** Eigen values ($\lambda_{max}$) are calculated for the pair-wise comparison matrix by dividing each element by its column sum and then taking the row average. The consistency ratios (CR) are calculated for each pair-wise comparison matrix by using equation (3.7), in order to control the responses of the respondents. If the CR comes out to be greater than 10%, then responses are recorded again in order to maintain the consistency.

$$CR = \left((\lambda_{max} - n) \big/ (n-1)\right) / Table\_value \tag{3.7}$$

**Step 5:** Here, various HCWD strategic options are evaluated with respect to each parameter to calculate the score for each alternative.

**Step 6:** Finally, the preference order is derived, as per the highest value alternative as the best alternative.

### 3.3 APPLICATION OF THE PROPOSED MODEL

#### 3.3.1 HCWD Alternatives and Selection Parameters

The proposed model is used to select the HCWD strategy for treating the waste coming from various HCFs situated in Uttarakhand, Northern State of India. The hierarchical structure for defining the problem of selecting the HCWD strategy is shown in Figure 3.2, which defines all the levels and its associated elements. The present study has defined the following two alternatives for the disposal of HCW: i) in-house disposal ii) outsourcing. For the proposed model, a total of 6 parameters have been defined as follows: 1) Access to expertise ($P_1$), 2) Overdependence ($P_2$), 3) Transportation & risk associated ($P_3$), 4) Government rules ($P_4$), 5) Environmental factors ($P_5$), and 6) Economic factors ($P_6$).

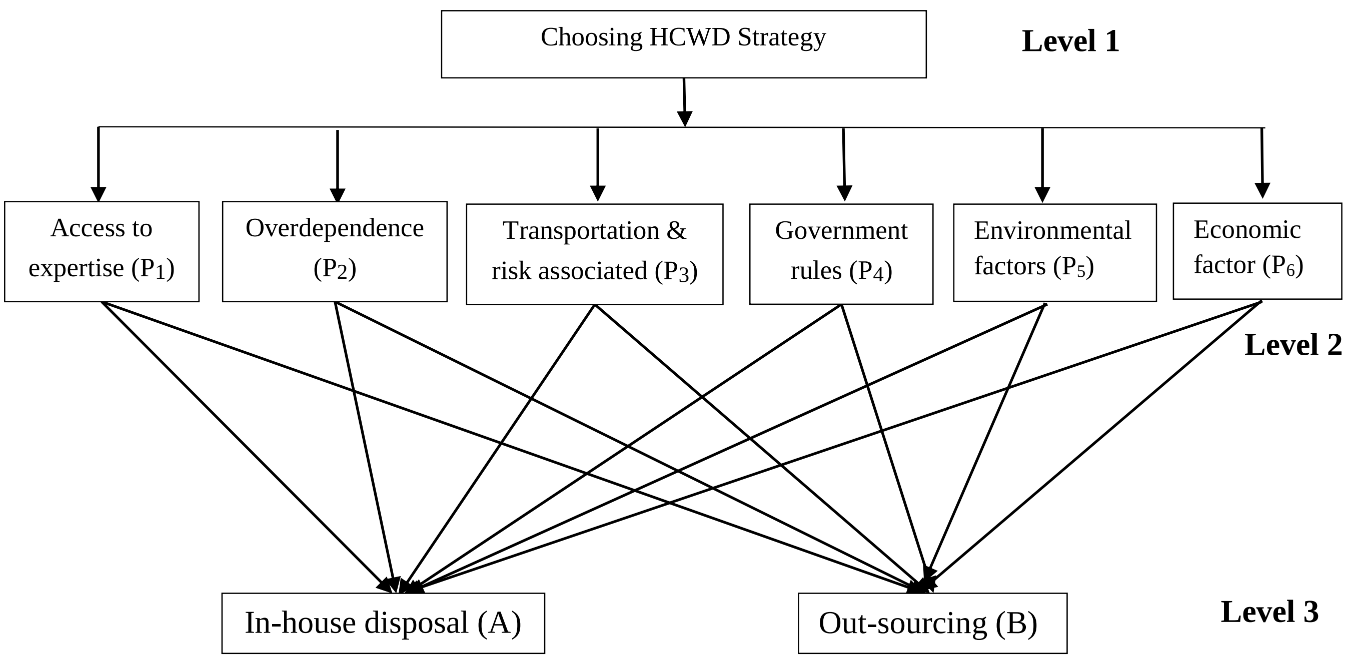


**Figure 3.2:** Hierarchy Structure for Selecting the HCWD Strategy

##### 3.3.1.1 Access to expertise (P1)

Out-sourcing the process to third party, will help to get the services from the experts in the field. Moreover, 'in-house treatment' of the HCW, may increase the risk to the hospital employees and patients in the hospital. Hence, outsourcing the HCWD to Government approved treatment facility, will help in reducing the risk of handling the infectious waste. As per Ho (2011), outsourcing to authorized CBWTFs will reduce all the risks, as the processes are more standardized there and we can have the access to the qualified firms working on the infectious waste disposal. Hsu et al. (2008) also stressed that supplier qualification and ability to provide the service is important for selecting the outsourcing partner.

#### 3.3.1.2 Overdependence (P2)

As per Swift (1995), the dependability is important criteria while going for outsourcing. Sometimes, the infectious waste lies in the hospital itself for more than 4-5 days, which is very harmful for the hospital premises and also as per the waste handling and management rules, 1998 the infectious waste should be transported to the waste treatment facility within 48 hours. Hence, outsourcing the disposal process, make the hospitals more dependent on the CBWTF.

#### 3.3.1.3 Transportation and risk associated (P3)

Outsourcing the HCWD process, requires the infectious waste to be transported to the treatment facility, which involves huge risk, as the infection may spread to the environment. So special vehicles equipped with global positioning system are required. As per Liao and Ho (2014), outsourcing the HCW treatment and transportation, leads to higher waste handling costs.

#### 3.3.1.4 Government rules (P4)

The process of handling the infectious MW is precise and well defined in the BMW Handling and Management Rules, 1998. As per Waste Disposal Act, to ensure the proper final disposal of the infectious HCW, is the joint responsibility of HCF and the outsourcing partner. Hence, HCFs prefer to outsource to the third party, who is approved by the Government and are having necessary equipment and qualified personnel (Ho, 2011). Conformance to Government environment protection rules is the key element while disposing the HCW (Yang et al., 2002; Hsu et al., 2008; Gumus, 2009).

#### 3.3.1.5 Environmental factors (P5)

Environmental factors play crucial role when outsourcing the infectious HCWD process to the third party. While selecting the waste treatment facility the environmental factors like: ‘geographical location’ (Dickson, 1966; Ho, 2011) and ‘hygiene and safety’ (Gumus, 2009; Ho et al., 2010) are some of the issues which must be considered. In-house treatment of the infectious waste may be very harmful for the hospital premises. Hence, it is always better to set up the treatment facility out of the town.

### 3.3.1.6 Economic factors (P6)

Outsourcing the HCWD process helps the HCFs to cut the cost of disposing the waste by avoiding the initial investment on setting up the treatment facility and also the permanent manpower cost (Ho, 2011). As per the Swift's factors and Dickson's evaluating criteria, price is the most important factor while going for outsourcing. Some of the important financial factors, which must be considered while selecting the HCWD strategy are: cost for treating per unit of waste (Ho et al., 2010; Ho, 2011), financial position of the HCF (Dickson, 1966; Ho, 2011) etc. As per Jiang et al. (2012), the operating cost and the equipment depreciation costs should be considered, while evaluating the waste disposal strategies.

### 3.3.2 Pair-wise Comparison Matrix for Criteria

A pair-wise comparison matrix is derived from the opinion collected from the experts' panel, which represents the relative importance of each criterion with respect to other. The experts' panel consists of five experts in the related field, whose profile is given in Table 3.3.

**Table 3.3:** Profile of Experts

| Expert No. | Industry | Designation | Experience (Years) | Education Qualification |
|---|---|---|---|---|
| E1 | Pollution Control Board | Member secretary | 27 | PhD |
| E2 | Pollution Control Board | Senior scientist | 13 | PhD |
| E3 | Healthcare facility | Chief medical officer | 22 | MD, MBBS |
| E4 | Healthcare facility | Professor, (Chairman, Pollution control committee) | 17 | PhD, MD, MBBS |
| E5 | Common biomedical waste treatment facility | Chairman, MPCC | 30 | PhD |

The scale described in Table 3.1, is used to compare all the criteria with respect to each other. If the expert vote 'very high' for a particular cell, that means the row criterion is very highly important than the column criterion. If the opinion is 'very low' that means row criterion is very less important than column element. In between the different levels of scale can be used to make the pair-wise comparison among various elements. For the reverse comparison among the criteria, a reciprocal value is assigned in the matrix, so that for pair-wise comparison matrix $a_{ij}*a_{ji} = 1$. The pair-wise comparison matrix in terms of linguistic variables among all the criteria is shown in Table 3.4.

**Table 3.4:** Pair-wise Comparison Matrix for Six Criteria

| **Criteria** | **$P_1$** | **$P_2$** | **$P_3$** | **$P_4$** | **$P_5$** | **$P_6$** |
|---|---|---|---|---|---|---|
| $P_1$ | 1 | $P_1$ $P_2$ | $P_1$ $P_3$ | $P_1$ $P_4$ | $P_1$ $P_5$ | $P_1$ $P_6$ |
| $P_2$ | 1/ $P_1$ $P_2$ | 1 | $P_2$ $P_3$ | $P_2$ $P_4$ | $P_2$ $P_5$ | $P_2$ $P_6$ |
| $P_3$ | 1/ $P_1$ $P_3$ | 1/ $P_2$ $P_3$ | 1 | $P_3$ $P_4$ | $P_3$ $P_5$ | $P_3$ $P_6$ |
| $P_4$ | 1/ $P_1$ $P_4$ | 1/ $P_2$ $P_4$ | 1/ $P_3$ $P_4$ | 1 | $P_4$ $P_5$ | $P_4$ $P_6$ |
| $P_5$ | 1/ $P_1$ $P_5$ | 1/ $P_2$ $P_5$ | 1/ $P_3$ $P_5$ | 1/ $P_4$ $P_5$ | 1 | $P_5$ $P_6$ |
| $P_6$ | 1/ $P_1$ $P_6$ | 1/ $P_2$ $P_6$ | 1/ $P_3$ $P_6$ | 1/ $P_4$ $P_6$ | 1/ $P_5$ $P_6$ | 1 |

Where, $P_1$ $P_2$ represents the importance of $P_1$ element over $P_2$ element.

To get the upper half of the matrix, the preferences of one element over other element are collected from the five experts (E1, E2, E3, E4, E5) and lower half comparison scores have been calculated by taking the inverse of the corresponding cell value. The experts' opinion are shown in Table 3.5.

**Table 3.5:** Linguistic Values given by the Experts

| **Pair-wise comparison** | **E1** | **E2** | **E3** | **E4** | **E5** |
|---|---|---|---|---|---|
| P1P2 | VHI | VHI | HI | VHI | VHI |
| P1P3 | VHI | VHI | HI | HI | VHI |
| P1P4 | HI | I | I | LI | I |
| P1P5 | I | LI | I | I | HI |
| P1P6 | HI | HI | I | HI | HI |
| P2P3 | HI | VHI | I | HI | HI |
| P2P4 | I | LI | I | LI | I |
| P2P5 | I | LI | I | I | I |
| P2P6 | I | I | HI | I | H |
| P3P4 | I | LI | HI | I | I |
| P3P5 | I | I | LI | HI | I |
| P3P6 | I | LI | I | I | HI |

| | | | | | |
|---|---|---|---|---|---|
| P4P5 | I | VHI | HI | HI | VHI |
| P4P6 | HI | VHI | HI | VHI | HI |
| P5P6 | HI | VHI | HI | HI | VHI |

The linguistic responses given by the experts are converted into grey numbers by using the scale given in Table 3.1 and after conversion, the values are shown in Table 3.6.

**Table 3.6:** Linguistic Variables in terms of Grey Numbers

| Pair-wise comparison | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| P1P2 | [0.75, 1] | [0.75, 1] | [0.5, 0.75] | [0.75, 1] | [0.75, 1] |
| P1P3 | [0.75, 1] | [0.75, 1] | [0.5, 0.75] | [0.5, 0.75] | [0.75, 1] |
| P1P4 | [0.5, 0.75] | [0.25, 0.5] | [0.25, 0.5] | [0, 0.25] | [0.25, 0.5] |
| P1P5 | [0.25, 0.5] | [0, 0.25] | [0.25, 0.5] | [0.25, 0.5] | [0.5, 0.75] |
| P1P6 | [0.5, 0.75] | [0.5, 0.75] | [0.25, 0.5] | [0.5, 0.75] | [0.5, 0.75] |
| P2P3 | [0.5, 0.75] | [0.75, 1] | [0.25, 0.5] | [0.5, 0.75] | [0.5, 0.75] |
| P2P4 | [0.25, 0.5] | [0, 0.25] | [0.25, 0.5] | [0, 0.25] | [0.25, 0.5] |
| P2P5 | [0.25, 0.5] | [0, 0.25] | [0.25, 0.5] | [0.25, 0.5] | [0.25, 0.5] |
| P2P6 | [0.25, 0.5] | [0.25, 0.5] | [0.5, 0.75] | [0.25, 0.5] | [0.5, 0.75] |
| P3P4 | [0.25, 0.5] | [0, 0.25] | [0.5, 0.75] | [0.25, 0.5] | [0.25, 0.5] |
| P3P5 | [0.25, 0.5] | [0.25, 0.5] | [0, 0.25] | [0.5, 0.75] | [0.25, 0.5] |
| P3P6 | [0.25, 0.5] | [0, 0.25] | [0.25, 0.5] | [0.25, 0.5] | [0.5, 0.75] |
| P4P5 | [0.25, 0.5] | [0.75, 1] | [0.5, 0.75] | [0.5, 0.75] | [0.75, 1] |
| P4P6 | [0.5, 0.75] | [0.75, 1] | [0.5, 0.75] | [0.75, 1] | [0.5, 0.75] |
| P5P6 | [0.5, 0.75] | [0.75, 1] | [0.5, 0.75] | [0.5, 0.75] | [0.75, 1] |

### 3.3.3 Preparing Crisp Values Matrix and Calculate ‘E-Vector’ and ‘Consistency Index (CI)’

The linguistic values are now converted into crisp values by applying the equations (3.1) to (3.5) as explained in the methodology. In the last, the e-vector and CI index have been calculated in order to prioritize each parameter as shown in Table 3.7. The e-vector or local priority vector represents the weighted priorities of the criteria, which has been calculated by using two steps (Ravi et al., 2005). Firstly, we calculated the column sum for each column and then each cell value is divided by its column sum and normalized matrix is obtained. Then to find the e-vector row average is computed for each row.

**Table 3.7:** E-vector and CI Index Results

| **Criteria** | **P1** | **P2** | **P3** | **P4** | **P5** | **P6** | **E-vector** | **CI** |
|---|---|---|---|---|---|---|---|---|
| P1 | 1.00 | 0.70 | 0.65 | 0.25 | 0.25 | 0.45 | 0.064 | 0.0974 |
| P2 | 1.43 | 1.00 | 0.49 | 0.15 | 0.20 | 0.24 | 0.055 | |
| P3 | 1.54 | 2.04 | 1.00 | 0.25 | 0.25 | 0.25 | 0.080 | |
| P4 | 4.00 | 6.67 | 4.00 | 1.00 | 0.55 | 0.60 | 0.239 | |
| P5 | 4.00 | 5.00 | 4.00 | 1.82 | 1.00 | 0.60 | 0.278 | |
| P6 | 2.20 | 4.11 | 4.00 | 1.67 | 1.67 | 1.00 | 0.285 | |

### 3.3.4 Alternatives Evaluation Matrix

Here, the pair-wise comparison is made for both the strategies with respect to all the criteria. The number of pair-wise comparisons will be equal to the number of criteria elements in the structure. A total of six criteria have been finalized and hence, six pair-wise comparison matrices have been developed. For each criterion, the evaluation of the alternatives is given below:

i) Alternatives evaluation with respect to 'Access to expertise (P1)'

Here, using Table 3.2, the experts are asked to evaluate both the HCWD strategies with respect to criterion 'access to expertise'.

**Table 3.8:** Pair-wise Comparison of Strategies under 'Access to Expertise' Criterion

3.8 (a)

| | A | B |
|---|---|---|
| A | 1 | AB |
| B | 1/AB | 1 |

3.8 (b)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | VP | P | VP | P | VP |

3.8 (c)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | [0,1] | [1,3] | [0,1] | [1,3] | [0,1] |

3.8 (d)

| | E-vector | CI |
|---|---|---|
| A | 0.2857 | 0 |
| B | 0.7143 | |

In the table 3.8 (a), pair-wise comparison matrix among the HCWD strategies is shown. The experts' decisions about the evaluation of each strategy is shown in Table 3.8 (b), which is converted into grey numbers from linguistic variable by using Table 3.2 and is shown in Table 3.8 (c). Finally, the priority vector for each alternative is shown in Table 3.8 (d). Similarly, for all other criteria the e-vectors have been calculated as shown below.

ii) Alternatives evaluation with respect to 'Overdependence ($P_2$)'

**Table 3.9:** Pair-wise Comparison of Strategies under 'Overdependence' Criterion

3.9 (a)

| | A | B |
|---|---|---|
| A | 1 | AB |
| B | 1/AB | 1 |

3.9 (b)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | P | MP | MP | F | MP |

3.9 (c)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | [1,3] | [3,4] | [3,4] | [4,5] | [3,4] |

3.9 (d)

| | E-vector | CI |
|---|---|---|
| A | 0.7368 | 0 |
| B | 0.2632 | |

iii) Alternatives evaluation with respect to 'Transportation & risk associated ($P_3$)'

**Table 3.10:** Pair-wise Comparison of Strategies under 'Transportation & Risk Associated'

3.10 (a)

| | A | B |
|---|---|---|
| A | 1 | AB |
| B | 1/AB | 1 |

3.10 (b)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | VG | VG | G | MG | VG |

3.10 (c)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | [9,10] | [9,10] | [6,9] | [5,6] | [9,10] |

3.10 (d)

| | E-vector | CI |
|---|---|---|
| A | .8837 | 0 |
| B | .1163 | |

iv) Alternatives evaluation with respect to 'Government rules ($P_4$)'

**Table 3.11:** Pair-wise Comparison of Strategies under 'Government Rules' Criterion

3.11 (a)

| | A | B |
|---|---|---|
| A | 1 | AB |
| B | 1/AB | 1 |

3.11 (b)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | VP | P | VP | P | VP |

3.11 (c)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | [0,1] | [1,3] | [0,1] | [1,3] | [0,1] |

3.11 (d)

| | E-vector | CI |
|---|---|---|
| A | 0.2857 | 0 |
| B | 0.7143 | |

v) Alternatives evaluation with respect to 'Environmental factors ($P_5$)'

**Table 3.12:** Pair-wise Comparison of Strategies under 'Environmental Factors' Criterion

3.12 (a)

| | A | B |
|---|---|---|
| A | 1 | AB |
| B | 1/AB | 1 |

3.12 (b)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | P | VP | VP | P | P |

3.12 (c)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | [1,3] | [0,1] | [0,1] | [1,3] | [1,3] |

3.12 (d)

| | E-vector | CI |
|---|---|---|
| A | 0.3750 | $4.44*10^{-16}$ |
| B | 0.6250 | |

vi) Alternatives evaluation with respect to 'Economic factors (P6)'

**Table 3.13:** Pair-wise Comparison of Strategies under 'Economic Factors' Criterion

3.13 (a)

| | A | B |
|---|---|---|
| A | 1 | AB |
| B | 1/AB | 1 |

3.13 (b)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | AB | VP | VP | P | VP |

3.13 (c)

| | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | [0,1] | [0,1] | [1,3] | [0,1] | [1,3] |

3.13 (d)

| | E-vector | CI |
|---|---|---|
| A | .2857 | 0 |
| B | .7143 | |

### 3.3.5 Calculating the Score for Each Alternative and Ranking

The priority of each HCWD strategy depends upon the result of the 'desirability index'. Desirability index is calculated by multiplying the preference matrix of both the strategies for all the criteria with the criteria weights. After getting the preferences of various parameters on HCWD strategic options, the score for each alternative is as follows:

$$\begin{bmatrix} & P1 & P2 & P3 & P4 & P5 & P6 \\ A & .2857 & .7368 & .8837 & .2857 & .3750 & .2857 \\ B & .7143 & .2632 & .1163 & .7143 & .6250 & .7143 \end{bmatrix} * \begin{bmatrix} .064 \\ .055 \\ .080 \\ .239 \\ .278 \\ .285 \end{bmatrix} = \begin{bmatrix} .39 \\ .61 \end{bmatrix} \qquad (3.8)$$

Hence, from the result it is clear that alternative B (outsourcing) is more preferred by the experts, as the desirability index for 'outsourcing' is higher than 'in-house treatment' as shown in Eq. (3.8).

## 3.4 DISCUSSION AND MANAGERIAL IMPLICATIONS

In India, the HCW has become big challenge for the HCFs, CPCB and SPCBs. Some HCFs have established their own treatment facilities and some are outsourcing the HCW to the third party. Hence, Indian HCWD market is fragmented and there is no quantitative tool to evaluate, whether a HCF should go for outsourcing or should treat the HCW in-house. In this chapter, grey theory based AHP model has been used to select the best HCWD strategy with respect to certain criteria related to HCWD process. The experts have assigned the weights to each criterion in terms of linguistic variables, which have been later on converted into grey numbers for further calculations. The priority vector for each criterion has been given in Table 3.7, which shows that while deciding for outsourcing the HCWD process, the ‘economic factors’ (0.285) have been given the highest importance by the experts. Due to increase in global competition HCFs are forced to provide the better healthcare services at reduced price. Hence, most of the HCFs are outsourcing the processes, which are not their core business areas. Therefore, HCFs go for outsourcing the HCWD process in order to reduce the operational cost. There are so many studies in the other fields also which stressed on the outsourcing in order to reduce and control the costs and quickly respond to the market demands (Lacity et al., 1994; Loh and Venkatraman, 1995; Smith et al., 1998).

‘Environmental factors’ (0.278) have been rated second highest on the priority level while selecting the HCWD strategy. Since, the HCW is very much hazardous in nature, so it is important to assess its impact on the hospital premises and outside environment. Geographical location of the treatment facility, hygiene and safety are some of the parameters which should be considered while disposing the infectious waste (Dickson, 1966; Gumus, 2009; Ho et al., 2010; Ho, 2011; Senthil et al., 2014). Hence, as per the experts opinion the treatment facility location is important in protecting the hospital surroundings and generally the Government approved CBWTFs are located well outside the city and is more safe location than with in the hospital itself. Indian Government Waste Handling Rules, 1998 define nature of each type HCW and also the category-wise treatment options are listed. As per the experts’ opinion, most of the HCFs used to incinerate the MW without following the Waste Handling Rules, 1998. But, CBWTFs are Government authorized treatment facilities and are equipped with all the treatment techniques. ‘Government rules’ (.239) conformance has been kept at third position in the importance of selecting the HCWD strategy. This is followed by ‘transportation and risk associated’ (0.080), ‘access to expertise’ (0.064) and ‘overdependence’ (.055).

It is clear from the Eqn. (3.8), that HCFs should outsource the HCWD process to the third party as rated by the experts. ‘Outsourcing’ strategic option (0.61) got the higher desirability index than ‘in-house treatment’ (0.39). According to Quinn (1992), outsourcing will help the firm to increase its performance by focusing on their key areas. Jiang et al. (2006) proved that outsourcing helps to achieve cost efficiency. Chanvarasuth (2008) stressed that outsourcing helps to improve the performance of the firm by reducing cycle times, better responsiveness and by service enhancement. Here, ‘outsourcing’ strategy has been rated higher than ‘in-house treatment’ with respect to the following four criteria: economic factors, environmental factors, Government rules, and access to expertise. But with respect to ‘transportation & risk associated’ and ‘overdependence’ ‘in-house treatment’ strategy has been rated best by the experts. While transporting the hazardous waste to the CBWTF, it is more exposed to the environment as the vehicles used in India are normally goods carrier and not equipped with global positioning system. In case of outsourcing the waste to third party, makes the HCFs more dependent on the CBWTFs and if they don’t collect the waste regularly, then the infectious waste lies in the hospital premises for long time, which is very harmful for the hospital staff and patients.

### 3.5 CHAPTER SUMMARY

This chapter proposes Grey -AHP based framework for selecting the HCWD strategy. Right now some HCFs are outsourcing and some are treating the HCW in-house. Hence, the present study evaluates both the strategies with respect to certain criteria using Grey based AHP methodology. Form the literature, six criteria has been used to evaluate the HCWD strategies: access to expertise, overdependence, transportation & risk associated, Government rules, environmental factors, and economic factors. The experts’ responses about the pair-wise comparisons among criteria have been collected in terms of linguistic variables and which have been converted into grey numbers for further calculations. Then grey numbers have been converted into crisp values and finally the elements have been prioritized. The AHP framework under grey environment suggested that the HCFs should go for outsourcing of the HCWD process to the third party. Since, the problem structure is same for all the HCFs and it does not vary with regions, hence the result can be generalized for all the HCFs irrespective of the State. The present study has been extended in the next chapter, where a model has been proposed for selecting the HCWD partner and also the criteria have been extended and sub-criteria have been defined for each criterion.

**CHAPTER 4**

# SELECTION OF HEALTHCARE WASTE DISPOSAL FIRM USING ANALYTIC NETWORK PROCESS AND TOPSIS UNDER GREY ENVIRONMENT

## 4.1 INTRODCUTION

The importance of Healthcare Waste Management (HCWM) is to provide the hygiene to the patients and preventing the spread of infection from Medical Waste (MW) in the hospital premises. HCWM is the part of healthcare system and optimizing the efficiency in waste management will ensure sustainability in the healthcare delivery system (Brent et al., 2007). Ho (2011) studied that after the implementation of national health insurance scheme, there is a sharp increase in the quantity of infectious MW. Also, the increased number of HCFs and medical centers creating an alarming situation to the environment management.

With increasing global competition, Healthcare Facilities (HCFs) are forced to provide advanced services with lower costs. Disposing of the MW in-house will require initial investment, which will lead to additional increase in the responsibility of meeting environmental regulations; hence, this will raise the cost of operations (Hsu et al., 2008; Liao and Ho, 2014). According to Ho (2011), outsourcing of the disposal of HCW will save the initial investment on setting up the waste treatment facility and also the personnel costs. Outsourcing will also help in reducing the risk, which may be associated with the disposal of infectious waste. Hsu et al. (2008) observed that in Taiwan, around 62% of all public and 76% of all private hospitals don't dispose the HCW in-house, rather outsource it to some waste disposal firm. Therefore, hospitals are outsourcing the non-essential activities like the Healthcare Waste Disposal (HCWD) (Liao and Ho, 2014) and focusing on the core competencies. For this reason, the outsourcing trends in MW disposal are increasing (Hsu et al., 2008). As observed in Chapter 3, in Indian scenario also, the experts have preferred 'outsourcing' in comparison to 'in-house treatment'.

*Part of this chapter is under review in Operational Research: An International Journal as:*

*Thakur, V. and Ramesh, A. (2015), "Multi-criteria decision-making for outsourcing healthcare waste disposal process: ANP and TOPSIS based approach".*

But, outsourcing process is not easy for the hospitals authorities, as it involves selecting the appropriate waste disposal firm, who can take care of the Government regulations and at the same time is cost effective. Mostly, during selection of the outsourcing partners, the organizations consider primarily their price and experience (Hsu et al., 2008), but dealing with selection of infectious waste handling firm is critical issue, hence, the decision must be more objective and it should involve the quantitative tools for evaluating the alternatives. Therefore, maintaining the quality of disposal process and striving towards minimizing the costs, while fulfilling all the legal norms, will require more rational selection of the waste disposal firm. Hence, this chapter aims the following objectives:

- To identify all the criteria and sub-criteria, which are used to evaluate the HCWD firms.
- To propose the quantitative model to select the appropriate HCWD firm for outsourcing the treatment of HCW.
- To apply the model to select the HCWD firm in Uttarakhand, a Northern State of India.

To achieve the above stated objectives, the present chapter proposes a quantitative model based on the combination of ANP and TOPSIS approaches under grey environment, for selecting the waste disposal firm. Grey theory approach is used to record the responses of the experts in linguistic variables, and subsequent to this, ANP steps have been applied for calculating the weights of various criteria and sub-criteria as well as for rating the various alternatives. Finally, TOPSIS is used to find out the preference order of all the HCWD firms.

## 4.2 LITERATURE REVIEW: HCWD FIRM SELECTION CRITERIA

The selection of HCWD firm is a Multi-Criteria Decision-Making (MCDM) process, whose output depends on the evaluation of the various available alternatives with respect to certain set of criteria. Outsourcing is crucial decision, as it involves the selection of appropriate strategic partner. Several studies have been conducted in various areas for choosing the best partner, but literature lacks studies in HCWD firm selection. For this study, articles from eight journals (International Journal of Environmental Health Research; International Journal of Healthcare Quality Assurance; Journal of Environmental Management; Journal of Hazardous Material; Journal of Material Cycles and Waste Management; Resources, Conservations and Recycling; Waste Management and Waste Management & Research) related to HCWM have been reviewed for last 10 years (2005–July 2014) and it was found that there are only three studies (Hsu et al., 2008; Ho 2011; Liao and Ho 2014) related to HCWD firm selection. Hsu et al. (2008) studied that the ‘matching degree’ for the selection of infectious MW disposal firms weighted higher than the ‘contractor’s qualification’ and ‘service capability’. Ho (2011) observed that ‘price’ is the highest weighted factor in comparison to ‘availability’ and ‘experience’, while evaluating the alternatives. Dickson (1966) used the 23 evaluating factors for selecting the suppliers, which are also considered while finalizing the criteria for this study. The 20 sub-criteria under the categories of six main criteria, used in the present study are depicted in Table 4.1.

**Table 4.1:** HCWD Firms’ Selection Criteria

| **Criteria** | **Sub-criteria** | **Explanation** | **References** |
|---|---|---|---|
| Experience | Desire for business | Focusing on covering more number of HCFs and volume to achieve the economy of the scale. | Dickson (1966); Ho (2011) |
| | Staff experience | Awareness about the activities and harm among all the employees working on the CBWTF. | Hsu et al. (2008); Ho (2011) |
| | Performance history | Records about the level of services provided by the waste treatment facility. | Dickson (1966); Mahdavi et al. (2008b); Liu and Wang (2009); Ho (2011); Amin and Zhang (2012); Senthil et al. (2014) |
| Relationship | Labor relations records | Relationships with the employees and workers, who are handling the MW. | Dickson (1966); Ho et al. (2010); Ho (2011) |
| | Attitude | Dealing with the customers and industrial relations. | Dickson (1966); Park (2010); Ho (2011) |
| | Reputation with other customers | Review from the other HCFs, who are getting their services. | Dickson (1966); Ho et al. (2010); Ho (2011) |
| Environmental factors | Geographical location | HCW treatment facility should be out of the city due | Dickson (1966); Ho (2011); Senthil et al. (2014) |

| Criteria | Sub-criteria | Explanation | References |
|---|---|---|---|
| | | to the harmful emission from the incinerators. | |
| | Hygiene and safety | Safety parameters used by the waste handling workers. | Gumus (2009); Ho et al. (2010); Dursun et al. (2011) |
| | Conformance to Government environment protection rules | Compliance with the BMW Handling & Management Rules, 1998 and keeping all the records. | Yang et al. (2002); Hsu et al. (2008); Gumus (2009) |
| Technology and qualification | Transporting vehicles equipped with global positioning system | Transportation of hazardous MW from HCF to CBWTF without any spread of infection. | Gu and Pan (1999); Chen (2000); Hsu et al. (2008) |
| | Management information system | Tracking of operations at each level and sharing the information with the customers. | Yang et al. (2002); Hsu et al. (2008) |
| | Use of advanced technology | Use of latest pollution free disposal technology and R & D facilities. | Dickson (1966); Mahdavi et al. (2009); Ho et al. (2010); Dursun et al. (2011); Park (2011); Savetpanuvong et al. (2011a); Senthil et al. (2014) |
| Economic factors | Financial position | Vendor's liquidity, solvency positions and its credit rating policy. | Dickson (1966); Ho et al. (2010); Ho (2011); Senthil et al. (2014) |
| | Discounts for long-term customers | Discounts for large volume and also for maintaining long term relationship. | Pan and Chen (1997); Hsiao et al. (2004); Hsu et al. (2008) |

| Criteria | Sub-criteria | Explanation | References |
|---|---|---|---|
| | Cost | Cost associated with disposing the each unit of waste. | Gumus (2009); Dursun et al. (2011); Ho et al. (2010); Ho (2011) |
| Firm's Capabilities | Timely and frequently transportation | Strong logistics capability and frequent service is provided to the HCF. | Askarian et al. (2004); Hsu et al. (2008); Gumus (2009) |
| | Provide container storage | Different containers for different categories of waste. | Pan and Chen (1997); Hsu et al. (2008) |
| | Reverse logistics process functions | Collection of wastes, Segregation, Packaging, storage and transportation of MW. | Meade and Sarkis (2002); Ha and Krishnan (2008); Boran et al. (2009); Senthil et al. (2014) |
| | Quality & Training aids | Training programs conducted for the waste handling employees. | Dickson (1966); Xiangru (2008); Gumus (2009); Chamodrakos et al. (2010); Ho (2011); Zouggari and Benyoucef (2012); Senthil et al. (2014); Jain and Rangnekar (2015); Jain and Samrat (2015) |
| | Disposal capacity | Refers to the amount of waste that can be disposed per hour. | Liu and Wang (2009); Ho (2011); Chen and Chao (2012); Senthil et al. (2014) |

## 4.3 METHODOLOGY

A quantitative model is proposed in this section to select the best HCWD firm for strategic outsourcing. The model is divided into three main stages: 1) Grey theory approach, 2) ANP, and 3) TOPSIS as shown in Figure 4.1. Grey theory approach is used to finalize the weights of various elements that are involved at different levels in the hierarchical structure. ANP steps are applied to find out the desirability indices of different alternatives with respect to various criteria. Finally, the ranking of the alternatives is done by TOPSIS. The details description for the proposed model is given below.

**4.3.1 Stage 1: Grey Theory Approach:** *Collect the opinion of the experts' in-terms of linguistic variables and convert into crisp values.*

The purpose of using grey numbers here, is to collect the experts' opinion on the various criteria weights and preference of various HCWD firms on each criterion under uncertain information. The first stage of the proposed model consists of two steps of grey theory approach:

**Step 1:** Develop a hierarchical structure of the problem.

The first step belongs to identifying the problem and its associated criteria and sub-criteria for evaluating the various HCWD firms. The complex problem is defined in the simple hierarchical structure, where the first level reflects the objective and the last level represents the various HCWD firms, which are to be evaluated. However, the intermediate levels contain the criteria and sub-criteria on which evaluations are to be made. The opinion of the experts about the relative weights of various elements involved in the structure are collected in-terms of linguistic variables and converted into grey numbers by using Table 3.1 and Table 3.2 as done in Chapter 3.

**Step 2:** Collect experts' opinion and convert grey values into crisp numbers.

In this step, the weights of all the elements in the hierarchical structure are collected in the terms of linguistic variables and the weights of final criteria are converted from grey values to crisp values by adopting the three–step "De-greying" procedure given in Chapter 3 (Eqn. 3.1-3.5).

**4.3.2 Stage 2: Analytic Network Process (ANP):** *Determine the weights for the selection criteria and rating the various HCWD firms by applying ANP.*

Criteria weights are calculated by using grey numbers, which are further used in the ANP process, which is more advanced than AHP in a complex MCDM situation (Meade and Sarkis, 1998; Lee and Kim, 2000; Yurdakul, 2003; Ravi et al., 2005). The main reasons for using ANP technique for the firm selection are:

i) Selecting the HCWD partners will depend on various criteria and sub-criteria, hence making the pair-wise comparison will be difficult in AHP. ANP can easily model the complex decision problems.

ii) ANP considers the interrelationships and feedback among various criteria and alternatives in its network structure. In addition to this, there exist dependencies among various elements in our problem of selecting the HCWD firm.

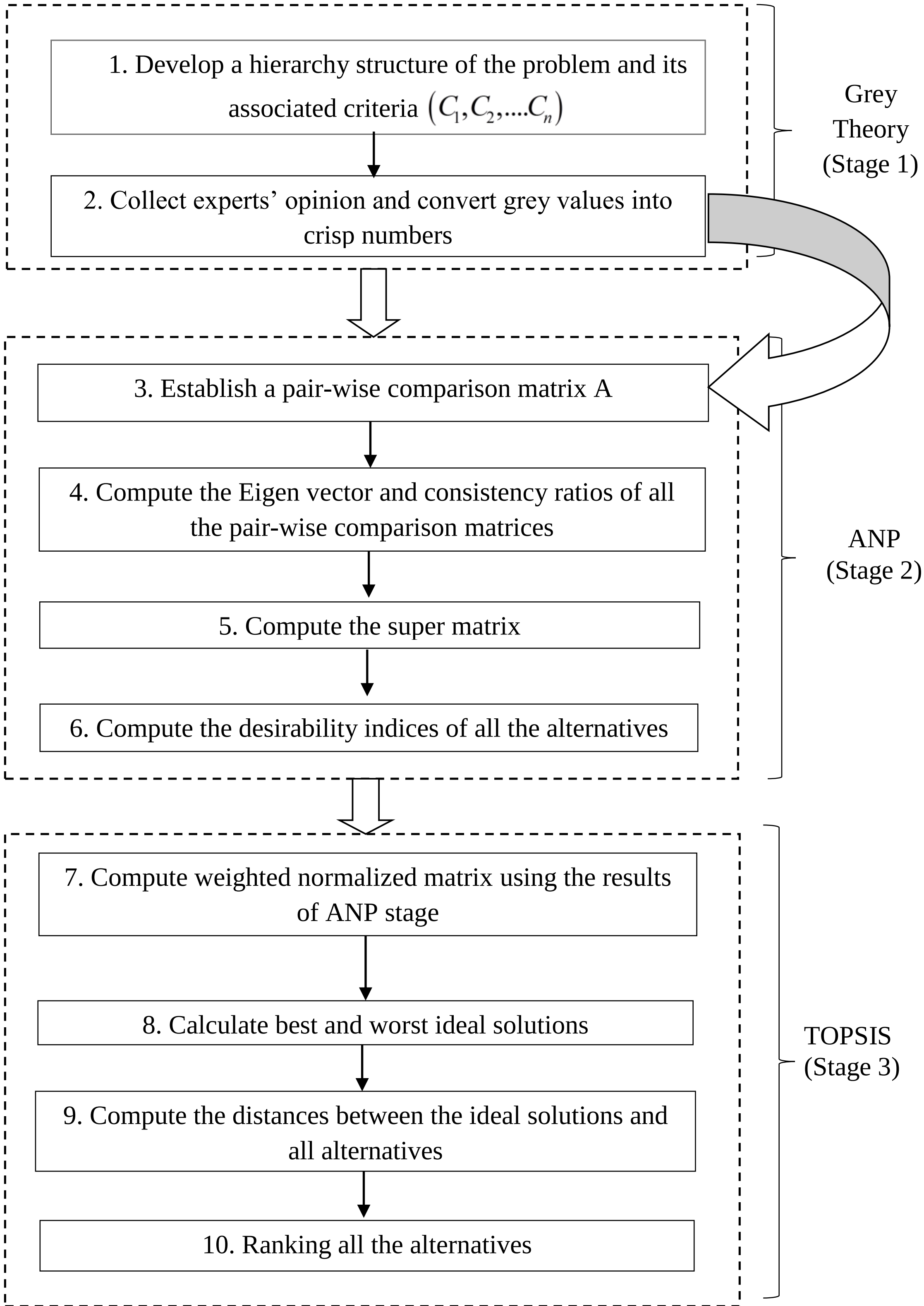


**Figure 4.1:** Proposed Model to Select the Appropriate HCWD Firm

iii) ANP permits consideration of all the tangible as well as intangible factors, which are having impact on the decision-making process.

iv) ANP also considers the non-linear interrelationships among the various elements in the selection hierarchical process.

The second stage of the proposed methodology includes the following four steps of ANP:

**Step 3:** Establish a pair-wise comparison matrix 'A'

Pair-wise comparisons are made for each element in the hierarchy by the experts. If there are 'n' number of elements in the structure, then a total of n(n-1)/2 pair-wise comparison will be made by the experts. Pair-wise comparison matrix represents the preference of row element over the column element. After calculating the upper triangle of pair-wise comparison of matrix A, the lower triangle values will be the reciprocal values of the upper triangle for the relative positions, as shown in equation (4.1). In this step, the interdependencies among various criteria and sub-criteria are also determined by supplying all the elements to the expert panel and subsequent to this the pair-wise comparisons are made.

$$A = \begin{bmatrix} 1 & a_{12} & a_{13} & a_{14} \\ 1/a_{12} & 1 & a_{23} & a_{24} \\ 1/a_{13} & 1/a_{23} & 1 & a_{34} \\ 1/a_{14} & 1/a_{24} & 1/a_{34} & 1 \end{bmatrix} \tag{4.1}$$

**Step 4:** Compute Eigen vector and consistency ratios for all pair-wise comparison matrices

Eigen vector is calculated by dividing each element by the sum of its column and then taking the row average. The maximum Eigen value $\lambda_{\max}$ is calculated as:

$$\lambda_{\max} = \sum_{j=1}^{n} a_{ij} \frac{w_j}{w_i} \tag{4.2}$$

The Consistency Ratios (*CR*) of all the matrices are checked for controlling the responses of the respondents. The consistency test is performed to avoid the unwanted responses given by any respondent. If preferences of the respondents are not consistent (i.e. CR>10%), the responses should be recorded repeatedly. *CR* is calculated as shown in Eqn. (4.3):

$$CR = \left( (\lambda_{\max} - n) \big/ (n-1) \right) / Table\_value \tag{4.3}$$

**Step 5:** Compute the super matrix

In the end, super matrix is constructed according to the relationship structures defined in the problem given in equation (4.4), where, $m_{ij}$ means that cluster '*i*' depends on cluster '*j*' and 0 value shows no interaction between the clusters.

$$M = \begin{bmatrix} m_{11} & m_{12} & m_{13} & 0 \\ m_{22} & 0 & m_{23} & 24 \\ m_{31} & 0 & m_{33} & 0 \\ m_{41} & 0 & m_{43} & 0 \end{bmatrix} \quad (4.4)$$

The weighted super matrix M converges to obtain a long-term stable set of weights through multiplication of the weighted super matrix by itself, until super matrix becomes 'column stochastic'. For super matrix to become 'column stochastic', the sum of the weight across each column needs to be one.

**Step 6:** Calculate the desirability indices of all the alternatives

The desirability indices are calculated by multiplying the criteria weights with alternatives' ratings and for each individual criterion, the alternative score is calculated. Finally, the desirability index values are normalized.

### 4.3.3 Stage 3: TOPSIS: *Ranking of various HCWD firms by applying TOPSIS*

Hwang and Yoon (1981) developed TOPSIS as a MCDM technique. The main advantage of using TOPSIS after ANP is that it gives the best alternatives solution, having the least distance from the positive ideal solution and the farthest distance from the negative ideal solution (Abo-Sinna and Amer, 2005; Jahanshahloo et al., 2006; Shih et al., 2007; Gumus, 2009). TOPSIS can also consider the relative weights of the selection criteria (Zolfani and Antucheviciene, 2012). The proposed methodology uses the following four steps of TOPSIS to rank all the alternatives:

**Step 7:** Compute the weighted normalized matrix using the results of ANP stage.

In this step, the intersection results of 'n' criteria and 'm' alternatives are described in the form of matrix $(x_{ij})_{m \times n}$ and it is normalized by applying the equation (4.5):

$$N = (r_{ij})_{m \times n} \quad (4.5)$$

where, $r_{ij} = \dfrac{x_{ij}}{\sqrt{\sum_{i=1}^{m} x_{ij}^2}}$

The normalized matrix is multiplied by the assigned weights in order to find out the weighted normalized matrix as shown in equation (4.6):

$$T = (t_{ij})_{m \times n} = (w_j r_{ij})_{m \times n} \tag{4.6}$$

where, $\forall i \in \{1, 2, 3 \ldots\ldots m\}$

and $$w_j = w_j \Big/ \sum_{j=1}^{n} w_j \tag{4.7}$$

where, $\forall j \in \{1, 2, 3 \ldots\ldots m\}$

**Step 8:** Calculate best and worst ideal solutions.

The best alternative solution ($S_b$) and worst alternative solution ($S_w$) are calculated as shown in equations (4.8) and (4.9), where $J^+$ represents the set of benefit attributes and $J^-$ shows the set of negative attributes.

$$S_w = \left\{ \langle \max(t_{ij} \mid i = 1, 2, \ldots, m) \mid j \in J^+ \rangle, \langle \min(t_{ij} \mid i = 1, 2, \ldots., m) \mid j \in J^+ \rangle \right\} = \left\{ t_{wj} \mid j = 1, 2, \ldots n \right\} \tag{4.8}$$

$$S_b = \left\{ \langle \min(t_{ij} \mid i = 1, 2, \ldots, m) \mid j \in J^- \rangle, \langle \max(t_{ij} \mid i = 1, 2, \ldots., m) \mid j \in J^+ \rangle \right\} = \left\{ t_{bj} \mid j = 1, 2, \ldots n \right\} \tag{4.9}$$

**Step 9:** Compute the distances between the ideal solutions and all alternatives.

After calculating the ideal solutions, the distance between each target alternative from the best and worst ideal solution is calculated. Euclidean distance (ED) between the target alternative and best positive ideal solution is given in equation (4.10):

$$ED_b = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{bj})^2} \tag{4.10}$$
$$where, i = 1, 2, \ldots. m$$

Euclidean distance between the target alternative and worst negative ideal solution is given in equation (4.11):

$$ED_w = \sqrt{\sum_{j=1}^{n} (t_{ij} - t_{wj})^2} \tag{4.11}$$
$$where, i = 1, 2, \ldots. m$$

**Step 10:** Ranking of all the alternatives.

Calculating the closeness of all the alternatives to the ideal solution by using equation (4.12) as well as finding out the preference order.

$$C_w = \left( ED_w \big/ \left( ED_w + ED_b \right) \right), 0 \le C_w \le 1 \tag{4.12}$$

$C_w = 1$, indicates that target alternative has worst condition

$C_w = 0$, indicates that target alternative has best condition

## 4.4 CASE STUDY: HCWD FIRM SELECTION IN UTTARAKHAND

The proposed model in Figure 4.1, is applied for the selection of the HCWD firm in two towns, Roorkee and Haridwar, in Uttarakhand, Northern State of India. According to the report of 2014 given by Environment Protection and Pollution Control Board, Uttarakhand, these two towns are having a total of 149 HCFs and 2790 beds. Out of 149 HCFs, 34 are having their own treatment and disposal facilities, and the rest 115 are outsourcing the MW to the vendors. Out of 115 HCFs, 94 are covered by the CBWTF situated in Mandawar village and the rest 21 are outsourcing the waste to other HCFs, which are having their own treatment plants. These HCFs are outsourcing the waste disposal process by evaluating the HCWD firms depending upon the experience, cost and include mainly those plants which are nearby. Hence, the proposed model has been applied for evaluating the various HCWD firms on certain parameters, rather than on subjective judgements. The various steps involved in the proposed model are:

### 4.4.1 Develop a Hierarchy Structure of the Problem and its Associated Elements

The first step defines the complex problem in the forms of hierarchical structure constituting of four different levels as shown in Figure 4.2. The first level defines the objective of applying the proposed model. The second level represents the various criteria for evaluating the HCWD firms. The third level highlights the sub-criteria under each criteria and the last level in the structure reflects various HCWD firms as alternatives, which are to be evaluated and ranked. Finalizing of the HCWD firm selection criteria consists of two main steps:

i) An experts' panel has been constituted to make the evaluations. The profile of the five panel members is given in Table 4.2.

**Table 4.2:** Profile of Experts for the Brain-storming Session

| Sl. No. | Industry | Designation | Experience (Years) | Education Qualification |
|---|---|---|---|---|
| 1. | Healthcare facility | Chief medical officer | 22 | MD, MBBS |
| 2. | Pollution Control Board | Senior scientist | 13 | PhD |
| 3. | Healthcare facility | Professor, (Chairman, Pollution Control Committee) | 17 | PhD, MD, MBBS |
| 4. | Academics | Assistant professor | 6 | PhD |
| 5. | Academics | Professor | 25 | PhD |

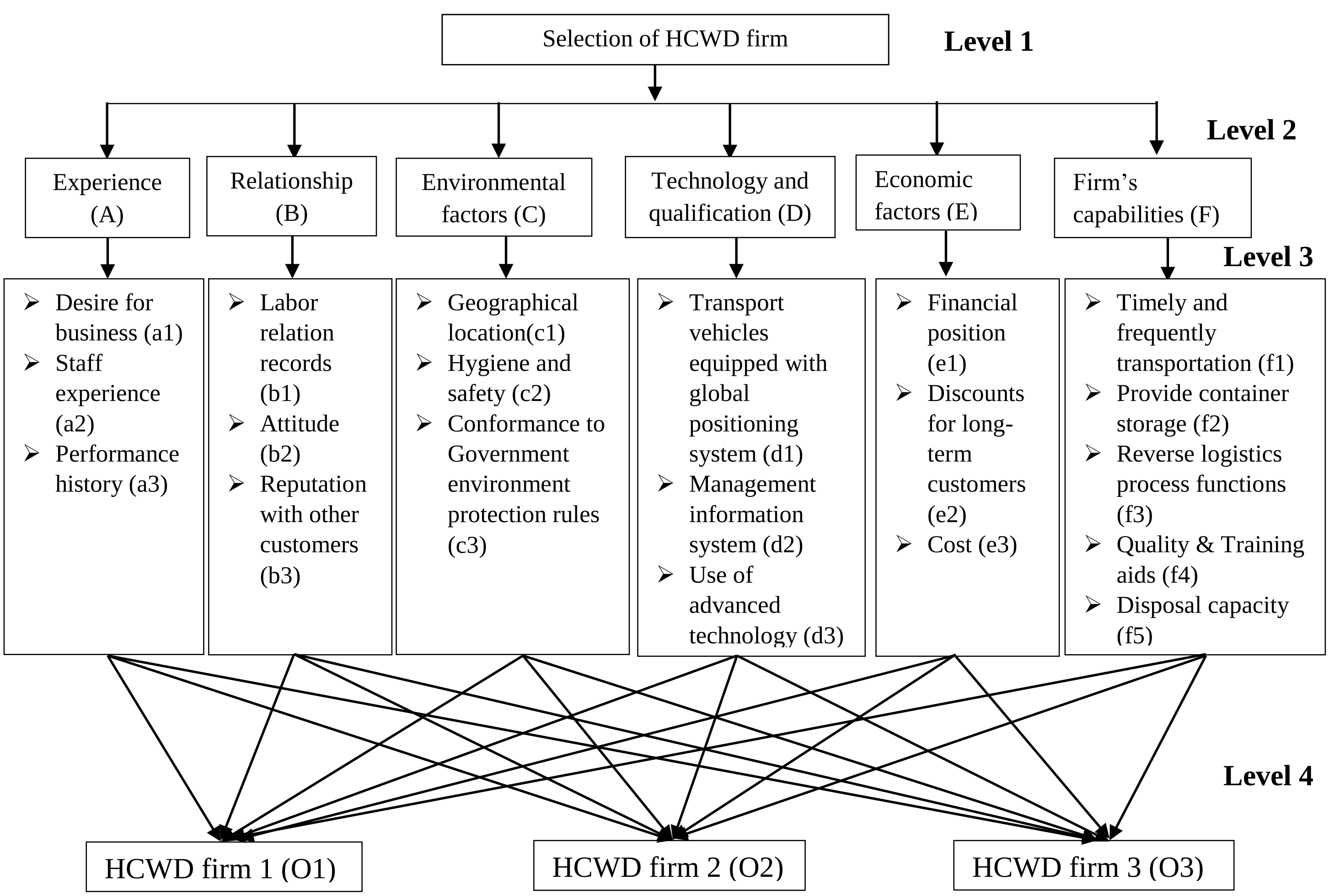


**Figure 4.2:** Hierarchical Structure for Evaluating and Ranking the various HCWD Firms

ii) Categorization of selection criteria: Initially, the literature review provided 20 criteria for making the evaluation of HCWD firms, but it was not possible to make pair-wise comparison matrices for 20 elements. So, experts were asked to categorize them. Finally, for the proposed model, total 20 sub-criteria are defined under the following six main criteria: 1) Experience, 2) Relationship, 3) Environmental factors, 4) Technology and qualification, 5) Economic factors, and 6) Firm's capabilities.

### 4.4.2 Establish Pair-wise Comparison Matrix for Criteria

Here, experts were asked to make the pair-wise comparisons for all the elements at level 2 ('experience', 'relationship', 'environmental factors', 'technology and qualification', 'economic factors', and 'firm's capabilities'). The experts' panel (E1, E2, E3, E4, and E5) gave their preferences over the importance of one element over the other as shown in Table 4.3. 'AB' in the cell represents the importance of element 'A' over element 'B'. After the collection of opinion from five experts, the values (in-terms of linguistic variables) for upper half of the matrix are shown in Table 4.3:

**Table 4.3:** Preference of one Element over other as given by five Experts

| **Pair-wise comparisons** | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | VHI | VHI | HI | VHI | VHI |
| AC | VHI | VHI | HI | HI | VHI |
| AD | HI | I | I | LI | I |
| AE | I | LI | I | I | HI |
| AF | HI | HI | I | HI | HI |
| BC | HI | VHI | I | HI | HI |
| BD | I | LI | I | LI | I |
| BE | I | LI | I | I | I |
| BF | I | I | HI | I | H |
| CD | I | LI | HI | I | I |
| CE | I | I | LI | HI | I |
| CF | I | LI | I | I | HI |
| DE | I | VHI | HI | HI | VHI |

| Pair-wise comparisons | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| DF | HI | VHI | HI | VHI | HI |
| EF | HI | VHI | HI | HI | VHI |

The preferences given by the experts are converted into the grey numbers as shown in Table 4.4, by using the scale given in Table 3.1. Now, the grey numbers are converted into crisp numbers by applying the three steps explained in the methodology from Eqn. (3.1) to Eqn. (3.5) in Chapter 3.

**Table 4.4:** Linguistic Variables in Terms of Grey Numbers

| Pair-wise comparisons | E1 | E2 | E3 | E4 | E5 |
|---|---|---|---|---|---|
| AB | [0.75, 1] | [0.75, 1] | [0.5, 0.75] | [0.75, 1] | [0.75, 1] |
| AC | [0.75, 1] | [0.75, 1] | [0.5, 0.75] | [0.5, 0.75] | [0.75, 1] |
| AD | [0.5, 0.75] | [0.25, 0.5] | [0.25, 0.5] | [0, .25] | [0.25, 0.5] |
| AE | [0.25, 0.5] | [0, 0.25] | [0.25, 0.5] | [0.25, 0.5] | [0.5, 0.75] |
| AF | [0.5, 0.75] | [0.5, 0.75] | [0.25, 0.5] | [0.5, 0.75] | [0.5, 0.75] |
| BC | [0.5, 0.75] | [0.75, 1] | [0.25, 0.5] | [0.5, 0.75] | [0.5, 0.75] |
| BD | [0.25, 0.5] | [0, 0.25] | [0.25, 0.5] | [0, 0.25] | [0.25, 0.5] |
| BE | [0.25, 0.5] | [0, 0.25] | [0.25, 0.5] | [0.25, 0.5] | [0.25, 0.5] |
| BF | [0.25, 0.5] | [0.25, 0.5] | [0.5, 0.75] | [0.25, 0.5] | [0.5, 0.75] |
| CD | [0.25, 0.5] | [0, 0.25] | [0.5, 0.75] | [0.25, 0.5] | [0.25, 0.5] |
| CE | [0.25, 0.5] | [0.25, 0.5] | [0, 0.25] | [0.5, 0.75] | [0.25, 0.5] |
| CF | [0.25, 0.5] | [0, 0.25] | [0.25, 0.5] | [0.25, 0.5] | [0.5, 0.75] |
| DE | [0.25, 0.5] | [0.75, 1] | [0.5, 0.75] | [0.5, 0.75] | [0.75, 1] |
| DF | [0.5, 0.75] | [0.75, 1] | [0.5, 0.75] | [0.75, 1] | [0.5, 0.75] |
| EF | [0.5, 0.75] | [0.75, 1] | [0.5, 0.75] | [0.5, 0.75] | [0.75, 1] |

The Eigen vector is calculated by using Eqn. (4.2) and corresponding CR is calculated by applying Eqn. (4.3). The results of the calculations are given in Table 4.5. These e-vectors are carried to 'desirability indices matrix' for prioritizing the HCWD firms.

**Table 4.5:** Eigen Vector and Consistency Ratio for all Elements at the Second Level

| Criteria | A | B | C | D | E | F | e-vector | CR |
|---|---|---|---|---|---|---|---|---|
| A | 1.00 | 0.70 | 0.65 | 0.25 | 0.25 | 0.45 | 0.064 | 0.0974 |
| B | 1.43 | 1.00 | 0.49 | 0.15 | 0.20 | 0.24 | 0.055 | |
| C | 1.54 | 2.04 | 1.00 | 0.25 | 0.25 | 0.25 | 0.080 | |
| D | 4.00 | 6.67 | 4.00 | 1.00 | 0.55 | 0.60 | 0.239 | |
| E | 4.00 | 5.00 | 4.00 | 1.82 | 1.00 | 0.60 | 0.278 | |
| F | 2.20 | 4.11 | 4.00 | 1.67 | 1.67 | 1.00 | 0.285 | |

### 4.4.3 Establish Pair-wise Comparison Matrix for Sub-criteria

Now, steps (2-4) are repeated for all the pair-wise comparison matrices. To prioritize the 20 elements under various categories, we collected the expert's judgments for preference of one sub-criteria over other sub-criteria under the related criteria in terms of grey numbers, and then calculated the crisp values by applying the Eqns.(3.1) to (3.5), subsequent to which the Eigen vector and CR for each matrix is calculated separately. This step generated a total of 6 pair-wise comparison matrices and the comprehensive results for all the matrices are compiled in Table 4.6. All these e-vector values are imported to 'desirability indices matrix' in order to calculate the preference order of the HCWD firms.

**Table 4.6:** Pair-wise Comparison Matrix of Sub-criteria

| Sub-criteria | e-vector | CR |
|---|---|---|
| Desire for business (a1) | 0.21 | 0.0111 |
| Staff experience (a2) | 0.27 | |
| Performance history (a3) | 0.53 | |
| Labor relations records (b1) | 0.04 | 0.0015 |
| Attitude (b2) | 0.13 | |
| Reputation with other customers (b3) | 0.83 | |
| Geographical location (c1) | 0.029 | 0.0575 |
| Hygiene and safety (c2) | 0.233 | |
| Conformance to Government rules (c3) | 0.738 | |

| Sub-criteria | e-vector | CR |
|---|---|---|
| Transport vehicles equipped with global positioning system (d1) | 0.152 | 0.0033 |
| Management information system (d2) | 0.205 | |
| Use of advanced technology (d3) | 0.644 | |
| Financial position (e1) | 0.047 | 0.016 |
| Discounts for long term (e2) | 0.409 | |
| Cost (e3) | 0.544 | |
| Timely and frequently transportation (f1) | 0.078 | 0.0971 |
| Provide container storage (f2) | 0.074 | |
| Reverse logistics process functions (f3) | 0.283 | |
| Quality & training aids (f4) | 0.258 | |
| Disposal capacity (f5) | 0.307 | |

**4.4.4 Establish Pair-wise Comparison Matrix for Sub-criteria Interdependence**

Here, all the elements have been checked for interdependencies. The experts were asked to evaluate the relative interdependencies among all the elements. This generated a total of 20 pair-wise comparisons matrices for all the elements. The e-vectors for these matrices are calculated and used to construct the 'super matrix'. The compiled results for all the 20 matrices are shown in Table 4.7.

**Table 4.7:** Establish Pair-wise Comparison Matrix for Sub-criteria Interdependence

| Controlled element | Elements under consideration | E-vector | CR |
|---|---|---|---|
| a1 | a2 | 0.130 | 0 |
| | a3 | 0.870 | |
| a2 | a1 | 0.2 | 0 |
| | a3 | 0.8 | |
| a3 | a1 | 0.259 | 0 |
| | a2 | 0.741 | |
| b1 | b2 | 0.167 | 4.4e-16 |
| | b3 | 0.833 | |

| Controlled element | Elements under consideration | E-vector | CR |
|---|---|---|---|
| b2 | b1 | 0.130 | 0 |
| | b3 | 0.870 | |
| b3 | b1 | 0.259 | 0 |
| | b2 | 0.741 | |
| c1 | c2 | 0.259 | 0 |
| | c3 | 0.741 | |
| c2 | c1 | 0.167 | 4.44e-16 |
| | c3 | 0.833 | |
| c3 | c1 | 0.231 | 0 |
| | c2 | 0.769 | |
| d1 | d2 | 0.259 | 0 |
| | d3 | 0.741 | |
| d2 | d1 | 0.2 | 0 |
| | d3 | 0.8 | |
| d3 | d1 | 0.333 | 0 |
| | d2 | 0.667 | |
| e1 | e2 | 0.286 | 0 |
| | e3 | 0.714 | |
| e2 | e1 | 0.130 | 0 |
| | e3 | 0.87 | |
| e3 | e1 | 0.2 | 0 |
| | e2 | 0.8 | |
| f1 | f2 | 0.044 | 0.051 |
| | f3 | 0.158 | |
| | f4 | 0.267 | |
| | f5 | 0.532 | |
| f2 | f1 | 0.033 | 0.062 |
| | f3 | 0.199 | |
| | f4 | 0.241 | |

| Controlled element | Elements under consideration | E-vector | CR |
|---|---|---|---|
| | f5 | 0.527 | |
| f3 | f1 | 0.120 | 0.089 |
| | f2 | 0.150 | |
| | f4 | 0.349 | |
| | f5 | 0.381 | |
| f4 | f1 | 0.034 | 0.001 |
| | f2 | 0.064 | |
| | f3 | 0.238 | |
| | f5 | 0.665 | |
| f5 | f1 | 0.064 | 0.077 |
| | f2 | 0.110 | |
| | f3 | 0.292 | |
| | f4 | 0.534 | |

### 4.4.5 Establish Alternatives Evaluation Matrix

The final pair-wise comparisons have been made to evaluate the relative preference of each alternative with respect to all the criteria elements. Hence, this will generate a total of 20 pair-wise comparison matrices. After prioritizing all the criteria (shown in Table 4.6), the various HCWD firms have been identified, which are covering Roorkee and Haridwar towns. From the information collected from Environment Protection and Pollution Control Board, Uttarakhand, there are only three HCWD treatment options. Out of the three, two are the CBWTFs, and the remaining one is the treatment plant established within the HCFs and also used by the others hospitals. So, three options have been evaluated here: CBWTF 1 (O1), CBWTF 2 (O2) and HCF (O3) with respect to each element as shown in Figure 4.2. Again the responses of the experts' panel are taken into consideration for each HCWD alternative, which are used for calculating the Eigen vectors for prioritizing each HCWD firm, and the results are given in Table 4.8, which are later on imported to 'desirability indices matrix'.

**Table 4.8:** Alternatives' Evaluation

| Criteria | Alternatives | Eigen vector | CR | Criteria | Alternatives | Eigen vector | CR |
|---|---|---|---|---|---|---|---|
| a1 | o1 | 0.532 | 0.030 | d2 | o1 | 0.409 | 0.043 |
| | o2 | 0.407 | | | o2 | 0.226 | |
| | o3 | 0.061 | | | o3 | 0.365 | |
| a2 | o1 | 0.435 | 0.099 | d3 | o1 | 0.238 | 0.087 |
| | o2 | 0.359 | | | o2 | 0.568 | |
| | o3 | 0.206 | | | o3 | 0.194 | |
| a3 | o1 | 0.666 | 0.005 | e1 | o1 | 0.279 | 7.90E-04 |
| | o2 | 0.091 | | | o2 | 0.288 | |
| | o3 | 0.243 | | | o3 | 0.433 | |
| b1 | o1 | 0.404 | 0.099 | e2 | o1 | 0.368 | 0.057 |
| | o2 | 0.462 | | | o2 | 0.482 | |
| | o3 | 0.134 | | | o3 | 0.149 | |
| b2 | o1 | 0.730 | 0.032 | e3 | o1 | 0.371 | 0.042 |
| | o2 | 0.136 | | | o2 | 0.2 | |
| | o3 | 0.134 | | | o3 | 0.429 | |
| b3 | o1 | 0.294 | 0.038 | f1 | o1 | 0.255 | 9.10E-04 |
| | o2 | 0.526 | | | o2 | 0.619 | |
| | o3 | 0.181 | | | o3 | 0.125 | |
| c1 | o1 | 0.252 | 0.086 | f2 | o1 | 0.246 | 0.002 |
| | o2 | 0.326 | | | o2 | 0.271 | |
| | o3 | 0.422 | | | o3 | 0.484 | |
| c2 | o1 | 0.229 | 0.002 | f3 | o1 | 0.336 | 0.009 |
| | o2 | 0.604 | | | o2 | 0.539 | |
| | o3 | 0.166 | | | o3 | 0.125 | |
| c3 | o1 | 0.324 | 0.020 | f4 | o1 | 0.307 | 0.003 |
| | o2 | 0.347 | | | o2 | 0.461 | |
| | o3 | 0.329 | | | o3 | 0.233 | |
| d1 | o1 | 0.248 | 0.012 | f5 | o1 | 0.443 | 0.005 |

| Criteria | Alternatives | Eigen vector | CR | Criteria | Alternatives | Eigen vector | CR |
|---|---|---|---|---|---|---|---|
| | o2 | 0.325 | | | o2 | 0.150 | |
| | o3 | 0.426 | | | o3 | 0.407 | |

### 4.4.6 Compute the Super Matrix

The super matrix allows for the resolution of the interdependencies that exist among the various criteria under consideration. Super matrix is constructed from the Table 4.7 and converted into weighted super matrix by multiplying the weights as explained in the methodology. Since we have 20 pair-wise comparisons for checking the interdependencies, hence, there will be 20 non-zero columns in the super matrix. Subsequently, the weighted super matrix is made to converge for obtaining a long-term stable set of weights by multiplying the weighted super matrix by itself until super matrix becomes 'column stochastic'. The final weighted super matrix is shown in 4.9.

### 4.4.7 Prepare the Desirability Indices Matrix for all the Alternatives

The desirability indices are calculated by multiplying the criteria weights with sub-criteria weights and finally with the criteria ratings of the alternatives. The results are shown in Table 4.10, which are further normalized to produce the normalized value of desirability index, as shown in Table 4.11.

**Table 4.9:** Weighted Super Matrix

| | a1 | a2 | a3 | b1 | b2 | b3 | c1 | c2 | c3 | d1 | d2 | d3 | e1 | e2 | e3 | f1 | f2 | f3 | f4 | f5 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **a1** | .189 | .189 | .189 | | | | | | | | | | | | | | | | | |
| **a2** | .359 | .359 | .359 | | | | | | | | | | | | | | | | | |
| **a3** | .452 | .452 | .452 | | | | | | | | | | | | | | | | | |
| **b1** | | | | .167 | .167 | .167 | | | | | | | | | | | | | | |
| **b2** | | | | .367 | .367 | .367 | | | | | | | | | | | | | | |
| **b3** | | | | .458 | .458 | .458 | | | | | | | | | | | | | | |
| **c1** | | | | | | | .168 | .168 | .168 | | | | | | | | | | | |
| **c2** | | | | | | | .386 | .386 | .386 | | | | | | | | | | | |
| **c3** | | | | | | | .446 | .446 | .446 | | | | | | | | | | | |
| **d1** | | | | | | | | | | .215 | .215 | .215 | | | | | | | | |
| **d2** | | | | | | | | | | .348 | .348 | .348 | | | | | | | | |
| **d3** | | | | | | | | | | .437 | .437 | .437 | | | | | | | | |
| **e1** | | | | | | | | | | | | | .143 | .143 | .143 | | | | | |
| **e2** | | | | | | | | | | | | | .404 | .404 | .404 | | | | | |
| **e3** | | | | | | | | | | | | | .453 | .453 | .453 | | | | | |
| **f1** | | | | | | | | | | | | | | | | .06 | .06 | .06 | .06 | .06 |
| **f2** | | | | | | | | | | | | | | | | .091 | .091 | .091 | .091 | .091 |
| **f3** | | | | | | | | | | | | | | | | .202 | .202 | .202 | .202 | .202 |
| **f4** | | | | | | | | | | | | | | | | .298 | .297 | .297 | .297 | .297 |
| **f5** | | | | | | | | | | | | | | | | .354 | .354 | .354 | .354 | .354 |

**Table 4.10:** Desirability Indices Matrix

| Criteria (1) | Pair-wise comparison (2) | Sub-criteria (3) | Pair-wise comparison matrix for sub-criteria (4) | From super matrix (5) | Alternate 1 (6) | Alternate 2 (7) | Alternate 3 (8) | Alternate 1 weight (2*4*5*6) | Alternate 2 weight (2*4*5*7) | Alternate 3 weight (2*4*5*8) |
|---|---|---|---|---|---|---|---|---|---|---|
| **A** | 0.064 | a1 | 0.210 | 0.189 | 0.532 | 0.407 | 0.061 | 0.001 | 0.001 | 0.000 |
| **A** | 0.064 | a2 | 0.266 | 0.359 | 0.435 | 0.359 | 0.206 | 0.003 | 0.002 | 0.001 |
| **A** | 0.064 | a3 | 0.525 | 0.452 | 0.666 | 0.091 | 0.243 | 0.010 | 0.001 | 0.004 |
| **B** | 0.055 | b1 | 0.04 | 0.167 | 0.404 | 0.462 | 0.134 | 0.000 | 0.000 | 0.000 |
| **B** | 0.055 | b2 | 0.13 | 0.367 | 0.730 | 0.136 | 0.134 | 0.002 | 0.000 | 0.000 |
| **B** | 0.055 | b3 | 0.83 | 0.458 | 0.294 | 0.526 | 0.181 | 0.006 | 0.011 | 0.004 |
| **C** | 0.080 | c1 | 0.029 | 0.168 | 0.252 | 0.326 | 0.422 | 0.000 | 0.000 | 0.000 |
| **C** | 0.080 | c2 | 0.233 | 0.386 | 0.230 | 0.604 | 0.166 | 0.002 | 0.004 | 0.001 |
| **C** | 0.080 | c3 | 0.738 | 0.446 | 0.324 | 0.347 | 0.329 | 0.009 | 0.009 | 0.009 |
| **D** | 0.239 | d1 | 0.152 | 0.215 | 0.248 | 0.325 | 0.426 | 0.002 | 0.003 | 0.003 |
| **D** | 0.239 | d2 | 0.205 | 0.348 | 0.410 | 0.226 | 0.365 | 0.007 | 0.004 | 0.006 |
| **D** | 0.239 | d3 | 0.644 | 0.437 | 0.238 | 0.568 | 0.194 | 0.016 | 0.038 | 0.013 |
| **E** | 0.278 | e1 | 0.047 | 0.143 | 0.279 | 0.288 | 0.433 | 0.001 | 0.001 | 0.001 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| **E** | 0.278 | e2 | 0.409 | 0.404 | 0.368 | 0.482 | 0.150 | 0.017 | 0.022 | 0.007 |
| **E** | 0.278 | e3 | 0.544 | 0.453 | 0.371 | 0.200 | 0.429 | 0.025 | 0.014 | 0.029 |
| **F** | 0.285 | f1 | 0.078 | 0.060 | 0.255 | 0.619 | 0.125 | 0.000 | 0.001 | 0.000 |
| **F** | 0.285 | f2 | 0.074 | 0.091 | 0.246 | 0.271 | 0.484 | 0.001 | 0.001 | 0.001 |
| **F** | 0.285 | f3 | 0.283 | 0.202 | 0.336 | 0.539 | 0.125 | 0.006 | 0.009 | 0.002 |
| **F** | 0.285 | f4 | 0.258 | 0.298 | 0.307 | 0.461 | 0.233 | 0.007 | 0.010 | 0.005 |
| **F** | 0.285 | f5 | 0.307 | 0.354 | 0.443 | 0.150 | 0.407 | 0.014 | 0.005 | 0.013 |

**Table 4.11:** Normalized Value of Desirability Index

| Alternatives | Desirability index | Normalized value |
|---|---|---|
| 1 | 0.1271 | 0.3506 |
| 2 | 0.1355 | 0.3739 |
| 3 | 0.0998 | 0.2755 |

**4.4.8 Find out the Best and Worst Ideal Solutions**

The results computed by ANP are used in the TOPSIS process for ranking all the three HCWD firms. After getting the evaluation weights for all the alternatives, the evaluation matrix consisting of six criteria and three alternatives (6×3) is obtained, which is further normalized by using the Eqn. (4.5), and finally, it is converted into weighted normalized decision matrix by applying Eqn. (4.6) as shown in Eqn. (4.13).

$$T = \begin{bmatrix} 0.057 & 0.019 & 0.021 \\ 0.030 & 0.043 & 0.016 \\ 0.042 & 0.055 & 0.041 \\ 0.107 & 0.190 & 0.097 \\ 0.177 & 0.150 & 0.153 \\ 0.181 & 0.169 & 0.141 \end{bmatrix} \quad (4.13)$$

Subsequent to this, the best positive solution and worst negative solution are calculated by applying Eqns. (4.8) and (4.9), respectively and results are shown in Eqns. (4.14) and (4.15):

Ideal positive solution= {0.057, 0.043, 0.055, 0.191, 0.177, 0.181} (4.14)

Ideal negative solution= {0.019, 0.016, 0.041, 0.097, 0.150, 0.141} (4.15)

**4.4.9 Compute the Distance between Ideal Solution and all Alternatives and Rank all the Alternatives**

The separation distance ($S^+$) between ideal positive solution and each target element (HCWD firm) is calculated by applying equation (4.10), and the separation ($S^-$) from ideal negative solution and the target element is computed using equation (4.11). In the final step, the similarity to the worst condition is calculated by applying equation (4.12), which is shown in Table 4.12 and depending upon the score, the final ranking is done as presented in Table 4.13. So, the second HCWD firm (o2) is rated as the best alternative, which is having the minimum distance from the positive ideal solution and the farthest from the negative ideal solution.

**Table 4.12:** Preferences Matrix

| | Alternate 1 (o1) | Alternate 2 (o2) | Alternate 3 (o3) |
|---|---|---|---|
| $S^+$ | 0.086 | 0.049 | 0.115 |
| $S^-$ | 0.064 | 0.103 | 0.004 |
| $S^++S^-$ | 0.150 | 0.151 | 0.119 |
| $S^- /S^++S^-$ | 0.428 | 0.677 | 0.035 |

**Table 4.13:** Alternatives Ranking

| Alternative | Rank |
|---|---|
| Alternate 1 (o1) | 2 |
| Alternate 2 (o2) | 1 |
| Alternate 3 (o3) | 3 |

## 4.5 DISCUSSION AND MANAGERIAL IMPLICATIONS

In the developing nations, the inefficient disposal of HCW is becoming a big challenge to the HCFs. In India, the HCWD industry is fragmented, as some of the HCFs are having their on-site incinerators, while others are outsourcing it to the third party. Because of the increase in global competition in the healthcare industry, the hospitals want to cut their operating costs by outsourcing the functions which are not their core functions. Moreover, disposing the HCW in-house may create risk for the hospitals' environment. Therefore, outsourcing the HCWD has become the trend among the hospitals. However, outsourcing requires a systematic approach for evaluating the HCWD firms. This chapter proposed a model which helps in evaluating and selecting the HCWD firms more rationally, rather than rooting the decision on subjective understanding. The proposed model includes the following three stages: i) application of the grey theory to collect the responses from the experts in terms of grey variables, ii) utilization of ANP approach to compute desirability index for all the HCWD firms, and iii) application of TOPSIS for ranking all the HCWD firms, depending upon their distances from the ideal solution. The application of the model for selection of the HCWD firm in Uttarakhand, Northern State of India revealed the following results:

i) Prioritization of main elements

The results of pair-wise comparison of all the six elements at the second level are shown in Table 4.7. The results reveal that HCWD firms have been evaluated on the basis of the following criteria weights: ‘experience’ (0.064), ‘relationship’ (0.055), ‘environmental factors’ (0.080), ‘technology and qualification’ (0.239), ‘economic factors’ (0.278), and ‘firm’s capabilities’ (0.285). The experts have given 80% weightage to the following three factors: ‘technology and qualification’, ‘economic factors’, and ‘firm’s capabilities’. ‘Firm’s capabilities’ is the highest rated factor among all the others, which is followed by ‘economic factors’ and ‘technology and qualification’. Because of the risk associated with the disposal of HCW, the experts’ panel considered abilities of the HCWD firm to be more important than cost factor.

ii) Prioritization of sub-criteria

The sub-criteria at the third level weights results are as follows:

a) Under the criterion ‘experience’, ‘performance history’ (0.034) has been given the highest rating, followed by ‘staff experience’ (0.017), and ‘desire for business’ (0.013). Although, the ‘staff experience’ has been rated at second position, the ‘performance history’ of any vendor plays a big role, while evaluating the partners.

b) Under the criterion ‘relationship’, ‘reputation’ of the HCWD firms with other customers (0.046) has been given the highest rating among all three factors in this category, because reputation of various players is influencing in making the decision about selection. This is followed by ‘attitude’ (0.007) and ‘labor relation records’ (0.002).

c) Under the criterion ‘environment factors’, the experts have given the highest importance to ‘conference to Government rules’ (0.059), because according to the Waste Handling Rules in India, this is the shared responsibility of both the HCF and HCWD firm to meet the Government requirements. ‘Hygiene and safety’ (0.019) and ‘geographical location’ (0.002) are given little importance, as these parameters are already standardized by the Indian Government.

d) With regard to ‘technology and qualification’ factor, ‘use of advanced technology’ (0.154) has been considered the most important, which is followed by ‘management information system’ (0.049) and ‘transport vehicle equipped with GPS’ (0.036). The outdated technologies generates more harmful gases to the environment and infectious ash after the final disposal. To track the infectious waste till the final disposal requires the strong management information system and also the vehicle carrying the infectious waste should be equipped with GPS.

e) Under the ‘economic factors’ criterion, ‘cost’ (0.151) has been given the highest priority, followed by ‘discounts for long term’ (0.114) and ‘financial position’ (0.013). During the process of making any decision related to outsourcing, cost minimization is the most important criteria. Also, the financial position of the HCWD firm should be strong enough to install all the necessary equipment.

f) With regard to ‘firm’s capabilities’ criterion, the HCWD firms have been evaluated based on the following weights of the sub-criteria: ‘disposal capacity’ (0.087), ‘reverse logistic process functions’ (0.081), ‘quality and training aids’ (0.074), ‘frequently and timely transportation’ (0.022) and ‘container storage’ (0.021). The capacity of all the machines working for disposing of the infectious material should match the demand from the all the HCFs. Also the training aids should be provided to the employees, to make them more aware about the hazardous material and its safe storage should be the focus of the selected HCWD firm.

iii) Ratings of the HCWD firms

Here, the overall evaluation was done to prioritize the HCWD firms and the firm getting the highest score is rated as the best. The CBWTF 2 (0.677) is ranked the first, followed by CBWTF 1 (0.428) and healthcare treatment facility (0.035). The CBWTF has the latest technology and the cost of disposing the HCW is also less and furthermore, in India all CBWTFs are authorized by the Government. Hence, the chances of violation of rules will be less in comparison to in-house treatment facility.

## 4.6 CHAPTER SUMMARY

Selecting the best HCWD firm is a crucial decision for any HCF, because under the Waste Disposal Act, 1998 the proper disposal of infectious waste, is the shared responsibility of both the generator and treatment facility. Mostly, the strategic partners are selected by the top management through subjective process based on experience and intuition. Hence, hospital authorities need some quantitative tools for dealing with the problem of outsourcing, which will assist in taking the decisions more objectively and quantitatively. This study proposed a methodology for selecting the HCWD firm that is based on ANP and TOPSIS under grey environment.

Experts have given the least importance to factors like experience, relationships, and environment factors. Although these factors are important for outsourcing decisions, but in India HCWD firms can operate under the authorization and regulation of State Environment Protection and Pollution Control Board. Hence, all existing firms are already qualified and are meeting the minimum requirements of environment rules and regulations. Nevertheless, price, capacity, levels of advanced technology, frequency of transportation are still some of the crucial variables and vital factors in the selection of HCWD firm. Finally, the proposed model has been implemented for selecting the most appropriate HCWD partner in (Roorkee and Haridwar), Uttarakhand, Northern State of India.

**CHAPTER 5**

# ANALYZING THE COMPOSITION AND GENERATION RATES OF MEDICAL WASTE IN SELECT HOSPITALS IN UTTARAKHAND, INDIA

## 5.1 INTRODUCTION

The concern for Medical Waste Management (MWM) is rising rapidly, due to increasing level of awareness among the hospital administration and people about the harm caused by the infectious waste. With increase in population and growing Healthcare Facilities (HCFs), the quantity of per capita Healthcare Waste (HCW) is escalating day by day. The HCFs and other medical institutions are finding it as big threat to the environment and public. Hence, researchers and academicians are now focusing more on Healthcare Waste Management (HCWM) and handling practices (Askarian et al., 2004; Talebbeydokhti and Kherandmand, 2006).

In the literature, numerous studies have been conducted on predicting the HCW generations rates and its associated factors. Some studies are considering both hazardous and non-hazardous waste as the Medical Waste (MW), while the others consider only the infectious waste as the MW. The various studies conducted to find out the generation rates in different countries have been shown in Table 5.1. Different researchers have used different units to measure the HCW quantity generated from various HCFs. Some, have considered the total number of beds in their studies and some have counted the active number of beds only, in order to get more accurate generation rate of HCW. Researchers advocated that HCW can be reduced by implementing better management practices (Almuneef and Memish, 2003; Tudor et al., 2005) and the proper waste management can be done only when, the reliable data about the quantity of HCW being generated and related to its composition is available. Unfortunately, the literature lacks studies focusing on analyzing the generation patterns of the HCW, it composition and the factors which are contributing towards the waste generation rates in India.

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**Table 5.1:** Literature on HCW Generation Rates across Different Countries

| Sl. No. | Source | Country | Generation rates |
|---|---|---|---|
| 1. | Patil and Pokhrel (2005) | India | 2.31 kg/bed/day |
| 2. | Jang et al. (2006) | Korea | 0.14-0.49 kg/bed/day |
| 3. | Gupta and Boojh (2006) | India | 0.5 kg/bed/day |
| 4. | Alhumoud and Alhumoud (2007) | Kuwait | 3.87-7.44 kg/bed/day |
| 5. | Bdour et al. (2007) | Jordan | 1.9-3.5 kg/bed/day |
| 6. | Abdulla et al. (2008) | Jordan | 0.61 kg/bed/day |
| 7. | Katoch and Kumar (2008) | India | 0.25 kg/occupied bed/day |
| 8. | Birpinar et al. (2009) | Turkey | 0.63kg/bed/day |
| 9. | Patwary et al. (2009) | Bangladesh | 0.25 kg/bed/day |
| 10. | Taghipour and Mosaferi (2009) | Iran | 0.4 - 1.91 kg/bed/day |
| 11. | Sanida et al. (2010) | North Greece | 0.58 kg/bed/day |
| 12. | El-Salam (2010) | Egypt | 0.23 - 2.07 kg/bed/day |
| 13. | Sanida et al. (2010) | South Greece | 1.4 kg/bed/day |
| 14. | Eker and Bilgili (2011) | Turkey | 2.11-3.83 kg/bed/day |
| 15. | Komilis et al. (2011) | South Greece | 1.4 kg/bed/day |

Hence, in order to get the appropriate statistics and analysis of the HCW coming out from various HCFs there is the need to replicate such kind of studies in all the States of India. With this purpose, the present chapter focuses on the following objectives:

- To analyze the composition of MW generated at various HCFs situated in Uttarakhnad, Northern State of India.
- To model the quantity of different types of MW generated at the various HCFs and find out the significant factors, which are contributing towards the MW quantity.
- To analyze the seasonal variation in the amount of MW generated from the various HCFs.

To achieve the above stated objectives, two types of data has been collected: firstly, cross-sectional data for May 2015, was collected from 75 HCFs to analyze the composition of HCW and modeled the quantity of HCW generated and secondly, longitudinal data for two years (2013 and 2014) has been collected to analyze the seasonal variation in the HCW quantity. The data has been modeled using Multiple Linear

Regression (MLR) and Artificial Neural Network (ANN) and results of both the modeling techniques have been compared.

### 5.2 NEED FOR THE STUDY

The amount of HCW generated depends on factors such as the structure, location and capacity of the HCF, waste management methods, reusable items employed in the hospital, level of instrumentation, hospital specialization, MW segregation system and number of patients treated on a daily basis (Askarian et al., 2004; DaSilva et al., 2005; Tudor, 2007; Cheng et al., 2009; Eker and Bilgili, 2011; Eleyan et al., 2013). Studies supported that the quantities of HCW generated from HCFs also depend on the local legislation (Askarian et al., 2004; Mohee, 2005; Bdour et al., 2007). According to Awad et al. (2004), MW generation rate depends on: number of departments, kind and size of the department, number of beds/patients available, and type of specialization. Cheng et al. (2009) in their study reported the number of beds and the amount of insurance reimbursement are the significant factors for predicting the HCW generation rates.

Studies on HCW generation, revealed that the waste generation rate differs not only from country to country (Alvim-Ferraz et al., 2005; Oweis et al., 2005; Tudor et al., 2005; Marinkovic et al., 2008), but also within the same country depending upon the structure and location of HCFs (Prüss et al., 1999; Mohee, 2005). The HCW generation rate is higher in high-income countries in comparison to low-income countries due to more and better HCFs provided in high-income countries (Shinee et al., 2008). As per Cheng et al. (2010), like generation rates, MW composition also varies with area, type of HCFs, practices and clinic specialty.

Although, the definitions of MW and its categorization differ across the countries, but it has been now identified that some categories of MW are very hazardous in nature which could result in some contagious diseases. Hence, it is important to analyze the composition rates of different types of wastes in order to plan and manage the Healthcare Waste Disposal (HCWD) practices. There is need to explore the factors which are contributing towards the HCW generation rates in order to plan the capacity of the treatment facility and allocate the required resources.

Most of the studies conducted in the literature, have considered the total number of beds and number of active beds or occupied beds for calculating the HCW in terms of kg/bed/day and kg/occupied bed/day respectively. Hence, all the studies have considered the number of in-patients only, who had been actually admitted in the hospitals and they have not considered the out-patients data. The out-patients, who are getting the treatment in the hospitals and not staying there for long time, are also contributing towards the quantity of HCW generated. This is the big gap in the measurement unit and has been taken up in the present study.

Another gap in the literature is, mostly studies have analyzed the HCW generation rates in five to seven hospitals by considering all the significant factors contributing to the HCW. Hence, there is need to conduct the study across large sample considering different types of HCFs and their contribution towards the HCW generation. To analyze the effect of the types of HCFs, this research have collected the data from 75 HCFs and divided all the HCFs into five different groups. Also there is need to collect the longitudinal data from the various HCFs, so that the seasonal variation in the quantity of HCW generated can be measured. The present study analyze the HCW data over two years (2013 & 2014) from the various HCFs to find out whether, the change in the weather conditions affect the quantity of HCW.

## 5.3 METHODOLOGY

The present study utilizes both, cross-sectional as well as longitudinal data from the various HCFs, in order to analyze the composition of the MW and to find out the various significant factors, which are contributing towards the HCW quantity. The Figure 5.1 gives the overview of the present research and methodologies adopted to achieve the above stated objectives.

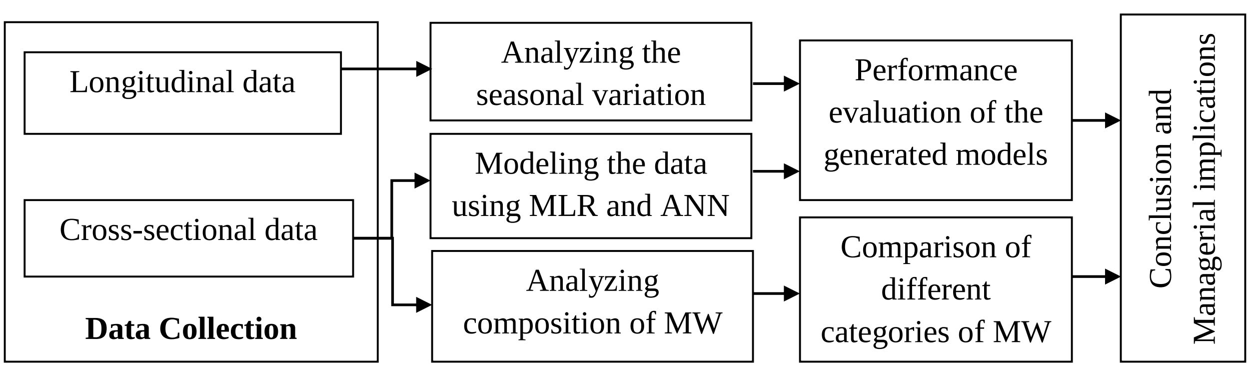


**Figure 5.1:** Overview of the Present Research

### 5.3.1 Data Collection

#### 5.3.1.1 Cross-sectional data

A total of 75 HCFs in Uttarakhand, Northern State of India have been covered in the present study. The complete dataset collected from various HCFs is shown in Appendix VII. Cross-sectional data was collected related to generation and segregation of MW from 75 HCFs for the month of May 2015 and then average waste per day was calculated. To calculate the daily total quantity of MW generated from the various HCFs, the amount of MW has been divided by the total number of in-patients and out-patients data from the hospital and represented in-terms of 'kg/patient/day'. Also to analyze the composition of MW, the average data related to yellow, red and blue dustbins were collected. In order to find out the role of different types of HCFs in the MW generation rates, all the HCFs included in the study have been categorized into five main categories as shown in Fig. 5.2. The distribution of different types of HCFs in total dataset is like: 'general hospitals' (44%), 'nursing home' (21.33%), 'pathology' (13.33%), 'clinic & centers' (12%) and 'child & maternity hospital' (9.33%).

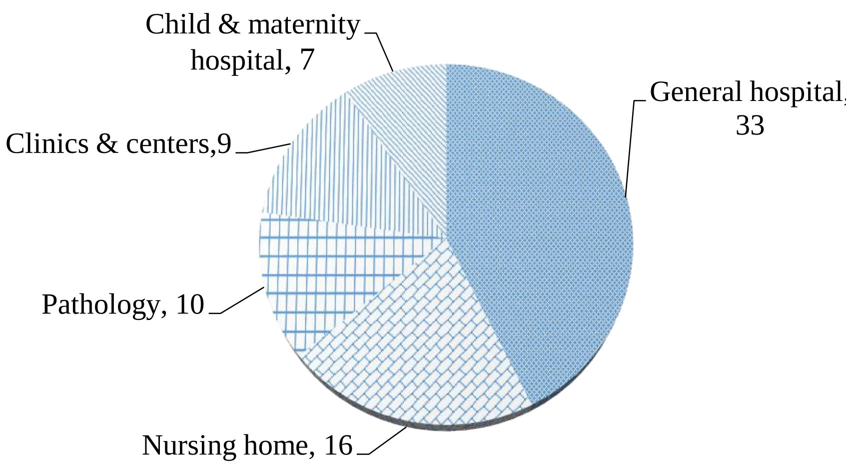


**Figure 5.2:** Categorization of HCFs

#### 5.3.1.2 Longitudinal data

Longitudinal data has been collected from the daily reports of the select HCFs from Jan. 2013 to Dec. 2014. This data has been used for the predictive analysis and developing the model. To consider the variation in the number of beds and the error in the waste data collection and record, the average waste per bed (kg/day/bed) has been calculated as shown in Table 5.2. The data about the number of HCFs and number of beds, has been taken as the average for the whole year, as the complete data was not available.

**Table 5.2:** Data collected from Select HCFs in Uttarakhand, (India) for 2013-14

| Month/Year | No. of HCFs covered | No. of total beds | Waste treated (kg) | | | Total | Waste (kg/day/bed) |
|---|---|---|---|---|---|---|---|
| | | | Red | Yellow | Blue | | |
| Jan-13 | 81 | 1926 | 5505 | 7605 | 190 | 13300 | 0.230 |
| Feb-13 | 81 | 1926 | 5280 | 7525 | 185 | 12990 | 0.225 |
| Mar-13 | 81 | 1926 | 5425 | 7835 | 195 | 13455 | 0.233 |
| Apr-13 | 81 | 1926 | 6257 | 8203 | 176 | 14636 | 0.253 |
| May-13 | 81 | 1926 | 6388 | 7900 | 200 | 14488 | 0.251 |
| Jun-13 | 81 | 1926 | 6980 | 7313 | 221 | 14514 | 0.251 |
| Jul-13 | 81 | 1926 | 7394 | 7013 | 219 | 14626 | 0.253 |
| Aug-13 | 81 | 1926 | 4858 | 7887 | 228 | 12973 | 0.225 |
| Sep-13 | 81 | 1926 | 4761 | 8377 | 185 | 13323 | 0.231 |
| Oct-13 | 81 | 1926 | 4979 | 9218 | 203 | 14400 | 0.249 |
| Nov-13 | 81 | 1926 | 5339 | 9129 | 194 | 14662 | 0.254 |
| Dec-13 | 81 | 1926 | 5687 | 9550 | 168 | 15405 | 0.267 |
| Jan-14 | 96 | 2126 | 4855 | 9473 | 172 | 14500 | 0.227 |
| Feb-14 | 96 | 2126 | 3739 | 9035 | 164 | 12938 | 0.203 |
| Mar-14 | 96 | 2126 | 4137 | 9394 | 185 | 13716 | 0.215 |
| Apr-14 | 96 | 2126 | 3876 | 8990 | 170 | 13036 | 0.204 |
| May-14 | 96 | 2126 | 4057 | 9155 | 171 | 13383 | 0.209 |
| Jun-14 | 96 | 2126 | 3899 | 8747 | 169 | 12815 | 0.201 |
| Jul-14 | 96 | 2126 | 4031 | 9105 | 177 | 13313 | 0.209 |
| Aug-14 | 96 | 2126 | 4067 | 9504 | 178 | 13749 | 0.216 |
| Sep-14 | 96 | 2126 | 5032 | 8991 | 260 | 14283 | 0.224 |
| Oct-14 | 96 | 2126 | 5495 | 9836 | 278 | 15609 | 0.245 |
| Nov-14 | 96 | 2126 | 5259 | 9562 | 284 | 15105 | 0.237 |
| Dec-14 | 96 | 2126 | 5522 | 10018 | 303 | 15843 | 0.248 |

### 5.3.2 Model Development

MLR and ANN modeling techniques have been carried out in order to include all the significant factors into the final model and finally both the models have been evaluated by calculating and comparing the performance parameters.

#### 5.3.2.1 Multiple Linear Regression (MLR)

In the present study, firstly the MLR modeling technique has been used to model the existing data and further the results have been improved by using ANN technique. The multiple regression model is given as:

$$y = \beta_o + \beta_1 x_1 + \beta_2 x_2 + \cdots \ldots + \beta_n x_n \tag{5.1}$$

In Eqn. (5.1), dependent variable 'y' represents the quantity of MW to be predicted and $x_1, x_2, \ldots \ldots x_n$ are the independent variables which are affecting the quantity of MW being generated from various HCFs. $\beta_1, \beta_2, \ldots \ldots \beta_n$ are the coefficients of corresponding independent variables, which represents the variation in the dependent variable with each unit variation in the independent variable. $\beta_0$ is the constant term and when independent variables' values are zero, it has no significance.

#### 5.3.2.2 Artificial Neural Network (ANN)

ANNs are statistical learning models, inspired by the neural networks and are used to predict the function, which is depending upon various independent variables. The ANNs are trained by providing certain set of data and then are used to estimate the dependent variable. The functioning of ANNs depends on the interconnected neurons, which exchange the information between each other. These linkages between neurons are assigned certain weights depending on the past data, so that Mean Square Error (MSE) is minimized and then network becomes adaptive to inputs and capable of learning. ANN model consists of following three main elements as shown in Figure 5.3: i) set of connections with certain weight on each connection, ii) an adder for getting the combined weight of all inputs and iii) an activation function for getting the amplitude of the output neuron. To start with, various networks are generated by varying the learning rates, iterations and number of hidden neurons and finally, the optimum network is selected by applying different training algorithms, which produces the minimum MSE. For the present data, the optimum neural network has been constructed by using MATLAB.

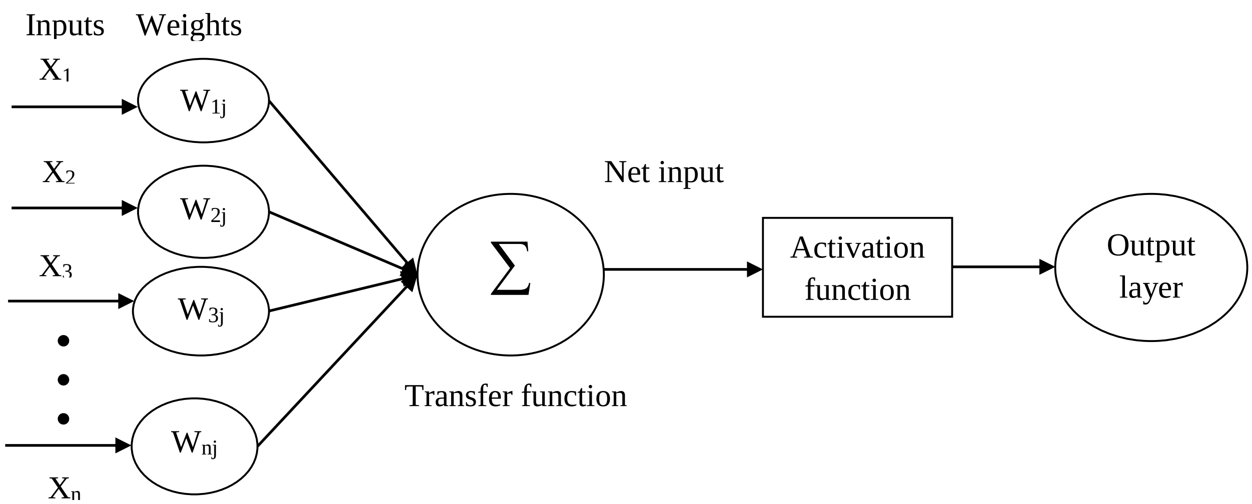


**Figure 5.3:** Elements of ANN

### 5.3.3 Definitions of Dependent and Independent Variables

In the present problem, the dependent variable is the quantity of MW and for different types of MW, separate equations have been generated. Among various independent variables from the literature, the present study has considered two main parameters for the cross-sectional study: 'type of HCF' and 'bed occupancy'. For modeling the data, the HCFs have been divided into five groups, but, because the 'pathologies' are just the labs and waste generated from these units cannot be measured in terms of 'kg/patient/day', hence, these have not been included into the final analysis. Rest of the four HCFs are entered into the equation by using the dummy variable regression. The four types of HCFs have been encoded as follows: type 1 ('general hospitals' - [0 0 0]), type 2 ('nursing home' - [1 0 0]), type 3 ('clinics & centers' - [0 1 0]) and type 4 ('child & maternity hospital' - [0 0 1]). The data related to these dependent and independent variables is given in Appendix VII.

For analyzing the seasonal variation in the quantity of HCW generated, the waste quantity has been taken as the dependent variable and month has been taken as the independent variable and seasonal fluctuations have been observed across the various months. Data has been collected over the 24 months, as shown in Table 5.2.

### 5.3.4 Performance Evaluation

To evaluate the performance of the models developed using MLR and ANN techniques, following three performance parameters were calculated: Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and coefficient of determination ($R^2$) (Jahandideh et al., 2009). MAE gives the most absolute and relative meaningful measures of the developed model error. RMSE represents the remaining variance, which is not explained by the model. $R^2$ highlights the total variance explained by the model. These values are calculated by applying following equations (Eqns. 5.2-5.4):

$$MAE(t) = \frac{1}{n}\sum_{i=1}^{n} \left| w_0(t) - w_p(t) \right| \tag{5.2}$$

$$RMSE(t) = \sqrt{\frac{1}{n}\sum_{i=1}^{n} (w_0(t) - w_p(t))^2} \tag{5.3}$$

$$R^2 = 1 - \frac{\sum_{i=1}^{n} (w_0(t) - w_p(t))^2}{\sum_{i=1}^{n} (w_0(t) - w_0'(t))^2} \tag{5.4}$$

Where $w_0(t)$ = observed value of BMW generation for 'type t'.

$w_0'(t)$ = average value

$w_p$ = predicted value of BMW

## 5.4 ANALYSIS AND RESULTS

### 5.4.1 Analysis of Cross-Sectional Data Collected from 75 HCFs

#### 5.4.1.1 Current HCW segregation practices

The waste handling and disposal processes were observed continuously during the data collection and questions were asked from the waste handling employees and managers. All the 75 HCFs considered for the present study, used to collect their waste daily and outsource the disposal process to Government approved Common Biomedical Waste Treatment Facility (CBWTF). CBWTF treat whole waste as per the predefined method for each type of MW. The categorization of the MW is done as per the guidelines issued by the Uttarakhand Pollution Control Board. The different colors of containers are used to collect the different types of wastes. The study results revealed that in Uttarakhand, all the HCFs are not segregating the waste as per guidelines issued by the Uttarakhand Pollution Control Board. As shown in Table 5.3, 4 out of 33 'general hospitals', 7 out of 16 'nursing homes', 4 out of 9 'clinics & centers', and 3 out of 7 'child & maternity hospitals' are not segregating their MW and dumping the whole waste into the same container, which turns non-infectious waste into infectious waste and requires extra efforts to handle and treat the same waste. No ‘pathology’ lab is segregating the waste, hence 100% labs are operating without implementation of waste disposal and handling policy.

**Table 5.3:** Current Status of Segregation of HCW at Various HCFs

| HCF type | HCF category | Total no. of HCFs | No. of HCFs with proper segregation and records | No. of HCFs without segregation | Percentage of defaulted HCFs |
|---|---|---|---|---|---|
| 1. | General hospital | 33 | 29 | 4 | 12.12 |
| 2. | Nursing home | 16 | 9 | 7 | 43.75 |
| 3. | Clinics and center | 9 | 5 | 4 | 44.44 |
| 4. | Child & maternity hospital | 7 | 4 | 3 | 42.86 |
| 5. | Pathology | 10 | 0 | 10 | 100 |

#### 5.4.1.2 Composition of waste for different types of HCFs

Figures 5.4-5.7 highlights the composition of MW for four different types of HCFs. Since, pathologies are not segregating the waste properly, hence these have not been considered for composition analysis. As for the total MW generation rate is concerned, the ‘pathologies’ are contributing at the rate of 0.94 kg/day. Figure 5.4 reflects the share of different categories of MW for ‘general hospitals’ where, ‘yellow waste’ carries 57.33% share followed by ‘red waste’ (23.06%) and ‘blue waste’ (19.61%). Figure 5.5 represents the composition for ‘nursing homes’ as: ‘yellow waste’ contributes 69.49%, ‘red waste’ 14.08% and ‘blue waste’ 16.43% in the total. Figure 5.6 highlights the contribution of each type of waste in the total amount for ‘clinics and centers’, where the maximum share is taken by ‘yellow waste’ (59.70%), followed by ‘red waste’ (26.87%) and ‘blue waste’ (13.43%). Figure 5.7 shows the composition for ‘child and maternity hospitals’, where ‘yellow waste’ contributes 48.31%, followed by ‘red waste’ (27.54%) and ‘blue waste’ (24.15%).

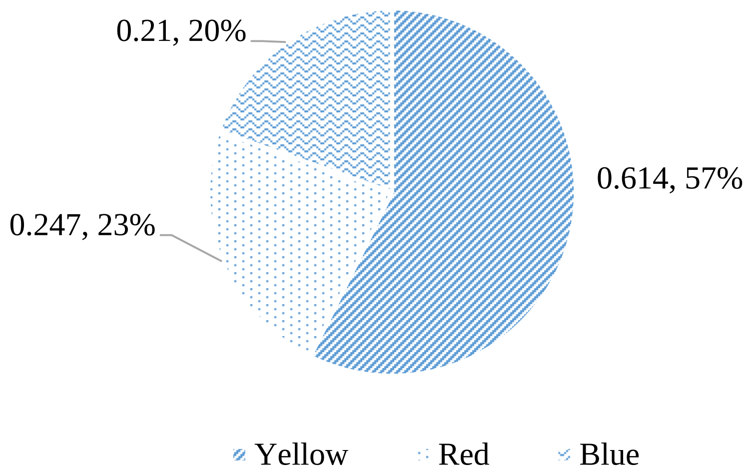


**Figure 5.4:** Composition of MW (kg/patient/day) for 'General Hospitals'

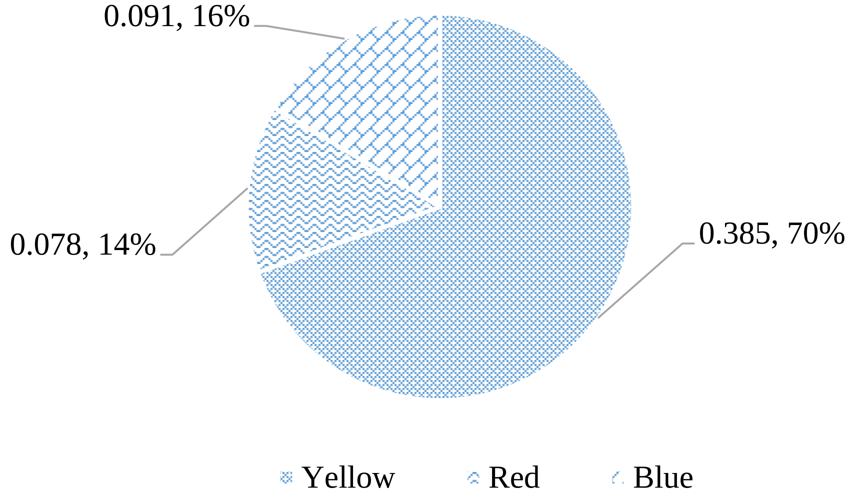


**Figure 5.5:** Composition of MW (kg/patient/day) for 'Nursing Homes'

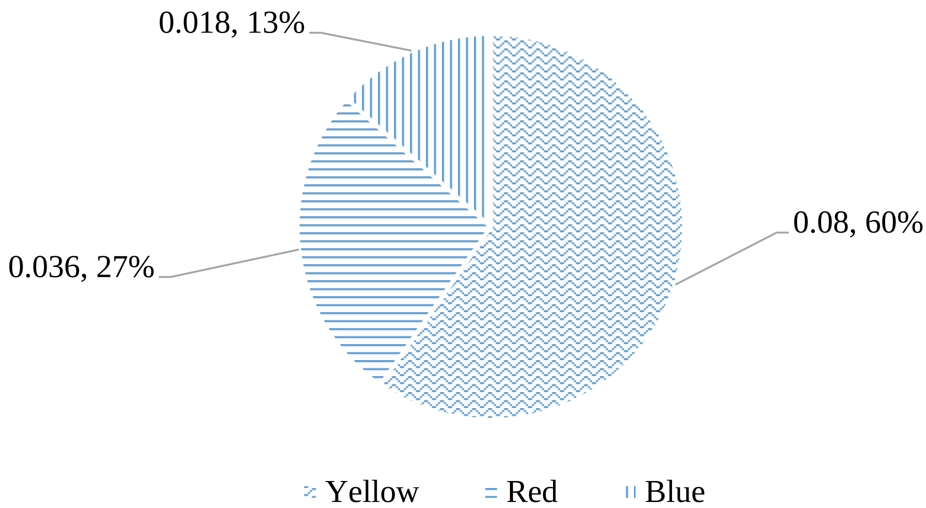


**Figure 5.6:** Composition of MW (kg/patient/day) for 'Clinics & Centers'

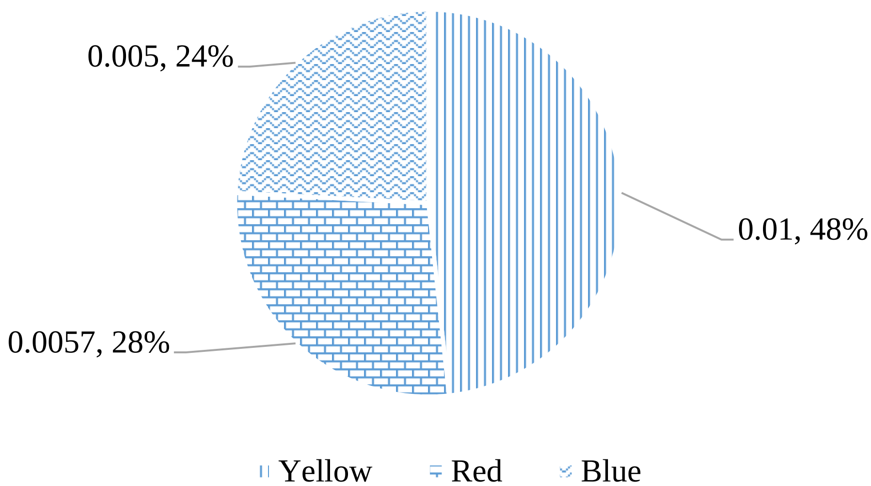


**Figure 5.7:** Composition of MW (kg/patient/day) for 'Child & Maternity Hospitals'

Tables 5.4-5.7 represent the results of 'paired sample t-test' for comparing the means of different categories of MW for all the types of HCFs. The results clearly reveal that the 'yellow waste' quantity is significantly higher than 'red' and 'blue' waste. But, the difference in the quantities of 'red' and 'blue' waste is not significant for all the HCFs.

**Table 5.4:** Paired Samples Test for Comparing Different Categories of MW for 'General Hospitals'

| Pair of different categories | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | t-value | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | | | |
| Yellow - Red | 0.367 | 0.196 | 0.037 | 0.293 | 0.442 | 10.102 | 28 | .000 |
| Yellow - Blue | 0.404 | 0.243 | 0.045 | 0.312 | 0.497 | 8.965 | 28 | .000 |
| Red - Blue | 0.037 | 0.130 | 0.024 | -0.013 | 0.087 | 1.516 | 28 | 0.141 |

**Table 5.5:** Paired Samples Test for Comparing Different Categories of MW for 'Nursing Homes'

| Pair of different categories | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | t-value | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | | | |
| Yellow - Red | 0.307 | 0.279 | 0.093 | 0.092 | 0.520 | 3.302 | 8 | 0.011 |
| Yellow - Blue | 0.294 | 0.262 | 0.087 | 0.092 | 0.495 | 3.361 | 8 | .010 |
| Red - Blue | -0.013 | 0.027 | 0.009 | -0.033 | 0.007 | -1.455 | 8 | 0.184 |

**Table 5.6:** Paired Samples Test for Comparing Different Categories of MW for 'Clinics & Centers'

| Pair of different categories | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference | | t-value | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | | | |
| Yellow - Red | 0.044 | 0.034 | 0.015 | 0.001 | 0.086 | 2.867 | 4 | 0.046 |
| Yellow - Blue | 0.062 | 0.048 | 0.021 | 0.003 | 0.121 | 2.910 | 4 | 0.044 |
| Red - Blue | 0.018 | 0.028 | 0.013 | -0.017 | 0.054 | 1.453 | 4 | 0.220 |

**Table 5.7:** Paired Samples Test for Comparing Different Categories of MW for 'Child & Maternity Hospitals'

| **Pair of different categories** | **Mean** | **Std. Deviation** | **Std. Error Mean** | **95% Confidence Interval of the Difference** | | **t-value** | **df** | **Sig. (2-tailed)** |
|---|---|---|---|---|---|---|---|---|
| | | | | Lower | Upper | | | |
| Yellow - Red | 0.004 | 0.003 | 0.002 | -0.001 | 0.010 | 2.497 | 3 | 0.088 |
| Yellow - Blue | 0.005 | 0.002 | 0.001 | 0.002 | 0.008 | 4.629 | 3 | 0.019 |
| Red - Blue | 0.001 | 0.001 | 0.001 | -0.001 | 0.003 | 1.192 | 3 | 0.319 |

### 5.4.1.3 Modeling the generation rates of different types of MW

#### *5.4.1.3.1 Prediction model using dummy variables multiple regressions*

Dummy variable multiple regression analysis has been applied on the data collected from various HCFs in order to model the quantity generated of different types of MW from various HCFs. The results for modeling of all types of MW are:

$$\boldsymbol{Total\ waste} = -0.073 - 0.246\ (D1) - 0.574\ (D2) - 0.414\ (D3) + 0.019\ (occupancy) \qquad (5.5)$$

$$\boldsymbol{Yellow\ waste} = -0.088 - 0.093\ (D1) - 0.338\ (D2) - 0.235\ (D3) + 0.012\ (occupancy) \qquad (5.6)$$

$$\boldsymbol{Red\ waste} = 0.025 - 0.126\ (D1) - 0.149\ (D2) - 0.124\ (D3) + 0.004\ (occupancy) \qquad (5.7)$$

$$\boldsymbol{Blue\ waste} = 0.048 - 0.088\ (D1) - 0.147\ (D2) - 0.120\ (D3) + 0.003\ (occupancy) \qquad (5.8)$$

where, D1, D2 and D3 represents the dummy variables for four types of HCFs considered for modeling the waste generation rates. The coding is done like: 'general hospital' = (0 0 0), 'nursing homes' = (1 0 0), 'clinics & centers' = (0 1 0), and 'child & maternity hospital' = (0 0 1). Occupancy represents percentage of total number of 'in-patients' as well as 'out-patients' data in a particular HCF. Eqn. (5.5) models the total MW generated from various HCFs. Since 'pathologies' are not segregating the MW at all, so we have not included this into our analysis for predicting different types of waste. The Eqns. (5.6, 5.7 and 5.8) are predicting the generation rates for 'yellow', 'red' and 'blue' respectively.

Table 5.8 represents the statistical parameters of the developed models using dummy variable multiple regressions. The overall 'F-values' for all the four models are highly significant, which represent that the models are very much capable of explaining the dependent variable. The statistical tests reflect that the 'type of HCF' and 'occupancy' are significant factors contributing towards the MW generation.

**Table 5.8:** Characteristics of Developed Multiple Regression Models

| HCW category | Parameters | Unstandardized coefficients | | Standardized coefficients | t-value | Sig. | Sig. F |
|---|---|---|---|---|---|---|---|
| | | B | Standard error | Beta | | | |
| Total waste | Intercept | -0.073 | 0.127 | | -0.573 | 0.57 | 48.587 |
| | D1 | -0.246 | 0.094 | -0.18 | -2.609 | 0.013 | |
| | D2 | -0.574 | 0.121 | -0.33 | -4.76 | 0 | |
| | D3 | -0.414 | 0.142 | -0.215 | -2.908 | 0.006 | |
| | Occupancy | 0.019 | 0.002 | 0.681 | 9.134 | 0 | |
| Yellow category | Intercept | -0.088 | 0.081 | | -1.088 | 0.283 | 46.038 |
| | D1 | -0.093 | 0.060 | -0.110 | -1.551 | 0.128 | |
| | D2 | -0.338 | 0.077 | -0.312 | -4.407 | 0 | |
| | D3 | -0.235 | 0.090 | -0.196 | -2.597 | 0.013 | |
| | Occupancy | 0.012 | 0.001 | 0.705 | 9.260 | 0 | |
| Red category | Intercept | 0.025 | 0.035 | | 0.707 | 0.483 | 36.845 |
| | D1 | -0.126 | 0.026 | -0.373 | -4.828 | 0 | |
| | D2 | -0.149 | 0.033 | -0.345 | -4.462 | 0 | |
| | D3 | -0.124 | 0.039 | -0.262 | -3.167 | 0.003 | |
| | Occupancy | 0.004 | 0.001 | 0.561 | 6.738 | 0 | |
| Blue category | Intercept | 0.048 | 0.052 | | 0.918 | 0.364 | 10.870 |
| | D1 | -0.088 | 0.038 | -0.262 | -2.279 | 0.028 | |
| | D2 | -0.147 | 0.049 | -0.344 | -2.987 | 0.005 | |
| | D3 | -0.120 | 0.058 | -0.254 | -2.064 | 0.045 | |
| | Occupancy | 0.003 | 0.001 | 0.413 | 3.337 | 0.002 | |

### *5.4.1.3.2 Prediction model using ANN*

ANN starting with 10 hidden layers was trained by supplying the 75% of the sample and resilient back-propagation method was used to develop the predictive model for all four cases. Initially, the developed model for each case was validated by supplying the 15% of the input sample and finally the model was tested by applying it for prediction over another 15% of the sample. All the best-fit lines shown in Figures 5.8 (a-d) represent the good fit of the observed data. Hence, using ANN, the prediction modeling can be done easily without specifying the non-linear relationship among the variables.

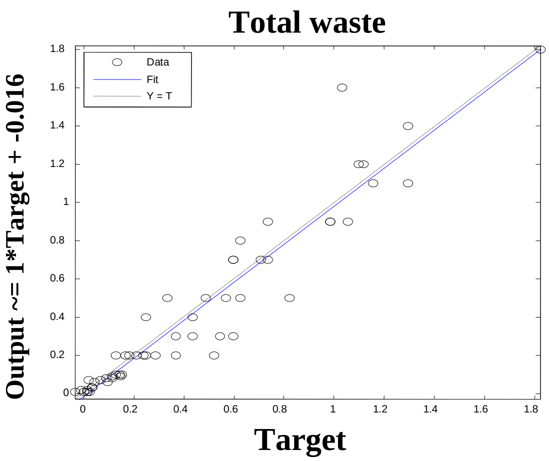


**Figure 5.8 (a):** Fit for 'Total MW'

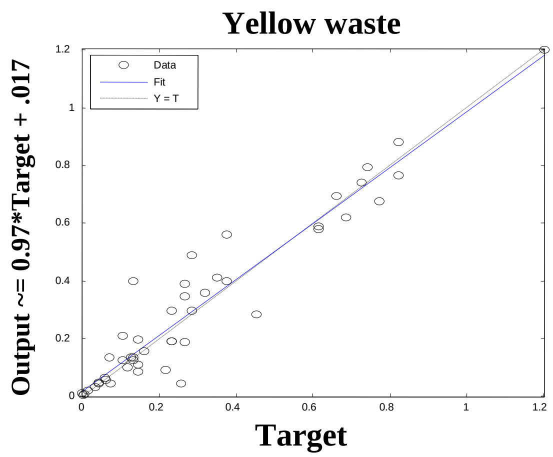


**Figure 5.8 (b):** Fit for 'Yellow Waste'

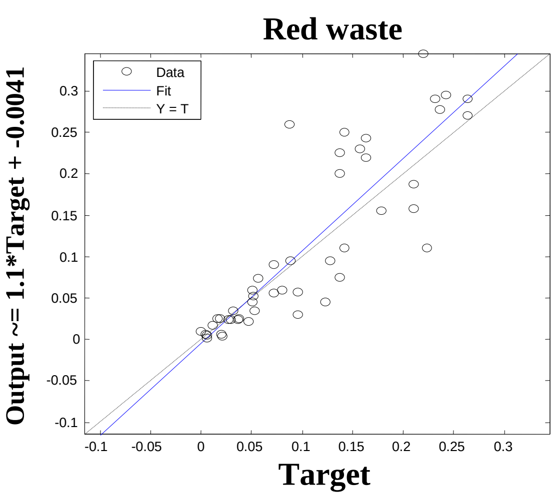


**Figure 5.8 (c):** Fit for 'Red Waste'

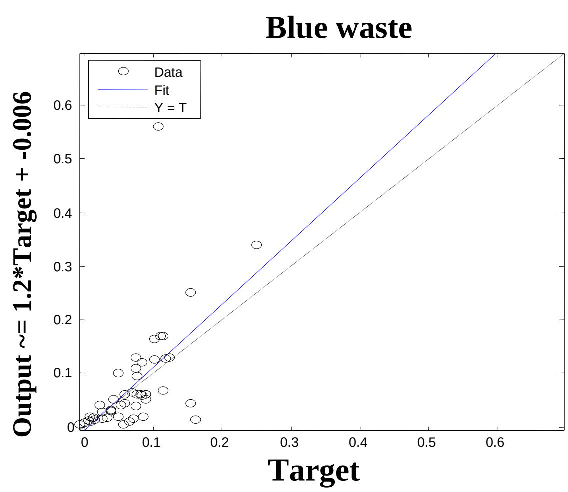


**Figure 5.8 (d):** Fit for 'Blue Waste'

**Figure 5.8:** ANN Modeling Output

#### 5.4.1.4 Performance comparison

Table 5.9 compares the performance of the models developed by two different techniques: MLR and ANN. Performance parameters clearly indicate that the results of model developed by using ANN are much better than MLR. The $R^2$ values of all the four models developed by ANN are showing good-fit of data in comparison to MLR. Also the error components are minimized in case of ANN models.

**Table 5.9:** Performance Parameters of the Developed Models

| Modeling technique | Performance parameters | Waste categories | | | |
|---|---|---|---|---|---|
| | | **Yellow** | **Red** | **Blue** | **Total** |
| MLR | MAE | 0.112 | 0.051 | 0.056 | 0.177 |
| | RMSE | 0.144 | 0.063 | 0.093 | 0.227 |
| | $R^2$ | 0.814 | 0.778 | 0.509 | 0.822 |
| ANN | MSE | 0.006 | 0.003 | 0.006 | 0.018 |
| | RMSE | 0.078 | 0.053 | 0.08 | 0.134 |
| | $R^2$ | 0.961 | 0.866 | 0.586 | 0.954 |

### 5.4.2 Analysis of Longitudinal Data for Checking the Seasonal Variation

#### 5.4.2.1 Seasonal variation analysis

Figures 5.9 (a, b, c, d) show the periodical variations in the different categories of MW. In Figure 5.9, the predicted value is following the actual value and is having at least one crest and trough throughout the year. Keeping this periodic fluctuation in view, a polynomial of degree 6 is found to be the good fit for the present data. The seasonal variation is obvious in the graph, as there is variation in the season from winters to summers in March to April, so the infectious diseases and viral fever results in increase in the number of patients. Hence, the waste in the general hospitals start increasing in the start of every season and as the temperature in the summers saturates, there is decrease in the number of patients, results in lesser MW. Again, in the month of September, the winter season starts, which leads to increase in number of patients and HCW quantity as well. The increasing trends in the last months in all the graphs may be due to the increased number of HCFs from 81 in 2013 to 96 in 2014 and the present study has considered the increased HCFs effective from Jan, 2014 only. Hence, it is clear that the illness patterns depend on the seasonal variation, which directly affects the quantity of HCW being generated.

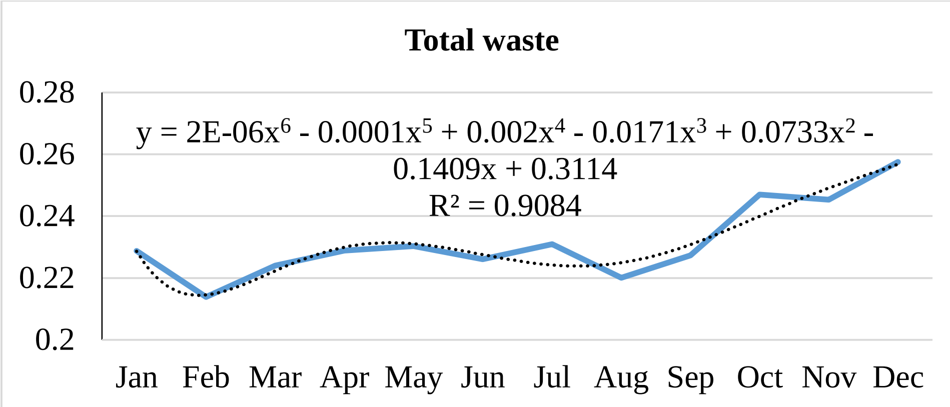


**Figure 5.9 (a):** Average Total Waste for Two Years

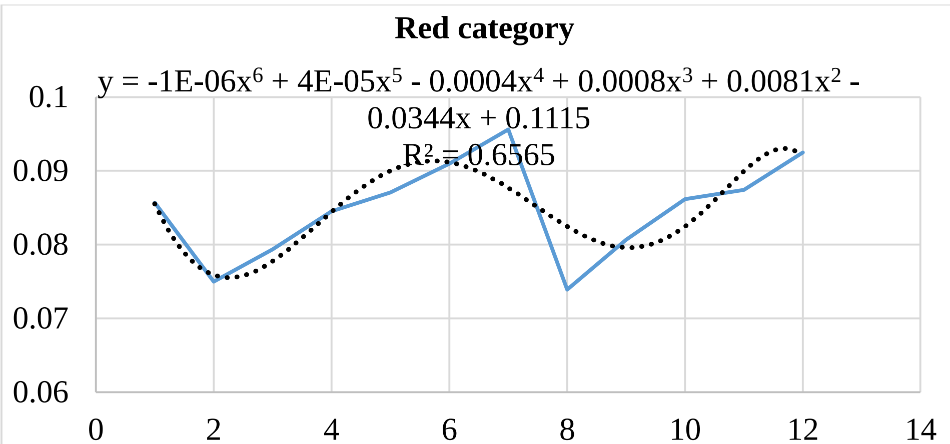


**Figure 5.9 (b):** Average Red Waste for Two Years

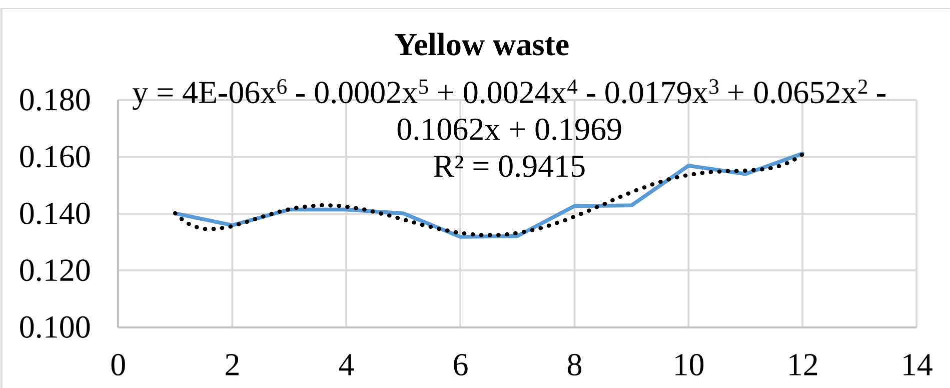


**Figure 5.9 (c):** Average Yellow Waste for Two Years

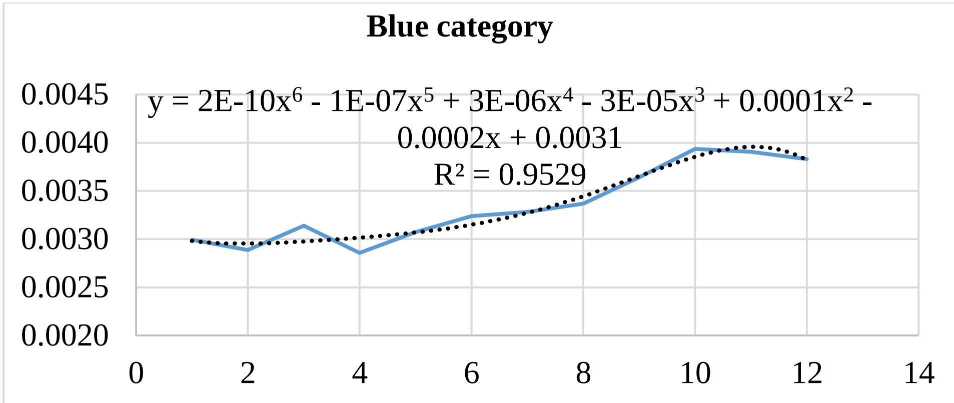


**Figure 5.9 (d):** Average Blue Waste for Two Years

**Figure 5.9:** Seasonal Variations in Different Types of MW

### 5.4.2.2 Statistical characteristics of the polynomial models developed

In this section, to analyze the periodic fluctuations in the MW generated, the data of 81 HCFs for 2013 and 96 HCFs in 2014, has been modelled. Table 5.10 highlights the various parameters of the polynomial regression model developed in this study and it is clear from the results, that some of the $R^2$ values are above 0.90 that means the model confirms a good fit of data.

**Table 5.10:** Statistical Characteristics of Waste Collected

| **Waste category** | **Year** | **Polynomial regression model** | **Pearson correlation coefficient ($R^2$)** | **p-value** |
|---|---|---|---|---|
| Total waste (kg/day/bed) | 2013 | $y = -1E-06x^6 + 2E-05x^5 - 0.005x^3 + 0.036x^2 - 0.079x + 0.279$ | 0.848 | 0.001 |
| | 2014 | $y = 6E-06x^6 + 0.003x^4 - 0.028x^3 + 0.110x^2 - 0.201x + 0.343$ | 0.936 | 8.77E-09 |
| Red category (kg/day/bed) | 2013 | $y = -7E-06x^6 - 0.003x^4 + 0.022x^3 - 0.064x^2 + 0.080x + 0.059$ | 0.804 | 4.085E-06 |
| | 2014 | $y = 4E-06x^6 + 0.002x^4 - 0.020x^3 + 0.080x^2 - 0.149x + 0.163$ | 0.953 | 9.283E-11 |
| Yellow category (kg/day/bed) | 2013 | $y = 6E-06x^6 + 0.003x^4 - 0.028x^3 + 0.103x^2 - 0.164x + 0.218$ | 0.972 | 8.327E-08 |

| Waste category | Year | Polynomial regression model | Pearson correlation coefficient ($R^2$) | p-value |
|---|---|---|---|---|
| | 2014 | $y = 2E\text{-}06x^6 - 7E\text{-}05x^5 + 0.001x^4 - 0.007x^3 + 0.027x^2 - 0.047x + 0.175$ | 0.676 | 6.503E-08 |
| Blue category (kg/day/bed) | 2013 | $y = -2E\text{-}07x^6 + 7E\text{-}06x^5 - 0.002x^2 + 0.003x + 0.001$ | 0.763 | 2.819E-11 |
| | 2014 | $y = 2E\text{-}07x^6 - 7E\text{-}06x^5 + 0.002x^2 - 0.004x + 0.005$ | 0.964 | 2.506E-05 |

**5.4.2.3 Performance parameters of the models developed**

The performance measures calculated, using polynomial regression models show some undesirable results, which may be due to the fact that here only the periodic variations in the quantity of waste generated have been considered, irrespective of the other factors which may be important in predicting the HCW. The MAE, RMSE and $R^2$ values are shown in Table 5.11. The $R^2$ value shows that for all the different types of waste categories, the seasonal variation is playing the important role.

**Table 5.11:** Performance Evaluation of the Polynomial Regression Models

| Waste Category | **Year** | **MAE (t)** | **RMSE (t)** | **$R^2$** |
|---|---|---|---|---|
| Total waste | 2013 | 0.018 | 0.023 | 0.67 |
| | 2014 | 0.084 | 0.086 | 0.97 |
| Red category | 2013 | 0.033 | 0.036 | 0.85 |
| | 2014 | 0.082 | 0.083 | 0.98 |
| Yellow category | 2013 | 0.056 | 0.058 | 0.95 |
| | 2014 | 0.023 | 0.023 | 0.95 |
| Blue category | 2013 | 0.002 | 0.002 | 0.98 |
| | 2014 | 0.002 | 0.002 | 0.82 |

**5.5 DISCUSSION AND MANAGERIAL IMPLICATIONS**

This chapter focuses on the current HCWM practices in various HCFs in Uttarakhand, a Northern State of India. The survey revealed that around 36% of the total HCFs are not segregating their MW wastes as per policy guidelines. Among all the types of HCFs, 'general hospitals' are with the highest percentage of facilities that are complying with the Waste Handling & Management Rules, 1998 and segregating the MW as per the WHO guidelines. 'Pathology' labs are not at all segregating the MW. The perception of the owners of these pathologies is that, since very small amount of waste being generated, so they don't keep separate bins in the labs. Hence, their 100 % waste is treated as infectious waste, which relatively increases the cost of treating per unit of MW. Hence, regulatory authorities should focus more on these small HCFs in implementing the HCWM system properly. The 'general hospitals' are generating the largest amount (0.68 kg/patient/day) of waste in comparison of all other types of HCFs. The reason is that in 'general hospitals' the outpatients number is high in comparison to other HCFs. 'Yellow waste' contributes more than 50 % of the 'total waste in all the HCFs, except 'child & maternity hospitals', where 'blue waste' is dominating the rest two categories. This is due to the reason that in delivery cases, mostly in surgery the sharps waste are generated and others disposable items like tubing's, catheters with blood are produced. These types of surgery produce 'blue category' waste more rather than 'yellow waste' and 'red waste'.

The MW generation rate varies with the type of HCF and is largely affected by the bed occupancy rate of the particular hospital. Also, the seasonal variation plays a big role by affecting the amount of MW generated from the HCFs. It was observed that ANN models are giving low error values in comparison to regression models and also the $R^2$ values are improved for the developed models.

Hence, by predicting the amount of MW to be generated from various HCFs, the treatment facilities can plan and allocate their resources and develop long-term strategies and better treatment options. The quantity predicted of three different waste categories (red, yellow, blue) can assist treatment facility manager to plan the running hours for three different machines (incinerator, microwave/autoclaving, shredder) installed in the plant and the manpower required. Hence, resources at CBWTF can be utilized more strategically and optimally. This study is beneficial for the society, as it helps in defining the composition of the HCW to be generated and the amount of each type of MW to be generated. Hence, the pre measures for handling the wastes can be taken and will help the hospital administration to protect the public and environmental health. This kind of study needs to be replicated, as the composition and amount of HCW to be generated may vary with the location and climate conditions.

## 5.6 CHAPTER SUMMARY

The proper implementation of HCWM requires the exact estimation of the amount of HCW to be generated and its composition. The present chapter focused on analyzing the current HCWM practices in Uttarakhand, a northern state of India and modeled the data of HCW generated from various HCFs using MLR and ANN. The composition of HCW identified in this chapter can be helpful for the hospital managers and CBWTF to allocate their resources as per the amount of different types of MW is to be generated. The present study have proposed the models for predicting the MW generation rates, which have given promising results and hence, can be used by the hospital management to manage their waste in more effective and efficient manner. Here, two modeling techniques have been used to fit the collected data: MLR and ANN. While comparing the performance parameters of both the models, it was observed that the errors terms measured in case of ANN are less in comparison to MLR modeling technique. Moreover, the ANN model represents good fit of data. Hence, ANN technique can be used to predict the BMW generation rates more accurately, but the main limitation of this technique is that it does not consider the relationship among the variables and treat the whole data into the black box. So, the behavior of the network cannot be explained and also the most important factor predicting the particular phenomena cannot be identified. There is clearly more need of such quantitative studies on predicting the MW generation rates and its associated factors in India in order to help the HCFs to handle and manage their waste in a proper way.

# CHAPTER 6

# ANALYZING THE INTERACTIONS AMONG BARRIERS OF HEALTHCARE WASTE MANAGEMENT IN INDIA

## 6.1 INTRODUCTION

Recently, the Healthcare Waste Management (HCWM) has attracted more public concern due to the infectious nature of the Medical Waste (MW) generated (Geng et al., 2013). Indian Government has also defined the Healthcare Waste (HCW) under Biomedical Waste (Management & Handling) Rule, 1998 and also the policies and procedures to ensure the proper HCWM.

HCWM mainly consists of the following practices: generation, composition, segregation, transportation, storage and final disposal (DaSilva et al., 2005; Jang et al., 2006; Yong et al., 2009; Mohamed et al., 2009; Farzadkia et al., 2009; El-Salam, 2010). HCWM practices have been studied widely in developed as well as developing countries like: Japan (Miyazaki and Une, 2005; Ikeda, 2012), China (Yong et al., 2009; Geng et al., 2013), South Africa (Aseweh and Bouwer 2008), India (Gupta and Boojh, 2006; Rao, 2009), Brazil (DaSilva et al. 2005), UK (Tudor et al., 2005), Greece (Tsakona et al., 2007), Egypt (Soliman and Ahmed, 2007; El-Salam, 2010), Botswana (Mbongwe et al., 2008), Indonesia (Chaerul et al., 2008b), Ethiopia (Haylamicheal et. al., 2011), Cameroon (Kuepouo, 2013), Taiwan (Fu, 1998) and Korea (Jang et al., 2006). But, all the studies focus on the technical aspects and on the various activities involved till the final disposal of the waste. Hence, in this chapter, the managerial issues in implementing the HCWM practices have been discussed.

## 6.2 NEED FOR HCWM SYSTEM

Irrespective of the WHO guidelines and local Government rules and regulations, the HCW is poorly handled and managed by the Healthcare Facilities (HCFs) and Common-Biomedical Waste Treatment Facilities (CBWTFs).

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*Part of this chapter is under review in International Journal of Health Care Quality Assurance as:*

*Thakur, V. and Ramesh, A. (2016), "Analyzing the interactions among barriers of HCWM practices using ISM and Fuzzy-MICMAC analysis".*

The various inadequacies found in sorting and disposal practices of MW are: the absence of use of coded and colored bags, no proper tracking techniques (Oweis et al., 2005), ineffective segregation at source (Tsakona et al., 2007; Stanković et al., 2008; Farzadkia et al., 2009), inappropriate collection methods, unsafe storage of waste, insufficient financial and human resources for proper management, and poor control of waste treatment and disposal (Jang et al., 2006; El-Salam, 2010).

Birpinar et al. (2009) in their case study done in Istanbul, observed that 25% of the hospitals use inappropriate containers for waste collection and 77% of the HCFs provide inadequate equipment to the waste handling workers. Tudor et al. (2005) mentioned that organizational structure and infrastructure for collecting the HCW are the biggest challenges for waste management. They observed that the staff habits for handling the waste and public perception about the infectious waste are the main barriers of HCWM system. Soliman and Ahmed (2007) in their study conducted in Egypt, witnessed that in the absence of written policies and protocols, the MW is processed in an inadequate manner and strongly recommended that the proper plans, policies, and protocols for handling waste should be developed. Lack of training programs (Oweis et al., 2005; Bendjoudi et al., 2009; Farzadkia et al., 2009; El-Salam, 2010) and waste minimization through reuse, recycling and reduction of waste at source are the main future research challenges, which need to be addressed (Jang et al., 2006). The proper management of HCW has become very important for the safety of waste-handling workers, who collect all infectious waste material from special storage spots and transport it to the treatment sites (Miyazaki and Une, 2005). Gupta et al. (2009) highlighted the lack of awareness among waste handling teams as the main barrier for implementing HCWM system and stressed on the training of the workers. Bendjoudi et al. (2009) observed that the lack of proper waste management strategies and absence of coordination among various departments at HCFs are the main drawbacks of the current HCWM system. Other reasons for inappropriate handling of HCW include: financial strains and a lack of awareness (Alagoz and Kocasoy, 2008b).

HCW treatment has been a major problem for every nation. Hence, it is important to analyze the main hurdles in implementing the proper HCWM practices, region-wise and country-wise. Few studies, especially in India, have been conducted regarding analyzing the barriers for implementing HCWM practices. Hence, the present chapter aims at identifying the barriers of HCWM practices in India and analyzes these barriers. The main objective are:

- To identify the important barriers affecting the implementation of HCWM practices in India.

- To establish and analyze the interrelationships among the identified barriers.
- To classify the barriers as per the operational, tactical and strategic issues in order to discuss managerial implications at different levels of management.
- To define all the barriers into four quadrants depending upon their driving power and dependence power using Fuzzy-MICMAC analysis.
- To discuss the implications of the present study for hospital administration and Government policy makers.

To achieve the above stated objectives, this chapter has been organized as follows: next section identifies the barriers of implementing HCWM practices in India, which is followed by the ISM methodology proposed for the development of the model. Up next the developed model is divided into three parts as per the barriers related to different levels of management: top level management, middle level management and lower level management. This is followed by the Fuzzy-MICMAC analysis and the discussion and managerial implications of the study and in the last, the whole chapter is summarized.

### 6.3 IDENTIFICATION OF HCWM BARRIERS AND OUTCOME VARIABLES

In this section, to identify the barriers of implementing HCWM practices in India, the literature review was done and two brainstorming sessions were held with the experts of the HCWM field. Some of the barriers were also identified at the time of survey done at various HCFs and interacting with hospital administration. Two brain-storming sessions were held which include the following members: three experts from academia, seven experts from Uttarakhand Council of Science and Technology (UCOST), three experts from HCFs, one manager from CBWTF and two scientists from Pollution Control Board, Uttarakhand, a northern state of India. All the experts were having the experience of more than 20 years in the waste handling projects and research. Before starting the brainstorming session, 20 barriers were identified from the literature and the survey done at various HCFs, for the proposed ISM model. At start of the session, these 20 elements were supplied to the experts for their opinion. In the first session, after the discussion on these elements, the panel clubbed four elements into two elements and added five more barriers for implementing the HCWM practices in India. This resulted into total of 23 barriers for implementing HCWM practices and their interrelationships were recorded in the end of this session. Now, the 23 elements identified in the first session, are given for discussion for the second session and the experts added two more variables into the existing model and voted for their relationships. In the end, all the interrelationships were analyzed by the experts again for any further modification. So, whole process of identification of barriers of HCWM practices in India resulted into 25 elements which are given in Table 6.1.

**Table 6.1:** List of Barriers for Implementing HCWM Practices in India

| S. No. | Barriers | Source of identification | S. No. | Barriers | Source of identification |
|---|---|---|---|---|---|
| 1 | Lack of benchmark in India (LBI) | Literature | 14 | Lack of doctors' commitment (LDC) | Survey |
| 2 | Lack of motivation (LM) | Literature | 15 | Lack of perception of self-harm (LPS) | Brainstorming session |
| 3 | Lack of knowledge and training (LKT) | Literature | 16 | Lack of convenience (LC) | Brainstorming session |
| 4 | Lack of infrastructure (LI) | Literature | 17 | Lack of enforcement of biomedical waste handling rules (LEBWHR) | Survey |
| 5 | Lack of controlling & monitoring (LCM) | Literature | 18 | Lack of maintenance at CBWTF (LOM) | Brainstorming session |
| 6 | Non-sustainable practices (NSP) | Literature | 19 | Lack of holistic mechanism to deal with biomedical waste (LHM) | Brainstorming session |
| 7 | Lack of commitment by hospital administration (LCHA) | Survey | 20 | Improper logistics for transporting BMW from HCF to CBWTF (ILT) | Survey |
| 8 | Lack of collaboration and integration among HCFs and CBWTF (LC&I) | Literature | 21 | Non-aligned operational goals among HCFs and CBWTF (NAOG) | Literature |

| S. No. | Barriers | Source of identification | S. No. | Barriers | Source of identification |
|---|---|---|---|---|---|
| 9 | Inconsistent and inadequate performance measures (ICIAPM) | Literature | 22 | Poor selection of CBWTF (PSOF) | Literature |
| 10 | Lack of budget (LOB) | Survey | 23 | Scaled up infectious waste due to improper segregation (SIW) | Brainstorming session |
| 11 | Lack of appreciation (LA) | Literature | 24 | Extra cost for handling HCW (EC) | Survey |
| 12 | Obsolete treatment technologies at CBWTF (OTT) | Survey | 25 | Ineffective HCWM practices (IHCWM) | Survey |
| 13 | Poor segregation of HCW (PS) | Survey | | | |

### 6.3.1 Lack of Benchmark in India

Benchmarking will help the strategic planners to identify the key potential areas in the related field and supports the decision making process. Whiting (1991) reported that benchmarking as the key component of the Total Quality Management (TQM) process in any organization. Subrahmanya and Rajashekhar (2009) analyzed the barriers for implementing TQM practices in Indian industries and highlighted 'benchmarking' as the main tool for analyzing the weaknesses and strengths with respect to the best practices in its class. Waste disposal firms in India lack the benchmark practices in HCWM field. Hence, treatment facilities and HCFs are not able to compare their practices with respect to standards.

### 6.3.2 Lack of Motivation

Motivation and reward concept is the key to achieve any organizational goal. Motivation can be provided through visibility, recognition, and inclusion of performance in appraisal systems. Okereke (2007) listed the following motivators for corporate climate actions: guiding against risk, fiduciary obligation, ethical considerations and profit credibility. As per the experts, lack of motivation is the main barrier for waste handling firms to implement the HCWM practices efficiently.

### 6.3.3 Lack of Knowledge & Training

It is important to impart knowledge to waste handling workers and make them aware about the harm, they may get from the infectious waste and training should be provided to staff and workers, who are involved into the waste handling practices. While implementing the green supply chain, Bowen et al. (2001) and Carter and Dresner (2001) stressed that training is important to change the mindset of the people against environmental illiteracy. Shen and Tam (2002) observed that lack of training as the most important hurdle in implementing environmental management. Experts in the brain storming session, also stressed on the need for training and awareness programs to the HCW handling workers in order to implement HCWM practices successfully.

### 6.3.4 Lack of Infrastructure

Tudor et al. (2005) outlined that organizational structure and lack of proper HCW collection infrastructure are the major barriers for the implementation of HCWM practices in United Kingdom. In the developing countries, due to lack of proper infrastructure to manage waste, they usually burry it or burn it into the open air (Nnorom and Osibanjo, 2008). The experts in brainstorming also emphasized on the poor IT infrastructure, outdated waste collection procedures and improper segregation and transportation methods as major challenges for implementing HCWM practices in India.

### 6.3.5 Lack of Monitoring & Controlling

Monitoring of the operational process is important, as it provides the continuous feedback which is required for controlling the process and improving the existing system. Long-term performance monitoring is resource intensive, but it is required to evaluate the efficacy of nonconventional systems and to refine the process design (Mitchell, 2006; Park and Park, 2011). Implementing proper monitoring process in the system will require tracking and analysis of the records and reporting on the operational processes of the waste management system.

### 6.3.6 Non-sustainable Practices

Sustainable practices should be adopted in order to reduce the quantity of HCW generated at the various sources and should also focus on the recycling and reuse of the non-infectious waste (Pathal et al., 2010;

Srivastava and Jain, 2010). Phillips et al. (1999) outlined reduce, recover and recycle as the main pillars of the sustainable waste management practices. Experts in the brainstorming session emphasized on minimizing the waste as it helps in achieving cost effectiveness and leads to sustainable waste management in terms of technical and environmental issues. Hence, India needs to focus more on sustainable HCWM strategic plans and waste treatment methods.

### 6.3.7 Lack of Commitment by Hospital Administration

Rogers and Tibben-Lembke (1999) identified that lack of top management commitment as the major barrier for implementing the reverse logistics functions. During the survey of various HCFs in the present research, it was observed that most of the HCFs are not even maintaining the records properly and they have outsourced the waste disposal process to some Government approved CBWTF. The hospital administration thinks that their main focus area is only to provide the better healthcare services to the people and for dealing with waste, they have collaborated with the Healthcare Waste Disposal (HCWD) firm. Hence, lack of hospital administration's commitment is the biggest threat to HCWM system.

### 6.3.8 Lack of Collaboration and Integration among HCFs and CBWTF

Collaboration and integration with the supply chain partners is important to facilitate the horizontal as well as vertical information sharing (Tanlamai, 2006). As per Husain and Pathak (2002), the success of collaboration lie in the faith which the partners have in technological capabilities of one another. Lack of supply chain visibility, lack of competitive advantage inflexible supply chain and non-aligned goals among partners as the biggest barriers of supply chain collaboration (Ramesh et al., 2010; Joseph and Sridharan, 2011). Due to the global competition, HCFs are forced to provide advanced services at reduced cost. Hence, hospitals are focusing more on collaborations for the work like waste management, which is not their core competency in order to improve service, reduce cost and gain competitive advantage. Therefore, collaboration and integration is important among the HCFs and CBWTFs for proper implementation of HCWM practices.

### 6.3.9 Inconsistent and Inadequate Performance Measures

It is important to design the performance matrix for the waste handling firms, so that their performance can be measured with respect to certain standards. Literature focused on the integration of various financial as well non-financial measures in the performance matrices related to various industries. But, literature lacks the performance evaluation criteria to assess the various firms dealing with HCW. Gaiardelli et al.

(2007) stressed on the performance measurement system for various partners involved in the supply chain to attain the strategic consistency. The developed performance matrix should be specific for evaluating HCF as well as CBWTF and flexible enough to account dynamic environment.

### 6.3.10 Lack of Budget

Financial constraints are the main barriers in implementing the reverse logistics processes properly (Rogers and Tibben-Lembke, 1999). During the survey it was observed that, while allocating the budgets in various HCFs the maximum budget is allocated to expand the existing facilities, get advanced machinery and their maintenance in order to provide better healthcare services and waste management is the most neglected area in the hospitals. Hospital administration's perception is that HCFs are evaluated on the basis of level of services they are delivering and not on the basis of waste management practices. Hence, their budget is mainly focused more on primary activities.

### 6.3.11 Lack of Appreciation

Since, HCWM is not considered as the essential function of HCF, hence it is rarely appreciated by the hospital administration. Waste handling workers and staff are not motivated for innovation and effective waste handling practices in managing waste. Geng et al. (2007) reported that 'lack of appreciation' on benefits in managing solid waste is the biggest drawback of the system. Krishna and Dangayach (2012) while developing the service operation strategy, observed that the employee satisfaction is important for the organization.  Hence, less recognition and rewards to the waste handling people, keeping their enthusiasm low about their job (Ojha, 2014a).

### 6.3.12 Obsolete Treatment Technologies at CBWTF

Most of the CBMTFs in the developing nations are simply incinerating the whole waste, which is costlier method and also harmful to the environment. Each ton of incinerated waste produces 25-30 kg of ash as residual, which must be removed carefully. Microwaving and autoclaving are the more efficient techniques, but in India, still the treatment facilities are sticking with the obsolete method of burning the waste, which is polluting the environment. Use of updated technology and innovation are two important steps to achieve the sustainable development (Savetpanuvong et al. (2011b). As per the experts, the CBWTFs are not ready to replace the incineration with microwaving as it requires lot of initial investments. Hence, Government should strictly make the policy regarding the removal of obsolete technologies for treating the waste.

#### 6.3.13 Poor Segregation of Waste

During survey, it was observed that due to the inconvenience and poor infrastructure for collecting the HCW are leading towards the improper segregation, which converts non-hazardous waste into hazardous waste. Most of the HCFs in India are failing to focus on the key area by ignoring the importance of segregation. As per the experts, segregation is the most important step to reduce the amount of infectious waste and implement proper HCWM system.

#### 6.3.14 Lack of Doctors' Commitment

Since, doctors are involved in the HCW generation process, hence, their role in implementing the proper HCWM system is important. During survey and interaction with doctors at various HCFs, revealed that doctors are least concerned about the HCWM practices. They think that HCWM is not their concerned area and they are not responsible for its proper disposal. Doctors are aware about the infectious diseases coming out from the MW, but unfortunately they don't have time to educate and train workers and staff who are actually dealing with it.

#### 6.3.15 Lack of Perception of Self-harm

In the brain storming session the 'lack of perception of self-harm' is considered to be an important threat in implementing the HCWM practices. Actually, most of the waste handling workers are illiterate and hospital administration is not providing any training regarding handling the infectious waste. Hence, these workers are not aware about the fact that if they will not follow the waste handling instructions properly, then various diseases can be developed in themselves. Therefore, 'lack of perception of self-harm' is obstructing the workers in implementing proper collection and segregation of HCW.

#### 6.3.16 Lack of Convenience

The experts present in brainstorming sessions, have realized that 'lack of convenience' is a big hurdle in implementing HCWM system. They noticed that the different color of bins are kept at some common place for the collection of different types of waste, but when doctors and staff attend any patient then, only one bin is placed, where all the waste is mixed. So it becomes tough to segregate it on later stage. Therefore, it is important to design the trolley, where all the four colored bins are placed on the down shelve along with the treatment equipment and medicine on the first shelves. This will ensure the proper segregation of waste at the generation point itself. Hence, convenience makes it easy to handle waste more efficiently and effectively.

### 6.3.17 Lack of Enforcement of BMW Handling Rules

The inappropriate legislation and ineffective control are the major reasons behind the failure of HCWM system. The experts agreed on the issue that monitoring of HCFs and CBWTFs by regulatory authorities is poor. The HCFs and treatment facilities are not even maintaining the records, which they are supposed to submit in the end of every year. So in order to implement the "Waste Management & Handling" rules 1998, the State and Central Pollution Control Boards have to coordinate and make various checks regularly to these facilities.

### 6.3.18 Lack of Maintenance at CBWTF

Practitioners in the HCWM area, emphasized on the need of maintenance engineer at each CBWTF and right now there is no such position at these facilities. If any machine gets down, then they have to wait for 20-25 days to get it fixed and till then the hazardous waste lees inside the hospital premises, which is very much dangerous for the environment. So, there should be at least one maintenance engineer who can ensure the proper functioning of all the machines.

### 6.3.19 Lack of Holistic Mechanism to deal with BMW

As per the experts, from Pollution Control Board, Uttarakhand, the sustainable waste management practices require the holistic approach including all the activities of collection, segregation, transportation and final disposal of the HCW. Holistic approach should include feedback loops, processes and flexibility in waste disposal methods. As per Chauhan et al. (2005), the functional effectiveness and personal effectiveness are two important factors, which must be focused in order to achieve the managerial effectiveness in India.

### 6.3.20 Improper Logistics for Transporting BMW from HCF to CBWTF

Due to poor logistics arrangements, there is infrequent transportation of the HCW from the HCF to the CBWTF. During the survey, it was observed that sometimes the waste remains in the hospital premises for more than 5-6 days, which is very dangerous for the hospital employees and patients. As per the Government guidelines the waste disposal firm's vehicle should come at least once in every 48 hours. Experts in the brainstorming session, also advised that after packing each type waste, hospital administration should track the baggage until the final disposal is over.

**Outcome Variables**

### 6.3.21 Non-aligned Operational Goals among HCFs and CBWTF

HCFs always focus on minimizing the waste disposal cost and allocate minimum budget for it. But, the waste treatment facilities need more budget to update the technology and install the proper equipment for handling and disposing the waste. For any organization to achieve its objectives, it is required to create a synergy with its strategic partners. Cetindamar et al. (2005) also stressed on the tuning of goals among the organizations and their partners. The operational excellence is the way to achieve the sustainability (Ojha, 2015). In the brainstorming session, the experts focused on outsourcing the waste treatment process and tuning of operational goals with the treatment facility.

### 6.3.22 Poor Selection of CBWTF

While outsourcing the HCWD process, it is crucial to evaluate the partner more strategically and quantitatively. Due to lack of performance evaluating criteria, HCFs are selecting their outsourcing partners without any quantitative and rational approach. According to Wadhwa and Ravindran (2007), outsourcing is strategic decision and partner selection is multi-objective optimization problem. Hence, each HCF should develop some model to select the waste disposal firm depending upon evaluating the various performance parameters.

### 6.3.23 Scaled-up Infectious Waste due to Improper Segregation

As per the practitioners of HCFs, the infectious waste constitutes only 15-20% of the total waste and rest 80-85% is non-infectious general waste. But, if this waste is not segregated properly, then it makes 100 % waste as infectious. This extra amount of infectious waste will require extra efforts to handle and dispose it. Hence, as per the experts the segregation is the most important step in whole HCWD process.

### 6.3.24 Extra Cost for Handling HCWD

Improper collection and segregation of HCW at the point of generation results in increased quantity of hazardous waste, which need special treatment and hence, the cost of treating per kg of waste increases proportionally. As a result, HCFs have to bear extra cost for handling the waste. Hence, HCFs need to identify the main operational areas, where the cost can be reduced by implementing proper HCWM practices.

### 6.3.25 Ineffective HCWM Practices

The inadequate collection and segregation of HCW, delayed transportation from HCF to CBWTF, outdated treatment technologies etc. are leading to ineffective and inefficient HCWM system. Experts in the brainstorming session, added that all the barriers mentioned above lead to poor HCWM practices. Hence, the collection, segregation, transportation and disposal processes need to be strengthen in order to implement the HCWM practices efficiently and effectively. A holistic approach need to be developed in order to assure the proper handling of HCW and protect the environment.

## 6.4 METHODOLOGY: INTERPRETIVE STRUCTURAL MODELING (ISM)

When the targeted problem is affected by the number of variables, then it becomes difficult to make the decisions and to consider their interrelationships. ISM is a qualitative and interpretive method, which helps to understand the complex and poorly articulated problems in terms of well-defined structured form, depending upon the pattern of interrelationships among various elements involved in the hierarchy (Pfohl et al., 2011). ISM helps the decision makers to identify the most critical elements in the defined problem and the direction of influence of these elements on the various other elements involved in the structure. In this chapter, ISM modeling technique has been used to model the barriers of implementing HCWM practices in India. To achieve the above stated objectives the step by step procedure is shown in Figure 6.1.

**Step 1:** The various barriers to implement HCWM practices are reported from literature review, survey of HCFs & CBWTF and brainstorming sessions.

**Step 2:** Contextual relationships among various barriers and outcome variables are examined in the brainstorming sessions.

**Step 3:** Structural Self-Interaction Matrix (SSIM) is developed from the consensus derived from the brainstorming session, which reflects the direction of influence of each variable on the other.

**Step 4:** SSIM is converted into initial reachability matrix by representing the interrelationships in terms of binary numbers and further initial reachability matrix is converted into final reachability matrix by including all the transitivity in the relationships. Transitivity represents the indirect relationship.

**Step 5:** The final reachability matrix is partitioned into different levels of hierarchical structure, depending upon the driving power and dependence power of the elements.

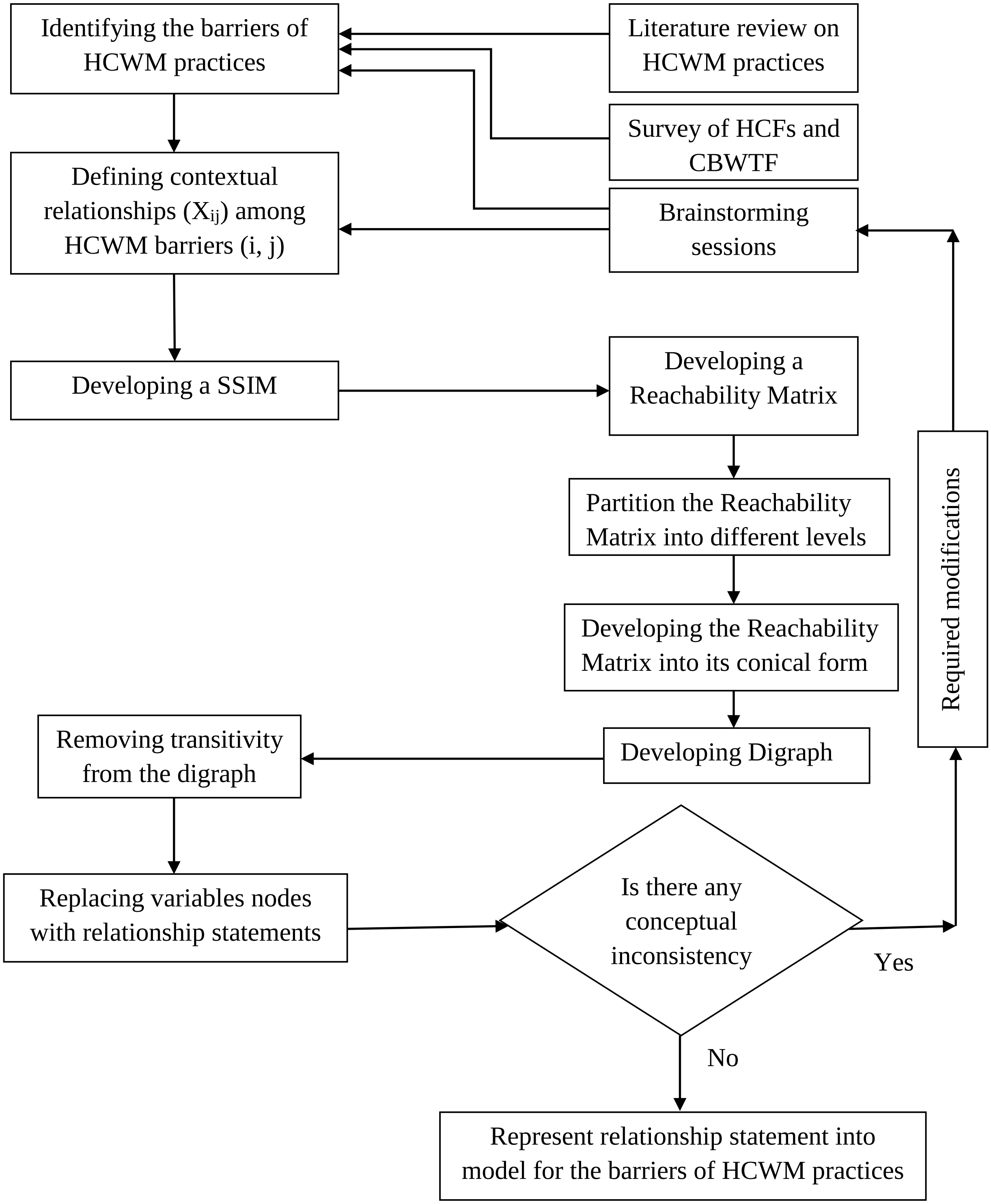


**Figure 6.1:** Process Flow Diagram for Developing ISM

(Adapted from: Ramesh et al., 2010)

**Step 6:** After level partitioning, the matrix is rearranged as per levels of barriers and canonical matrix has been derived, which can be directly used for constructing hierarchical relationship model for the barriers of implementing HCWM system. The transitive links are removed from the digraph based on the relationship defined.

**Step 7:** Final ISM model is developed from the resultant digraph.

**Step 8:** In the last the ISM model is checked for any conceptual inconsistency and required modifications are done.

### 6.4.1 Developing Structural Self-Interaction Matrix (SSIM)

In ISM, different types of relationships like: definitive, comparative, influence and temporal can be defined among the elements (Bolanos et al., 2005). But, the present study has used 'leads to' contextual relationship to define the direction of relationship among various barriers. The directions of relationships among all the barriers and output variables are concluded from the brainstorming sessions, after reaching on consensus of all the experts present. To make the SSIM matrix, four types of relationships are defined among barriers (i and j) by using following four symbols:

**F:** Forward relationship, representing 'i' leads to 'j'.

**B:** Backward influence represents 'j' leads to 'i'.

**X:** Cross relationship represents 'i' and 'j' leads to each other.

**O:** No relationship between 'i' and 'j'.

The following relationship statements among barriers would explain the use of symbols F, B, X, O in SSIM (Table 6.2).

- Barrier 1 leads to barrier 5. This means that 'lack of benchmark in India' leads to 'lack of monitoring & controlling'. Hence, the relationship symbol 'F' is used in the corresponding cell ($C_{1,5}$).
- Barrier 4 is led by barrier 10. This means that 'lack of budget' will result into 'lack of infrastructure'. Hence, the cell ($C_{4,10}$) has been assigned 'B' symbol.

- Barrier 1 and 9 will lead each other. This signifies that ‘lack of benchmark in India’ and ‘inconsistent and inadequate performance measures’ are having bidirectional relationship and is represented by symbol ‘X’ in the related cell ($C_{1,9}$).
- Barrier 1 and 10 are not influencing each other. Hence, the corresponding cell value is assigned ‘O’, which represents that ‘lack of benchmark in India’ and ‘lack of budget’ barriers are having no relationship.

Table 6.2 represents the SSIM matrix resulted from the brainstorming sessions and representing the direction of relationships among all the barriers of implementing HCWM practices.

### 6.4.2 Developing Initial Reachability Matrix

The SSIM matrix shown in Table 6.2 is converted into perceptual binary matrix, known as initial reachability matrix. The relationships are converted into binary form by using following rules:

i) If, cell (i,j) = F, then enter 1 in the (i,j) cell and 0 in the (j,i) cell.

ii) If, cell (i,j) = B, then enter 0 in the (i,j) cell and 1 in the (j,i) cell.

iii) If, cell (i,j) = X, then enter 1 in both the cells (i,j) and (j,i).

iv) If, cell (i,j) = O, then enter 0 in both the cells (i,j) and (j,i).

### 6.4.3 Developing Final Reachability Matrix

The initial reachability matrix is converted into final reachability matrix by incorporating the transitivity, which represents the indirect relationship among the barriers. Transitivity condition states that if barrier 1 is leading to barrier 2 and barrier 2 is leading to barrier 3, then barrier 1 is necessarily leading to barrier 3. The final reachability matrix is shown in Table 6.3 and it also reflects the driving power and dependence power of each barrier of HCWM. The driving power of a particular barrier represents the total number of barriers it is influencing and dependence power is the total number of barriers from which it is being influenced.

### 6.4.4 Carryout Level Partitioning

Here, all the barriers are placed at particular level in the hierarchical model depending upon their power to influence other elements and being influenced by the other elements in the hierarchy. Table 6.3 is used to carry out the level partitioning of all the elements. To start partitioning, the reachability sets and antecedent sets are derived for each barrier from the final reachability matrix. Reachability set for a particular barrier includes all the barriers for which the cell entry is 1 in the corresponding row, which means the barrier itself and all the other barriers which are influenced by the barrier under consideration. Antecedent set includes the all the barriers for which the cell entry is 1 in the corresponding column, which means that barrier itself and all the other barriers which are influencing the barrier under consideration. From these two sets, intersection set is established, which includes the common elements in reachability set and antecedent set. Now, if the reachability set and intersection set are same for the particular element then that element is kept at level 1 and placed at the top of the ISM hierarchy model. After identifying the first level elements, those elements are removed from the table and same steps are repeated again and again until all the barriers are defined with their specific levels in the model. The stepwise partitioning of the barriers at different levels along with reachability, antecedents and intersection sets are shown in Appendix (VIII (a)-VIII (k)). Table 6.4 represents the results of partitioning of all the barriers into different levels.

**Table 6.2:** Structural Self-interaction Matrix for the Barriers of Implementing HCWM

| **Barriers** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | | B | B | B | F | B | B | O | X | O | B | F | B | B | O | B | B | B | F | F | O | F | O | O | F |
| **2** | | | X | X | O | F | B | O | F | B | X | F | F | B | O | F | B | X | F | F | F | F | F | F | F |
| **3** | | | | X | F | F | B | F | F | B | X | F | F | B | F | F | B | X | F | F | F | F | F | F | F |
| **4** | | | | | O | F | B | F | F | B | X | F | F | B | O | F | O | X | F | F | O | F | F | F | F |
| **5** | | | | | | B | B | F | B | B | B | F | B | B | O | B | B | B | F | F | F | X | B | B | F |
| **6** | | | | | | | B | F | F | B | O | F | B | B | O | B | B | B | F | O | F | F | X | X | F |
| **7** | | | | | | | | F | F | F | F | F | F | X | F | F | B | F | F | F | F | F | F | F | F |
| **8** | | | | | | | | | B | O | B | F | B | B | B | O | O | B | F | X | F | B | B | B | F |
| **9** | | | | | | | | | | O | B | F | B | O | O | B | B | B | F | F | F | F | B | B | F |
| **10** | | | | | | | | | | | F | F | F | B | F | F | B | F | F | F | F | F | F | F | F |
| **11** | | | | | | | | | | | | O | F | B | O | O | O | X | F | F | F | F | F | F | F |
| **12** | | | | | | | | | | | | | B | O | B | B | B | B | X | B | X | B | O | B | F |
| **13** | | | | | | | | | | | | | | B | B | B | B | O | F | F | F | O | F | F | F |
| **14** | | | | | | | | | | | | | | | F | F | B | F | F | F | F | F | F | F | F |
| **15** | | | | | | | | | | | | | | | | X | O | B | F | F | F | O | F | F | F |
| **16** | | | | | | | | | | | | | | | | | B | B | F | F | F | F | F | F | F |
| **17** | | | | | | | | | | | | | | | | | | F | F | F | F | F | F | F | F |
| **18** | | | | | | | | | | | | | | | | | | | F | O | F | F | O | F | F |
| **19** | | | | | | | | | | | | | | | | | | | | B | X | B | B | B | F |
| **20** | | | | | | | | | | | | | | | | | | | | | F | B | B | B | F |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **21** | | | | | | | | | | | | | | | | | | | | | B | B | B | F |
| **22** | | | | | | | | | | | | | | | | | | | | | | B | B | F |
| **23** | | | | | | | | | | | | | | | | | | | | | | | X | F |
| **24** | | | | | | | | | | | | | | | | | | | | | | | | F |
| **25** | | | | | | | | | | | | | | | | | | | | | | | | |

**Table 6.3:** Final Reachability Matrix

| **Barriers** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **Driving power** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1* | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1* | 1 | 0 | 0 | 1 | 10 |
| **2** | 1 | 1 | 1 | 1 | 1* | 1 | 0 | 1* | 1 | 0 | 1 | 1 | 1 | 0 | 1* | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 21 |
| **3** | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 21 |
| **4** | 1 | 1 | 1 | 1 | 1* | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1* | 1 | 0 | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 1 | 21 |
| **5** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 8 |
| **6** | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1* | 1 | 1 | 1 | 1 | 1 | 13 |
| **7** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 24 |
| **8** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 6 |
| **9** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 10 |
| **10** | 1* | 1 | 1 | 1 | 1 | 1 | 0 | 1* | 1* | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 22 |
| **11** | 1 | 1 | 1 | 1 | 1 | 1* | 0 | 1 | 1 | 0 | 1 | 1* | 1 | 0 | 1* | 1* | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 21 |
| **12** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 4 |
| **13** | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 14 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **14** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1* | 1 | 1 | 1* | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 24 |
| **15** | 1* | 0 | 0 | 0 | 1* | 1* | 0 | 1 | 1* | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 16 |
| **16** | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1* | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 16 |
| **17** | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 1* | 1 | 1 | 1* | 1 | 1 | 1 | 1* | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 25 |
| **18** | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1* | 0 | 1 | 1 | 0 | 1 | 1 | 1* | 1 | 1 | 1* | 1 | 1 | 21 |
| **19** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 4 |
| **20** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 | 6 |
| **21** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 4 |
| **22** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 8 |
| **23** | 1* | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1* | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 13 |
| **24** | 1* | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 13 |
| **25** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 |
| **Dependence power** | 17 | 9 | 9 | 9 | 19 | 15 | 3 | 21 | 17 | 4 | 9 | 24 | 12 | 3 | 11 | 11 | 1 | 9 | 24 | 21 | 24 | 19 | 15 | 15 | 25 | 17 |

* Represents the transitive positions.

**Table 6.4:** Level Partitioning (Representing all the iterations)

| Barrier | Reachability Set | Antecedent set | Intersection set | Level |
|---|---|---|---|---|
| 1 | 1,5,8,9,12,19,20,21,22,25 | 1,2,3,4,6,7,9,10,11,13,14,15,16,17,18,23,24 | 1,9 | Level 5 |
| 2 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21, 22,23,24,25 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | Level 9 |

| | | | | |
|---|---|---|---|---|
| 3 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | Level 9 |
| 4 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | Level 9 |
| 5 | 5,8,12,19,20,21,22,25 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,17,18,22,23,24 | 5,22 | Level 4 |
| 6 | 1,5,6,8,9,12,19,20,21,22,23,24,25 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 6,23,24 | Level 6 |
| 7 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22,23,24,25 | 7,14,17 | 7,14 | Level 11 |
| 8 | 8,12,19,20,21,25 | 1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,17,18,20,22,23,24 | 8,20 | Level 3 |
| 9 | 1,5,8,9,12,19,20,21,22,25 | 1,2,3,4,6,7,9,10,11,13,14,15,16,17,18,23,24 | 1,9 | Level 5 |
| 10 | 1,2,3,4,5,6,8,9,10,11,12,13,15,16,18,19,20,21,22,23,24,25 | 7,10,14,17 | 10 | Level 10 |
| 11 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | Level 9 |
| 12 | 12,19,21,25 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24 | 12,19,21 | Level 2 |
| 13 | 1,5,6,8,9,12,13,19,20,21,22,23,24,25 | 2,3,4,7,10,11,13,14,15,16,17,18 | 13 | Level 7 |
| 14 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22,23,24,25 | 7,14,17 | 7,14 | Level 11 |
| 15 | 1,5,6,8,9,12,13,15,16,19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | Level 8 |
| 16 | 1,5,6,8,9,12,13,15,16,19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | Level 8 |

| | | | | |
|---|---|---|---|---|
| 17 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25 | 17 | 17 | Level 12 |
| 18 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | Level 9 |
| 19 | 12,19,21,25 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24 | 12,19,21 | Level 2 |
| 20 | 8,12,19,20,21,25 | 1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,17,18,20,22,23,24 | 8,20 | Level 3 |
| 21 | 12,19,21,25 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24 | 12,19,21 | Level 2 |
| 22 | 5,8,2,19,20,21,22,25 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,17,18,22,23,24 | 5,22 | Level 4 |
| 23 | 1,5,8,9,12,19,20,21,22,23,24,25 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | Level 6 |
| 24 | 1,5,8,9,12,19,20,21,22,23,24,25 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | Level 6 |
| 25 | 25 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25 | 25 | Level 1 |

### 6.4.5 Build Hierarchical Relationship Structure Based on ISM

The different levels defined in Table 6.4, are used to build up digraph and final ISM model. The barriers at various levels are connected by the arrows pointing in the direction of relationship among the elements. For example, if barrier 1 leads to barrier 2, then an arrow pointing towards 2 from 1 is drawn. If both the barriers are lading each other, then a bidirectional arrow is drawn connecting the two elements. This step will generate a digraph, which is finally converted into ISM model by removing the transitivity as shown in Figure 6.2.

The developed model has been further classified based on the decision hierarchy as follows: strategic, tactical and operational decisions. Figure 6.3 shows all the barriers into three groups depending upon their position defined in the ISM model. Generally, the barriers at the bottom of the model are related to the operational factors, which are the independent variables and have the strongest driving power. In the present study the operational barriers are as follows: ‘LM’, ‘LKT’, ‘LI’, ‘LCHA’, ‘LOB’, ‘LA’, ‘PS’, ‘LDC’, ‘LPS’, ‘LC’, ‘LEBWHR’, and ‘LOM’. These operational barriers are related to the day to day activities and are short-term horizon. These barriers should be handled by the lower level management. The barriers in the middle of the model are related to the tactical decisions and these are important in order to implement the strategic plans. In the present study, following are the tactical barriers: ‘LBI’, ‘LMC’, ‘NSP’, ‘ICIAPM’, ‘ILT’, ‘PSOF’, ‘SIW’, and ‘EC’. Middle level management should take care of these barriers in order to implement the proper HCWM practices.

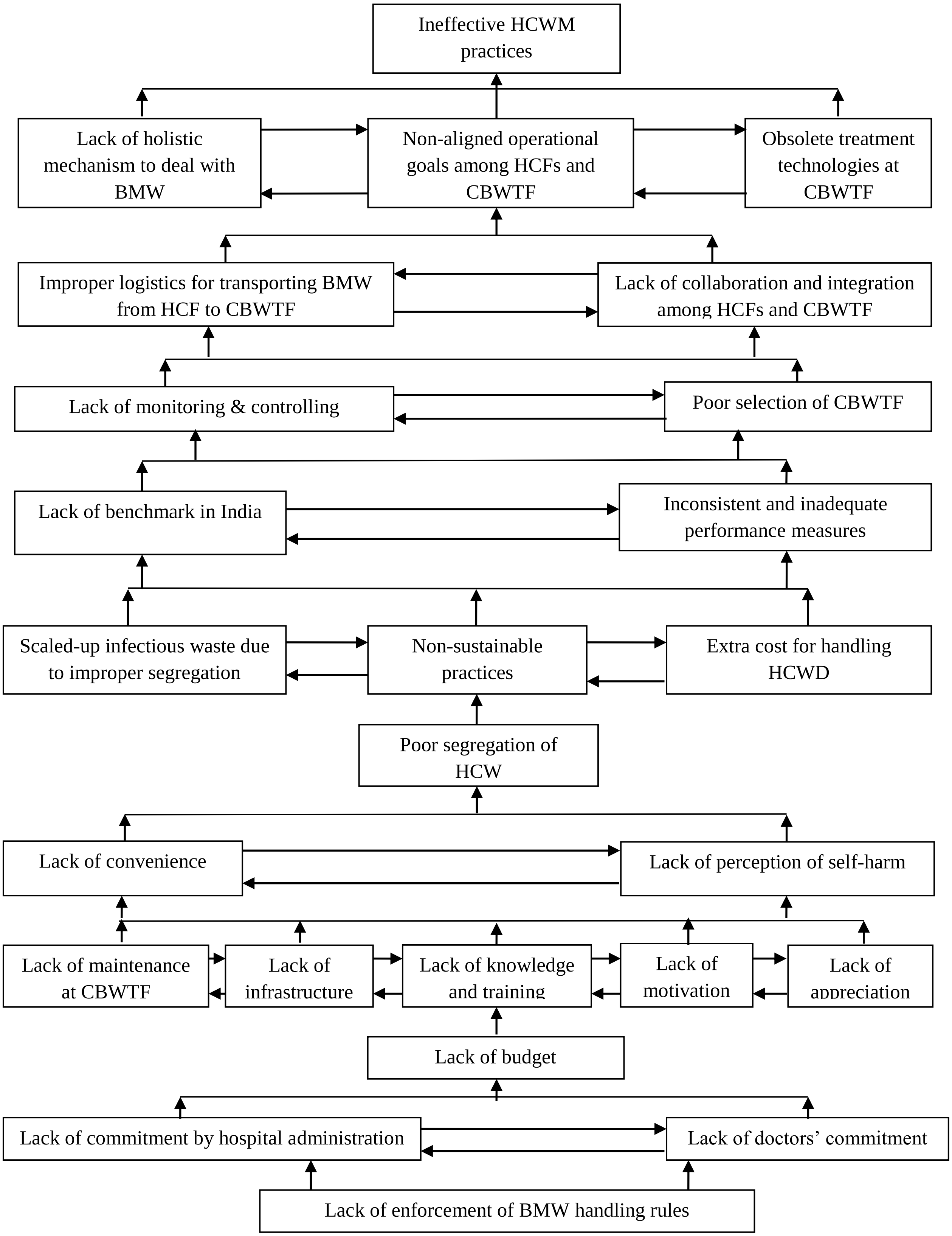


**Figure 6.2:** ISM-based Model for Barriers of Implementing HCWM

The barriers placed at the top of the model are the strategic factors and having the long-term influence on the whole HCWM system. These barriers are having high dependence power and are the responsibility of the top level hospital administration. This research has defined five strategic barriers for implementing HCWM practices: 'LC&I', 'OTT', 'LHM', 'NAOG', and 'IHCWM'.

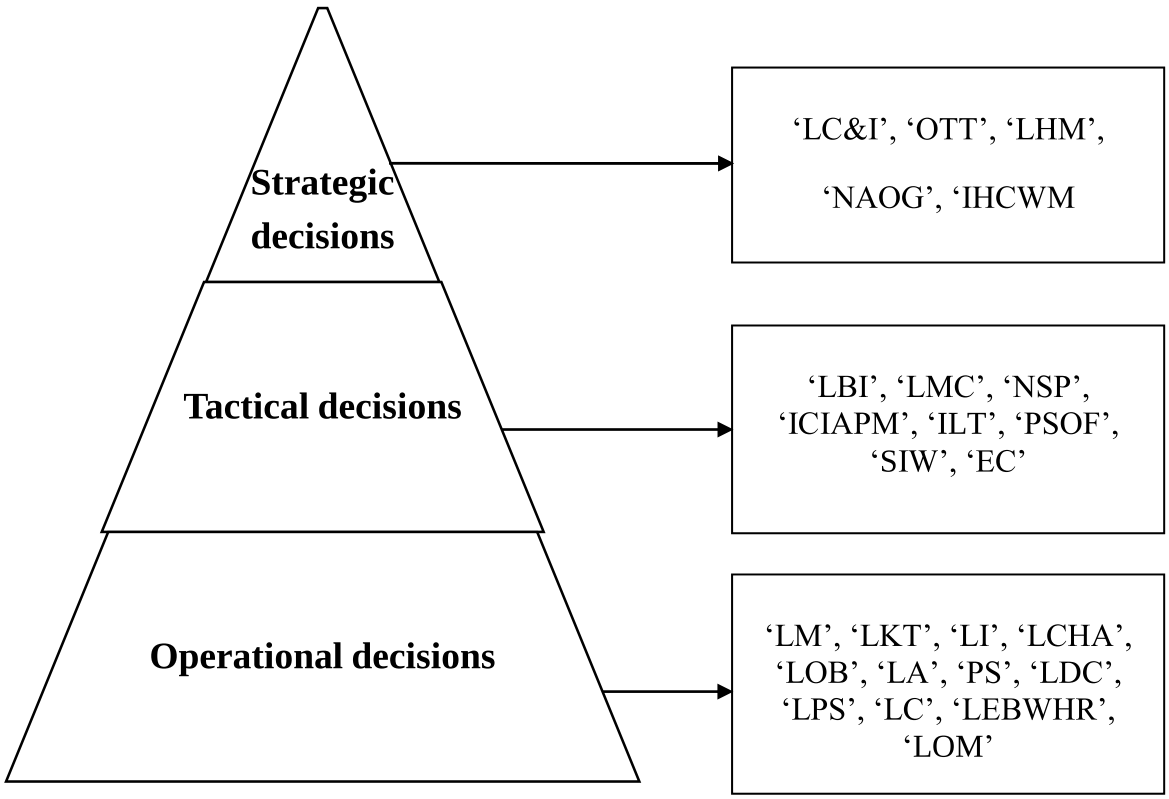


**Figure 6.3:** Decision Hierarchy of ISM Model

**6.5 FUZZY-MICMAC ANALYSIS** (Matriced' Impacts Croisés Multiplication Appliquée á un Classement)

MICMAC analysis is also known as "cross impact matrix-multiplication applied to classification". The main purpose of MICMAC analysis is to analyze driving power and dependence power of all the barriers involved in the model (Mandal and Deshmukh, 1994). Depending upon the score of each barrier on driving power and dependence power, all the barriers are classified into four clusters in MICMAC analysis. Adding the fuzzy values to define the interrelationships among the barriers will help the hospital administration to understand more precisely about the direction and strength of influence of the barriers. Fuzzy-MICMAC analysis includes following steps:

### 6.5.1 Binary Direct Relationship Matrix (BDRM)

Here the initial direct matrix obtained from the relationship matrix is converted into BDRM, by converting the diagonal elements to zero and ignoring the transitivity. The resultant matrix is shown in Table 6.5.

**Table 6.5:** Binary Direct Reachability Matrix

| **Barriers** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 |
| **2** | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **3** | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **4** | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 |
| **5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| **6** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 |
| **7** | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **8** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| **9** | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 1 |
| **10** | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **11** | 1 | 1 | 1 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **12** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| **13** | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |
| **14** | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **15** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 1 |

| | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **16** | 1 | 0 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 1 | 1 | 0 | 1 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **17** | 1 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 |
| **18** | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 1 | 1 | 0 | 1 | 1 |
| **19** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 |
| **20** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 1 |
| **21** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 |
| **22** | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 | 0 | 0 | 1 |
| **23** | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 0 | 1 | 1 |
| **24** | 0 | 0 | 0 | 0 | 1 | 1 | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 0 | 1 |
| **25** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

### 6.5.2 Developing Fuzzy Direct Relationship Matrix (FDRM)

The MICMAC analysis divide all the barriers into four quadrants, depending upon the binary relationship defined in the reachability matrix. The binary relationship defines either the presence of relationship or absence of relationship depending upon 1 and 0 score respectively. But, fuzzy-MICMAC analysis helps to define the possibility of reachability on 0-1 scale, as shown in Table 6.6. Hence, use of fuzzy numbers in defining the possibility of interaction among all the barriers makes MICMAC analysis more sensitive and results can be better interpreted by the decision makers.

**Table 6.6:** Fuzzy Scale of Possibility of Reachability

| **Degree of possibility** | **No** | **Negligible** | **Low** | **Medium** | **High** | **Very high** | **Full** |
|---|---|---|---|---|---|---|---|
| Value | 0 | 0.1 | 0.3 | 0.5 | 0.7 | 0.9 | 1 |

The possibility of numerical value of the reachability is superimposed on the BDRM shown in Table 6.5 and converted into a FDRM, shown in Table 6.7.

### 6.5.3 Developing Fuzzy Indirect Relationship Matrix (FIRM)

In order to get the FIRM, the FDRM matrix is multiplied repeatedly up to the power until the hierarchies of the driving power and dependence power are stabilized. Fuzzy matrix multiplication is like Boolean matrix multiplication, which results in fuzzy matrix only. The following rule has been used to find out the product of two fuzzy matrix 'A' and 'B' (Khurana et al., 2010):

$$A * B = maxk[\min(a_{ik}, b_{kj})] \quad (1)$$

where $A = [a_{ik}], B = [b_{kj}]$

After getting the stabilized matrix, the driving power and dependence power of each barrier is calculated by taking the row sum and column sum respectively. Ranking of the barriers is done according to their scores of driving and dependence power. The stabilized fuzzy matrix along with ranking of all the barriers is shown in Table 6.8.

### 6.5.4 Key Barriers of HCWM Practices

After getting the stabilized fuzzy-MICMAC matrix, the barriers of implementing HCWM practices were classified into four clusters, depending upon the driving power and dependence power as shown in Figure 6.4. The barriers on the upper half of the graph are having strong driving power and are the key barriers for implementing the HCWM practices. So, the identification of these barriers is important for hospital administration in order to implement the effective and efficient HCWM practices. Hence, dividing the barriers into four categories will help the hospital waste managers to prioritize as per the importance of the direct and indirect barriers of implementing HCWM practices.

**Table 6.7:** FDRM matrix

| **Barriers** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | 0 | 0 | 0 | 0 | .7 | 0 | 0 | 0 | .9 | 0 | 0 | .9 | 0 | 0 | 0 | 0 | 0 | 0 | .9 | .3 | 0 | .5 | 0 | 0 | .9 |
| **2** | .3 | 0 | .5 | .3 | 0 | .7 | 0 | 0 | .5 | 0 | .5 | .5 | .9 | 0 | 0 | .3 | 0 | .1 | .5 | .5 | .3 | .3 | .3 | .1 | .7 |
| **3** | .7 | .7 | 0 | .7 | .7 | .9 | 0 | .1 | .5 | 0 | .3 | .7 | .9 | 0 | .9 | .7 | 0 | .5 | .7 | .5 | .3 | .9 | .5 | .3 | .9 |
| **4** | .7 | .5 | .7 | 0 | 0 | .7 | 0 | .1 | .1 | 0 | .1 | .9 | .7 | 0 | 0 | .1 | 0 | .5 | .7 | .5 | 0 | .3 | .3 | .1 | .7 |
| **5** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .9 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | .7 | .7 | .5 | 0 | 0 | .7 |
| **6** | .5 | 0 | 0 | 0 | .3 | 0 | 0 | .3 | .3 | 0 | 0 | .7 | 0 | 0 | 0 | 0 | 0 | 0 | .9 | 0 | .3 | .3 | .7 | .5 | .7 |
| **7** | .7 | .7 | .9 | .9 | .5 | .7 | 0 | .7 | .5 | .9 | .9 | .7 | .9 | .7 | .5 | .7 | 0 | .5 | .9 | .7 | .7 | .9 | .7 | .5 | .9 |
| **8** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .9 | 0 | 0 | 0 | 0 | 0 | 0 | .7 | .9 | .9 | 0 | 0 | 0 | .7 |
| **9** | .7 | 0 | 0 | 0 | .9 | 0 | 0 | 1 | .5 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .9 | .5 | .5 | .9 | 0 | 0 | .7 |
| **10** | 0 | .7 | .7 | .9 | .5 | .5 | 0 | 0 | 0 | 0 | .7 | .9 | .3 | 0 | .1 | .3 | 0 | .7 | .7 | .5 | .3 | .1 | .1 | .3 | .9 |
| **11** | .5 | .9 | .3 | .5 | .1 | 0 | 0 | .5 | .3 | 0 | 0 | 0 | .7 | 0 | 0 | 0 | 0 | .3 | .1 | .5 | .7 | .5 | .5 | .1 | .5 |
| **12** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | .5 | 0 | 0 | 0 | .7 |
| **13** | .5 | 0 | 0 | 0 | .1 | .7 | 0 | .1 | .3 | 0 | 0 | .1 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | .3 | .1 | 0 | .9 | .7 | .7 |
| **14** | .3 | .3 | .5 | .1 | .3 | .5 | .1 | .3 | 0 | .1 | .5 | 0 | .7 | 0 | .3 | .5 | 0 | .1 | .3 | .1 | .1 | .3 | .5 | .3 | .5 |
| **15** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .3 | 0 | 0 | 0 | .3 | .7 | 0 | 0 | .5 | 0 | 0 | .3 | .7 | .3 | 0 | .1 | .1 | .5 |
| **16** | .7 | 0 | 0 | 0 | .5 | .5 | 0 | 0 | .1 | 0 | 0 | .1 | .7 | 0 | .1 | 0 | 0 | 0 | .7 | .7 | .1 | .1 | .3 | .1 | .5 |
| **17** | .7 | .5 | .5 | 0 | .7 | .5 | .9 | 0 | .7 | .5 | 0 | .7 | .7 | .5 | 0 | .3 | 0 | .5 | .7 | .9 | .1 | .3 | .3 | .1 | .9 |
| **18** | .3 | .1 | .1 | .5 | .5 | .1 | 0 | .1 | .1 | 0 | .1 | .5 | 0 | 0 | .1 | .1 | 0 | 0 | .1 | 0 | .1 | .1 | 0 | .5 | .5 |
| **19** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .9 | 0 | 0 | 0 | .9 |
| **20** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0.5 | 0 | 0 | 0 | .1 | 0 | 0 | 0 | 0 | 0 | 0 | .1 | 0 | .3 | 0 | 0 | 0 | .3 |

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|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **21** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .7 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | .5 |
| **22** | 0 | 0 | 0 | 0 | .3 | 0 | 0 | .7 | 0 | 0 | 0 | .7 | 0 | 0 | 0 | 0 | 0 | 0 | .3 | .7 | .7 | 0 | 0 | 0 | .7 |
| **23** | 0 | 0 | 0 | 0 | .1 | .5 | 0 | .1 | .1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .1 | .1 | .1 | .1 | 0 | .9 | .5 |
| **24** | 0 | 0 | 0 | 0 | .3 | .5 | 0 | .1 | .1 | 0 | 0 | .9 | 0 | 0 | 0 | 0 | 0 | 0 | .3 | .7 | .3 | .1 | .1 | 0 | .5 |
| **25** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |

**Table 6.8:** Fuzzy MICMAC Stabilized Matrix

| **Barriers** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** | **24** | **25** | **Driving power** | **Ranking** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **1** | .7 | 0 | 0 | 0 | .7 | 0 | 0 | .7 | .5 | 0 | 0 | .7 | 0 | 0 | 0 | 0 | 0 | 0 | .7 | .7 | .7 | .7 | 0 | 0 | .7 | 6.8 | 9 |
| **2** | .5 | .5 | .5 | .5 | .5 | .5 | 0 | .5 | .5 | 0 | .5 | .5 | .5 | 0 | .5 | .5 | 0 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | 10.5 | 7 |
| **3** | .7 | .5 | .7 | .5 | .7 | .7 | 0 | .7 | .7 | 0 | .5 | .7 | .7 | 0 | .5 | .5 | 0 | .5 | .7 | .7 | .7 | .7 | .7 | .7 | .7 | 13.5 | 5 |
| **4** | .7 | .7 | .5 | .7 | .7 | .7 | 0 | .7 | .7 | 0 | .5 | .7 | .7 | 0 | .7 | .7 | 0 | .5 | .7 | .7 | .7 | .7 | .7 | .7 | .7 | 14.1 | 4 |
| **5** | 0 | 0 | 0 | 0 | .3 | 0 | 0 | .5 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | .5 | .5 | 0 | 0 | 0 | .5 | 3.3 | 13 |
| **6** | .5 | 0 | 0 | 0 | .5 | .5 | 0 | .5 | .5 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | 6.5 | 12 |
| **7** | .7 | .7 | .7 | .7 | .7 | .7 | .1 | .7 | .7 | .1 | .5 | .7 | .7 | 0 | .7 | .7 | 0 | .5 | .7 | .7 | .7 | .7 | .7 | .7 | .7 | 14.5 | 2 |
| **8** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | .5 | 0 | 0 | 0 | .5 | 2.5 | 4 |
| **9** | .5 | 0 | 0 | 0 | .7 | 0 | 0 | .7 | .7 | 0 | 0 | .7 | 0 | 0 | 0 | 0 | 0 | 0 | .7 | .7 | .7 | .5 | 0 | 0 | .7 | 6.6 | 11 |
| **10** | .7 | .7 | .7 | .7 | .7 | .7 | 0 | .7 | .7 | 0 | .5 | .7 | .7 | 0 | .7 | .7 | 0 | .5 | .7 | .7 | .7 | .7 | .7 | .7 | .7 | 14.3 | 3 |
| **11** | .5 | .5 | .5 | .5 | .5 | .5 | 0 | .5 | .5 | 0 | .5 | .5 | .5 | 0 | .5 | .5 | 0 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | 10.5 | 7 |
| **12** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | .5 | 0 | 0 | 0 | .5 | 2 | 15 |
| **13** | .5 | 0 | 0 | 0 | .5 | .5 | 0 | .5 | .5 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | 6.5 | 12 |
| **14** | .5 | .5 | .5 | .5 | .5 | .5 | 0 | .5 | .5 | .1 | .5 | .5 | .5 | .1 | .5 | .5 | 0 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | 10.7 | 6 |
| **15** | .5 | 0 | 0 | 0 | .5 | .5 | 0 | .5 | .5 | 0 | 0 | .5 | .1 | 0 | .1 | 0 | 0 | 0 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | 6.7 | 10 |
| **16** | .5 | 0 | 0 | 0 | .7 | .5 | 0 | .7 | .7 | 0 | 0 | .7 | .1 | 0 | 0 | .1 | 0 | 0 | .7 | .7 | .7 | .5 | .5 | .5 | .7 | 8.3 | 8 |

| | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **17** | .7 | .7 | .7 | .7 | .7 | .7 | .1 | .7 | .7 | .1 | .5 | .7 | .7 | .1 | .7 | .7 | 0 | .5 | .7 | .7 | .7 | .7 | .7 | .7 | .7 | 14.6 | 1 |
| **18** | .5 | .5 | .5 | .5 | .5 | .5 | 0 | .5 | .5 | 0 | .5 | .5 | .5 | 0 | .5 | .5 | 0 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | 10.5 | 7 |
| **19** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | .5 | 0 | 0 | 0 | .5 | 2 | 15 |
| **20** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | .5 | .5 | 0 | 0 | 0 | .5 | 2.5 | 14 |
| **21** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | .5 | 0 | 0 | 0 | .5 | 2 | 15 |
| **22** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | .5 | .5 | .3 | 0 | 0 | .5 | 3.3 | 13 |
| **23** | .5 | 0 | 0 | 0 | .5 | .5 | 0 | .5 | .5 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | 6.5 | 12 |
| **24** | .5 | | 0 | 0 | .5 | .5 | 0 | .5 | .5 | 0 | 0 | .5 | 0 | 0 | 0 | 0 | 0 | 0 | .5 | .5 | .5 | .5 | .5 | .5 | .5 | 6.5 | 12 |
| **25** | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 16 |
| **Dependence** | 9.7 | 5.3 | 5.3 | 5.3 | 10.4 | 8.5 | 0.2 | 11.6 | 9.9 | 0.3 | 4.5 | 13.6 | 5.7 | 0.2 | 5.4 | 5.4 | 0 | 4.5 | 13.6 | 11.6 | 13.6 | 10 | 8.5 | 8.5 | 13.6 | | |
| **Rankin** | 6 | 10 | 10 | 10 | 3 | 7 | 13 | 2 | 5 | 12 | 11 | 1 | 8 | 13 | 9 | 9 | 14 | 11 | 1 | 2 | 1 | 4 | 7 | 7 | 1 | | |

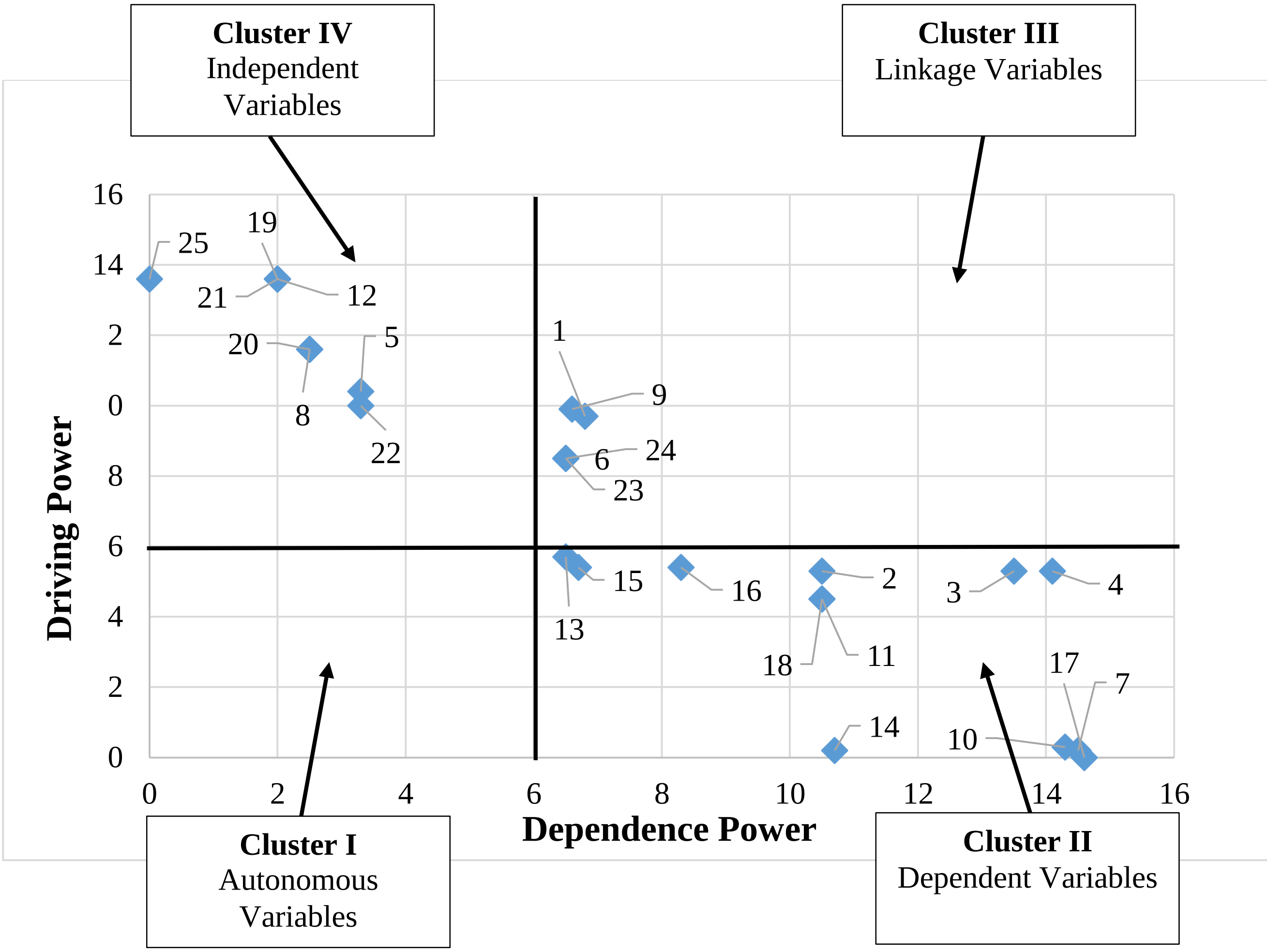


**Figure 6.4:** Analysis of Driving and Dependence Power of Barriers of HCWM

## 6.6 DISCUSSION AND MANAGERIAL IMPLICATIONS

The model developed in Figure 6.2, has kept the barrier ‘lack of enforcement of BMW handling rules’ at the base of the hierarchy, which is representing that it is the most significant and fundamental barrier for implementing the HCWM practices in India. As the HCFs mainly focus on delivering the better healthcare services and waste generated while delivering the services is not their key focus area. So, HCFs don’t give much importance to infectious waste generated. Hence, the regulatory authorities should enforce every HCF to ensure the proper implementation of ‘Biomedical Waste Handling Rules, 1998’ in order to provide the healthy environment and safe hospital premises to the patients. ‘Ineffective HCWM practices’ has come out as the outcome variable and has been placed at the top of the hierarchy with highest dependence power.

Model has shown that ‘lack of commitment by hospital administration’ and ‘lack of doctors’ commitment’ are leading less budget allocation in the waste handling activities, which is leading to the ‘poor infrastructure’, ‘low motivation to waste handling workers’, ‘less appreciation’ and ‘no knowledge & training aids to the employees’. The waste handling workers should be trained and they must be aware about the harm that may be caused by the hazardous waste. ‘Lack of convenience’ will lead to poor waste collection and segregation practices at HCFs and will scale-up extra infectious waste and will also rise up the cost of treating the HCW. Non-sustainable HCWM practices result into ‘lack of benchmark’ in India, which further leads to inconsistent and inadequate performance measures to evaluate the HCFs and CBWTFs. No standard performance measures will lead to poor selection of outsourcing partner (CBWTF) and poor control of the process. Poor selection of waste treatment firm will result into infrequent transportation of HCW from the HCF and low collaboration and integration with the HCF, which will lead to non-aligned operational goals among HCF and CBWTF. ‘Lack of holistic mechanism to deal with biomedical waste and ‘obsolete treatment technologies’ will lead to ‘ineffective HCWM practices’.

Figure 6.3 divides the whole model into three managerial aspects: operational, tactical and strategic levels. This classification will help to define the key focus areas for low level, middle level and top level management. Hence, hospital administration can easily formulate the strategies by targeting the elements placed on the top of the hierarchy and can execute through middle and low level management.

Further, Figure 6.4 divide all the barriers into four groups depending upon the driving power dependence power obtained from fuzzy-MICMAC analysis. This clustering can better insights to hospital administration and Pollution Control Boards, so that they can proactively deal with these barriers. Some of the important managerial implications derived from the Fuzzy-MICMAC analysis are discussed below:

### 6.6.1 Cluster I: Weak Driving and Dependence Power

This cluster includes all the excluded barriers and known as autonomous group. The variables in this particular group are having very low driving power and dependence power and they do not have much influence on the system. In the present study, none of the barriers appeared in the first quadrant and hence, all the 25 barriers are significant, to be considered for making the strategic decisions.

### 6.6.2 Cluster II: Weak Driving Power and Strong Dependence Power

The barriers in the second quadrant are the outcome variables, which are having the strong dependence power and less influent. In the present study the barriers: 'LCM (5)', 'LC&I (8)', 'OTT (12)', 'LHM (19)', 'ILT (20)', 'NAOG (21)', 'PSOF (22)' and 'IHCWM (25)' have come out with high dependence power and weak driving power and have been placed at the top levels (Level 1,2,3,4) in the ISM model. This indicates that all other barriers are coming together to add to these barriers in order to hinder the implementation of HCWM practices. The hospital administration should critically investigate the dependence power of these barriers on other related barriers while implementing HCWM practices. While making the overall strategy for HCW disposal, these barriers should have lower priorities in comparison to the barriers on which these are depending. But, in the latter stage these barriers should be addressed more carefully in order to improve the efficiency and effectiveness of the HCWM system.

### 6.6.3 Cluster III: Strong Driving and Dependence Power

The barriers in the third quadrant are also known as relay barriers with high driving and dependence power. This cluster includes the linkage variables. These variables are very influent and at the same time influenced by others in the system. In the present study 5 barriers fell in this cluster as shown in Figure 6.4: 'LBI (1)', 'NSP (6)', 'ICIAPM (9)', 'SIW (23)' and 'EC (24)'. These linkage barriers are coming in the middle levels of the model (Level 5, 6). The presence of 5 barriers in this cluster represent that these barriers are the most unstable variables among all and hospital managers should handle with the utmost care while implementing the HCWM practices.

### 6.6.4 Cluster IV: Strong Driving Power and Weak Dependence Power

These barriers are known as the determinant variables and are influent with little dependence power. These independent barriers drive the whole system and are considered as the key elements. The hospital administration should focus primarily on these barriers on the first stage and these should be on the top priority while planning the strategy for implementing HCWM practices. In the current study, 12 barriers fell in cluster 4: 'LM (2)', 'LKT (3)', 'LI (4)', 'LCHA (7)', 'LOB (10)', 'LA (11)', 'PS (13)', 'LDC (14)', 'LPS (15)', 'LC (16)', 'LEBWHR (17)' and 'LOM (18)'.

Hence, the ISM model proposed in this chapter could act as a guiding mechanism through which the hospital administration and regulatory authorities would be able to identify and target the barriers of implementing the HCWM practices in India. Policies and guidelines can be framed keeping in mind the role of each element in the hierarchy.

## 6.7 CHAPTER SUMMARY

The HCFs and Pollution Control Boards now have realized the importance of HCWM practices due to the infectious nature of the MW. The objective of developing ISM model was to analyze the hierarchy of barriers, which are obstructing the effective and efficient implementation of HCWM practices in India. These barriers got importance in order to provide the healthy and safe environment to patients, doctors, staff and public from the infectious MW. These barriers hindering the implementation of HCWM practices, pose considerable challenges for both hospital administration and Government policy makers on BMWM.

This chapter focused on analyzing the current HCWM practices in India and identified 25 barriers from the literature, survey of HCFs, CBWTFs and brainstorming sessions, which hinder the implementation of HCWM system. ISM modeling technique helps to place the barriers at various levels in the developed model (Figure 6.2), depending upon their interrelationships and direction of relationship. The study also defined the barriers at various levels of management and hospital administration concern. Barriers related to operational, tactical and strategic issues have been classified. Fuzzy-MICMAC analysis defined the strength of the relationship among various elements more precisely. It gives the chance to the decision makers to define the relationship on 0-1 scale, rather than in terms of binary numbers only. MICMAC analysis helps to prioritize the barriers depending upon their importance in the system and suggests the hospital managers to have more strategic orientation on the barriers lying in the fourth quadrant. The next chapter provides the empirical evidences on some critical issues related to HCWM system in India.

# CHAPTER 7

# EMPIRICAL EVIDENCES OF OBJECTIVES, ENABLERS AND BARRIERS OF HEALTHCARE WASTE MANAGEMENT SYSTEM

## 7.1 INTRODUCTION

Healthcare Waste Management (HCWM) is now the key focus in the national health polices in many of the countries. In the developing countries, the HCWM has been neglected area in the history and still it is mixed with the general waste in most of the HCFs and disposed of in the regular fashion, which may cause a serious harm to waste handling workers, public and environment (Abor and Bouwer, 2008). As per Moreira and Günther (2012), HCWM involves all the activities performed to manage Healthcare Waste (HCW) and analyzing the characteristics and risks associated with each type of waste generated. As per WHO (2005), a robust HCWM system based on legislation and planning, dedicated operational resources, trained staff and hospital waste management experts' commitment should be developed. As HCWM is the evolving field, hence proper plans and policies should be laid down for controlling the waste management process.

Various empirical studies have been conducted to analyze the HCWM practices at different hospitals (Askarian et al., 2004; Patil and Pokhrel, 2005; DaSilva et al., 2005; Taru and Kuvarega, 2005), but literature lacks the studies related to assessing the perception of the employees and organizations involved in the generation and handling of the MW. In this chapter, survey has been conducted to collect the opinion from the practitioners in the field on the various issues related to implementation of HCWM system in India. The employees from the HCFs, Common Biomedical Waste Treatment Facilities (CBWTFs) and Government Regulatory Authorities were targeted to get the opinion about the importance of implementing the HCWM system, the objectives of implementing the HCWM system and the enablers and barriers of implementing the HCWM system.

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*Part of this chapter is under review in Waste Management & Research as:*

*Thakur, V. and Ramesh, A. (2016), "Empirical investigation into the importance, objectives, enablers and barriers of HCWM system".*

## 7.2 FORMULATION OF HYPOTHESES

### 7.2.1 Importance of Implementing HCWM System

Implementing proper HCWM system is important for the society, due to its infectious nature and harm caused to the public and environment (Muduli and Barve, 2012). The enforcement of BMW (Handling & Management) Rules, 1998 by Indian Government and increased level of awareness among the public about the infectious nature of HCW, the HCFs are forced to manage their waste more effectively. But, still the HCFs mainly focus on providing the better healthcare services at lesser cost in order to compete with the various competitors. Hence, waste treatment facilities are not able to use the latest disposal technology due to huge investment and less budget. Therefore, it is crucial to analyze the perception of the various organizations involved in the process (like: HCFs, CBWTFs and Pollution Control Boards), about the importance of implementing HCWM system with respect to their core business. This led to the formulation of hypothesis H1 as following:

**H1:** *There is significant difference in perception regarding importance of implementing HCWM system with respect to the core business among the five groups under consideration.*

### 7.2.2 Objectives of Implementing HCWM System

Hazardous MW is threatening the society and environment and it needs the special treatment before the final disposal (Hassan et al., 2008). This is coming as huge challenge to the developing nations, due to the exercise of inappropriate and poor handling of HCW and disposal methods, which are leading to environmental and human health hazards (Hossain et al., 2011). Although, the policies and guidelines have been provided by WHO and Central Pollution Control Board (CPCB), but still the efforts have been unsuccessful in most of the nations (Muduli and Barve, 2012). In countries like India, where there is huge population burden and also the resources are limited (Pathak, 2008), the HCWM system is full of challenges and threats. Hence, there is rising need of implementing better HCWM system and define clearly and specifically the major objectives of implementing HCWM system. With this reference, the second hypothesis (H2) has been framed.

**H2:** *There is significant difference in the perception regarding the principles objectives in implementing HCWM system among five groups of respondents.*

### 7.2.3 Enablers for HCWM System

In order to build up a strong HCWM system, it is important to identify and focus on the key issues, which are the main drivers of the whole system. The various issues are like: training programs (Oweis et al., 2005; Bendjoudi et al., 2009; Farzadkia et al., 2009; El-Salam, 2010), waste minimization through reuse, recycling and reduction of waste at source (Jang et al., 2006), organizational structure and infrastructure (Tudor et al., 2005, Ojha, 2014b), written policies and protocols (Soliman and Ahmed, 2007), educations of the waste handling workers (Gupta and Boojh, 2006), coordination among different departments (Bendjoudi et al., 2009). The enablers for implementing the effective and efficient system may vary from nation to nation and from one region to another. Hence, the present hypothesis focuses on finding the key enablers for implementing HCWM system in India.

**H3:** *There is significant difference in the perception of level of importance in addressing the issues for the effective implementation of HCWM practices.*

### 7.2.4 Barriers of HCWM System

Although there are well-defined policies and guidelines for handling the infectious waste, but still the HCWM system is full of inadequacies, which are acting as the barriers for implementing the HCWM system, like: the absence of use of coded and colored bags, no proper tracking techniques (Oweis et al., 2005), ineffective segregation at source (Tsakona et al., 2007; Stanković et al., 2008; Farzadkia et al., 2009), inappropriate collection methods, unsafe storage of waste, insufficient financial and human resources for proper management, and poor control on waste treatment and disposal process (Jang et al., 2006; Alagoz and Kocasoy, 2008a; El-Salam, 2010). Birpinar et al. (2009) in their case study done in Istanbul, found that 25% of the hospitals used inappropriate containers for waste collection and 77% of the HCFs provided inadequate equipment to the waste handling team. Hence, the last hypothesis finds the perception of the respondents about the barriers of implementing HCWM system in India.

**H4:** *There is significant difference in the perception of the respondents, regarding the barriers of HCWM system in India.*

## 7.3 METHODOLOGY

Here, the perception about the implementation of HCWM system has been studied, both by quantitative as well as qualitative approach. The data has been collected through structured interview and questionnaire survey. The questionnaire was designed with the help of literature review and field survey and in the end, it was finalized in the brain storming sessions held at U-COST Dehradun and Indian Institute of Technology Roorkee, with the experts and Government officials in the related field. The final questionnaire has been shown in Appendix IX.

### 7.3.1 Validity of the Survey

The survey is considered as valid if it measures the concept, for what it has been designed to measure. The questionnaire has been checked for content validity as well as face validity (Carmines and Zeller, 1991). The content ensures that the designed instrument covers all the aspects of the variables being measured (Nunally and Bernstein, 1978). The content validity was tested during pilot survey as per Forza (2002) and some questions have been reframed to make it more specific. The face validity refers to that question should measure what it was intended to measure. So, in the brainstorming session several questions were asked from the experts to check the face validity like: i) whether question was designed properly? ii) is it the right way to collect the information from the respondents? iii) does it collect the reliable information?

### 7.3.2 Reliability of the Survey

The survey or the questionnaire is said to be reliable if it yields the same results again and again when it is repeated on the sample. However, internal consistency test is the most important measure to check the reliability, which refers to the extent to which the tests analyses the same characteristics. Cronbach's alpha ($\alpha$) is the most common measure to check the internal consistency. The Cronbach's coefficient (Cronbach, 1951) represents the percentage of variance, the observed scale can explain in the hypothetical true scale, which composed of all possible items in the universe. As per Nunally and Bernstein (1978), '$\alpha$' should be at least 0.5 for the exploratory work, but mostly it is by convention that if $\alpha$ is higher than 0.70, then the scale is considered to be an adequate scale. The '$\alpha$' value for Question 2.2 is 0.890 for 9 items and 126 cases. Similarly, '$\alpha$' for Question 2.3 is 0.908 for 9 items and 126 cases and for Question 2.4 is 0.922 for 10 items and 126 cases. Since, all the reliability values are greater than 0.7, which testify that the items are retained on an adequate scale. Hence, all the scales are internally consistent.

### 7.3.3 Sample Design

Initially, the questionnaire was sent to 300 respondents, from hospitals, CBWTFs and PCBs. But, after so many reminders, we could manage to get only 23 questionnaires filled. Nobody wanted to talk on such a sensitive and critical issue. Then the data was collected personally, by conducting face-to-face interviews by adopting convenience sampling. Then, the survey could manage another 103 questionnaires. So in the end, 126 questionnaires were analyzed to get the perception of the respondents.

## 7.4 DATA ANALYSIS

The collected data has been analyzed in two ways: i) preliminary analysis ii) statistical analysis. Statistical test have been performed using Statistical Package for Social Sciences (SPSS) in order to test the stated hypothesis for all the groups. The opinion collected from different groups have been compared over the various issues related to HCWM. The total sample has been divided into five groups: 'Doctors' (G1), 'Professors and Doctors' (G2), 'Hospital and CBWTF Managers' (G3), 'MD Students and Practitioners' (G4) and 'Government Regulatory Authority' (G5). Table 7.1 shows the grouping of the respondents. Table 7.2 represents the distribution of the respondents as per the experience.

**Table 7.1:** Frequency Distribution of Respondents as per Groups

| Group No. | Group category | No. of samples |
|---|---|---|
| G1 | Doctors | 51 |
| G2 | Professors & Doctors | 19 |
| G3 | Hospital & CBWTF Managers | 15 |
| G4 | MD Students & Practitioners | 23 |
| G5 | Government Regulatory Authority | 18 |

**Table 7.2:** Respondents Distribution as per Experience

| Experience (Years) | Doctors | Professors & Doctors | Hospital & CBWTF Managers | MD Students & Practitioners | Government Regulatory Authority |
|---|---|---|---|---|---|
| 2-5 | 0 | 0 | 0 | 23 | 0 |
| 5-10 | 11 | 2 | 3 | 0 | 4 |
| 10-15 | 19 | 9 | 4 | 0 | 9 |
| 15-20 | 8 | 6 | 6 | 0 | 3 |
| >20 | 13 | 2 | 2 | 0 | 2 |

### 7.4.1 Preliminary Analysis

In the preliminary analysis section, the responses of the different groups have been categorized and represented in terms of aggregate score. The responses have been analyzed statically in the next section.

#### 7.4.1.1 Analysis of Hypothesis 1 (question 2.1)

From Question 2.1, it was possible to ascertain the importance given to HCWM system in comparison to core business by each respondents group. The data collected from the various respondents is summarized in Table 7.3. From Table 7.3, the weighted average was obtained for importance of HCWM within each group.

**Table 7.3:** Summary of Responses to Question 2.1

| Group | Number of respondents in each group assigning degree of importance to HCWM in their business using 1-5 scale | | | | | Total |
|---|---|---|---|---|---|---|
| | Not important (1) | Least important (2) | Important (3) | Highly important (4) | Critical (5) | |
| G1 | 0 | 13 | 27 | 9 | 2 | 51 |
| G2 | 0 | 4 | 7 | 5 | 3 | 19 |
| G3 | 0 | 0 | 2 | 4 | 9 | 15 |
| G4 | 0 | 9 | 11 | 3 | 0 | 23 |
| G5 | 0 | 0 | 3 | 4 | 11 | 18 |

Table 7.4 represents the degree of importance given by each group to HCWM system. It is clear from the Table 7.4 that G5 ('Government Regulatory Authority') has assigned the highest weightage (4.444) to HCWM, followed by G3 ('Hospital & CBWTF Managers'), (4.467). The G4 ('MD Students & Practitioners') has given the least importance to HCWM system with respect to their profession. Groups G1 ('Doctors'), (3.0) and G2 ('Professors and Doctors'), (3.368) have also given little importance to HCWM system in comparison to their core business. To test the significance of the difference, one way ANOVA has been conducted in statistical analysis of this chapter.

**Table 7.4:** Group-wise Weighted Average Importance Score of HCWM System

| | Profile-wise groups | | | | |
|---|---|---|---|---|---|
| | G1 | G2 | G3 | G4 | G5 |
| Degree of importance assigned (Weighted average score) | 3 | 3.368 | 4.467 | 2.74 | 4.444 |

**7.4.1.2 Analysis of Hypothesis 2 (question 2.2)**

To test hypothesis 2, the respondents were asked to give their weightage for Question 2.2 on the scale 1 to 5, where 1 corresponds to 'strongly disagree' and 5 to 'strongly agree'. The summary of responses collected from various groups is presented in Table 7.5. From Table 7.5, the weighted average score was calculated for each objective within each group. The average score for each objective is shown in Table 7.6 and depicted in Figure 7.1. For a group, the objective which is having the highest value in Table 7.6 is considered to be the most important. For example, for group (G1), objective 2 (To protect people in hospital from the infectious waste) is the most important with maximum value (4.784) and objective 4 (To reduce the infectious waste) is least important with minimum value (3.059). This implies that the doctors (G1) believe that the main objective to implement the HCWM system is to protect the people in the hospital premises from the infectious waste. To reduce the waste and recycle it, is not their area of concern. Similarly, G2 has given highest importance to objective 1 (Better hospital premises) (4.474) and 2 (To protect people in hospital from the infectious waste) (4.474) and objective 4 (To reduce the infectious waste) (2.368) has been rated lowest. G3 has given the objective 4 (To reduce the infectious waste) (4.733) highest priority and lowest to objective 7 (Provide convenience to waste handling workers) (3.0). G4 has rated objective 2 (To protect people in hospital from the infectious waste) (4.696) highest and objective 4 (To reduce the infectious waste) (2.739) with least score. G5 has given highest weightage to objective 9 (Training & skills enhancement) (4.833) and lowest to objective 5 (Reduce cost of disposing HCW) (2.611).

Subsequently, the objectives were ranked group-wise depending upon their score in Table 7.6 and final ranking of each objective is given in Table 7.7. From Table 7.7, it is clear that different groups have ranked the objectives of implementing HCWM system differently. From the overall responses, it can be concluded that, respondents have given the highest importance to objectives: 2 (Protect the people in hospitals surroundings), 9 (Training & skills enhancement), 1 (Better hospital premises), 6 (Sustainable waste handling practices), 3 (Proper segregation) and 8 (Holistic mechanism to deal with HCW). The objectives: 5 (Reduce cost of disposing HCW), 4 (Reduce the waste quantity) and 7 (Provide convenience to waste handling workers) are rated less comparatively.

**Table 7.5:** Summary of Responses to Question 2.2

| Groups | 5 Point scale | Number of respondents in each group giving their opinions on each objective by using 1-5 scale | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Objectives of implementing HCWM system | | | | | | | | |
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| G1 | 1 | 0 | 0 | 0 | 6 | 2 | 2 | 3 | 4 | 0 |
| | 2 | 0 | 0 | 1 | 13 | 10 | 3 | 17 | 7 | 1 |
| | 3 | 6 | 1 | 11 | 9 | 2 | 3 | 6 | 4 | 2 |
| | 4 | 13 | 9 | 14 | 18 | 18 | 25 | 21 | 18 | 30 |
| | 5 | 32 | 41 | 25 | 5 | 19 | 18 | 4 | 18 | 18 |
| | Sub-total | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 |
| G2 | 1 | 0 | 0 | 0 | 7 | 1 | 0 | 0 | 0 | 0 |
| | 2 | 1 | 0 | 1 | 6 | 0 | 0 | 3 | 1 | 2 |
| | 3 | 0 | 0 | 3 | 0 | 2 | 1 | 2 | 0 | 0 |
| | 4 | 7 | 10 | 10 | 4 | 6 | 15 | 11 | 9 | 8 |
| | 5 | 11 | 9 | 5 | 2 | 10 | 3 | 3 | 9 | 9 |
| | Sub-total | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| G3 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 2 | 0 | 0 |
| | 2 | 5 | 4 | 1 | 0 | 1 | 1 | 5 | 0 | 1 |
| | 3 | 1 | 5 | 0 | 0 | 2 | 0 | 0 | 2 | 0 |
| | 4 | 6 | 4 | 4 | 4 | 7 | 5 | 7 | 5 | 8 |
| | 5 | 2 | 2 | 10 | 11 | 5 | 9 | 1 | 8 | 6 |
| | Sub-total | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| G4 | 1 | 0 | 0 | 0 | 3 | 1 | 0 | 3 | 1 | 0 |
| | 2 | 2 | 0 | 1 | 10 | 4 | 2 | 8 | 3 | 2 |
| | 3 | 0 | 1 | 3 | 2 | 1 | 0 | 1 | 0 | 1 |
| | 4 | 8 | 5 | 12 | 6 | 8 | 13 | 8 | 9 | 9 |
| | 5 | 13 | 17 | 7 | 2 | 9 | 8 | 3 | 10 | 11 |
| | Sub-total | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 |
| G5 | 1 | 0 | 0 | 0 | 1 | 2 | 0 | 1 | 0 | 0 |
| | 2 | 1 | 3 | 1 | 2 | 10 | 0 | 4 | 2 | 0 |
| | 3 | 1 | 2 | 4 | 0 | 0 | 1 | 3 | 0 | 0 |
| | 4 | 7 | 6 | 8 | 12 | 5 | 7 | 8 | 4 | 3 |
| | 5 | 9 | 7 | 5 | 3 | 1 | 10 | 2 | 12 | 15 |
| | Sub-total | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |

**Table 7.6:** Group-wise Weighted Average Importance Score given to Each Objective

| | Objectives of implementing HCWM system | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| G1 | 4.510 | 4.784 | 4.235 | 3.059 | 3.824 | 4.059 | 3.118 | 3.765 | 4.275 |
| G2 | 4.474 | 4.474 | 4.000 | 2.368 | 4.263 | 4.105 | 3.737 | 4.368 | 4.263 |
| G3 | 3.200 | 3.267 | 4.533 | 4.733 | 4.067 | 4.467 | 3.000 | 4.400 | 4.267 |
| G4 | 4.391 | 4.696 | 4.087 | 2.739 | 3.870 | 4.174 | 3.000 | 4.043 | 4.261 |
| G5 | 4.333 | 3.944 | 3.944 | 3.778 | 2.611 | 4.500 | 3.333 | 4.444 | 4.833 |

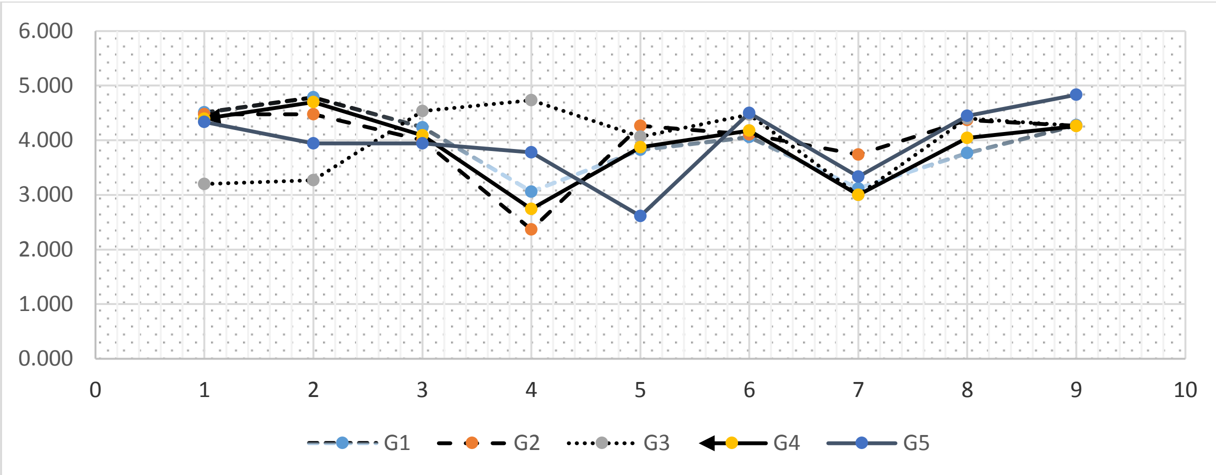


**Figure 7.1:** Weighted Average Scores for Objectives within Each Group

**Table 7.7:** Group-wise Ranking of all the Objectives

| Objectives | G1 | G2 | G3 | G4 | G5 | Total | Ranking |
|---|---|---|---|---|---|---|---|
| **1** | 2 | 1 | 8 | 2 | 4 | 17 | 2 |
| **2** | 1 | 1 | 7 | 1 | 5 | 15 | 1 |
| **3** | 4 | 5 | 2 | 5 | 5 | 21 | 4 |
| **4** | 9 | 7 | 1 | 9 | 6 | 32 | 7 |
| **5** | 6 | 3 | 6 | 7 | 8 | 30 | 6 |
| **6** | 5 | 4 | 3 | 4 | 2 | 18 | 3 |
| **7** | 8 | 6 | 9 | 8 | 7 | 38 | 8 |
| **8** | 7 | 2 | 4 | 6 | 3 | 22 | 5 |
| **9** | 3 | 3 | 5 | 3 | 1 | 15 | 1 |

#### 7.4.1.3 Analysis of Hypothesis 3 (question 2.3)

To test hypothesis 3, the respondents were asked to give their weightage for various enablers of implementing HCWM system (Question 2.3) on the scale 1 to 5, where 1 corresponds to ‘not important’ and 5 to ‘extremely important’. The summary of responses collected from various groups is presented in Table 7.8. From Table 7.8, the weighted average score was calculated for each enabler within each group. The scores are shown in Table 7.9 and depicted in Figure 7.2. From Table 7.9, it is clear that G1 has given highest importance to issue 7 (Latest technology adoption) (4.255) and 8 (Segregation and collection of HCW) (4.255) and least importance to enabler 3 (Infrastructure and convenience) (2.235) in implementing

HCWM system. G2 has rated enabler 8 (Segregation and collection of HCW) (4.526) highest and enabler 6 (Budget allocation) (2.158) lowest. G3 has given highest score to enabler 8 (Segregation and collection of HCW) (4.867) and rated enabler 9 least important (Frequent transportation of HCW) (2.733). G4 assigned highest weightage to enabler 7 (Latest technology adoption) (4.522) and comparatively less weightage to enabler 6 (Budget allocation) (2.0). G5 rated enabler 8 (Segregation and collection of HCW) (4.556) most important and enabler 9 (Frequent transportation of HCW) (2.833) less important.

Subsequently, the enablers were ranked group-wise depending upon their average weights and final ranking of each enabler is given in Table 7.10. From Table 7.10, it is clear that different groups have ranked the enablers of implementing HCWM system differently. From the overall responses, it can be concluded that, respondents have given the highest importance to enablers: 8 (Segregation and collection of HCW), 7 (Latest technology adoption), 1 (Knowledge and training aids), 2 (Appreciation and motivation) and 5 (Performance matrices). The enablers: 3 (Infrastructure and convenience), 6 (Budget allocation), 4 (Collaboration and integration among HCF and CBWTF) and 9 (Frequent transportation of HCW) have been rated less important comparatively.

**Table 7.8:** Summary of Responses to Question 2.3

| Groups | 5 Point scale | Number of respondents in each group giving their opinions on issues for effective implementation of HCWM system by using 1-5 scale | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | Enablers of implementing HCWM system | | | | | | | | |
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| G1 | 1 | 1 | 0 | 13 | 1 | 1 | 16 | 0 | 0 | 5 |
| | 2 | 0 | 2 | 21 | 3 | 7 | 11 | 5 | 4 | 28 |
| | 3 | 15 | 31 | 11 | 31 | 23 | 21 | 8 | 7 | 15 |
| | 4 | 24 | 11 | 4 | 11 | 9 | 0 | 7 | 12 | 2 |
| | 5 | 11 | 7 | 2 | 5 | 11 | 3 | 31 | 28 | 1 |
| | Sub-total | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 | 51 |
| G2 | 1 | 0 | 0 | 2 | 0 | 0 | 5 | 0 | 0 | 0 |
| | 2 | 1 | 0 | 5 | 3 | 1 | 9 | 1 | 0 | 12 |
| | 3 | 2 | 8 | 11 | 9 | 7 | 3 | 3 | 1 | 7 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | 4 | 9 | 7 | 1 | 6 | 10 | 1 | 6 | 7 | 0 |
| | 5 | 7 | 4 | 0 | 1 | 1 | 1 | 9 | 11 | 0 |
| | Sub-total | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 | 19 |
| G3 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 1 | 0 | 0 | 3 | 4 | 0 | 0 | 0 | 6 |
| | 3 | 1 | 7 | 2 | 10 | 5 | 2 | 0 | 0 | 8 |
| | 4 | 5 | 5 | 7 | 0 | 3 | 6 | 4 | 2 | 0 |
| | 5 | 8 | 3 | 6 | 2 | 3 | 7 | 11 | 13 | 1 |
| | Sub-total | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 | 15 |
| G4 | 1 | 0 | 2 | 4 | 0 | 0 | 7 | 0 | 2 | 0 |
| | 2 | 2 | 0 | 7 | 5 | 5 | 12 | 0 | 0 | 7 |
| | 3 | 0 | 11 | 10 | 17 | 9 | 2 | 1 | 2 | 13 |
| | 4 | 9 | 8 | 2 | 0 | 6 | 1 | 9 | 6 | 0 |
| | 5 | 12 | 2 | 0 | 1 | 3 | 1 | 13 | 13 | 3 |
| | Sub-total | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 | 23 |
| G5 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | 2 | 0 | 4 | 0 | 2 | 0 | 0 | 0 | 1 | 8 |
| | 3 | 0 | 7 | 2 | 11 | 7 | 2 | 3 | 0 | 7 |
| | 4 | 11 | 5 | 5 | 2 | 5 | 5 | 8 | 5 | 1 |
| | 5 | 7 | 2 | 11 | 3 | 6 | 11 | 7 | 12 | 2 |
| | Sub-total | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 | 18 |

**Table 7.9:** Group-wise Weighted Average Importance Score Given to Issues for Effective Implementation of HCWM System

| | Enablers of implementing HCWM system | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** |
| G1 | 3.863 | 3.451 | 2.235 | 3.314 | 3.431 | 2.275 | 4.255 | 4.255 | 2.333 |
| G2 | 4.158 | 3.789 | 2.579 | 3.263 | 3.579 | 2.158 | 4.211 | 4.526 | 2.368 |
| G3 | 4.333 | 3.733 | 4.267 | 3.067 | 3.333 | 4.333 | 4.733 | 4.867 | 2.733 |
| G4 | 4.348 | 3.348 | 2.435 | 2.870 | 3.304 | 2.000 | 4.522 | 4.217 | 2.957 |
| G5 | 4.389 | 3.278 | 4.500 | 3.333 | 3.944 | 4.500 | 4.222 | 4.556 | 2.833 |

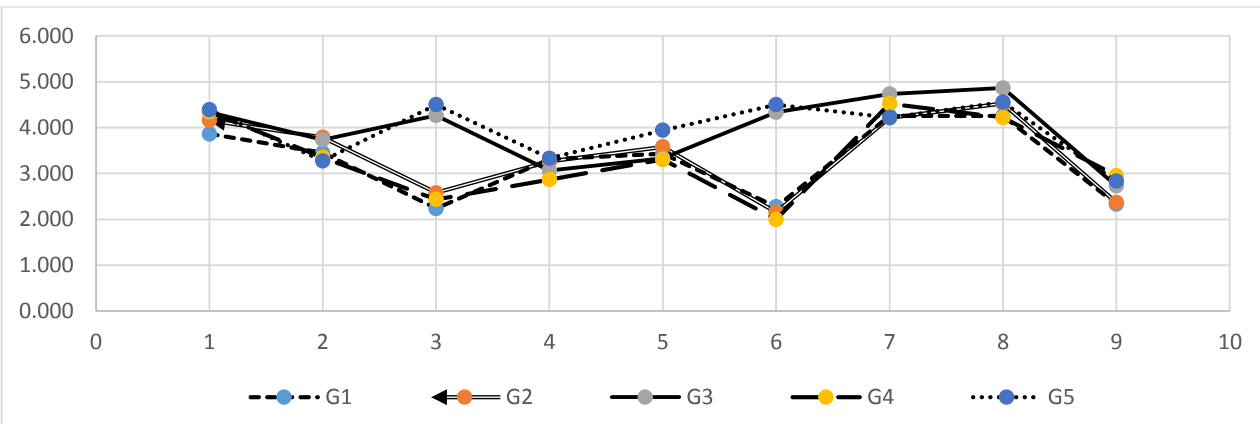


**Figure 7.2:** Weighted Average Scores for Enablers within Each Group

**Table 7.10:** Group-wise Ranking of all the Enablers

| **Enablers** | **G1** | **G2** | **G3** | **G4** | **G5** | **Total** | **Ranking** |
|---|---|---|---|---|---|---|---|
| **1** | 2 | 3 | 3 | 2 | 3 | 13 | 3 |
| **2** | 3 | 4 | 5 | 4 | 7 | 23 | 4 |
| **3** | 8 | 7 | 4 | 8 | 2 | 29 | 6 |
| **4** | 5 | 6 | 7 | 7 | 6 | 31 | 8 |
| **5** | 4 | 5 | 6 | 5 | 5 | 25 | 5 |
| **6** | 7 | 9 | 3 | 9 | 2 | 30 | 7 |
| **7** | 1 | 2 | 2 | 1 | 4 | 10 | 2 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **8** | 1 | 1 | 1 | 3 | 1 | 7 | 1 |
| **9** | 6 | 8 | 8 | 6 | 8 | 36 | 9 |

#### 7.4.1.4 Analysis of Hypothesis 4 (question 2.4)

To test hypothesis 4, the respondents were asked to give their weightage for various barriers of implementing HCWM system (Question 2.4) on the scale 1 to 5, where 1 corresponds to ‘not important’ and 5 to ‘strongly important’. The data collected from various groups is presented in Table 7.11 in summary form. From Table 7.11, the weighted average score was calculated for each barrier within each group. The scores are shown in Table 7.12 and depicted in Figure 7.3. From Table 7.12, it is clear that G1 has given the highest importance to barrier 3 (Budget problems) (4.392) and least importance to barrier 1 (Lack of administration and doctors commitment) (1.725) in obstructing the implementation of effective HCWM system. Group G2 rated barrier 9 (No frequent transportation of waste) (4.316) very important element to tackle and barrier 4 (Lack of perception of self-harm) (1.684) comparatively less important. Group G3 has given highest weightage to barrier 1 (Lack of administration and doctors commitment) (4.80) and lowest weightage to barrier 6 (Lack of benchmark in India) (1.913). Group G4 considered that barrier 1 (Lack of administration and doctors commitment) (4.87) as strongest obstacle and barrier 4 (Lack of perception of self-harm) (1.696) as less important comparatively. Group 5 rated barrier 1 (Lack of administration and doctors commitment) (4.611) as the most important and barrier 6 (Lack of benchmark in India) (2.333) least important in implementing the HCWM system.

Subsequently, the barriers were ranked group-wise depending upon their average weights in Table 7.12 and final ranking of each barrier is given in Table 7.13. From Table 7.13, it is clear that different groups have ranked the barriers of implementing HCWM system differently. From the overall responses, it can be concluded that, respondents have given the highest importance to barriers: 3 (Budget problems), 2 (Lack of infrastructure and convenience), 7 (Lack of awareness), 9 (No frequent transportation of waste) and 5 (Lack of monitoring). The barriers: 1 (Lack of administration and doctors commitment), 8 (No maintenance staff), 10 (Non-aligned operational objectives among HCF and CBWTF), 4 (Lack of perception of self-harm) and 6 (Lack of benchmark in India) are rated less important comparatively.

**Table 7.11:** Summary of Responses to Question 2.4

| Groups | 5 Point scale | Number of respondents in each group giving their opinions on barriers for effective implementation of HCWM system by using 1-5 scale | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Barriers for implementing HCWM system | | | | | | | | | |
| | | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| G1 | 1 | 27 | 0 | 2 | 11 | 4 | 14 | 2 | 3 | 2 | 0 |
| | 2 | 15 | 2 | 1 | 26 | 2 | 23 | 7 | 3 | 7 | 13 |
| | 3 | 5 | 5 | 3 | 9 | 9 | 12 | 2 | 4 | 3 | 2 |
| | 4 | 4 | 26 | 14 | 2 | 29 | 2 | 12 | 29 | 18 | 22 |
| | 5 | 0 | 18 | 31 | 3 | 7 | 0 | 28 | 12 | 21 | 14 |
| | Sub-total | **51** | **51** | **51** | **51** | **51** | **51** | **51** | **51** | **51** | **51** |
| G2 | 1 | 7 | 0 | 0 | 9 | 0 | 7 | 2 | 0 | 0 | 1 |
| | 2 | 9 | 1 | 3 | 7 | 3 | 9 | 3 | 5 | 3 | 2 |
| | 3 | 3 | 0 | 1 | 3 | 0 | 1 | 1 | 0 | 0 | 3 |
| | 4 | 0 | 11 | 4 | 0 | 7 | 2 | 5 | 10 | 4 | 13 |
| | 5 | 0 | 7 | 11 | 0 | 9 | 0 | 8 | 4 | 12 | 0 |
| | Sub-total | **19** | **19** | **19** | **19** | **19** | **19** | **19** | **19** | **19** | **19** |
| G3 | 1 | 0 | 0 | 0 | 3 | 0 | 6 | 0 | 2 | 1 | 1 |
| | 2 | 0 | 0 | 2 | 7 | 2 | 9 | 2 | 4 | 3 | 0 |
| | 3 | 1 | 0 | 0 | 2 | 1 | 0 | 1 | 0 | 1 | 2 |
| | 4 | 1 | 4 | 5 | 2 | 10 | 0 | 5 | 5 | 6 | 11 |
| | 5 | 13 | 11 | 8 | 1 | 2 | 0 | 7 | 4 | 4 | 1 |
| | Sub-total | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** | **15** |
| G4 | 1 | 5 | 0 | 0 | 11 | 0 | 8 | 1 | 2 | 1 | 2 |
| | 2 | 9 | 1 | 0 | 8 | 3 | 11 | 2 | 3 | 3 | 3 |
| | 3 | 6 | 0 | 1 | 4 | 0 | 2 | 1 | 0 | 1 | 3 |
| | 4 | 2 | 13 | 1 | 0 | 18 | 2 | 7 | 8 | 4 | 11 |

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 5 | 1 | 9 | 21 | 0 | 2 | 0 | 12 | 10 | 14 | 4 |
| | Sub-total | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **23** | **23** |
| G5 | 1 | 0 | 0 | 0 | 1 | 1 | 3 | 0 | 2 | 0 | 0 |
| | 2 | 0 | 2 | 1 | 2 | 1 | 10 | 2 | 0 | 2 | 3 |
| | 3 | 3 | 0 | 0 | 1 | 2 | 2 | 0 | 1 | 1 | 0 |
| | 4 | 1 | 9 | 4 | 12 | 8 | 2 | 5 | 10 | 5 | 10 |
| | 5 | 14 | 7 | 13 | 2 | 6 | 1 | 11 | 5 | 10 | 5 |
| | Sub-total | **18** | **18** | **18** | **18** | **18** | **18** | **18** | **18** | **18** | **18** |

**Table 7.12:** Group-wise Weighted Average Importance Score Given to Barriers of Implementing HCWM System

| | Barriers of implementing HCWM system | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** | **9** | **10** |
| G1 | 1.725 | 4.176 | 4.392 | 2.216 | 3.647 | 2.039 | 4.118 | 3.863 | 3.961 | 3.725 |
| G2 | 1.789 | 4.263 | 4.211 | 1.684 | 4.158 | 1.895 | 3.737 | 3.684 | 4.316 | 3.474 |
| G3 | 4.800 | 4.733 | 4.267 | 2.400 | 3.800 | 1.600 | 4.133 | 3.333 | 3.600 | 3.733 |
| G4 | 2.348 | 4.304 | 4.870 | 1.696 | 3.826 | 1.913 | 4.174 | 3.913 | 4.174 | 3.522 |
| G5 | 4.611 | 4.167 | 4.611 | 3.667 | 3.944 | 2.333 | 4.389 | 3.889 | 4.278 | 3.944 |

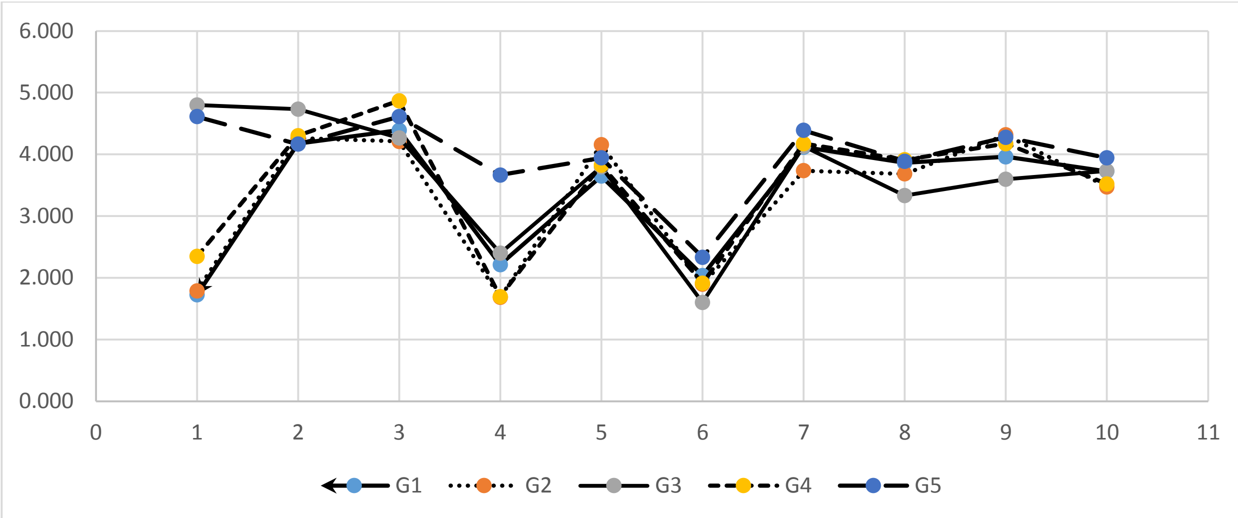


**Figure 7.3:** Weighted Average Scores for Barriers within Each Group

**Table 7.13:** Group-wise Ranking of all the Barriers

| Objectives | G1 | G2 | G3 | G4 | G5 | Total | Ranking |
|---|---|---|---|---|---|---|---|
| **1** | 10 | 9 | 1 | 7 | 1 | 28 | 6 |
| **2** | 2 | 2 | 2 | 2 | 5 | 13 | 2 |
| **3** | 1 | 3 | 3 | 1 | 2 | 10 | 1 |
| **4** | 8 | 10 | 9 | 9 | 8 | 44 | 9 |
| **5** | 7 | 4 | 5 | 5 | 6 | 27 | 5 |
| **6** | 9 | 8 | 10 | 8 | 9 | 44 | 9 |
| **7** | 3 | 5 | 4 | 3 | 3 | 18 | 3 |
| **8** | 5 | 6 | 8 | 4 | 7 | 30 | 7 |
| **9** | 4 | 1 | 7 | 3 | 4 | 19 | 4 |
| **10** | 6 | 7 | 6 | 6 | 6 | 31 | 8 |

### 7.4.2 Statistical Analysis

#### 7.4.2.1 Statistical Analysis of Hypothesis 1 (question 2.1)

To test the Hypothesis 1, the respondents were asked to rate their perception on scale from 1 to 5, towards the importance of implementing HCWM system with respect to your core business. Value 1 on scale represents 'Not important' and 5 represents 'Critical'. Question 2.1 in the questionnaire in Appendix IX has been asked to respondents to check the Hypothesis 1. To analyze the difference in the perception of all the five groups, one way ANOVA was conducted. One way ANOVA test reveals that there exists the difference among the perception of five groups as shown in Table 7.14.

**Table 7.14:** ANOVA for Hypothesis 1

| Source of Variation | SS | df | MS | F | P-value | F crit |
|---|---|---|---|---|---|---|
| Between Groups | 54.911 | 4 | 13.728 | 21.563 | 1.89859E-13 | 2.447 |
| Within Groups | 77.034 | 121 | 0.637 | | | |
| Total | 131.944 | 125 | | | | |

Furthermore, to analyze the differentiating groups, the post hoc analysis has been done using Tukey test for all the groups as shown in Table 7.15. Tukey test has been applied using simple harmonic means of the samples due to unequal sizes of all the five groups.

**Table 7.15:** Post Hoc Analysis for Hypothesis 1

| (I) Groups | (J) Groups | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 2 | -0.37 | 0.214 | 0.427 | -0.96 | 0.23 |
| | 3 | -1.47* | 0.234 | 0.000 | -2.12 | -0.82 |
| | 4 | 0.26 | 0.200 | 0.691 | -0.29 | 0.82 |
| | 5 | -1.44* | 0.219 | 0.000 | -2.05 | -0.84 |
| 2 | 1 | 0.37 | 0.214 | 0.427 | -0.23 | 0.96 |
| | 3 | -1.10* | 0.276 | 0.001 | -1.86 | -0.34 |
| | 4 | 0.63 | 0.247 | 0.088 | -0.06 | 1.31 |
| | 5 | -1.08* | 0.262 | 0.001 | -1.80 | -0.35 |
| 3 | 1 | 1.47* | 0.234 | 0.000 | 0.82 | 2.12 |
| | 2 | 1.10* | 0.276 | 0.001 | 0.34 | 1.86 |
| | 4 | 1.73* | 0.265 | 0.000 | 0.99 | 2.46 |
| | 5 | 0.02 | 0.279 | 1.000 | -0.75 | 0.79 |
| 4 | 1 | -0.26 | 0.200 | 0.691 | -0.82 | 0.29 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | 2 | -0.63 | 0.247 | 0.088 | -1.31 | 0.06 |
| | 3 | -1.73* | 0.265 | 0.000 | -2.46 | -0.99 |
| | 5 | -1.71* | 0.251 | 0.000 | -2.40 | -1.01 |
| 5 | 1 | 1.44* | 0.219 | 0.000 | 0.84 | 2.05 |
| | 2 | 1.08* | 0.262 | 0.001 | 0.35 | 1.80 |
| | 3 | -0.02 | 0.279 | 1.000 | -0.79 | 0.75 |
| | 4 | 1.71* | 0.251 | 0.000 | 1.01 | 2.40 |

The error term is Mean Square (Error) = 0.637.

* The mean difference is significant at the 0.05 level.

**Table 7.16:** Homogeneous Subsets for Hypothesis 1

| Tukey HSD | | | |
|---|---|---|---|
| Groups | N | Subset | |
| | | 1 | 2 |
| 4 | 23 | 2.74 | |
| 1 | 51 | 3.00 | |
| 2 | 19 | 3.37 | |
| 5 | 18 | | 4.44 |
| 3 | 15 | | 4.47 |
| Sig. | | 0.085 | 1.000 |

The error term is Mean Square (Error) = 0.637.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

Table 7.16 divides all the five groups into subsets depending upon their preferences for implementing HCWM system. Post hoc analysis shows that the HCW dealing managers and Government regulatory board employees are more concerned about the implementation of HCWM system than the doctors, professors and MD students. The doctors think that their main purpose is to provide better healthcare services to the public and to implement the HCWM system, is not their responsibility.

### 7.4.2.2 Statistical analysis of Hypothesis 2 (question 2.2)

The respondents were asked to rate the objectives on the scale of 1 (Strongly disagree) to 5 (Strongly agree). The results of statistical analysis are shown in Table 7.17. It is clear from the Table 7.17 that all the groups have not given the same importance to each objective. Different groups have different perception about the objectives of implementing HCWM system. Generally, the healthcare services providers are having the different opinion than the respondents from HCW handling and management team. Here, the test results are significant for some objectives, which represents that groups are having different perception over the following objectives: 1 (To provide better hospital premises and quality services to the patients), 2 (To protect the patients, staff and public from the infectious waste), 4 (To reduce the infectious waste by implementing 3 Rs: reduce, reuse, and recycle) and 5 (To reduce the cost of disposing the HCW).

**Table 7.17:** ANOVA Results for Hypothesis 2

| Source | Dependent Variable (Objectives) | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Intercept | 1 | 1837.227 | 1 | 1837.227 | 2544.689 | .000 | 0.955 |
| | 2 | 1882.606 | 1 | 1882.606 | 3919.961 | .000 | 0.970 |
| | 3 | 1818.279 | 1 | 1818.279 | 2567.821 | .000 | 0.955 |
| | 4 | 1168.945 | 1 | 1168.945 | 833.367 | .000 | 0.873 |
| | 5 | 1459.306 | 1 | 1459.306 | 1057.875 | .000 | 0.897 |
| | 6 | 1907.578 | 1 | 1907.578 | 2679.223 | .000 | 0.957 |
| | 7 | 1101.310 | 1 | 1101.310 | 798.059 | .000 | 0.868 |
| | 8 | 1857.127 | 1 | 1857.127 | 1512.211 | .000 | 0.926 |
| | 9 | 2015.408 | 1 | 2015.408 | 3711.267 | .000 | 0.968 |
| Group | 1 | 21.179 | 4 | 5.295 | 7.334 | .000 | 0.195 |
| | 2 | 32.595 | 4 | 8.149 | 16.967 | .000 | 0.359 |
| | 3 | 3.820 | 4 | .955 | 1.349 | 0.256 | 0.043 |
| | 4 | 60.316 | 4 | 15.079 | 10.750 | .000 | 0.262 |
| | 5 | 30.457 | 4 | 7.614 | 5.520 | .000 | 0.154 |
| | 6 | 3.889 | 4 | 0.972 | 1.366 | 0.250 | 0.043 |

| Source | Dependent Variable (Objectives) | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| | 7 | 7.657 | 4 | 1.914 | 1.387 | 0.242 | 0.044 |
| | 8 | 10.608 | 4 | 2.652 | 2.159 | 0.078 | 0.067 |
| | 9 | 4.926 | 4 | 1.231 | 2.268 | 0.066 | 0.070 |
| Error | 1 | 87.360 | 121 | 0.722 | | | |
| | 2 | 58.112 | 121 | 0.480 | | | |
| | 3 | 85.680 | 121 | 0.708 | | | |
| | 4 | 169.724 | 121 | 1.403 | | | |
| | 5 | 166.916 | 121 | 1.379 | | | |
| | 6 | 86.151 | 121 | 0.712 | | | |
| | 7 | 166.978 | 121 | 1.380 | | | |
| | 8 | 148.598 | 121 | 1.228 | | | |
| | 9 | 65.709 | 121 | 0.543 | | | |
| Total | 1 | 2440.000 | 126 | | | | |
| | 2 | 2553.000 | 126 | | | | |
| | 3 | 2277.000 | 126 | | | | |
| | 4 | 1519.000 | 126 | | | | |
| | 5 | 1973.000 | 126 | | | | |
| | 6 | 2311.000 | 126 | | | | |
| | 7 | 1470.000 | 126 | | | | |
| | 8 | 2256.000 | 126 | | | | |
| | 9 | 2454.000 | 126 | | | | |

The Post-HOC analysis results are shown in Appendix X and the various homogeneous subsets after Post-HOC analysis, for each objective are shown below:

For objective 1 (To provide better hospital premises and quality services to the patients), all the groups except G3 have rated very high as shown in Table 7.18. Hence, the main objective of implementing HCWM system is to provide the better hospital premises to the people. But, the CBWTF managers have given it comparatively less important, as they are not much concerned about the hospital premises. The mean score of each group shows that all are agree with the objective 1 of providing better hospital premises to the people.

**Table 7.18:** Homogeneous Subsets for 'Objective 1'

| Group | N | Subset | |
|---|---|---|---|
| | | 1 | 2 |
| 3 | 15 | 3.2000 | |
| 5 | 18 | | 4.3333 |
| 4 | 23 | | 4.3913 |
| 2 | 19 | | 4.4737 |
| 1 | 51 | | 4.5098 |

The error term is Mean Square (Error) = 0.722.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

For objective 2 (To protect patients, staff and public from the infectious waste), the groups G1, G2, G4 and G5 have given high weightage in comparison to G3 as shown in Table 7.19. Since, G3 mostly belongs to treatment facility managers, hence, for them this function is not important, as they are not directly concerned about the hospital staff and patients. But, all the groups consider that objective 2 is very important while implementing the HCWM system.

**Table 7.19:** Homogeneous Subsets for 'Objective 2'

| Group | N | Subset | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 3 | 15 | 3.2667 | | |
| 5 | 18 | | 3.9444 | |
| 2 | 19 | | 4.4737 | 4.4737 |
| 4 | 23 | | | 4.6957 |
| 1 | 51 | | | 4.7843 |

The error term is Mean Square (Error) = 0.480.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

For objective 3 (To implement proper segregation system), all the groups strongly agree that this is very important issues while dealing with infectious waste as shown in Table 7.20. This is the because of the fact that, in all the processes of handling and disposing the waste, segregation is the most important step. Poor segregation of HCW at the source point will make the whole waste as hazardous waste. The ANOVA-test reveals that there is no significant difference among the different groups' responses.

**Table 7.20:** Homogeneous Subsets for 'Objective 3'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 5 | 18 | 3.9444 |
| 2 | 19 | 4.0000 |
| 4 | 23 | 4.0870 |
| 1 | 51 | 4.2353 |
| 3 | 15 | 4.5333 |

The error term is Mean Square (Error) = 0.708.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

**Table 7.21:** Homogeneous Subsets for 'Objective 4'

| Group | N | Subset | | |
|---|---|---|---|---|
| | | 1 | 2 | 3 |
| 2 | 19 | 2.3684 | | |
| 4 | 23 | 2.7391 | | |
| 1 | 51 | 3.0588 | 3.0588 | |
| 5 | 18 | | 3.7778 | 3.7778 |
| 3 | 15 | | | 4.7333 |

The error term is Mean Square (Error) = 1.403.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

For objective 4 (To reduce the infectious waste) as shown in Table 7.21, Groups G1, G2 and G4 disagree, while G3 and G5 think that waste minimization should be the aim of any sound HCWM system. But, as per doctors and professionals, their main aim is to provide better healthcare services to the people and in that process it may sometimes leads to extra amount of waste. So, as per their perception, waste amount cannot be controlled, but waste management can be done effectively.

The objective 5 (To reduce the cost of disposing the HCW), has been rated average important by all the groups except the regulatory boards members as shown in Table 7.22. As per G5, the hospital administration and CBWTF should invest more on getting the latest technologies of treating the waste and ensure the proper disposal of HCW. While the hospital administration and doctors think that this is not their main business and hence, the cost should be cut by outsourcing the process.

**Table 7.22:** Homogeneous Subsets for 'Objective 5'

| Group | N | Subset | |
|---|---|---|---|
| | | 1 | 2 |
| 5 | 18 | 2.6111 | |
| 1 | 51 | | 3.8235 |
| 4 | 23 | | 3.8696 |
| 3 | 15 | | 4.0667 |
| 2 | 19 | | 4.2632 |

The error term is Mean Square (Error) = 1.379.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

The objective 6 (To develop sustainable waste handling practices) as shown in Table 7.23, is strongly recommended by all the groups. The test results reveal that there is no significant difference among the respondents opinion about the importance of objective 6 in the HCWM system.

**Table 7.23:** Homogeneous Subsets for 'Objective 6'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 1 | 51 | 4.0588 |
| 2 | 19 | 4.1053 |
| 4 | 23 | 4.1739 |
| 3 | 15 | 4.4667 |
| 5 | 18 | 4.5000 |

The error term is Mean Square (Error) = 0.712.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

For objective 7 (To provide convenience to waste handling workers), there is no significant difference among the respondents ratings of all the groups as shown in Table 7.24. Respondents have not given the high importance to this issue while implementing the HCWM system.

**Table 7.24:** Homogeneous Subsets for 'Objective 7'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 3 | 15 | 3.0000 |
| 4 | 23 | 3.0000 |
| 1 | 51 | 3.1176 |
| 5 | 18 | 3.3333 |
| 2 | 19 | 3.7368 |

The error term is Mean Square (Error) = 1.380.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

The objective 8 (To develop holistic mechanism to deal with biomedical waste), has been rated very important by all the respondent groups. There is no significant difference among the mean scores assigned by each group as shown in Table 7.25. As per the respondents, holistic mechanism for dealing the infectious waste should be developed which starts from the point of generation of HCW and ends with the final disposal of residual ash from the incinerators.

**Table 7.25:** Homogeneous Subsets for 'Objective 8'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 1 | 51 | 3.7647 |
| 4 | 23 | 4.0435 |
| 2 | 19 | 4.3684 |
| 3 | 15 | 4.4000 |
| 5 | 18 | 4.4444 |

The error term is Mean Square (Error) = 1.228.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

The homogeneous subsets for objective 9 (Providing training and enhancing skills) as shown in Table 7.26, has also been very highly rated by all the respondents and there is no significant difference among the mean scores assigned by each group. Hence, providing training and education to the waste handling workers about the infectious nature of the MW and its proper handling techniques, is very important element for any HCWM system.

**Table 7.26:** Homogeneous Subsets for 'Objective 9'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 4 | 23 | 4.2609 |
| 2 | 19 | 4.2632 |
| 3 | 15 | 4.2667 |
| 1 | 51 | 4.2745 |
| 5 | 18 | 4.8333 |

The error term is Mean Square (Error) = 0.543.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

#### 7.4.2.3 Statistical Analysis of Hypothesis 3 (question 2.3)

The respondents were asked to rate the various enablers of implementing HCWM system in India on the scale of 1 (Not important) to 5 (Extremely important). The results of statistical analysis are shown in Table 7.27. It is clear from the Table 7.27 that all the groups have not given the same importance to each enabler. Different groups have different perception about the enablers of implementing HCWM system, which will help to achieve the robust waste management system. Here, the test results are significant for some of the enablers, which represent that groups are having different perception over the following enablers: 3 (Infrastructure and convenience), 6 (Budget allocation in HCWM), and 9 (Frequent transportation of HCW).

**Table 7.27:** ANOVA Results for Hypothesis 3

| Source | Dependent Variable (Enablers) | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Intercept | Enabler 1 | 1869.452 | 1 | 1869.452 | 2849.126 | .000 | 0.959 |
| | Enabler 2 | 1301.751 | 1 | 1301.751 | 1799.166 | .000 | 0.937 |
| | Enabler 3 | 1078.013 | 1 | 1078.013 | 1318.990 | .000 | 0.916 |
| | Enabler 4 | 1055.350 | 1 | 1055.350 | 1632.820 | .000 | 0.931 |
| | Enabler 5 | 1300.724 | 1 | 1300.724 | 1377.105 | .000 | 0.919 |
| | Enabler 6 | 979.419 | 1 | 979.419 | 999.942 | .000 | 0.892 |
| | Enabler 7 | 2023.549 | 1 | 2023.549 | 2701.705 | .000 | 0.957 |
| | Enabler 8 | 2112.692 | 1 | 2112.692 | 2594.919 | .000 | 0.955 |
| | Enabler 9 | 735.056 | 1 | 735.056 | 1109.771 | .000 | 0.902 |
| Group | Enabler 1 | 6.574 | 4 | 1.644 | 2.505 | 0.051 | 0.076 |
| | Enabler 2 | 3.945 | 4 | 0.986 | 1.363 | 0.251 | 0.043 |
| | Enabler 3 | 103.551 | 4 | 25.888 | 31.675 | .000 | 0.512 |
| | Enabler 4 | 3.833 | 4 | 0.958 | 1.483 | 0.212 | 0.047 |
| | Enabler 5 | 5.203 | 4 | 1.301 | 1.377 | 0.246 | 0.044 |
| | Enabler 6 | 123.809 | 4 | 30.952 | 31.601 | .000 | 0.511 |
| | Enabler 7 | 4.007 | 4 | 1.002 | 1.338 | 0.260 | 0.042 |
| | Enabler 8 | 5.843 | 4 | 1.461 | 1.794 | 0.134 | 0.056 |
| | Enabler 9 | 8.713 | 4 | 2.178 | 3.289 | 0.013 | 0.098 |
| Error | Enabler 1 | 79.394 | 121 | 0.656 | | | |
| | Enabler 2 | 87.547 | 121 | 0.724 | | | |
| | Enabler 3 | 98.894 | 121 | 0.817 | | | |
| | Enabler 4 | 78.207 | 121 | 0.646 | | | |
| | Enabler 5 | 114.289 | 121 | 0.945 | | | |
| | Enabler 6 | 118.517 | 121 | 0.979 | | | |
| | Enabler 7 | 90.628 | 121 | 0.749 | | | |
| | Enabler 8 | 98.514 | 121 | 0.814 | | | |

| Source | Dependent Variable (Enablers) | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| | Enabler 9 | 80.144 | 121 | 0.662 | | | |
| Total | Enabler 1 | 2232.000 | 126 | | | | |
| | Enabler 2 | 1628.000 | 126 | | | | |
| | Enabler 3 | 1254.000 | 126 | | | | |
| | Enabler 4 | 1371.000 | 126 | | | | |
| | Enabler 5 | 1656.000 | 126 | | | | |
| | Enabler 6 | 1209.000 | 126 | | | | |
| | Enabler 7 | 2478.000 | 126 | | | | |
| | Enabler 8 | 2549.000 | 126 | | | | |
| | Enabler 9 | 922.000 | 126 | | | | |

The results of Post-HOC analysis are shown in Appendix XI and the various homogeneous subsets for each enabler are shown below. All the groups are strongly agree on enabler 1 (Knowledge and training aids to waste handling workers and staff) and there is no statistical difference among the ratings given by different groups as shown in Table 7.28. Hence, all the groups have given very high importance to the education of the workers and staff who are actually managing and handling the infectious waste.

**Table 7.28:** Homogeneous Subsets for 'Enabler 1'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 1 | 51 | 3.8627 |
| 2 | 19 | 4.1579 |
| 3 | 15 | 4.3333 |
| 4 | 23 | 4.3478 |
| 5 | 18 | 4.3889 |

The error term is Mean Square (Error) = 0.656.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

Similarly, there is no difference in the perception among the respondents regarding enabler 2 ('Appreciation and motivation'), but it has been rated little lower side as shown in Table 7.29. The recognition of the waste handling team is important to motivate them and implement the HCWM system more efficiently and effectively.

**Table 7.29:** Homogeneous Subsets for 'Enabler 2'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 5 | 18 | 3.2778 |
| 4 | 23 | 3.3478 |
| 1 | 51 | 3.4510 |
| 3 | 15 | 3.7333 |
| 2 | 19 | 3.7895 |

The error term is Mean Square (Error) = 0.724.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

Post-HOC analysis for Enabler 3 (Infrastructure and convenience) divide all the groups into different homogeneous sets after analyzing the perception of the respondents. It is clear from the results shown below in Table 7.30 that the healthcare services providers have given less importance to build infrastructure, as they think that HCFs should outsource these waste handling activities and should focus on the primary business.

**Table 7.30:** Homogeneous Subsets for 'Enabler 3'

| Group | N | Subset | |
|---|---|---|---|
| | | 1 | 2 |
| 1 | 51 | 2.2353 | |
| 4 | 23 | 2.4348 | |
| 2 | 19 | 2.5789 | |
| 3 | 15 | | 4.2667 |
| 5 | 18 | | 4.5000 |

The error term is Mean Square (Error) = 0.817.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

For enabler 4 (Collaboration and integration among HCFs and CBWTFs), the respondents have given the average response as shown in Table 7.31. They think that collaboration and integration among the HCFs and CBWTFs is not very important, as the whole process is very much specific and not much flexibility is required. Once, the HCWD process is outsourced, then it becomes the responsibility of CBWTF to collect the waste daily and should process it as per rules.

**Table 7.31:** Homogeneous Subsets for 'Enabler 4'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 4 | 23 | 2.8696 |
| 3 | 15 | 3.0667 |
| 2 | 19 | 3.2632 |
| 1 | 51 | 3.3137 |
| 5 | 18 | 3.3333 |

The error term is Mean Square (Error) = 0.646.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

The respondents from different group have the same opinion about the importance of the enabler 5 (Development of the performances matrices) as shown in Table 7.32. Their perception is that there should be standard evaluation criteria for evaluating the CBWTFs in order to ensure the proper functioning of HCWM system.

**Table 7.32:** Homogeneous Subsets for 'Enabler 5'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 4 | 23 | 3.3043 |
| 3 | 15 | 3.3333 |
| 1 | 51 | 3.4314 |
| 2 | 19 | 3.5789 |
| 5 | 18 | 3.9444 |

The error term is Mean Square (Error) = 0.945.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

**Table 7.33:** Homogeneous Subsets for 'Enabler 6'

| Group | N | Subset | |
|---|---|---|---|
| | | 1 | 2 |
| 4 | 23 | 2.0000 | |
| 2 | 19 | 2.1579 | |
| 1 | 51 | 2.2745 | |
| 3 | 15 | | 4.3333 |
| 5 | 18 | | 4.5000 |

The error term is Mean Square (Error) = 0.979.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

Post-HOC analysis has divided the groups into two subsets on enabler 6 (Budget allocation in HCWM) as shown in Table 7.33. The results reveal that the healthcare service providers think that on their part not much budget is required to implement the HCWM system, but it is the core responsibility of the waste treatment facilities to implement the strong system. Hence, CBWTFs should allocate their maximum budget for the proper functioning of HCWM system.

Enabler 7 (Adoption of latest technology in treating the waste) has been very highly rated by all the groups and there is no difference in the perception of the different groups as shown in Table 7.34. The updated technology will help to reduce the amount of pollution to be ejected in the environment while treating the MW.

**Table 7.34:** Homogeneous Subsets for 'Enabler 7'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 2 | 19 | 4.2105 |
| 5 | 18 | 4.2222 |
| 1 | 51 | 4.2549 |
| 4 | 23 | 4.5217 |
| 3 | 15 | 4.7333 |

The error term is Mean Square (Error) = 0.749.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

**Table 7.35:** Homogeneous Subsets for ‘Enabler 8’

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 4 | 23 | 4.2174 |
| 1 | 51 | 4.2549 |
| 2 | 19 | 4.5263 |
| 5 | 18 | 4.5556 |
| 3 | 15 | 4.8667 |

The error term is Mean Square (Error) = 0.814.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

Also, for enabler 8 (Segregation and collection of HCW), the respondents have given very high consent about their perception about the importance in implementing HCWM system as highlighted in Table 7.35. Segregation has been considered the main activity in comparison to all other activities involved in the HCWM system. All the groups have been placed on the same subset regarding the importance of segregation in managing the infectious waste.

The enabler 9 (Frequent transportation of HCW) has been very low rated by the respondents as shown in Table 7.36. The importance of the strong logistics capabilities have been given little importance in case of managing the HCW.

**Table 7.36:** Homogeneous Subsets for ‘Enabler 9’

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 1 | 51 | 2.3333 |
| 2 | 19 | 2.3684 |
| 3 | 15 | 2.7333 |
| 5 | 18 | 2.8333 |
| 4 | 23 | 2.9565 |

The error term is Mean Square (Error) = 0.662.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

### 7.4.2.4 Statistical Analysis of Hypothesis 4 (question 2.4)

Here, the respondents were asked to rate the various barriers for implementing HCWM system in India on the scale of 1 (Not important) to 5 (Extremely important). The results of statistical analysis are shown in Table 7.37. It is clear from the Table 7.37 that all the groups have not given the same importance to each barrier. Different groups have different perception about the barriers for implementing HCWM system, which will obstruct the waste management practices. Here, the test results are significant for some of the barriers, which represent that groups are having different perception over the barriers like: 1 (Lack of hospital administration and doctors commitment) and 4 (Lack of perception of self-harm).

**Table 7.37:** ANOVA Results for Hypothesis 4

| Source | Dependent Variable (Barrier) | Type III Sum of Squares | df | Mean Square | F | Sig. | Partial Eta Squared |
|---|---|---|---|---|---|---|---|
| Intercept | Barrier1 | 980.466 | 1 | 980.466 | 1272.787 | .000 | 0.913 |
| | Barrier2 | 1968.824 | 1 | 1968.824 | 3534.594 | .000 | 0.967 |
| | Barrier3 | 2099.369 | 1 | 2099.369 | 2511.739 | .000 | 0.954 |
| | Barrier4 | 571.603 | 1 | 571.603 | 610.977 | .000 | 0.835 |
| | Barrier5 | 1577.749 | 1 | 1577.749 | 1606.667 | .000 | 0.930 |
| | Barrier6 | 402.013 | 1 | 402.013 | 533.740 | .000 | 0.815 |
| | Barrier7 | 1774.936 | 1 | 1774.936 | 1232.214 | .000 | 0.911 |
| | Barrier8 | 1466.864 | 1 | 1466.864 | 1037.461 | .000 | 0.896 |
| | Barrier9 | 1736.734 | 1 | 1736.734 | 1246.837 | .000 | .912 |
| | Barrier10 | 1422.678 | 1 | 1422.678 | 1242.822 | .000 | 0.911 |
| Group | Barrier1 | 198.258 | 4 | 49.565 | 64.342 | .000 | 0.680 |
| | Barrier2 | 3.879 | 4 | 0.970 | 1.741 | 0.145 | 0.054 |
| | Barrier3 | 6.238 | 4 | 1.560 | 1.866 | 0.121 | 0.058 |
| | Barrier4 | 49.623 | 4 | 12.406 | 13.260 | .000 | 0.305 |
| | Barrier5 | 3.979 | 4 | 0.995 | 1.013 | 0.403 | 0.032 |
| | Barrier6 | 4.831 | 4 | 1.208 | 1.604 | 0.178 | 0.050 |
| | Barrier7 | 4.151 | 4 | 1.038 | 0.720 | 0.580 | 0.023 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | Barrier8 | 4.133 | 4 | 1.033 | 0.731 | 0.573 | 0.024 |
| | Barrier9 | 6.069 | 4 | 1.517 | 1.089 | 0.365 | 0.035 |
| | Barrier10 | 2.791 | 4 | 0.698 | 0.610 | 0.657 | 0.020 |
| Error | Barrier1 | 93.210 | 121 | 0.770 | | | |
| | Barrier2 | 67.399 | 121 | 0.557 | | | |
| | Barrier3 | 101.135 | 121 | 0.836 | | | |
| | Barrier4 | 113.202 | 121 | 0.936 | | | |
| | Barrier5 | 118.822 | 121 | 0.982 | | | |
| | Barrier6 | 91.137 | 121 | 0.753 | | | |
| | Barrier7 | 174.294 | 121 | 1.440 | | | |
| | Barrier8 | 171.082 | 121 | 1.414 | | | |
| | Barrier9 | 168.542 | 121 | 1.393 | | | |
| | Barrier10 | 138.511 | 121 | 1.145 | | | |
| Total | Barrier1 | 1161.000 | 126 | | | | |
| | Barrier2 | 2377.000 | 126 | | | | |
| | Barrier3 | 2623.000 | 126 | | | | |
| | Barrier4 | 812.000 | 126 | | | | |
| | Barrier5 | 1959.000 | 126 | | | | |
| | Barrier6 | 592.000 | 126 | | | | |
| | Barrier7 | 2308.000 | 126 | | | | |
| | Barrier8 | 1981.000 | 126 | | | | |
| | Barrier9 | 2247.000 | 126 | | | | |
| | Barrier10 | 1850.000 | 126 | | | | |

The Post-HOC test classifies the groups into different sub-sets over barrier 1 and 4 and for rest of the barriers the perception of all the groups is same. The test results for Post-HOC analysis are shown in Appendix XII and the various subsets for each barrier are shown below:

The hospitals employees have given very less importance to ‘barrier 1’ (Lack of hospital administration and doctors commitment) as shown in Table 7.38. The respondents groups (G1, G2 and G4) have rated ‘barrier 1’ moderately, while the groups (G4 and G5) have given very high importance to hospitals administration and doctors’ commitment in implementing the HCWM system.

**Table 7.38:** Homogeneous Subsets for 'Barrier 1'

| Group | N | Subset | |
|---|---|---|---|
| | | 1 | 2 |
| 1 | 51 | 1.7255 | |
| 2 | 19 | 1.7895 | |
| 4 | 23 | 2.3478 | |
| 5 | 18 | | 4.6111 |
| 3 | 15 | | 4.8000 |

The error term is Mean Square (Error) = 0.770.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

For barrier 2 (Lack of infrastructure and convenience), all the respondents groups have rated very high as reflected in Table 7.39 and agree on the issue that strong infrastructure plays very crucial role in facilitating the HCWM practices. The conveniences provided to the waste handling workers, will help them to handle the infectious waste more easily and safely.

**Table 7.39:** Homogeneous Subsets for 'Barrier 2'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 5 | 18 | 4.1667 |
| 1 | 51 | 4.1765 |
| 2 | 19 | 4.2632 |
| 4 | 23 | 4.3043 |
| 3 | 15 | 4.7333 |

The error term is Mean Square (Error) = 0.557.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

The barrier 3 (Budget problems) as shown in Table 7.40, has been rated very important for implementing the HCWM system in India. As the HCWM is not the primary business for the HCFs and they want to minimize the cost of handling the waste. Hence, very less budget is allocated to install the updated technology, which has become the big threat for the HCWM system. Therefore, the HCFs have to realize the responsibility and come forward to establish the strong waste management infrastructure. All respondents agree on the fact that very less budget is given to implement the HCWM system, which is harmful for the society.

**Table 7.40:** Homogeneous Subsets for 'Barrier 3'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 2 | 19 | 4.2105 |
| 3 | 15 | 4.2667 |
| 1 | 51 | 4.3922 |
| 5 | 18 | 4.6111 |
| 4 | 23 | 4.8696 |

The error term is Mean Square (Error) = 0.836.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

The barrier 4 (Lack of perception of self-harm) has been rated on the lower side by all the groups as shown in Table 7.41. Although, Group G5 has considered that the waste handling workers are not aware about the harm that can be caused by the infectious waste and they handle the waste without following the instructions. Hence, the workers need to be trained and educated to make the waste handling process more efficient.

**Table 7.41:** Homogeneous Subsets for 'Barrier 4'

| Group | N | Subset | |
|---|---|---|---|
| | | 1 | 2 |
| 2 | 19 | 1.6842 | |
| 4 | 23 | 1.6957 | |
| 1 | 51 | 2.2157 | |
| 3 | 15 | 2.4000 | |
| 5 | 18 | | 3.6667 |

The error term is Mean Square (Error) = 0.936.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

The barrier 5 (‘Lack of monitoring’) has been rated average by all the five respondents groups as shown in Table 7.42. Respondents agree on the fact that there has been very less monitoring of the waste handling activities and also the disposal methods at the treatment facility. As per the respondents, there should be the tracking system to monitor the movement of each bag of infectious waste, till the final disposal is over.

**Table 7.42:** Homogeneous Subsets for ‘Barrier 5’

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 1 | 51 | 3.6471 |
| 3 | 15 | 3.8000 |
| 4 | 23 | 3.8261 |
| 5 | 18 | 3.9444 |
| 2 | 19 | 4.1579 |

The error term is Mean Square (Error) = 0.982.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

**Table 7.43:** Homogeneous Subsets for ‘Barrier 6’

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 3 | 15 | 1.6000 |
| 2 | 19 | 1.8947 |
| 4 | 23 | 1.9130 |
| 1 | 51 | 2.0392 |
| 5 | 18 | 2.3333 |

The error term is Mean Square (Error) = 0.753.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

The respondents have given very less ratings to ‘barrier 6’ (Lack of benchmark in India) as reflected in Table 7.43 and they think that the whole procedure is well defined in the Biomedical Waste Management and Handling Rules, 1998, which act as the guidelines for implementing the HCWM system. Although, the Pollution Control Board employees have given little high ratings comparatively and they argued that we need to standardize the whole waste management process. Lack of awareness among waste handling staff & workers, has been rated as important barrier for implementing the HCWM system. All the groups agree on the 'barrier 7' as shown in Table 7.44. Respondents stressed on the regular training for the waste handling workers and staff.

**Table 7.44:** Homogeneous Subsets for 'Barrier 7'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 2 | 19 | 3.7368 |
| 1 | 51 | 4.1176 |
| 3 | 15 | 4.1333 |
| 4 | 23 | 4.1739 |
| 5 | 18 | 4.3889 |

The error term is Mean Square (Error) = 1.440.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

**Table 7.45:** Homogeneous Subsets for 'Barrier 8'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 3 | 15 | 3.3333 |
| 2 | 19 | 3.6842 |
| 1 | 51 | 3.8627 |
| 5 | 18 | 3.8889 |
| 4 | 23 | 3.9130 |

The error term is Mean Square (Error) = 1.414.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

The barrier 8 (No maintenance staff at treatment facility) has been rated moderately by all the respondents groups as shown in Table 7.45. As per the respondents, the lack of maintenance at the treatment facilities obstructs the disposal process and stressed that there should be at least one maintenance engineer at each treatment facility.

The barrier 9 (No frequent transportation of bio-medical waste from HCF to CBWTF) has been rated important by all the respondents groups. As per the hospitals employees, sometimes the waste remains in the hospital premises for more than 4-5 days, which is very harmful for the hospital environment. As per the waste handling rules also, the HCW should be transported to the treatment facility within 48 hours. Hence, poor logistic infrastructure leads to improper HCWM system.

**Table 7.46:** Homogeneous Subsets for 'Barrier 9'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 3 | 15 | 3.6000 |
| 1 | 51 | 3.9608 |
| 4 | 23 | 4.1739 |
| 5 | 18 | 4.2778 |
| 2 | 19 | 4.3158 |

The error term is Mean Square (Error) = 1.393.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

**Table 7.47:** Homogeneous Subsets for 'Barrier 10'

| Group | N | Subset |
|---|---|---|
| | | 1 |
| 2 | 19 | 3.4737 |
| 4 | 23 | 3.5217 |
| 1 | 51 | 3.7255 |
| 3 | 15 | 3.7333 |
| 5 | 18 | 3.9444 |

The error term is Mean Square (Error) = 1.145.

Uses Harmonic Mean Sample Size = 21.014. Alpha = 0.05.

The barrier 10 (Non-aligned operational objectives among HCFs & CBWTFs) has been given the average importance, while implementing the HCWM system. As shown in Table 7.47, all the groups agree on the importance of collaboration among hospitals and treatment facilities and stressed that it is the shared responsibility of both the HCFs and CBWTFs to ensure the proper disposal of HCW.

## 7.5 CONCLUSION AND MANAGERIAL IMPLICATIONS

To establish the robust HCWM system is now the matter of concern for HCFs, CBWTFs, CPCBs and SPCBs. Therefore, the hospitals and treatment facilities have to work collaboratively, to implement the efficient and effective HCWM system. The present study has identified some enablers and barriers, which should be anticipated and emphasized in order to achieve the objectives of implementing the HCWM system.

### 7.5.1 Implication from Hypothesis 1

Hypothesis 1 reveals that all the respondents groups have given the importance to HCWM system, but the employees from the hospitals have rated less in comparison to waste treatment facilities' managers and Government Regulatory Board's employees. Since, doctors are involved in the HCW generation process, hence, they have to be more responsible in order to protect the hospital premises from the infectious waste. Doctors' participation is very important to train and educate the waste handling workers and lay down the policies and procedures.

### 7.5.2 Implications from Hypothesis 2

The overall responses from all the respondent groups have rated the following objectives of implementing HCWM system highly important: 'to protect the people in the hospitals', 'training and skills enhancement', 'provide better hospital premises', 'sustainable waste handling practices', 'proper segregation' and 'to develop holistic mechanism to deal with HCW'.

### 7.5.3 Implications from Hypothesis 3

The HCFs, CBWTFs and Pollution Control Boards, should focus primarily on the identified enablers of implementing the effective and efficient HCWM system. The list of various enablers and corresponding action plan to implement the HCWM system, are given in Table 7.48

**Table 7.48:** Recommendations to Enhance the Enablers of Implementing HCWM System

| Sl. No. | Enablers | Action Plan |
|---|---|---|
| 1. | Knowledge & training aids to waste handling workers and staff | Conduct the training programs for all the workers and staff of HCFs and CBWTFs regularly. They should be made aware about the precautions to be taken while handling the infectious waste. |
| 2. | Appreciation and motivation | Develop the incentive mechanism to share the rewards to the waste handling workers and motivate them by appreciating them time to time. |
| 3. | Infrastructure and convenience | Provide proper infrastructure and means to collect the HCW and transport it to the waste treatment facility. |
| 4. | Collaboration and integration among HCFs and CBWTFs | Realize the importance of CBWTF for disposing the waste and make the decisions jointly with the collaborative partner. |
| 5. | Development of the performances matrices | Develop the performance measurement tools to evaluate and control the activities of HCFs and CBWTFs. |
| 6. | Budget allocation in HCWM | Proper budgetary plan should be developed for treating the HCW by the HCFs and CBWTFs. |
| 7. | Adoption of latest technology in treating the waste | Replace the outdated harmful treatment techniques with the latest technology. |
| 8. | Segregation and collection of HCW | Segregate the waste into different categories at the generation source itself and collect into different color coded bins. |
| 9. | Frequent transportation of HCW | Ensure the transportation of the HCW from the HCF to CBWTF within 48 hours after the production. |

### 7.5.4 Implications from Hypothesis 4

The hospital administration and CBWTF managers should anticipate and address the barriers effectively. The list of various barriers and corresponding action plan to overcome these barriers, are given in Table 7.49.

**Table 7.49:** Recommendations to Overcome the Barriers of Implementing HCWM System

| Sl. No. | Barriers | Action Plan |
|---|---|---|
| 1. | Lack of hospital administration and doctors' commitment | Enforcement of the Biomedical Waste Handling and Management Rules, 1998 to the hospital administration by the SPCB. Involve the doctors for training the waste handling workers. |
| 2. | Lack of infrastructure and convenience | Provide the proper infrastructure for handling the waste and regular monitoring of the waste handling equipment. |
| 3. | Budget problems | Allocate the necessary budget for disposing the waste and installing the latest technology. |
| 4. | Lack of perception of self-harm | Educate the workers and staff about the harm that may be caused by the infectious waste. |
| 5. | Lack of monitoring | Regular monitoring of the waste handling activities. |
| 6. | Lack of benchmark in India | Set the standards for each activity involved in the waste disposal process. |
| 7. | Lack of awareness among waste handling staff & workers | Regular training and skills development workshop for staff and workers involved in the waste handling process. |
| 8. | No maintenance staff at treatment facility | Appoint the maintenance engineer at each waste treatment facility to ensure the no delay in disposing the infectious waste. |
| 9. | No frequent transportation of bio-medical waste from HCF to CBWTF | Establish strong logistic infrastructure in order to ensure the frequent transportation of waste from the hospital premises to the treatment facility. |
| 10. | Non-aligned operational objectives among HCFs & CBWTFs | Set the combined operational goals for HCFs and CBWTFs to ensure the proper tuning with the outsourcing partner. |

## 7.6 CHAPTER SUMMARY

Everyone related to healthcare industry is feeling the need to implementing the strong HCWM system which can effectively and efficiently meet the environmental expectations. So there is great scope for the further improvement in the existing system. In this chapter, the survey was conducted to test the perception of the experts and practitioners in the field on various issues related to: importance of implementing HCWM system, objectives of HCWM system, barriers and enablers of implementing the HCWM system in India. The survey has come out with some strong issues for implementing HCWM system, which hospital administration and CBWTF managers should focus on in order to establish robust system for dealing with the infectious waste.

# CHAPTER 8

# SUMMARY, LIMITATIONS AND SCOPE FOR FUTURE RESEARCH

## 8.1 INTRODUCTION

The hazardous Healthcare Waste Management (HCWM) coming out from the various Healthcare Facilities (HCFs) has become very important issue for hospitals, treatment facilities and Government regulatory authorities. The infectious Medical Waste (MW) generated as the byproduct during the diagnosis, surgical procedures and providing the healthcare services to the patients, is very harmful for the public and environmental health. Most of the hospitals in the developing countries are outsourcing the Healthcare Waste Disposal (HCWD) process to the third party and final disposal of the infectious waste has not been done as per the World Health Organization (WHO) rules. Hence, there is strong need to assess the current HCWM practices and formulate the policies and measures to deal with the hazardous waste.

The Government regulatory authority has very important role in enforcing the public and private HCFs to implement the HCWM policy. The Government guidelines will act as the blueprint for the State Pollution Control Boards and HCFs to make the decisions and allocate the operational resources to establish the HCWM system. Hence, the primary motivation of the present research is to explore the opportunities to implement the effective and efficient HCWM system. The study has been conducted to analyze the various elements of strong HCWM system and how the better HCWD operational strategy can be developed.

## 8.2 SUMMARY OF WORK DONE

The current HCWM system is full of drawbacks and has been ineffective and inefficient to deal with the infectious waste. Hence, there is huge scope for the research in order to improve the existing system and laid down some robust sustainable system, which can meet environmental expectations. The summary of the work done in this research is given below:

- A structured literature review of articles appearing in eight esteemed journals in the related field over a period from 2005-June, 2014 has been done and classified the whole literature as per the various issues of HCWM. Then, gaps have been identified in the contemporary research on HCW.
- A quantitative model has been developed to select the best HCWD strategy depending upon some qualitative as well as quantitative parameters.

- Various criteria and sub-criteria have been prioritized in order to select the strategic outsourcing partner for disposing the HCW and an analytic framework based on ANP and TOPSIS has been developed to rank the various options.
- The data related to generation of MW has been collected from various HCFs and has been analyzed using multiple regression and Artificial Neural Network (ANN).
- HCWM practices at various HCFs in Uttarakhand, (India) have been assessed and waste generation patterns have been analyzed for different types of HCFs.
- ISM-based model has been developed to analyze the interrelationships among the various barriers of implementing HCWM system.
- Four hypotheses have been developed. In the first hypothesis, the importance of implementing HCWM system was analyzed among various sample groups. Second hypothesis tested the perception about the main objectives of implementing HCWM system. Third hypothesis analyzed the perception about the enablers of implementing the HCWM system and fourth hypothesis tested the opinion about the barriers of implementing HCWM system.
- The questionnaire was developed in order to collect the responses from the experts in the field. The first part of the questionnaire collects the information about the profile of the employee and his/her organization. The second part captures the perception of the respondents about the importance of HCWM system, objectives of implementing HCWM system, barriers and enablers of implementing HCWM system in India.
- The questionnaire targeted the doctors, professors, hospital managers, waste treatment facility managers and Government officials. A total of 126 complete responses were analyzed to test the hypotheses.

Table 8.1 represents the various gaps identified in the literature and through the field survey, objectives addressing the identified gaps, methodologies used to bridge the identified gaps and in the end, the results of the study.

**Table 8.1:** Summary of Work Done

| Sl. No. | Identified gaps | Objectives | Methodologies used and frameworks developed | Results |
|---|---|---|---|---|
| **1.** | No comprehensive literature review has been conducted so far in the field of HCWM. | To conduct the structured literature review targeting the HCWM field. | Structured literature review has been done for a period of 2005 to June, 2014.<br>(Chapter 2) | • Divided the whole HCWM area into five broad topics and 19 sub-topics.<br>• Analyzed the trends in the methodologies adopted by the researchers over the decade. |
| **2.** | Literature lacks the studies in analyzing the HCWD strategies and developing criteria in the Indian context. | To propose a model for prioritizing the waste disposal strategy selection criteria and selecting the appropriate HCWD strategy. | Grey theory based AHP framework has been developed.<br>(Chapter 3) | • 'Outsourcing (0.61)' has been selected as the best HCWD strategy for HCFs.<br>• 'Economic factors' (0.285), 'Environmental factors' (0.278), 'Government rules' (0.239) have been prioritized on the top while selecting the HCWD strategy. |
| **3.** | Literature lacks the research in prioritizing the criteria and sub-criteria for selecting the HCWD outsourcing partner and a framework to evaluate the various | To propose a framework for selecting the outsourcing partner to dispose the HCW. | ANP and TOPSIS based hybrid model in grey environment has been developed.<br>(Chapter 4) | • The criteria have been prioritized as per following: 'Firm's capabilities' (.285), 'Economic factors' (.278), 'Technology & qualification' (.239), |

| Sl. No. | Identified gaps | Objectives | Methodologies used and frameworks developed | Results |
|---|---|---|---|---|
| | alternatives with respect to selected criteria. | | | ‘Environmental factors’ (.080), ‘Experience’ (.064) and ‘Relationship’ (.055).<br>• The proposed model helped to select the HCWD firm for outsourcing in Uttarakhand, India. |
| **4.** | In Indian healthcare industry, the MW composition and generations rates have not been studied comprehensively. | To analyze the composition and generations rates of MW from various HCFs in Uttarakhand, Northern State of India. | MLR and ANN modeling techniques have been applied to analyze the generation patterns of HCW.<br>(Chapter 5) | • ‘General Hospitals’ contributing the highest amount (0.68 kg/patient/day).<br>• ANN yielded better results than MLR modeling.<br>• 36% of the total HCFs are not segregating.<br>• Yellow waste is contributing highest among all the categories in all the HCFs except ‘child & maternity hospitals’. |
| **5.** | Literature lacks the research finding the important factors | To find out the significant factors contributing in the | Multiple regressions have been applied to find out the important factors contributing | • ‘Occupancy’ and ‘Type of HCF’ are significant factors. |

| Sl. No. | Identified gaps | Objectives | Methodologies used and frameworks developed | Results |
|---|---|---|---|---|
| | which are contributing towards HCW quantity in India. | quantity of MW being generated from HCFs. | to the MW generation rates. (Chapter 5) | • 'Seasonal variation' is also playing significant role. |
| **6.** | Barriers of implementing HCWM system in India have not been studied thoroughly. | To analyze the barriers hindering the implementation of HCWM system. | ISM-based model has been developed and Fuzzy-MICMAC analysis has been done to understand the interrelationships among various barriers. (Chapter 6) | • 25 barriers have been identified.<br>• Divided into four groups depending upon driving and dependence power using Fuzzy-MICMAC analysis. |
| **7.** | No comprehensive survey has been conducted on the managerial issues related to HCWM system in India. | To test the hypotheses on various issues related to HCWM system. | Hypotheses related to managerial issues were framed and tested by conducting the statistical tests. (Chapter 7) | • Employees related to HCFs are having different opinion on some issues in comparison to CBWTF managers and Government officials.<br>• Doctors give less preference to HCWM system in comparison to their main business. |

## 8.3 MAJOR CONTRIBUTIONS OF THE RESEARCH

The major contributions of the present research are:

- The structured review conducted, divided the whole HCWM area into five major topics and 19 sub-topics. Structured review also highlighted the trends in the methodologies adopted by various researchers to explore the current field.
- A model has been developed based on grey theory and AHP to select the best HCWD strategy.
- A framework based on ANP and TOPSIS under grey environment has been developed to select the best outsourcing partner for disposing the HCW.
- The generation patterns and composition of MW have been analyzed through MLR and ANN modeling techniques.
- The interrelationships among various barriers of implementing the HCWM system, have been analyzed through ISM methodology.
- The barriers of implementing HCWM system have been classified into four groups using Fuzzy-MICMAC analysis.
- Importance, objectives, enablers and barriers of implementing HCWM system in India have been tested empirically.

## 8.4 KEY FINDINGS FROM THE RESEARCH

The key findings of whole research are:

- The structured literature review revealed the trends in various methodologies adopted by the researchers to explore the area of HCWM over the last decade.
- The review conducted in Chapter 2 resulted into 19 areas of HCWM and provided the future research directions into the related fields.
- In Chapter 3, grey theory and AHP based model has been developed to evaluate the HCWD strategies: ‘outsourcing’ or ‘in-house treatment’. The model was applied in Uttarakhand, Northern State of India, which resulted that HCFs should go for outsourcing the HCWD process to the third party as rated by the experts. ‘Outsourcing’ strategic option (0.61) got the higher desirability index than ‘in-house treatment’ (0.39).

- While deciding for outsourcing the HCWD process, the 'economic factors' (0.285) have been given the highest importance by the experts. Due to increase in global competition HCFs are forced to provide the better healthcare services at reduced price.
- 'Environmental factors' (0.278) have been rated second highest on the priority level while selecting the HCWD strategy. Since, the HCW is very much hazardous in nature, so it is important to assess its impact on the hospital premises and outside environment. 'Government rules' (0.239) conformance has been kept at third position in the importance of selecting the HCWD strategy. This is followed by 'transportation and risk associated' (0.080), 'access to expertise' (0.064) and 'overdependence' (0.055).
- Chapter 4 proposed a quantitative model based on ANP and TOPSIS under grey environment, for evaluating and ranking HCWD firms and has been applied to select the appropriate outsourcing partner for disposing the HCW in Uttarakhand, Northern State of India.
- The results revealed that HCWD firms are evaluated on the basis of the following criteria weights given by the five experts: 'experience' (0.064), 'relationship' (0.055), 'environmental factors' (0.080), 'technology and qualification' (0.239), 'economic factors' (0.278), and 'firm's capabilities' (0.285). The experts have given 80% weightage to the three factors: 'technology and qualification', 'economic factors', and 'firm's capabilities'.
- Chapter 5 analyzed the composition and generation rates of MW from 75 HCFs in Uttarakhand, Northern State of India and developed the predictive models using MLR and ANN and compared the performance parameters of both the models. ANN yielded better results than multiple regression modeling.
- The composition of the MW in various HCFs is like: for 'general hospital' yellow waste carries 57.65% share followed by red (23.09%) and blue (14.56%). In 'nursing homes', 'yellow waste' contributes 68.57%, 'red' 14.05% and 'blue' 17.38% in the total. In clinics and centers', maximum share is taken by 'yellow waste' (58.33%), followed by 'red' (25.93%) and 'blue' (15.74%). In 'child and maternity hospitals', 'blue waste' contributes 50% of the total waste and 'yellow' 30% and 'red' is 20% only. 'Yellow waste' contributes more than 50 % of the total waste in all the HCFs, except 'child & maternity hospitals', where 'blue waste' is dominating the rest two categories.

- The survey revealed that 36% of the total HCFs are not segregating their wastes as per Uttarakhand Pollution Control Board guidelines.
- Study resulted that ‘general hospitals’ contributing the highest amount (0.68 kg/patient/day) of MW among all the five categories of HCFs considered.
- ‘Hospital type’ and ‘occupancy’ are found to be the significant factors in contributing towards the quantity of MW generated.
- Chapter 5 also analyzed the seasonal variation in the quantity of MW generated from various HCFs and observed that amount of waste generated is also affected by the change in the season.
- In Chapter 6, a total of 25 key barriers were identified from the literature, field survey and brainstorming sessions, which hinder the implementation of HCWM system.
- The identified barrier were analyzed using ISM methodology, which has kept the barrier ‘lack of enforcement of biomedical waste handling rules’ at the base of the hierarchy, which is representing that it is the most significant and fundamental barrier for implementing the HCWM practices in India. “Ineffective HCWM practices” has come out as the outcome variable and has been placed at the top of the hierarchy with highest dependence power.
- The 25 barriers have been classified into four groups depending upon their driving power and dependence power, using Fuzzy-MICMAC analysis.
- The questionnaire survey reveals that group G5 (Government Regulatory Authority) has assigned the highest weightage (4.444) to importance of HCWM system (on 1-5 scale), followed by G3 (Hospital & CBWTF Managers), (4.467). The G4 (MD Students & Practitioners) has given the least importance to HCWM system with respect to their profession. Groups G1 (Doctors), (3.0) and G2 (Professors and Doctors), (3.368) have also given little importance to HCWM system in comparison to their main business. Statistical analysis shows that the HCW dealing managers and Government regulatory board employees are more concerned about the implementation of HCWM system than the doctors, professors and MD students.
- Respondents have given the highest importance to objectives: 2 (Protect the people in hospitals surroundings), 9 (Training & skills enhancement), 1 (Better hospital premises), 6 (Sustainable waste handling practices), 3 (Proper segregation) and 8 (Holistic mechanism

to deal with HCW). The objectives: 5 (Reduce cost of disposing HCW), 4 (Reduce the waste quantity) and 7 (Provide convenience to waste handling workers) are rated less comparatively.

- Questionnaire analysis reveals that respondents have given the highest importance to enablers: 8 (Segregation and collection of HCW), 7 (Latest technology adoption), 1 (Knowledge and training aids), 2 (Appreciation and motivation) and 5 (Performance matrices). The enablers: 3 (Infrastructure and convenience), 6 (Budget allocation), 4 (Collaboration and integration among HCF and CBWTF) and 9 (Frequent transportation of HCW) are rated less important comparatively.
- Respondents have given the highest importance to barriers: 3 (Budget problems), 2 (Lack of infrastructure and convenience), 7 (Lack of awareness), 9 (No frequent transportation of waste) and 5 (Lack of monitoring). The barriers: 1 (Lack of administration and doctors commitment), 8 (No maintenance staff), 10 (Non-aligned operational objectives among HCF and CBWTF), 4 (Lack of perception of self-harm) and 6 (Lack of benchmark in India) are rated less important comparatively.

## 8.5 IMPLICATIONS OF THE RESEARCH

The findings of the research have made important contributions to the literature on various issues on HCWM. The present research has following practical implications:

### 8.5.1 Implications to Hospital Administration and CBWTF Managers

- Hospital administration can use the AHP and grey based model to select the appropriate waste disposal strategy for their HCF.
- Hospital manager can select their outsourcing partners more rationally and logically, by applying the model developed in Chapter 4.
- By predicting the amount of MW to be generated by the HCF, the treatment facility managers can plan and allocate their resources as per the requirements.
- Barriers interrelationships analyzed in Chapter 6, will help the hospital administration and CBWTF managers to focus on the key areas and make the HCWM system more effective and efficient.

### 8.5.2 Implications to Academicians

- The structured review resulted the future research directions in 19 related areas, which can be taken up by the researchers for future research.
- The present study has developed a grey based AHP model for prioritizing the strategic alternatives, which can be further used by the researchers in other strategy selection process, which involves the Multi-Criteria Decision-Making (MCDM) process.
- The study has also proposed another MCDM framework based on ANP and TOPSIS in grey environment to evaluate the outsourcing partners. The researchers in other fields can also use this framework for selecting the best outsourcing partner.
- ANN modeling technique has been rated as the best tool to model the data. Hence, this technique can be used in other fields to model the longitudinal data.
- The questionnaire developed can be further used for empirical studies in order to get the perception about the respondents regarding other waste categories management.

### 8.5.3 Implications to Government Regulatory Authority

- The current status of the HCWM system in Uttarakhand, reveals that Pollution Control Boards need to make more strict policies and has to ensure the proper implementation by the HCFs.
- The Central Pollution Control Board (CPCB) need to allocate more budget in order to improve the HCWM system in India and develop more robust regulatory mechanism.
- The barriers highlighted in the ISM model will help the regulatory authority to set the measures for the HCFs and CBWTFs.
- Government authorities need to conduct extensive training programs to create the awareness among the waste handling workers and staff.

## 8.6 LIMITATIONS AND SCOPE FOR FUTURE RESEARCH

The HCWM is sensitive issue and research and techniques are ever evolving. The findings of this research add valuable contributions to the literature. However, the area of HCWM is still a fledgling. There is huge scope for the future research in this area.

The framework developed using ANP and TOPSIS under grey environment involves very tedious calculations, which is sometimes not possible practically. Hence, a program/software must be developed to make it more users friendly.

The present work has been targeted only on the Uttarakhand, Northern State of India, to calculate the waste generation rates and its composition, which may vary over the regions. Hence, such kind of studies needs to be replicated in order to find out the more clear information about the amount of waste to be generated and treated. Also, the department-wise generation rates should be analyzed. A comparative study between Government HCFs and private HCFs, will help more to find out the key focus areas and also help in benchmarking the processes.

The ISM model developed on the barriers of implementing HCWM system in India has not been validated statistically. Hence, the model can be validated by using the Structural Equation Modeling (SEM).

In the present study, the convenience questionnaire survey was done. Hence, we need to conduct it State-wise to get more clear idea about situation and make the policies accordingly.

**8.7 CHAPTER SUMMARY**

With the rising concern of public and environmental health, the handling of infectious waste has become serious issue for everyone. The last chapter summarizes the whole work done and major contributions of the present research. Various research implications have been highlighted for HCFs, CBWTFs, Government Regulatory Authorities and researchers in the related field. The present study suggested that HCFs and CBWTFs have to be more responsible to ensure the proper disposal of HCW. Also, the Government regulatory authorities have to ensure the proper implementation of the BMW Management & Handling Rules. Hence, there is an urgent need to understand the importance of HCWM system and develop the operational plans.

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## APPENDIX I

## SCHEDULE I

(Rule 5)

**Categories of Bio-Medical Waste**

| Category | Waste category type | Treatment & Disposal |
|---|---|---|
| Category I | **Human anatomical waste**<br>(Human tissue, organs, body parts) | Incineration /deep burial |
| Category 2 | **Animal waste**<br>(Tissue, organs, body parts, fluid, blood, experimental animals, waste from veterinary hospitals, college, discharge from hospitals, animal house) | Incineration / deep burial |
| Category 3 | **Microbiology and biotechnology waste***<br>(Waste from lab culture, human and animal cell culture used in research, waste from production of biological toxins, dishes and devices used for transfer of cultures) | Autoclaving / micro-waving / incineration |
| Category 4 | **Waste sharps**<br>(Needles, Syringes, scalpels, blades, glass, etc. that may cause puncture and cuts. This includes both used and unused sharps) | Disinfection (chemical treatment /auto claving / micro-waving and mutilation/ shredding |
| Category 5 | **Discarded medicines and cytotoxic drugs**<br>(Waste comprising of outdated, contaminated and discarded medicines) | Incineration /destruction and drugs disposal in secured landfills/ drugs disposal in secured |
| Category 6 | **Soiled waste**<br>(Items contaminated with blood, anybody fluid including cotton, dressing, soiled plaster cast, lines, beddings, other material contaminated with blood | Incineration autoclaving / micro-waving |

| | | |
|---|---|---|
| Category 7 | **Solid waste**<br>(Waste generated from disposable items other than waste sharps such as tubing's, catheters with blood) | Disinfection by chemical treatment autoclaving /micro-waving and mutilation/shredding |
| Category 8 | **Liquid waste****<br>(Waste from lab, washing, cleaning, housekeeping and disinfection activities) | Disinfection by chemical treatment and discharge into drains. |
| Category 9 | **Incineration ash**<br>(Ash from incineration of any bio medical waste) | disposal in municipal landfill |
| Category 10 | **Chemical waste**<br>(Chemical used in production of biological, disinfection, as insecticides etc.) | chemical treatment and discharge into drains for liquids and secured landfill for solids |

* Category 03, if disinfected locally need not to be put up in containers

**Liquid waste category 8 does not require container/bags.

## APPENDIX II

## SCHEDULE II

(Rule 6)

**Color Coding and Type of Container for Disposal of Bio-Medical Wastes**

| Color Coding | Type of Container -I | Waste Category | Treatment options as per Schedule I |
|---|---|---|---|
| Yellow | Plastic bag | Cat. 1, Cat. 2, and Cat. 3, Cat. 6. | Incineration/deep burial |
| Red | Disinfected container/plastic bag | Cat. 3, Cat. 6, Cat.7. | Autoclaving/Microwaving/ Chemical Treatment |
| Blue/White translucent | Plastic bag/puncture proof Container | Cat. 4, Cat. 7. | Autoclaving/Microwaving/ Chemical Treatment and destruction/shredding |
| Black | Plastic bag | Cat. 5 and Cat. 9 and Cat. 10. (solid) | Disposal in secured landfill |

**Notes:**

1. Color coding of waste categories with multiple treatment options as defined in Schedule I, shall be selected depending on treatment option chosen, which shall be as specified in Schedule I.

2. Waste collection bags for waste types needing incineration shall not be made of chlorinated plastics.

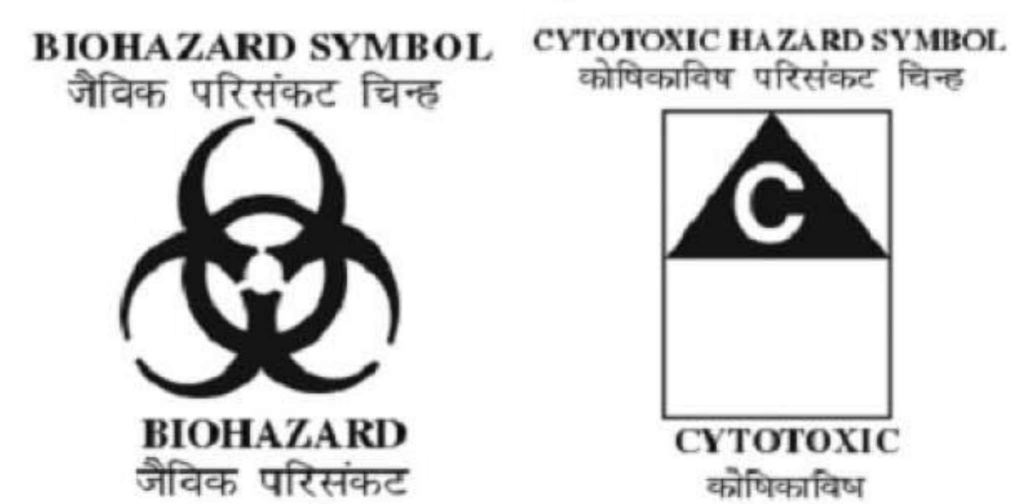
3. Categories 8 and 10 (liquid) do not require containers/bags.

4. Category 3 if disinfected locally need not be put in containers/bags.

## APPENDIX III

## SCHEDULE III

**Schedule III:** Label for Bio-Medical Waste Containers/Bags




Note: Label shall be non-washable and prominently visible.

## APPENDIX IV

## SCHEDULE IV

(Rule 6)

**Label for Transport of Bio-Medical Waste Containers/Bags**

Day............ Month..............Year...........

Date of generation...................

Waste category No........

Waste class……

Waste description………..

| **Sender's Name & Address** | **Receiver's Name & Address** |
|---|---|
| | |
| Phone No........ | Phone No............... |
| Telex. No.... | Telex. No............... |
| Fax No............... | Fax No................. |
| Contact Person........ | Contact Person......... |

**In case of emergency please contact**

Name & Address:

Phone No.

Note: Label shall be non-washable and prominently visible.

## APPENDIX V

## SCHEDULE V

(Rule 5 and Schedule 1)

## Standards for Treatment and Disposal of Bio-Medical Wastes

**Standards for Incinerators:**

All incinerators shall meet the following operating and emission standards

**A. Operating Standards**

1. Combustion efficiency (CE) shall be at least 99.00%.

2. The Combustion efficiency is computed as follows:

$$C.E. = \frac{\%C0_2}{\%C0_2 + \%\ CO} \times 100$$

3. The temperature of the primary chamber shall be 800 ± 50 deg. C°.

4. The secondary chamber gas residence time shall be at least I (one) second at 1050 ± 50 C°, with minimum 3% Oxygen in the stack gas.

**B. Emission Standards**

| Parameters | Concentration mg/Nm$^3$ at (12% $CO_2$ correction) |
|---|---|
| (1) Particulate matter | 150 |
| (2) Nitrogen Oxides | 450 |
| (3) HCI | 50 |

(4) Minimum stack height shall be 30 meters above ground

(5) Volatile organic compounds in ash shall not be more than 0.01%

## APPENDIX VI

**Reading list (176 Papers Reviewed in this Study)**

| Sl. No. | Year | First Author | Country | Journal | Vol | Issue | Title | Methodology | Topic Category |
|---|---|---|---|---|---|---|---|---|---|
| 1. | 2006 | Yong-Chul Jang | South Korea | JEM | 80 | 2 | Medical waste management in Korea | Empirical study | 1.1 |
| 2. | 2007 | Ajay Kumar Gautam | India | JEM | 83 | 3 | Preliminary study of physio-chemical treatment options for hospital wastewater | Experimental study | 2.1 |
| 3. | 2010 | Magda Magdy Abd El-Salam | Egypt | JEM | 91 | 3 | Hospital waste management in El-Beheira Governorate, Egypt | Empirical study | 1.1 |
| 4. | 2011 | Daiane Bopp Fuentefria | Brazil | JEM | 92 | 1 | Antibiotic-resistant Pseudomonas aeruginosa from hospital wastewater and superficial water: Are they genetically related? | Experimental study | 2.2 |
| 5. | 2011 | Pranav Nagarnaik | USA | JEM | 92 | 3 | Source characterization of nervous system active pharmaceutical ingredients in healthcare facility wastewaters | Experimental study | 2.3 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 6. | 2011 | Masum A. Patwary | Bangladesh | JEM | 92 | 11 | An illicit economy: Scavenging and recycling of medical waste | Empirical study | 1.2 |
| 7. | 2012 | J. Jean | France | JEM | 103 | | Identification and prioritization of bioaccumulable pharmaceutical substances discharged in hospital effluents | Theoretical/conceptual | 2.3 |
| 8. | 2012 | Anita Rajor | India | JEM | 108 | | An overview on characterization, utilization and leachate analysis of biomedical waste incinerator ash | Theoretical/conceptual | 5.1 |
| 9. | 2005 | Ah Subratty | Mauritius | IJEHR | 15 | 1 | A survey on home generated medical waste in Mauritius | Empirical Study | 1.3 |
| 10. | 2010 | Andrew Wheatley | UAE | IJEHR | 20 | 5 | Carcinogenic risk assessment for emissions from clinical waste incineration and road traffic | Experimental study | 5.2 |
| 11. | 2005 | C. Genazzini | Argentina | WM | 25 | 6 | Cement-based materials as containment systems for ash from hospital waste incineration | Experimental | 5.3 |
| 12. | 2005 | L.F. Diaz | USA | WM | 25 | 6 | Alternatives for the treatment and disposal of healthcare wastes in developing countries. | Theoretical/conceptual | 4.1 |

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| 13. | 2005 | M. Miyazaki | Japan | WM | 25 | 6 | Infectious waste management in Japan: A revised regulation and a management process in medical institutions | Theoretical/conceptual | 1.1 |
| 14. | 2005 | C.E. Da Silva | Brazil | WM | 25 | 6 | Medical wastes management in the south of Brazil | Empirical study | 1.1 |
| 15. | 2005 | Elly Kizlary | Greece | WM | 25 | 6 | Composition and production rate of dental solid waste in Xanthi, Greece: variability among dentist groups | Empirical study | 3.1 |
| 16. | 2005 | S.A. Tamplin | USA | WM | 25 | 6 | Issues and options for the safe destruction and disposal of used injection materials | Theoretical/conceptual | 4.1 |
| 17. | 2005 | M.C.M. Alvim-Ferraz | Portugal | WM | 25 | 6 | Incineration of healthcare wastes: management of atmospheric emissions through waste segregation | Experimental | 5.2 |
| 18. | 2005 | Rami Oweis | Jordan | WM | 25 | 6 | Medical waste management in Jordan: A study at the King Hussein Medical Center | Case study | 1.1 |
| 19. | 2005 | T.L. Tudor | UK | WM | 25 | 6 | Healthcare waste management: a case study from the National Health Service in Cornwall, United Kingdom | Case study | 1.1 |
| 20. | 2005 | Gayathri V. Patil | India | WM | 25 | 6 | Biomedical solid waste management in an Indian hospital: a case study | Case study | 1.3 |

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| 21. | 2005 | R. Mohee | Mauritius | WM | 25 | 6 | Medical wastes characterization in healthcare institutions in Mauritius | Case study | 1.4 |
| 22. | 2006 | J.I. Blenkharn | Brazil | WM | 26 | 3 | Medical wastes management in the south of Brazil | Theoretical/conceptual | 1.1 |
| 23. | 2006 | David E.C. Rogers | South Africa | WM | 26 | 11 | Small-scale medical waste incinerators – experiences and trials in South Africa | Experimental | 4.2 |
| 24. | 2007 | Motonobu Miyazaki | Japan | WM | 27 | 1 | The treatment of infectious waste arising from home health and medical care services: Present situation in Japan | Empirical study | 1.1 |
| 25. | 2007 | Mohammad Reza Sabour | Iran | WM | 27 | 4 | A mathematical model to predict the composition and generation of hospital wastes in Iran | Mathematical modelling | 1.3 |
| 26. | 2007 | Mohammad Karamouz | Iran | WM | 27 | 5 | Developing a master plan for hospital solid waste management: A case study | Case study | 1.3 |
| 27. | 2007 | A. Bdour | Jordan | WM | 27 | 6 | Assessment of medical wastes management practice: A case study of the northern part of Jordan | Case study | 4.1 |
| 28. | 2007 | M. Tsakona | Greece | WM | 27 | 7 | Hospital waste management and toxicity evaluation: A case study | Case study | 1.1 |
| 29. | 2007 | Sahar Mohamed Soliman | Egypt | WM | 27 | 12 | Overview of biomedical waste management in selected Governorates in Egypt: A pilot study | Empirical study | 1.1 |

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| 30. | 2008 | Bontle Mbongwe | Botswana | WM | 28 | 1 | Healthcare waste management: Current practices in selected healthcare facilities, Botswana | Report | 1.1 |
| 31. | 2008 | Mochammad Chaerul | Japan | WM | 28 | 2 | A system dynamics approach for hospital waste management | Theoretical/conceptual | 1.1 |
| 32. | 2008 | Enkhtsetseg Shinee | Japan | WM | 28 | 2 | Healthcare waste management in the capital city of Mongolia | Empirical study | 1.4 |
| 33. | 2008 | Fayez Abdulla | Jordan | WM | 28 | 2 | Site investigation on medical waste management practices in northern Jordan | Empirical study | 4.1 |
| 34. | 2008 | L.R.S. Tonuci | Brazil | WM | 28 | 5 | Microwave inactivation of Escherichia coli in healthcare waste | Experimental | 4.2 |
| 35. | 2008 | Natalija Marinkovic | Croatia | WM | 28 | 6 | Management of hazardous medical waste in Croatia | Review | 1.2 |
| 36. | 2008 | Aylin Zeren Alago¨z | Turkey | WM | 28 | 7 | Determination of the best appropriate management methods for the health-care wastes in Istanbul | Empirical study | 4.2 |
| 37. | 2008 | Felicia Nemathaga | South Africa | WM | 28 | 7 | Hospital solid waste management practices in Limpopo Province, South Africa: A case study of two hospitals | Case study | 1.1 |
| 38. | 2008 | L.F. Diaz | USA | WM | 28 | 7 | Characteristics of healthcare wastes | Theoretical/conceptual | 1.4 |

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| 39. | 2008 | T.L. Tudor | UK | WM | 28 | 7 | Realizing resource efficiency in the management of healthcare waste from the Cornwall National Health Service (NHS) in the UK | Empirical study | 1.7 |
| 40. | 2008 | Aylin Zeren Alago¨ z | Turkey | WM | 28 | 8 | Improvement and modification of the routing system for the health-care waste collection and transportation in _Istanbul | Mathematical modelling | 1.1 |
| 41. | 2008 | Pi-Fang Hsu | Taiwan | WM | 28 | 8 | Selection of infectious medical waste disposal firms by using the analytic hierarchy process (ANP) and sensitivity analysis | Mathematical modelling | 4.3 |
| 42. | 2008 | Deng Na | China | WM | 28 | 9 | Thermogravimetric analysis and kinetic study on pyrolysis of representative medical waste composition | Experimental | 1.3 |
| 43. | 2008 | Lalji K. Verma | India | WM | 28 | 12 | Biomedical waste management in nursing homes and smaller hospitals in Delhi | Empirical study | 1.1 |
| 44. | 2009 | Mehmet Emin Birpınar | Turkey | WM | 29 | 1 | Medical waste management in Turkey: A case study of Istanbul | Case study | 1.1 |
| 45. | 2009 | Y.W. Cheng | Taiwan | WM | 29 | 1 | Medical waste production at hospitals and associated factors | Empirical study | 1.3 |

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| 46. | 2009 | Gehan M.A. Mostafa | Egypt | WM | 29 | 1 | Development of a waste management protocol based on assessment of knowledge and practice of healthcare personnel in surgical departments | Theoretical/conceptual | 1.5 |
| 47. | 2009 | Saurabh Gupta | India | WM | 29 | 2 | Rules and management of biomedical waste at Vivekananda Polyclinic: A case study | Case study | 1.1 |
| 48. | 2009 | Akinwale Coker | Nigeria | WM | 29 | 2 | Medical waste management in Ibadan, Nigeria: Obstacles and prospects | Empirical study | 1.2 |
| 49. | 2009 | Lijuan Zhao | China | WM | 29 | 3 | Chemical properties of heavy metals in typical hospital waste incinerator ashes in China | Experimental | 5.1 |
| 50. | 2009 | Cristina Dutra Vieira | Brazil | WM | 29 | 4 | Composition analysis of dental solid waste in Brazil | Experimental | 3.1 |
| 51. | 2009 | Z. Bendjoudi | Algeria | WM | 29 | 4 | Healthcare waste management in Algeria and Mostaganem department | Theoretical/conceptual | 1.1 |
| 52. | 2009 | Zhang Yong | China | WM | 29 | 4 | Medical waste management in China: A case study of Nanjing | Case study | 1.1 |
| 53. | 2009 | M. Sawalem | Germany | WM | 29 | 4 | Hospital waste management in Libya: A case study | Case study | 4.1 |
| 54. | 2009 | Chen Yang | China | WM | 29 | 6 | Sustainable management measures for healthcare waste in China | Empirical study | 1.1 |

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| 55. | 2009 | L.F. Mohamed | Bahrain | WM | 29 | 8 | Hazardous healthcare waste management in the Kingdom of Bahrain | Empirical study | 1.1 |
| 56. | 2009 | Issam A. Al-Khatib | USA | WM | 29 | 8 | Solid health care waste management status at health care centers in the West Bank – Palestinian Territory | Empirical study | 1.1 |
| 57. | 2009 | Masum A. Patwary | UK | WM | 29 | 8 | Quantitative assessment of medical waste generation in the capital city of Bangladesh | Empirical study | 1.3 |
| 58. | 2009 | Sepideh Jahandideh | Iran | WM | 29 | 11 | The use of artificial neural networks and multiple linear regression to predict rate of medical waste generation | Mathematical modelling | 1.3 |
| 59. | 2010 | A. Prem Ananth | China | WM | 30 | 1 | Healthcare waste management in Asia | Theoretical/conceptual | 1.1 |
| 60. | 2010 | A. Karagiannidis | Greece | WM | 30 | 2 | A multi-criteria assessment of scenarios on thermal processing of infectious hospital wastes: A case study for Central Macedonia | Case study | 4.2 |
| 61. | 2010 | Gai Ruoyan | China | WM | 30 | 2 | Investigation of health care waste management in Binzhou District, China | Empirical study | 1.5 |
| 62. | 2010 | G. Sanida | Greece | WM | 30 | 3 | Assessing generated quantities of infectious medical wastes: A case study | Empirical study | 1.3 |

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| 63. | 2010 | Y.W. Cheng | Taiwan | WM | 30 | 8-9. | Medical waste generation in selected clinical facilities in Taiwan | Empirical study | 1.3 |
| 64. | 2010 | Anastasios Graikos | Greece | WM | 30 | 8-9. | Composition and production rate of medical waste from a small producer in Greece | Mathematical modelling | 1.3 |
| 65. | 2010 | E.A. Oliveira | Brazil | WM | 30 | 11 | Microwave inactivation of Bacillus atrophaeus spores in healthcare waste | Experimental | 4.2 |
| 66. | 2010 | Mehrdad Askarian | Iran | WM | 30 | 11 | A total quality management approach to healthcare waste management in Namazi Hospital, Iran | Mathematical modelling | 1.6 |
| 67. | 2010 | Vera Ferreira | Portugal | WM | 30 | 12 | Healthcare waste management practices and risk perceptions: Findings from hospitals in the Algarve region, Portugal | Case study | 1.1 |
| 68. | 2011 | Md. Sohrab Hossain | Malaysia | WM | 31 | 4 | Clinical solid waste management practices and its impact on human health and environment – A review | Theoretical/conceptual | 1.1 |
| 69. | 2011 | Cristina Dutra Vieira | Brazil | WM | 31 | 6 | Count, identification and antimicrobial susceptibility of bacteria recovered from dental solid waste in Brazil | Experimental | 3.1 |

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| 70. | 2011 | Chao Chung Ho | Taiwan | WM | 31 | 7 | Optimal evaluation of infectious medical waste disposal companies using the fuzzy analytic hierarchy process | Mathematical modelling | 4.3 |
| 71. | 2011 | Chao Chung Ho | Taiwan | WM | 31 | 12 | The use of failure mode and effects analysis to construct an effective disposal and prevention mechanism for infectious hospital waste | Mathematical modelling | 1.7 |
| 72. | 2012 | Mi Yan | China | WM | 32 | 7 | Sludge as dioxins suppressant in hospital waste incineration | Experimental | 5.2 |
| 73. | 2012 | Evangelos Voudrias | Greece | WM | 32 | 7 | Composition and production rate of pharmaceutical and chemical waste from Xanthi General Hospital in Greece | Mathematical modelling | 1.3 |
| 74. | 2012 | Dimitrios Komilis | Greece | WM | 32 | 7 | Hazardous medical waste generation rates of different categories of health-care facilities | Mathematical modelling | 1.3 |
| 75. | 2013 | Sebastião Roberto Soares | Brazil | WM | 33 | 1 | Applications of life cycle assessment and cost analysis in health care waste management | Experimental | 4.2 |
| 76. | 2013 | Hanqiao Liu | China | WM | 33 | 1 | Removal of carbon constituents from hospital solid waste incinerator fly ash by column flotation | Experimental | 5.1 |

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| 77. | 2013 | A.M.M. Moreira | Brazil | WM | 33 | 1 | Assessment of medical waste management at a primary health-care center in São Paulo, Brazil | Theoretical/conceptual | 1.5 |
| 78. | 2013 | Ying Chen | China | WM | 33 | 5 | Generation and distribution of PAHs in the process of medical waste incineration | Experimental | 5.2 |
| 79. | 2013 | Hu-Chen Liu | Japan | WM | 33 | 12 | Assessment of health-care waste disposal methods using a VIKOR-based fuzzy multi-criteria decision making method | Mathematical modelling | 4.2 |
| 80. | 2014 | Yukihiro Ikeda | Japan | WM | 34 | 7 | Importance of patient education on home medical care waste disposal in Japan | Empirical study | 1.5 |
| 81. | 2014 | Ching-Jong Liao | Taiwan | WM | 34 | 7 | Risk management for outsourcing biomedical waste disposal – Using the failure mode and effects analysis | Empirical study | 4.3 |
| 82. | 2008 | Patience Aseweh Abor | South Africa | IJHCQA | 21 | 4 | Medical waste management practices in a Southern African hospital | Empirical Study | 1.1 |
| 83. | 2012 | Peter Ikome Kuwoh Mochungong | Denmark | IJHCQA | 25 | 1 | Clinical waste incinerators in Cameroon – a case study | Case study | 5.4 |

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| 84. | 2013 | Patience Aseweh Abor | Ghana | IJHCQA | 26 | 4 | Managing healthcare waste in Ghana: a comparative study of public and private hospitals | Empirical Study | 1.1 |
| 85. | 2005 | E. Emmanuel | France | JHM | 117 | 1 | Eco toxicological risk assessment of hospital wastewater: a proposed framework for raw effluents discharging into urban sewer network | Theoretical/conceptual | 2.2 |
| 86. | 2006 | Puangrat Kajitvichyanukul | Thailand | JHM | 138 | 2 | Evaluation of biodegradability and oxidation degree of hospital wastewater using photo-Fenton process as the pretreatment method | Experimental study | 2.1 |
| 87. | 2007 | J.H. Yan | China | JHM | 147 | 1-2. | Degradation of PCDD/Fs by mechanochemical treatment of fly ash from medical waste incineration | Experimental study | 5.1 |
| 88. | 2008 | H.M. Zhu | China | JHM | 153 | 1-2. | Study on pyrolysis of typical medical waste materials by using TG-FTIR analysis | Experimental study | 1.2 |
| 89. | 2008 | Lijuan Zhao | China | JHM | 158 | 2-3. | Chemical properties of rare earth elements in typical medical waste incinerator ashes in China | Experimental study | 5.1 |
| 90. | 2009 | E. Gomez | UK | JHM | 161 | 2-3. | Thermal plasma technology for the treatment of wastes: A critical review | Review | 4.1 |

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| 91. | 2009 | J.H. Yan | China | JHM | 162 | 2-3. | Analysis of volatile species kinetics during typical medical waste materials pyrolysis using a distributed activation energy model | Experimental study | 5.2 |
| 92. | 2009 | Rong Xie | China | JHM | 166 | 1 | Emissions investigation for a novel medical waste incinerator | Experimental study | 5.2 |
| 93. | 2009 | Da Bo | China | JHM | 170 | 2-3. | Influence of supercritical water treatment on heavy metals in medical waste incinerator fly ash | Experimental study | 5.1 |
| 94. | 2009 | Tong Chen | China | JHM | 172 | 2-3. | Polychlorinated biphenyls emission from a medical waste incinerator in China | Experimental study | 5.2 |
| 95. | 2009 | Evangelos Gidarakos | Greece | JHM | 172 | 2-3. | Characterization and hazard evaluation of bottom ash produced from incinerated hospital waste | Experimental study | 5.1 |
| 96. | 2010 | Lijuan Zhao | China | JHM | 173 | 1-3. | Typical pollutants in bottom ashes from a typical medical waste incinerator | Experimental study | 5.1 |
| 97. | 2010 | Christina I. Kosma | Greece | JHM | 179 | 1-3. | Occurrence and removal of PPCPs in municipal and hospital wastewaters in Greece | Experimental study | 2.3 |
| 98. | 2010 | Xiao-dong Li | China | JHM | 179 | 1-3. | Levels of PCDD/Fs in soil in the vicinity of a medical waste incinerator in China: | Experimental study | 5.4 |

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| 99. | 2011 | Irene Kougemitrou | Greece | JHM | 187 | 1-3. | Characterization and management of ash produced in the hospital waste incinerator of Athens, Greece | Experimental study | 5.1 |
| 100. | 2011 | Meng Nan Chong | Australia | JHM | 199 - 200 | | Photocatalytic treatment of high concentration carbamazepine in synthetic hospital wastewater | Experimental study | 2.1 |
| 101. | 2012 | Kalliopi Anastasiadou | Greece | JHM | 207 - 208 | | Solidification/stabilization of fly and bottom ash from medical waste incineration facility | Experimental study | 5.3 |
| 102. | 2012 | C. Köhler | Luxembour g | JHM | 239 - 240 | | Elimination of pharmaceutical residues in biologically pre-treated hospital wastewater using advanced UV irradiation technology: A comparative assessment | Experimental study | 2.1 |
| 103. | 2013 | Won-Jin Sim | Republic of Korea | JHM | 248 - 249 | | Evaluation of pharmaceuticals and personal care products with emphasis on anthelmintic in human sanitary waste, sewage, hospital wastewater, livestock wastewater and receiving water | Empirical | 2.3 |

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| 104. | 2005 | Anne Woolridge | UK | RCR | 44 | 2 | The development of strategic and tactical tools, using systems analysis, for waste management in large complex organizations: a case study in UK healthcare waste | Case study | 4.1 |
| 105. | 2007 | Terry L. Tudor | UK | RCR | 50 | 3 | Towards the development of a standardized measurement unit for healthcare waste generation | Theoretical/conceptual | 1.3 |
| 106. | 2007 | T.L. Tudor | UK | RCR | 51 | 1 | Linking intended behaviour and actions: A case study of healthcare waste management in the Cornwall NHS | Case study | 1.2 |
| 107. | 2008 | Anne C.Woolridge | UK | RCR | 52 | 10 | Developing a methodology for the systematic analysis of radioactive healthcare waste generation in an acute hospital in the UK | Case study | 1.3 |
| 108. | 2010 | E. Insa | Spain | RCR | 54 | 12 | Critical review of medical waste legislation in Spain | Theoretical/conceptual | 1.1 |
| 109. | 2010 | Mohamad I. Al-Widyan | Jordan | RCR | 55 | 2 | Composition and energy content of dental solid waste | Empirical study | 3.1 |
| 110. | 2011 | Veronica E. Manga | Cameroon | RCR | 57 | | Health care waste management in Cameroon: A case study from the Southwestern Region | Case study | 1.1 |

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| 111. | 2011 | Mehtap Dursun | Turkey | RCR | 57 | | Assessment of health-care waste treatment alternatives using fuzzy multi-criteria decision making approaches | Mathematical modelling | 4.2 |
| 112. | 2013 | Gilbert Kuepouo | Cameroon | RCR | 71 | | Estimating environmental release of mercury from medical-thermometers and potential "hot spot" development: Case study of need for improved waste management capacity in Cameroon | Case study | 1.1 |
| 113. | 2005 | Idris Azni | Malaysia | JMCWM | 7 | 1 | Stabilization and utilization of hospital waste as road and asphalt aggregate | Experimental study | 5.3 |
| 114. | 2009 | Moazzam Ali | Pakistan | JMCWM | 11 | 3 | Status and challenges of hospital solid waste management: case studies from Thailand, Pakistan, and Mongolia | Case study | 1.5 |
| 115. | 2010 | Mushtaq Ahmed Memon | Japan | JMCWM | 12 | 1 | Integrated solid waste management based on the 3R approach | Theoretical/conceptual | 1.6 |
| 116. | 2011 | Mi Yan | China | JMCWM | 13 | 3 | Persistent organic pollutant emissions from medical waste incinerators in China | Experimental study | 5.2 |
| 117. | 2012 | Yukihiro Ikeda | Japan | JMCWM | 14 | 3 | Current status of waste management at home-visit nursing stations and during home visits in Japan | Empirical study | 1.1 |

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| 118. | 2013 | Yong Geng | China | JMCWM | 15 | 3 | Regional medical waste management in China: a case study of Shenyang | Case study | 1.1 |
| 119. | 2013 | Yijun Xie | China | JMCWM | 15 | 4 | Leaching toxicity and heavy metal bioavailability of medical waste incineration fly ash | Empirical study | 5.1 |
| 120. | 2005 | William K. Townend | UK | WMR | 23 | 5 | Guidelines for the evaluation and assessment of the sustainable use of resources and of wastes management at healthcare facilities | Theoretical/conceptual | 1.7 |
| 121. | 2005 | Soulivanh Phengxay | Japan | WMR | 23 | 6 | Health-care waste management in Lao PDR: a case study | Case study | 1.4 |
| 122. | 2006 | Saurabh Gupta | India | WMR | 24 | 6 | Report: Biomedical waste management practices at Balrampur Hospital, Lucknow, India | Report | 1.1 |
| 123. | 2007 | B. Aylin Zeren Alagöz | Turkey | WMR | 25 | 1 | Treatment and disposal alternatives for health-care waste in developing countries – a case study in Istanbul, Turkey | Empirical study | 4.1 |
| 124. | 2008 | Mohammad Arab | Iran | WMR | 26 | 3 | Report: The assessment of hospital waste management: a case study in Tehran | Report | 1.1 |

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| 125. | 2008 | P. Hanumantha Rao | India | WMR | 26 | 3 | Report: Hospital waste management – awareness and practices: a study of three states in India | Report | 1.5 |
| 126. | 2008 | Aleksandra Stanković | Serbia | WMR | 26 | 3 | Report: Treatment of medical waste in Nišava and Toplica districts, Serbia | Report | 1.1 |
| 127. | 2008 | Mochammad Chaerul | Japan | WMR | 26 | 3 | Resolving complexities in healthcare waste management: a goal programming approach | Mathematical modelling | 1.1 |
| 128. | 2008 | Surjit S. Katoch | India | WMR | 26 | 3 | Modelling seasonal variation in biomedical waste generation at healthcare facilities | Mathematical modelling | 1.3 |
| 129. | 2008 | Athanasios Valavanidis | Greece | WMR | 26 | 3 | Metal leachability, heavy metals, polycyclic aromatic hydrocarbons and polychlorinated biphenyls in fly and bottom ashes of a medical waste incineration facility | Experimental study | 5.1 |
| 130. | 2008 | Gita Nataraj | India | WMR | 26 | 3 | Report: Medical students for monitoring biomedical waste segregation practices – why and how? Experience from a medical college | Report | 1.4 |
| 131. | 2008 | Terry L. Tudor | UK | WMR | 26 | 3 | Utilizing a 'systems' approach to improve the management of waste from | Mathematical modelling | 1.6 |

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| | | | | | | | healthcare facilities: best practice case studies from England and Wales | | |
| 132. | 2008 | Md Maksud Alam | Bangladesh | WMR | 26 | 3 | Report: Healthcare waste characterization in Chittagong Medical College Hospital, Bangladesh | Report | 1.4 |
| 133. | 2009 | Mahdi Farzadkia | Iran | WMR | 27 | 4 | Hospital waste management status in Iran: a case study in the teaching hospitals of Iran University of Medical Sciences | Case study | 1.1 |
| 134. | 2009 | William K. Townend | UK | WMR | 27 | 4 | Factors driving the development of healthcare waste management in the United Kingdom over the past 60 years | Theoretical/conceptual | 1.1 |
| 135. | 2009 | Alireza Mesdaghinia | Iran | WMR | 27 | 4 | Waste management in primary healthcare centers of Iran | Empirical study | 2.3 |
| 136. | 2009 | René Stolze | Germany | WMR | 27 | 4 | Treatment of infectious waste: development and testing of an add-on set for used gravity displacement autoclaves | Experimental study | 1.6 |
| 137. | 2009 | Ruoyan Gai | China | WMR | 27 | 4 | Hospital medical waste management in Shandong Province, China | Empirical study | 1.1 |

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| 138. | 2009 | Hassan Taghipour | Iran | WMR | 27 | 4 | The challenge of medical waste management: a case study in northwest Iran-Tabriz | Case study | 1.1 |
| 139. | 2009 | P. Hanumantha Rao | India | WMR | 27 | 4 | Hospital waste management system – a case study of a south Indian city | Case study | 1.1 |
| 140. | 2009 | Issam A. Al-Khatib | Palestine | WMR | 27 | 4 | Management of healthcare waste in circumstances of limited resources: a case study in the hospitals of Nablus city, Palestine | Case study | 1.7 |
| 141. | 2010 | Michael A. Adedigba | Nigeria | WMR | 28 | 9 | Assessment of dental waste management in a Nigerian tertiary hospital | Theoretical/conceptual | 3.2 |
| 142. | 2010 | Hasan Hu¨seyin Eker | Turkey | WMR | 28 | 11 | Evaluation of the regulation changes in medical waste management in Turkey | Empirical study | 1.5 |
| 143. | 2011 | Olajumoke A Morenikeji | Nigeria | WMR | 29 | 3 | An investigation of the disposal of dental clinical waste in Ibadan City, south-west Nigeria | Empirical study | 3.2 |
| 144. | 2011 | E Bazrafshan | Iran | WMR | 29 | 4 | Survey of medical waste characterization and management in Iran: a case study of Sistan and Baluchestan Province | Case study | 1.4 |

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| 145. | 2011 | Akansha Nema | India | WMR | 29 | 6 | A case study: biomedical waste management practices at city hospital in Himachal Pradesh | Case study | 1.1 |
| 146. | 2011 | Israel Deneke Haylamicheal | Ethiopia | WMR | 29 | 8 | Assessing the management of healthcare waste in Hawassa city, Ethiopia | Empirical study | 1.1 |
| 147. | 2011 | Dimitrios Komilis | Greece | WMR | 29 | 8 | Hazardous medical waste generation in Greece: case studies from medical facilities in Attica and from a small insular hospital | Case study | 1.3 |
| 148. | 2011 | Hasan Hu¨seyin Eker | Turkey | WMR | 29 | 8 | Statistical analysis of waste generation in healthcare services: a case study | Case study | 1.3 |
| 149. | 2011 | Patthanasak Khammaneechan | Thailand | WMR | 29 | 10 | Effects of an incinerator project on a healthcare-waste management system | Empirical study | 5.4 |
| 150. | 2012 | Zhongxin Tan | China | WMR | 30 | 3 | Leaching characteristics of fly ash from Chinese medical waste incineration | Experimental study | 5.1 |
| 151. | 2012 | Terry Grimmond | US | WMR | 30 | 6 | Impact on carbon footprint: a life cycle assessment of disposable versus reusable sharps containers in a large US hospital | Experimental study | 5.2 |
| 152. | 2012 | Branislava Ratkovic | Serbia | WMR | 30 | 6 | Measuring the efficiency of a healthcare waste management system in Serbia with data envelopment analysis | Mathematical modelling | 1.7 |

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| 153. | 2012 | Mehrdad Askarian | Iran | WMR | 30 | 6 | Clinical laboratory waste management in Shiraz, Iran | Empirical study | 1.1 |
| 154. | 2012 | Samuel Sasu | Ghana | WMR | 30 | 6 | Assessment of pharmaceutical waste management at selected hospitals and homes in Ghana | Empirical study | 1.1 |
| 155. | 2012 | Ramin Nabizadeh | Iran | WMR | 30 | 6 | Composition and production rate of dental solid waste and associated management practices in Hamadan, Iran | Empirical study | 3.1 |
| 156. | 2012 | Israel Deneke Haylamicheal | Ethiopia | WMR | 30 | 6 | A review of legal framework applicable for the management of healthcare waste and current management practices in Ethiopia | Review | 1.1 |
| 157. | 2012 | Ali Koolivand | Iran | WMR | 30 | 6 | Investigating composition and production rate of healthcare waste and associated management practices in Bandar Abbass, Iran. | Empirical study | 1.3 |
| 158. | 2012 | Tatjana Gavrancic | Serbia | WMR | 30 | 6 | Medical waste management at the Oncology Institute of Vojvodina: possibilities of successful implementation of medical waste regulation in Serbia | Theoretical/conceptual | 1.1 |

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| 159. | 2012 | Jothiganesh Shanmugasundaram | Thailand | WMR | 30 | 6 | Geographic information system-based healthcare waste management planning for treatment site location and optimal transportation routing | Mathematical modelling | 4.2 |
| 160. | 2012 | Nesli Ciplak | Turkey | WMR | 30 | 6 | A system dynamics approach for healthcare waste management: a case study in Istanbul Metropolitan City, Turkey | Mathematical modelling | 1.3 |
| 161. | 2012 | Ezechiel O Longe | Nigeria | WMR | 30 | 6 | Healthcare waste management status in Lagos State, Nigeria: a case study from selected healthcare facilities in Ikorodu and Lagos metropolis | Empirical study | 1.1 |
| 162. | 2012 | Veronica Di Bella | Somaliland | WMR | 30 | 6 | Constraints to healthcare waste treatment in low-income countries – a case study from Somaliland | Case study | 1.5 |
| 163. | 2012 | Jan-Gerd Kühling | Germany | WMR | 30 | 9 | Management of healthcare waste: developments in Southeast Asia in the twenty-first century | Report | 1.1 |
| 164. | 2012 | João A Ferreira | Brazil | WMR | 30 | 12 | Chemical healthcare waste management in small Brazilian municipalities | Empirical study | 1.1 |

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|---|---|---|---|---|---|---|---|---|---|
| 165. | 2012 | Yitayal Shiferaw | Ethiopia | WMR | 30 | 12 | Sharps injuries and exposure to blood and bloodstained body fluids involving medical waste handlers | Empirical study | 1.1 |
| 166. | 2013 | Aysun Özkan | Turkey | WMR | 31 | 2 | Evaluation of healthcare waste treatment/ disposal alternatives by using multi-criteria decision-making techniques | Mathematical modelling | 4.2 |
| 167. | 2013 | Pooyaneh Aghapour | Iran | WMR | 31 | 3 | Analysis of the health and environmental status of sterilizers in hospital waste management: a case study of hospitals in Tehran | Empirical study | 5.4 |
| 168. | 2013 | Ibijoke Idowu | Nigeria | WMR | 31 | 5 | Profile of medical waste management in two healthcare facilities in Lagos, Nigeria: a case study | Case study | 1.1 |
| 169. | 2013 | Hao-Jun Zhang | China | WMR | 31 | 6 | Investigation of medical waste management in Gansu province, China | Empirical study | 1.1 |
| 170. | 2013 | Kyle M Johnson | USA | WMR | 31 | 7 | Improving waste segregation while reducing costs in a tertiary-care hospital in a lower–middle-income country in Central America | Empirical study | 1.5 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 171. | 2013 | Agnieszka Gielar | Poland | WMR | 31 | 7 | Environmental impact of a hospital waste incineration plant in Krakow (Poland) | Experimental study | 5.4 |
| 172. | 2013 | Derar Eleyan | Palestine | WMR | 31 | 10 | System dynamics model for hospital waste characterization and generation in developing countries | Mathematical modelling | 1.4 |
| 173. | 2013 | Yang Chen | China | WMR | 31 | 12 | Application countermeasures of nonincineration technologies for medical waste treatment in China | Experimental study | 5.2 |
| 174. | 2013 | Meriem EL Bakkali | Morocco | WMR | 31 | 12 | Characterization of bottom ash from two hospital waste incinerators in Rabat, Morocco | Experimental study | 5.1 |
| 175. | 2014 | Edris Bazrafshan | Iran | WMR | 32 | 2 | Dental solid waste characterization and management in Iran: a case study of Sistan and Baluchestan Province | Empirical study | 3.2 |
| 176. | 2014 | Esubalew Tesfahun | Ethiopia | WMR | 32 | 3 | Assessment of composition and generation rate of healthcare wastes in selected public and private hospitals of Ethiopia | Empirical study | 1.3 |

## APPENDIX VII

**Waste Generation Data for 75 HCFs (MAY, 2015)**

| S. No. | HCF Name | Hospital type | Bed occupancy (%) | Waste (kg/patient/day) | | | |
|---|---|---|---|---|---|---|---|
| | | | | Yellow | Red | Blue | Total |
| 1. | Jeevan Jyoti hospital | 1 | 45 | 0.696 | 0.166 | 0.061 | 0.923 |
| 2. | Civil hospital | 1 | 74 | 0.875 | 0.155 | 0.293 | 1.323 |
| 3. | Arpit hospital | 1 | 57 | 0.596 | 0.306 | 0.222 | 1.124 |
| 4. | Kalavati hospital | 1 | 54 | 0.257 | 0.128 | 0.239 | 0.624 |
| 5. | Hemant hospital | 1 | 61 | 0.627 | 0.352 | 0.146 | 1.124 |
| 6. | Saksham hospital | 1 | 76 | 0.968 | 0.379 | 0.276 | 1.624 |
| 7. | Chirnjeevi hospital | 1 | 39 | 0.404 | 0.173 | 0.246 | 0.823 |
| 8. | Brahama hospital | 1 | 55 | 0.424 | 0.212 | 0.090 | 0.727 |
| 9. | Tripta hospital | 1 | 47 | 0.314 | 0.086 | 0.226 | 0.625 |
| 10. | Mega city hospital | 1 | 58 | 0.513 | 0.191 | 0.218 | 0.923 |
| 11. | Tulsi hospital | 1 | 62 | 0.608 | 0.371 | 0.144 | 1.124 |
| 12. | St. Joseph hospital | 1 | 89 | 1.113 | 0.341 | 0.369 | 1.823 |
| 13. | IIT Roorkee hospital | 1 | 77 | 1.040 | 0.364 | 0.219 | 1.623 |
| 14. | Shiromani hospital | 1 | 47 | 0.442 | 0.127 | 0.154 | 0.723 |
| 15. | Bhagwati hospital | 1 | 71 | 0.816 | 0.223 | 0.284 | 1.323 |
| 16. | Shanta ram hospital | 1 | 79 | 0.902 | 0.394 | 0.227 | 1.523 |
| 17. | Leela gupta hospital | 1 | 42 | 0.282 | 0.171 | 0.171 | 0.624 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 18. | Daksh Bala ji Ortho hospital | 1 | 57 | 0.415 | 0.168 | 0.141 | 0.724 |
| 19. | SR City hospital | 1 | 65 | 0.496 | 0.270 | 0.157 | 0.923 |
| 20. | City hospital | 1 | 71 | 0.828 | 0.264 | 0.231 | 1.323 |
| 21. | HMG hospital | 1 | 57 | 0.527 | 0.344 | 0.252 | 1.123 |
| 22. | Ganga mata eye hospital | 1 | 23 | 0.291 | 0.099 | 0.133 | 0.523 |
| 23. | Rajarai hospital | 1 | 28 | 0.385 | 0.100 | 0.139 | 0.623 |
| 24. | Shatabdi hospital | 1 | 39 | 0.356 | 0.160 | 0.107 | 0.623 |
| 25. | Metro hospital & heart institute | 1 | 58 | 0.717 | 0.366 | 0.141 | 1.223 |
| 26. | Patanjli | 1 | 62 | 0.790 | 0.310 | 0.222 | 1.323 |
| 27. | Quadra hospital | 1 | 13 | 0.250 | 0.128 | 0.135 | 0.513 |
| 28. | CHC Bahadrabad Govt. hospital | 1 | 89 | 1.022 | 0.388 | 0.113 | 1.523 |
| 29. | CRW hospital | 1 | 73 | 0.856 | 0.425 | 0.743 | 2.023 |
| 30. | Sadhran Nursing Home | 2 | 79 | 1.293 | 0.280 | 0.344 | 1.918 |
| 31. | Dev nursing home | 2 | 47 | 0.213 | 0.040 | 0.081 | 0.333 |
| 32. | Pratap nursing home | 2 | 33 | 0.204 | 0.010 | 0.022 | 0.236 |
| 33. | Lakshmi nursing home | 2 | 41 | 0.230 | 0.041 | 0.064 | 0.334 |
| 34. | Abhilasha nursing home | 2 | 57 | 0.398 | 0.061 | 0.076 | 0.535 |
| 35. | Anant nursing home | 2 | 29 | 0.264 | 0.043 | 0.033 | 0.339 |
| 36. | Anand nursing home | 2 | 13 | 0.124 | 0.047 | 0.045 | 0.216 |
| 37. | Luthra nursing home | 2 | 61 | 0.458 | 0.095 | 0.082 | 0.635 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 38. | Mehra nursing home | 2 | 57 | 0.279 | 0.087 | 0.073 | 0.438 |
| 39. | Dr. Pal clinic | 4 | 41 | 0.074 | 0.031 | 0.012 | 0.118 |
| 40. | Hans eye center | 4 | 55 | 0.155 | 0.060 | 0.011 | 0.226 |
| 41. | Ganga valley clinic | 4 | 32 | 0.048 | 0.036 | 0.009 | 0.093 |
| 42. | Matrachhaya medical center | 4 | 44 | 0.060 | 0.046 | 0.021 | 0.126 |
| 43. | Doodhari barfani international medical & research center | 4 | 35 | 0.062 | 0.008 | 0.036 | 0.106 |
| 44. | Dr. Bansal child hospital | 5 | 21 | 0.006 | 0.005 | 0.003 | 0.014 |
| 45. | Dr. Mahaveer child hospital | 5 | 18 | 0.005 | 0.002 | 0.001 | 0.007 |
| 46. | Nanhe munno ka hospital (child) | 5 | 29 | 0.010 | 0.006 | 0.005 | 0.021 |
| 47. | Mother & child hospital | 5 | 41 | 0.019 | 0.010 | 0.011 | 0.039 |
| 48. | Sanjeevan hospital | 1 | 58 | NA | NA | NA | 0.75 |
| 49. | Bardhman hospital | 1 | 41 | NA | NA | NA | 1.05 |
| 50. | Deepshikha hospital | 1 | 39 | NA | NA | NA | 0.45 |
| 51. | Dev bhumi hospital | 1 | 67 | NA | NA | NA | 0.47 |
| 52. | Bhargav nursing home | 2 | 25 | NA | NA | NA | 0.57 |
| 53. | Bhatnagar nursing home | 2 | 32 | NA | NA | NA | 0.39 |
| 54. | Vinay nursing home | 2 | 29 | NA | NA | NA | 0.40 |
| 55. | Kasturi nursing home | 2 | 21 | NA | NA | NA | 0.49 |
| 56. | Prem nursing home | 2 | 48 | NA | NA | NA | 0.25 |
| 57. | Vadera nursing home | 2 | 39 | NA | NA | NA | 0.52 |
| 58. | Soundhi nursing home | 2 | 26 | NA | NA | NA | 0.36 |
| 59. | Vishal pathology | 3 | NA | NA | NA | NA | 1.02* |
| 60. | Tayagi pathology | 3 | NA | NA | NA | NA | 0.60* |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 61. | Narayan pathology | 3 | NA | NA | NA | NA | 0.91* |
| 62. | Singh pathology | 3 | NA | NA | NA | NA | 1.10* |
| 63. | Kaushik pathology | 3 | NA | NA | NA | NA | 0.59* |
| 64. | Soni Pathology | 3 | NA | NA | NA | NA | 0.88* |
| 65. | Novus pathology | 3 | NA | NA | NA | NA | 1.25* |
| 66. | Ravi diagnostic lab | 3 | NA | NA | NA | NA | 1.42* |
| 67. | Nav jeevan pathology | 3 | NA | NA | NA | NA | 0.91* |
| 68. | Mishra pathology | 3 | NA | NA | NA | NA | 0.79* |
| 69. | Jan Jeevan clinic | 4 | 49 | NA | NA | NA | 0.097 |
| 70. | Aditya Medicare center | 4 | 59 | NA | NA | NA | 0.135 |
| 71. | Ratan Bharti diagnostic center | 4 | 53 | NA | NA | NA | 0.089 |
| 72. | Suneet medical center | 4 | 37 | NA | NA | NA | 0.109 |
| 73. | Ananya child hospital | 5 | 23 | NA | NA | NA | 0.012 |
| 74. | Seema maternity home | 5 | 19 | NA | NA | NA | 0.042 |
| 75. | Preet maternity | 5 | 35 | NA | NA | NA | 0.033 |

***** No segregation at the point of generation. Since patients are not staying in the labs for long time, so we have not considered the active beds here to calculate the waste quantity and waste has been calculated as the daily average.

## APPENDIX VIII

### Reachability, Antecedent and Intersection Set for Each Barrier

**VIII (a):** Reachability, Antecedent and Intersection Set for First Level

| Barriers | Reachability Set | Antecedent set | Intersection set | Level |
|---|---|---|---|---|
| 1 | 1,5,8,9,12,19,20,21,22,25 | 1,2,3,4,6,7,9,10,11,13,14,15, 16,17,18,23,24 | 1,9 | |
| 2 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18, 19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 3 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18, 19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 4 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18, 19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 5 | 5,8,12,19,20,21,22,25 | 1,2,3,4,5,6,7,9,10,11,13,14,1 5,16,17,18,22,23,24 | 5,22 | |
| 6 | 1,5,6,8,9,12,19,20,21,22,23,24,25 | 2,3,4,6,7,10,11,13,14,15,16,1 7,18,23,24 | 6,23,24 | |
| 7 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,1 5,16,18,19,20,21,22,23,24,25 | 7,14,17 | 7,14 | |
| 8 | 8,12,19,20,21,25 | 1,2,3,4,5,6,7,8,9,10,11,13,14, 15,16,17,18,20,22,23,24 | 8,20 | |
| 9 | 1,5,8,9,12,19,20,21,22,25 | 1,2,3,4,6,7,9,10,11,13,14,15, 16,17,18,23,24 | 1,9 | |
| 10 | 1,2,3,4,5,6,8,9,10,11,12,13,15,16, 18,19,20,21,22,23,24,25 | 7,10,14,17 | 10 | |

| | | | | |
|---|---|---|---|---|
| 11 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 12 | 12,19,21,25 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24 | 12,19,21 | |
| 13 | 1,5,6,8,9,12,13,19,20,21,22,23,24,25 | 2,3,4,7,10,11,13,14,15,16,17,18 | 13 | |
| 14 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22,23,24,25 | 7,14,17 | 7,14 | |
| 15 | 1,5,6,8,9,12,13,15,16,19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 16 | 1,5,6,8,9,12,13,15,16,19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 17 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25 | 17 | 17 | |
| 18 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21,22,23,24,25 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 19 | 12,19,21,25 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24 | 12,19,21 | |
| 20 | 8,12,19,20,21,25 | 1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,17,18,20,22,23,24 | 8,20 | |
| 21 | 12,19,21,25 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24 | 12,19,21 | |

| | | | | |
|---|---|---|---|---|
| 22 | 5,8,12,19,20,21,22,25 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,17,18,22,23,24 | 5,22 | |
| 23 | 1,5,8,9,12,19,20,21,22,23,24,25 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | |
| 24 | 1,5,8,9,12,19,20,21,22,23,24,25 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | |
| 25 | 25 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24,25 | 25 | Level 1 |

**VIII (b):** Reachability, Antecedent and Intersection Set for Second Level

| **Barriers** | **Reachability Set** | **Antecedent set** | **Intersection set** | **Level** |
|---|---|---|---|---|
| 1 | 1,5,8,9,12,19,20,21,22 | 1,2,3,4,6,7,9,10,11,13,14,15,16,17,18,23,24 | 1,9 | |
| 2 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 3 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 4 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 5 | 5,8,12,19,20,21,22 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,17,18,22,23,24 | 5,22 | |
| 6 | 1,5,6,8,9,12,19,20,21,22,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 6,23,24 | |

| | | | | |
|---|---|---|---|---|
| 7 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22,23,24 | 7,14,17 | 7,14 | |
| 8 | 8,12,19,20,21 | 1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,17,18,20,22,23,24 | 8,20 | |
| 9 | 1,5,8,9,12,19,20,21,22 | 1,2,3,4,6,7,9,10,11,13,14,15,16,17,18,23,24 | 1,9 | |
| 10 | 1,2,3,4,5,6,8,9,10,11,12,13,15,16,18,19,20,21,22,23,24 | 7,10,14,17 | 10 | |
| 11 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 12 | 12,19,21 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24 | 12,19,21 | Level 2 |
| 13 | 1,5,6,8,9,12,13,19,20,21,22,23,24 | 2,3,4,7,10,11,13,14,15,16,17,18 | 13 | |
| 14 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,18,19,20,21,22,23,24 | 7,14,17 | 7,14 | |
| 15 | 1,5,6,8,9,12,13,15,16,19,20,21,22,23,24 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 16 | 1,5,6,8,9,12,13,15,16,19,20,21,22,23,24 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 17 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24 | 17 | 17 | |
| 18 | 1,2,3,4,5,6,8,9,11,12,13,15,16,18,19,20,21,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |

| | | | | |
|---|---|---|---|---|
| 19 | 12,19,21 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24 | 12,19,21 | Level 2 |
| 20 | 8,12,19,20,21 | 1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,17,18,20,22,23,24 | 8,20 | |
| 21 | 12,19,21 | 1,2,3,4,5,6,7,8,9,10,11,12,13,14,15,16,17,18,19,20,21,22,23,24 | 12,19,21 | Level 2 |
| 22 | 5,8,12,19,20,21,22 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,17,18,22,23,24 | 5,22 | |
| 23 | 1,5,8,9,12,19,20,21,22,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | |
| 24 | 1,5,8,9,12,19,20,21,22,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | |

**VIII (c):** Reachability, Antecedent and Intersection Set for Third Level

| **Barriers** | **Reachability Set** | **Antecedent set** | **Intersection set** | **Level** |
|---|---|---|---|---|
| 1 | 1,5,8,9,,20,22 | 1,2,3,4,6,7,9,10,11,13,14,15,16,17,18,23,24 | 1,9 | |
| 2 | 1,2,3,4,5,6,8,9,11,13,15,16,18,20,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 3 | 1,2,3,4,5,6,8,9,11,13,15,16,18,20,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |

| | | | | |
|---|---|---|---|---|
| 4 | 1,2,3,4,5,6,8,9,11,13,15,16,18,20,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 5 | 5,8,20,22 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,17,18,22,23,24 | 5,22 | |
| 6 | 1,5,6,8,9,20,22,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 6,23,24 | |
| 7 | 1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,18,20,22,23,24 | 7,14,17 | 7,14 | |
| 8 | 8,20 | 1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,17,18,20,22,23,24 | 8,20 | Level 3 |
| 9 | 1,5,8,9,20,22 | 1,2,3,4,6,7,9,10,11,13,14,15,16,17,18,23,24 | 1,9 | |
| 10 | 1,2,3,4,5,6,8,9,10,11,13,15,16,18,20,22,23,24 | 7,10,14,17 | 10 | |
| 11 | 1,2,3,4,5,6,8,9,11,13,15,16,18,20,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 13 | 1,5,6,8,9,13,20,22,23,24 | 2,3,4,7,10,11,13,14,15,16,17,18 | 13 | |
| 14 | 1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,18,20,22,23,24 | 7,14,17 | 7,14 | |
| 15 | 1,5,6,8,9,13,15,16,20,22,23,24 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 16 | 1,5,6,8,9,13,15,16,20,22,23,24 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 17 | 1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,17,18,20,22,23,24 | 17 | 17 | |

| | | | | |
|---|---|---|---|---|
| 18 | 1,2,3,4,5,6,8,9,11,13,15,16,18,20,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 20 | 8,20 | 1,2,3,4,5,6,7,8,9,10,11,13,14,15,16,17,18,20,22,23,24 | 8,20 | Level 3 |
| 22 | 5,8,20,22 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,17,18,22,23,24 | 5,22 | |
| 23 | 1,5,8,9,20,22,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | |
| 24 | 1,5,8,9,20,22,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | |

**VIII (d):** Reachability, Antecedent and Intersection Set for Fourth Level

| **Barriers** | **Reachability Set** | **Antecedent set** | **Intersection set** | **Level** |
|---|---|---|---|---|
| 1 | 1,5,9,,22 | 1,2,3,4,6,7,9,10,11,13,14,15,16,17,18,23,24 | 1,9 | |
| 2 | 1,2,3,4,5,6,9,11,13,15,16,18,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 3 | 1,2,3,4,5,6,9,11,13,15,16,18,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 4 | 1,2,3,4,5,6,9,11,13,15,16,18,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 5 | 5,22 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,17,18,22,23,24 | 5,22 | Level 4 |
| 6 | 1,5,6,9,22,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 6,23,24 | |
| 7 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,18,22,23,24 | 7,14,17 | 7,14 | |

| | | | | |
|---|---|---|---|---|
| 9 | 1,5,9,22 | 1,2,3,4,6,7,9,10,11,13,14,15,16,17,18,23,24 | 1,9 | |
| 10 | 1,2,3,4,5,6,9,10,11,13,15,16,18,22,23,24 | 7,10,14,17 | 10 | |
| 11 | 1,2,3,4,5,6,9,11,13,15,16,18,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 13 | 1,5,6,9,13,22,23,24 | 2,3,4,7,10,11,13,14,15,16,17,18 | 13 | |
| 14 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,18,22,23,24 | 7,14,17 | 7,14 | |
| 15 | 1,5,6,9,13,15,16,22,23,24 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 16 | 1,5,6,9,13,15,16,22,23,24 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 17 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,17,18,22,23,24 | 17 | 17 | |
| 18 | 1,2,3,4,5,6,9,11,13,15,16,18,22,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 22 | 5,22 | 1,2,3,4,5,6,7,9,10,11,13,14,15,16,17,18,22,23,24 | 5,22 | Level 4 |
| 23 | 1,5,9,22,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | |
| 24 | 1,5,9,22,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | |

**VIII (e):** Reachability, Antecedent and Intersection Set for Fifth Level

| **Barriers** | **Reachability Set** | **Antecedent set** | **Intersection set** | **Level** |
|---|---|---|---|---|
| 1 | 1,9, | 1,2,3,4,6,7,9,10,11,13,14,15,16,17,18,23,24 | 1,9 | Level 5 |
| 2 | 1,2,3,4,6,9,11,13,15,16,18,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |

| | | | | |
|---|---|---|---|---|
| 3 | 1,2,3,4,6,9,11,13,15,16,18,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 4 | 1,2,3,4,6,9,11,13,15,16,18,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 6 | 1,6,9,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 6,23,24 | |
| 7 | 1,2,3,4,6,7,9,10,11,13,14,15,16,18,23,24 | 7,14,17 | 7,14 | |
| 9 | 1,9 | 1,2,3,4,6,7,9,10,11,13,14,15,16,17,18,23,24 | 1,9 | Level 5 |
| 10 | 1,2,3,4,6,9,10,11,13,15,16,18,23,24 | 7,10,14,17 | 10 | |
| 11 | 1,2,3,4,6,9,11,13,15,16,18,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 13 | 1,6,9,13,23,24 | 2,3,4,7,10,11,13,14,15,16,17,18 | 13 | |
| 14 | 1,2,3,4,6,7,9,10,11,13,14,15,16,18,23,24 | 7,14,17 | 7,14 | |
| 15 | 1,6,9,13,15,16,23,24 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 16 | 1,6,9,13,15,16,23,24 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 17 | 1,2,3,4,6,7,9,10,11,13,14,15,16,17,18,23,24 | 17 | 17 | |
| 18 | 1,2,3,4,6,9,11,13,15,16,18,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 23 | 1,9,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | |
| 24 | 1,9,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | |

**VIII (f):** Reachability, Antecedent and Intersection Set for Sixth Level

| **Barriers** | **Reachability Set** | **Antecedent set** | **Intersection set** | **Level** |
|---|---|---|---|---|
| 2 | 2,3,4,6,11,13,15,16,18,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 3 | 2,3,4,6,11,13,15,16,18,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 4 | 2,3,4,6,11,13,15,16,18,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 6 | 6,23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 6,23,24 | Level 6 |
| 7 | 2,3,4,6,7,10,11,13,14,15,16,18,23,24 | 7,14,17 | 7,14 | |
| 10 | 2,3,4,6,10,11,13,15,16,18,23,24 | 7,10,14,17 | 10 | |
| 11 | 2,3,4,6,11,13,15,16,18,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 13 | 6,13,23,24 | 2,3,4,7,10,11,13,14,15,16,17,18 | 13 | |
| 14 | 2,3,4,6,7,10,11,13,14,15,16,18,23,24 | 7,14,17 | 7,14 | |
| 15 | 6,13,15,16,23,24 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 16 | 6,13,15,16,23,24 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 17 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 17 | 17 | |
| 18 | 2,3,4,6,11,13,15,16,18,23,24 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 23 | 23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | Level 6 |

| | | | | |
|---|---|---|---|---|
| 24 | 23,24 | 2,3,4,6,7,10,11,13,14,15,16,17,18,23,24 | 23,24 | Level 6 |

**VIII (g):** Reachability, Antecedent and Intersection Set for Seventh Level

| **Barriers** | **Reachability Set** | **Antecedent set** | **Intersection set** | Level |
|---|---|---|---|---|
| 2 | 2,3,4,11,13,15,16,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 3 | 2,3,4,11,13,15,16,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 4 | 2,3,4,11,13,15,16,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 7 | 2,3,4,7,10,11,13,14,15,16,18, | 7,14,17 | 7,14 | |
| 10 | 2,3,4,10,11,13,15,16,18 | 7,10,14,17 | 10 | |
| 11 | 2,3,4,11,13,15,16,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 13 | 13 | 2,3,4,7,10,11,13,14,15,16,17,18 | 13 | Level 7 |
| 14 | 2,3,4,7,10,11,13,14,15,16,18 | 7,14,17 | 7,14 | |
| 15 | 13,15,16 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 16 | 13,15,16 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | |
| 17 | 2,3,4,7,10,11,13,14,15,16,17,18 | 17 | 17 | |
| 18 | 2,3,4,11,13,15,16,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |

**VIII (h):** Reachability, Antecedent and Intersection Set for Eighth Level

| Barriers | Reachability Set | Antecedent set | Intersection set | Level |
|---|---|---|---|---|
| 2 | 2,3,4,11,15,16,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 3 | 2,3,4,11,15,16,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 4 | 2,3,4,11,15,16,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 7 | 2,3,4,7,10,11,14,15,16,18 | 7,14,17 | 7,14 | |
| 10 | 2,3,4,10,11,15,16,18 | 7,10,14,17 | 10 | |
| 11 | 2,3,4,11,15,16,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |
| 14 | 2,3,4,7,10,11,14,15,16,18 | 7,14,17 | 7,14 | |
| 15 | 15,16 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | Level 8 |
| 16 | 15,16 | 2,3,4,7,10,11,14,15,16,17,18 | 15,16 | Level 8 |
| 17 | 2,3,4,7,10,11,14,15,16,17,18 | 17 | 17 | |
| 18 | 2,3,4,11,15,16,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | |

**VIII (i):** Reachability, Antecedent and Intersection Set for Ninth Level

| Barriers | Reachability Set | Antecedent set | Intersection set | Level |
|---|---|---|---|---|
| 2 | 2,3,4,11,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | Level 9 |
| 3 | 2,3,4,11,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | Level 9 |
| 4 | 2,3,4,11,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | Level 9 |
| 7 | 2,3,4,7,10,11,14,18 | 7,14,17 | 7,14 | |
| 10 | 2,3,4,10,11,18 | 7,10,14,17 | 10 | |

| | | | | |
|---|---|---|---|---|
| 11 | 2,3,4,11,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | Level 9 |
| 14 | 2,3,4,7,10,11,14,18 | 7,14,17 | 7,14 | |
| 17 | 2,3,4,7,10,11,14,17,18 | 17 | 17 | |
| 18 | 2,3,4,11,18 | 2,3,4,7,10,11,14,17,18 | 2,3,4,11,18 | Level 9 |

**VIII (j):** Reachability, Antecedent and Intersection Set for Tenth Level

| **Barriers** | **Reachability Set** | **Antecedent set** | **Intersection set** | **Level** |
|---|---|---|---|---|
| 7 | 7,10,14 | 7,14,17 | 7,14 | |
| 10 | 10 | 7,10,14,17 | 10 | Level 10 |
| 14 | 7,10,14 | 7,14,17 | 7,14 | |
| 17 | 7,10,14,17 | 17 | 17 | |

**VIII (j):** Reachability, Antecedent and Intersection Set for Eleventh Level

| **Barriers** | **Reachability Set** | **Antecedent set** | **Intersection set** | **Level** |
|---|---|---|---|---|
| 7 | 7,14 | 7,14,17 | 7,14 | Level 11 |
| 14 | 7,14 | 7,14,17 | 7,14 | Level 11 |
| 17 | 7,14,17 | 17 | 17 | |

**VIII (k):** Reachability, Antecedent and Intersection Set for Twelfth Level

| **Barriers** | **Reachability Set** | **Antecedent set** | **Intersection set** | **Level** |
|---|---|---|---|---|
| 17 | 17 | 17 | 17 | Level 12 |

**APPENDIX IX**

**QUESTIONNAIRE**

**A Survey on Healthcare Waste Management System Conducted by IIT Roorkee**

**Section I: Organizational Profile**

**1.1 Name of the organization ________________________________.**

**1.2 Type of organization**

(a) HCF (b) CBWTF (c) Educational Research Institution (d) Pollution Control Board

**1.3 Total number of employees in the organizations_________.**

**1.4 For HCF:**

**1.4.1 Type of HCF**

(a) General hospitals (b) Nursing home (c) Pathology (d) Clinic & center (e) Child & maternity hospital (f) Any other_________________

**1.4.2 Bed capacity _________.**

**1.4.3 Average number of inpatients _______.**

**1.4.4 Average number of outpatients' _______.**

**1.4.5 Average quantity of total biomedical waste generated per day (kg/day/bed) _______.**

**Section II: HCWM Practices**

**2.1 Please provide your opinion on how important HCWM is to your core business?**

Tick the option that suits your opinion most: 1=Not important, 2=Least important, 3=Important, 4=Highly important, 5=Critical

(a) Not important (b) Least important (c) Important (d) Highly important (e) Critical

**2.2 What are the principal objectives in implementing HCWM system in your organization?**

| Principal Objectives | Strongly Disagree (1) | Disagree (2) | Neutral (3) | Agree (4) | Strongly Agree (5) |
|---|---|---|---|---|---|
| 1. To provide better hospital premises and quality services to the patients. | | | | | |
| 2. To protect the patients, staff and public from the infectious waste. | | | | | |
| 3. To implement proper segregation system. | | | | | |
| 4. To reduce the infectious waste by implementing 3 Rs: reduce, reuse, and recycle. | | | | | |
| 5. To reduce the cost of disposing the HCW. | | | | | |
| 6. To develop sustainable practices of handling waste | | | | | |
| 7. To provide convenience to waste handling workers. | | | | | |
| 8. To develop holistic mechanism to deal with biomedical waste. | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 9. Providing training and enhancing skills of waste handling staff and workers. | | | | | |

**2.3 Please indicate the level of importance in addressing the following issues for the effective implementation of HCWM practices in your organization.**

| Issues | Not Important (1) | Moderately Important (2) | Important (3) | Very Important (4) | Extremely Important (5) |
|---|---|---|---|---|---|
| 1. Knowledge & training aids to waste handling workers and staff. | | | | | |
| 2. Appreciation and motivation. | | | | | |
| 3. Infrastructure and convenience. | | | | | |
| 4. Collaboration and integration among HCFs and CBWTFs. | | | | | |
| 5. Development of the performances matrices. | | | | | |
| 6. Budget allocation in HCWM. | | | | | |
| 7. Adoption of latest technology in treating the waste. | | | | | |
| 8. Segregation and collection of HCW. | | | | | |
| 9. Frequent transportation of HCW. | | | | | |

**2.4 Please indicate the level of importance of each barrier in inhibiting the implementation of HCWM practices:**

| Barriers of implementing HCWM practices | Not Important (1) | Moderately Important (2) | Important (3) | Very Important (4) | Extremely Important (5) |
|---|---|---|---|---|---|
| 1. Lack of hospital administration and doctors commitment. | | | | | |
| 2. Lack of infrastructure& convenience. | | | | | |
| 3. Budget problems. | | | | | |
| 4. Lack of perception of self-harm. | | | | | |
| 5. Lack of monitoring. | | | | | |
| 6. Lack of benchmark in India. | | | | | |
| 7. Lack of awareness among waste handling staff & workers. | | | | | |
| 8. No maintenance staff at treatment facility. | | | | | |
| 9. No frequent transportation of bio-medical waste from HCF to CBWTF. | | | | | |

| | | | | | |
|---|---|---|---|---|---|
| 10. Non-aligned operational objectives among HCFs & CBWTFs. | | | | | |

**2.5 Please indicate that how the following enablers of HCWM influence the level of implementation of waste handling & disposal practices.**

| Enabler | Exceptionally Low (1) | Very Low (2) | Average (3) | Above 4average (4) | High (5) | Very High (6) | Exceptionally High (7) |
|---|---|---|---|---|---|---|---|
| 1. Hospital administration commitment (E1). | | | | | | | |
| 2. Knowledge and training aids (E2). | | | | | | | |
| 3. Enforcement of Biomedical Waste Handling Rules by Government (E3). | | | | | | | |
| 4. Proper segregation and collection of HCW (E4). | | | | | | | |
| 5. Proper selection of CBWTF (E5). | | | | | | | |

**Section III: Respondent Profile**

**3.1 Name (optional) ____________________________.**

**3.2 Contact address __________________________________.**

**3.3 Designation in the organization ____________________________.**

**3.4 Work profile**

(a) Administration (b) Doctors (c) Manager (d) Staff (e) Waste handling workers (f) Policy maker

**3.5 Your experience (in years) in the current field**

(a) Less than 5 (b) 5-10 (c) 10-15 (d) 15-20 (e) More than 20

**Abbreviations used:**

CBWTF: Common-Biomedical Waste Treatment Facility

HCF: Healthcare Facility

HCW: Healthcare Waste

HCWM: Healthcare Waste Management

**APPENDIX X**

**Post-HOC Analysis for Hypothesis 2 (Question 2.2)**

**Post-HOC Test (Tukey-HSD)**

| **Dependent Variable (Objective)** | **(I) Group** | **(J) Group** | **Mean Difference (I-J)** | **Std. Error** | **Sig.** | **95% Confidence Interval** | |
|---|---|---|---|---|---|---|---|
| | | | | | | **Lower Bound** | **Upper Bound** |
| **Objective 1** | 1 | 2 | .0361 | .22838 | 1.000 | -.5963 | .6686 |
| | | 3 | 1.3098* | .24958 | .000 | .6186 | 2.0010 |
| | | 4 | .1185 | .21342 | .981 | -.4725 | .7095 |
| | | 5 | .1765 | .23295 | .942 | -.4687 | .8216 |
| | 2 | 1 | -.0361 | .22838 | 1.000 | -.6686 | .5963 |
| | | 3 | 1.2737* | .29348 | .000 | .4609 | 2.0864 |
| | | 4 | .0824 | .26342 | .998 | -.6471 | .8119 |
| | | 5 | .1404 | .27948 | .987 | -.6336 | .9143 |
| | 3 | 1 | -1.3098* | .24958 | .000 | -2.0010 | -.6186 |
| | | 2 | -1.2737* | .29348 | .000 | -2.0864 | -.4609 |
| | | 4 | -1.1913* | .28200 | .000 | -1.9723 | -.4104 |
| | | 5 | -1.1333* | .29706 | .002 | -1.9560 | -.3107 |
| | 4 | 1 | -.1185 | .21342 | .981 | -.7095 | .4725 |
| | | 2 | -.0824 | .26342 | .998 | -.8119 | .6471 |
| | | 3 | 1.1913* | .28200 | .000 | .4104 | 1.9723 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5 | .0580 | .26740 | 1.000 | -.6825 | .7985 |
| | 5 | 1 | -.1765 | .23295 | .942 | -.8216 | .4687 |
| | | 2 | -.1404 | .27948 | .987 | -.9143 | .6336 |
| | | 3 | 1.1333* | .29706 | .002 | .3107 | 1.9560 |
| | | 4 | -.0580 | .26740 | 1.000 | -.7985 | .6825 |
| **Objective 2** | 1 | 2 | .3106 | .18626 | .458 | -.2052 | .8265 |
| | | 3 | 1.5176* | .20355 | .000 | .9539 | 2.0814 |
| | | 4 | .0887 | .17406 | .986 | -.3934 | .5707 |
| | | 5 | .8399* | .18999 | .000 | .3137 | 1.3660 |
| | 2 | 1 | -.3106 | .18626 | .458 | -.8265 | .2052 |
| | | 3 | 1.2070* | .23936 | .000 | .5441 | 1.8699 |
| | | 4 | -.2220 | .21484 | .840 | -.8169 | .3730 |
| | | 5 | .5292 | .22794 | .145 | -.1020 | 1.1605 |
| | 3 | 1 | -1.5176* | .20355 | .000 | -2.0814 | -.9539 |
| | | 2 | -1.2070* | .23936 | .000 | -1.8699 | -.5441 |
| | | 4 | -1.4290* | .23000 | .000 | -2.0659 | -.7920 |
| | | 5 | -.6778* | .24228 | .046 | -1.3487 | -.0068 |
| | 4 | 1 | -.0887 | .17406 | .986 | -.5707 | .3934 |
| | | 2 | .2220 | .21484 | .840 | -.3730 | .8169 |
| | | 3 | 1.4290* | .23000 | .000 | .7920 | 2.0659 |
| | | 5 | .7512* | .21809 | .007 | .1472 | 1.3552 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 1 | -.8399* | .18999 | .000 | -1.3660 | -.3137 |
| | | 2 | -.5292 | .22794 | .145 | -1.1605 | .1020 |
| | | 3 | .6778* | .24228 | .046 | .0068 | 1.3487 |
| | | 4 | -.7512* | .21809 | .007 | -1.3552 | -.1472 |
| **Objective 3** | 1 | 2 | .2353 | .22617 | .836 | -.3910 | .8616 |
| | | 3 | -.2980 | .24717 | .748 | -.9825 | .3864 |
| | | 4 | .1483 | .21136 | .956 | -.4370 | .7337 |
| | | 5 | .2908 | .23070 | .716 | -.3480 | .9297 |
| | 2 | 1 | -.2353 | .22617 | .836 | -.8616 | .3910 |
| | | 3 | -.5333 | .29065 | .358 | -1.3382 | .2716 |
| | | 4 | -.0870 | .26087 | .997 | -.8094 | .6355 |
| | | 5 | .0556 | .27678 | 1.000 | -.7109 | .8221 |
| | 3 | 1 | .2980 | .24717 | .748 | -.3864 | .9825 |
| | | 2 | .5333 | .29065 | .358 | -.2716 | 1.3382 |
| | | 4 | .4464 | .27927 | .501 | -.3270 | 1.2198 |
| | | 5 | .5889 | .29419 | .271 | -.2258 | 1.4036 |
| | 4 | 1 | -.1483 | .21136 | .956 | -.7337 | .4370 |
| | | 2 | .0870 | .26087 | .997 | -.6355 | .8094 |
| | | 3 | -.4464 | .27927 | .501 | -1.2198 | .3270 |
| | | 5 | .1425 | .26481 | .983 | -.5908 | .8759 |
| | 5 | 1 | -.2908 | .23070 | .716 | -.9297 | .3480 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 | -.0556 | .27678 | 1.000 | -.8221 | .7109 |
| | | 3 | -.5889 | .29419 | .271 | -1.4036 | .2258 |
| | | 4 | -.1425 | .26481 | .983 | -.8759 | .5908 |
| **Objective 4** | 1 | 2 | .6904 | .31832 | .199 | -.1911 | 1.5719 |
| | | 3 | -1.6745* | .34787 | .000 | -2.6379 | -.7111 |
| | | 4 | .3197 | .29747 | .819 | -.5041 | 1.1435 |
| | | 5 | -.7190 | .32470 | .181 | -1.6182 | .1803 |
| | 2 | 1 | -.6904 | .31832 | .199 | -1.5719 | .1911 |
| | | 3 | -2.3649* | .40907 | .000 | -3.4978 | -1.232 |
| | | 4 | -.3707 | .36717 | .851 | -1.3875 | .6461 |
| | | 5 | -1.4094* | .38955 | .004 | -2.4882 | -.3306 |
| | 3 | 1 | 1.6745* | .34787 | .000 | .7111 | 2.6379 |
| | | 2 | 2.3649* | .40907 | .000 | 1.2321 | 3.4978 |
| | | 4 | 1.9942* | .39306 | .000 | .9057 | 3.0827 |
| | | 5 | .9556 | .41405 | .149 | -.1911 | 2.1022 |
| | 4 | 1 | -.3197 | .29747 | .819 | -1.1435 | .5041 |
| | | 2 | .3707 | .36717 | .851 | -.6461 | 1.3875 |
| | | 3 | -1.9942* | .39306 | .000 | -3.0827 | -.9057 |
| | | 5 | -1.0386* | .37271 | .048 | -2.0708 | -.0065 |
| | 5 | 1 | .7190 | .32470 | .181 | -.1803 | 1.6182 |
| | | 2 | 1.4094* | .38955 | .004 | .3306 | 2.4882 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3 | -.9556 | .41405 | .149 | -2.1022 | .1911 |
| | | 4 | 1.0386* | .37271 | .048 | .0065 | 2.0708 |
| **Objective 5** | 1 | 2 | -.4396 | .31568 | .634 | -1.3138 | .4346 |
| | | 3 | -.2431 | .34498 | .955 | -1.1985 | .7122 |
| | | 4 | -.0460 | .29500 | 1.000 | -.8630 | .7709 |
| | | 5 | 1.2124* | .32200 | .002 | .3207 | 2.1042 |
| | 2 | 1 | .4396 | .31568 | .634 | -.4346 | 1.3138 |
| | | 3 | .1965 | .40567 | .989 | -.9269 | 1.3199 |
| | | 4 | .3936 | .36412 | .816 | -.6148 | 1.4020 |
| | | 5 | 1.6520* | .38632 | .000 | .5822 | 2.7219 |
| | 3 | 1 | .2431 | .34498 | .955 | -.7122 | 1.1985 |
| | | 2 | -.1965 | .40567 | .989 | -1.3199 | .9269 |
| | | 4 | .1971 | .38980 | .987 | -.8824 | 1.2766 |
| | | 5 | 1.4556* | .41061 | .005 | .3184 | 2.5927 |
| | 4 | 1 | .0460 | .29500 | 1.000 | -.7709 | .8630 |
| | | 2 | -.3936 | .36412 | .816 | -1.4020 | .6148 |
| | | 3 | -.1971 | .38980 | .987 | -1.2766 | .8824 |
| | | 5 | 1.2585* | .36961 | .008 | .2349 | 2.2820 |
| | 5 | 1 | -1.2124* | .32200 | .002 | -2.1042 | -.3207 |
| | | 2 | -1.6520* | .38632 | .000 | -2.7219 | -.5822 |
| | | 3 | -1.4556* | .41061 | .005 | -2.5927 | -.3184 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 | -1.2585* | .36961 | .008 | -2.2820 | -.2349 |
| **Objective 6** | 1 | 2 | -.0464 | .22679 | 1.000 | -.6745 | .5816 |
| | | 3 | -.4078 | .24784 | .472 | -1.0942 | .2785 |
| | | 4 | -.1151 | .21194 | .983 | -.7020 | .4718 |
| | | 5 | -.4412 | .23133 | .319 | -1.0818 | .1995 |
| | 2 | 1 | .0464 | .22679 | 1.000 | -.5816 | .6745 |
| | | 3 | -.3614 | .29144 | .728 | -1.1685 | .4457 |
| | | 4 | -.0686 | .26159 | .999 | -.7931 | .6558 |
| | | 5 | -.3947 | .27754 | .615 | -1.1633 | .3739 |
| | 3 | 1 | .4078 | .24784 | .472 | -.2785 | 1.0942 |
| | | 2 | .3614 | .29144 | .728 | -.4457 | 1.1685 |
| | | 4 | .2928 | .28004 | .834 | -.4828 | 1.0683 |
| | | 5 | -.0333 | .29499 | 1.000 | -.8503 | .7836 |
| | 4 | 1 | .1151 | .21194 | .983 | -.4718 | .7020 |
| | | 2 | .0686 | .26159 | .999 | -.6558 | .7931 |
| | | 3 | -.2928 | .28004 | .834 | -1.0683 | .4828 |
| | | 5 | -.3261 | .26554 | .735 | -1.0615 | .4093 |
| | 5 | 1 | .4412 | .23133 | .319 | -.1995 | 1.0818 |
| | | 2 | .3947 | .27754 | .615 | -.3739 | 1.1633 |
| | | 3 | .0333 | .29499 | 1.000 | -.7836 | .8503 |
| | | 4 | .3261 | .26554 | .735 | -.4093 | 1.0615 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Objective 7 | 1 | 2 | -.6192 | .31574 | .291 | -1.4936 | .2552 |
| | | 3 | .1176 | .34505 | .997 | -.8379 | 1.0732 |
| | | 4 | .1176 | .29506 | .995 | -.6995 | .9348 |
| | | 5 | -.2157 | .32206 | .963 | -1.1076 | .6762 |
| | 2 | 1 | .6192 | .31574 | .291 | -.2552 | 1.4936 |
| | | 3 | .7368 | .40575 | .369 | -.3868 | 1.8605 |
| | | 4 | .7368 | .36418 | .261 | -.2717 | 1.7454 |
| | | 5 | .4035 | .38639 | .834 | -.6665 | 1.4736 |
| | 3 | 1 | -.1176 | .34505 | .997 | -1.0732 | .8379 |
| | | 2 | -.7368 | .40575 | .369 | -1.8605 | .3868 |
| | | 4 | .0000 | .38987 | 1.000 | -1.0797 | 1.0797 |
| | | 5 | -.3333 | .41069 | .927 | -1.4707 | .8040 |
| | 4 | 1 | -.1176 | .29506 | .995 | -.9348 | .6995 |
| | | 2 | -.7368 | .36418 | .261 | -1.7454 | .2717 |
| | | 3 | .0000 | .38987 | 1.000 | -1.0797 | 1.0797 |
| | | 5 | -.3333 | .36968 | .896 | -1.3571 | .6904 |
| | 5 | 1 | .2157 | .32206 | .963 | -.6762 | 1.1076 |
| | | 2 | -.4035 | .38639 | .834 | -1.4736 | .6665 |
| | | 3 | .3333 | .41069 | .927 | -.8040 | 1.4707 |
| | | 4 | .3333 | .36968 | .896 | -.6904 | 1.3571 |
| Objective 8 | 1 | 2 | -.6037 | .29785 | .260 | -1.4286 | .2211 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3 | -.6353 | .32550 | .296 | -1.5367 | .2661 |
| | | 4 | -.2788 | .27834 | .854 | -1.0496 | .4921 |
| | | 5 | -.6797 | .30382 | .173 | -1.5211 | .1616 |
| | 2 | 1 | .6037 | .29785 | .260 | -.2211 | 1.4286 |
| | | 3 | -.0316 | .38276 | 1.000 | -1.0916 | 1.0284 |
| | | 4 | .3249 | .34356 | .878 | -.6265 | 1.2764 |
| | | 5 | -.0760 | .36450 | 1.000 | -1.0855 | .9334 |
| | 3 | 1 | .6353 | .32550 | .296 | -.2661 | 1.5367 |
| | | 2 | .0316 | .38276 | 1.000 | -1.0284 | 1.0916 |
| | | 4 | .3565 | .36779 | .868 | -.6620 | 1.3751 |
| | | 5 | -.0444 | .38743 | 1.000 | -1.1174 | 1.0285 |
| | 4 | 1 | .2788 | .27834 | .854 | -.4921 | 1.0496 |
| | | 2 | -.3249 | .34356 | .878 | -1.2764 | .6265 |
| | | 3 | -.3565 | .36779 | .868 | -1.3751 | .6620 |
| | | 5 | -.4010 | .34874 | .780 | -1.3668 | .5648 |
| | 5 | 1 | .6797 | .30382 | .173 | -.1616 | 1.5211 |
| | | 2 | .0760 | .36450 | 1.000 | -.9334 | 1.0855 |
| | | 3 | .0444 | .38743 | 1.000 | -1.0285 | 1.1174 |
| | | 4 | .4010 | .34874 | .780 | -.5648 | 1.3668 |
| **Objective 9** | 1 | 2 | .0114 | .19806 | 1.000 | -.5372 | .5599 |
| | | 3 | .0078 | .21645 | 1.000 | -.5916 | .6073 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 | .0136 | .18509 | 1.000 | -.4989 | .5262 |
| | | 5 | -.5588 | .20203 | .050 | -1.1183 | .0007 |
| | 2 | 1 | -.0114 | .19806 | 1.000 | -.5599 | .5372 |
| | | 3 | -.0035 | .25453 | 1.000 | -.7084 | .7014 |
| | | 4 | .0023 | .22846 | 1.000 | -.6304 | .6350 |
| | | 5 | -.5702 | .24239 | .136 | -1.2414 | .1011 |
| | 3 | 1 | -.0078 | .21645 | 1.000 | -.6073 | .5916 |
| | | 2 | .0035 | .25453 | 1.000 | -.7014 | .7084 |
| | | 4 | .0058 | .24457 | 1.000 | -.6715 | .6831 |
| | | 5 | -.5667 | .25763 | .187 | -1.2801 | .1468 |
| | 4 | 1 | -.0136 | .18509 | 1.000 | -.5262 | .4989 |
| | | 2 | -.0023 | .22846 | 1.000 | -.6350 | .6304 |
| | | 3 | -.0058 | .24457 | 1.000 | -.6831 | .6715 |
| | | 5 | -.5725 | .23191 | .105 | -1.2147 | .0698 |
| | 5 | 1 | .5588 | .20203 | .050 | -.0007 | 1.1183 |
| | | 2 | .5702 | .24239 | .136 | -.1011 | 1.2414 |
| | | 3 | .5667 | .25763 | .187 | -.1468 | 1.2801 |
| | | 4 | .5725 | .23191 | .105 | -.0698 | 1.2147 |

Based on observed means.

The error term is Mean Square (Error) = .543.

*. The mean difference is significant at the .05 level.

## APPENDIX XI

### Post-HOC Analysis for Hypothesis 3 (Question 2.3)

### Post-HOC Test (Tukey-HSD)

| Dependent Variable (Enabler) | (I) Group | (J) Group | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Enabler 1 | 1 | 2 | -.2951 | .21772 | .657 | -.8981 | .3078 |
| | | 3 | -.4706 | .23793 | .283 | -1.1295 | .1883 |
| | | 4 | -.4851 | .20345 | .127 | -1.0485 | .0784 |
| | | 5 | -.5261 | .22208 | .131 | -1.1412 | .0889 |
| | 2 | 1 | .2951 | .21772 | .657 | -.3078 | .8981 |
| | | 3 | -.1754 | .27978 | .970 | -.9502 | .5994 |
| | | 4 | -.1899 | .25112 | .942 | -.8854 | .5055 |
| | | 5 | -.2310 | .26643 | .908 | -.9688 | .5069 |
| | 3 | 1 | .4706 | .23793 | .283 | -.1883 | 1.1295 |
| | | 2 | .1754 | .27978 | .970 | -.5994 | .9502 |
| | | 4 | -.0145 | .26883 | 1.000 | -.7590 | .7300 |
| | | 5 | -.0556 | .28319 | 1.000 | -.8398 | .7287 |
| | 4 | 1 | .4851 | .20345 | .127 | -.0784 | 1.0485 |
| | | 2 | .1899 | .25112 | .942 | -.5055 | .8854 |
| | | 3 | .0145 | .26883 | 1.000 | -.7300 | .7590 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5 | -.0411 | .25491 | 1.000 | -.7470 | .6649 |
| | 5 | 1 | .5261 | .22208 | .131 | -.0889 | 1.1412 |
| | | 2 | .2310 | .26643 | .908 | -.5069 | .9688 |
| | | 3 | .0556 | .28319 | 1.000 | -.7287 | .8398 |
| | | 4 | .0411 | .25491 | 1.000 | -.6649 | .7470 |
| **Enabler 2** | 1 | 2 | -.3385 | .22862 | .577 | -.9716 | .2946 |
| | | 3 | -.2824 | .24984 | .790 | -.9743 | .4096 |
| | | 4 | .1032 | .21365 | .989 | -.4885 | .6948 |
| | | 5 | .1732 | .23320 | .946 | -.4726 | .8190 |
| | 2 | 1 | .3385 | .22862 | .577 | -.2946 | .9716 |
| | | 3 | .0561 | .29380 | 1.000 | -.7575 | .8698 |
| | | 4 | .4416 | .26370 | .453 | -.2886 | 1.1719 |
| | | 5 | .5117 | .27978 | .362 | -.2631 | 1.2865 |
| | 3 | 1 | .2824 | .24984 | .790 | -.4096 | .9743 |
| | | 2 | -.0561 | .29380 | 1.000 | -.8698 | .7575 |
| | | 4 | .3855 | .28230 | .651 | -.3963 | 1.1673 |
| | | 5 | .4556 | .29737 | .544 | -.3680 | 1.2791 |
| | 4 | 1 | -.1032 | .21365 | .989 | -.6948 | .4885 |
| | | 2 | -.4416 | .26370 | .453 | -1.1719 | .2886 |
| | | 3 | -.3855 | .28230 | .651 | -1.1673 | .3963 |
| | | 5 | .0700 | .26768 | .999 | -.6713 | .8114 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 5 | 1 | -.1732 | .23320 | .946 | -.8190 | .4726 |
| | | 2 | -.5117 | .27978 | .362 | -1.2865 | .2631 |
| | | 3 | -.4556 | .29737 | .544 | -1.2791 | .3680 |
| | | 4 | -.0700 | .26768 | .999 | -.8114 | .6713 |
| **Enabler 3** | 1 | 2 | -.3437 | .24298 | .620 | -1.0166 | .3293 |
| | | 3 | -2.0314* | .26554 | .000 | -2.7667 | -1.2960 |
| | | 4 | -.1995 | .22707 | .904 | -.8283 | .4293 |
| | | 5 | -2.2647* | .24785 | .000 | -2.9511 | -1.5783 |
| | 2 | 1 | .3437 | .24298 | .620 | -.3293 | 1.0166 |
| | | 3 | -1.6877* | .31225 | .000 | -2.5525 | -.8230 |
| | | 4 | .1442 | .28027 | .986 | -.6320 | .9203 |
| | | 5 | -1.9211* | .29736 | .000 | -2.7445 | -1.0976 |
| | 3 | 1 | 2.0314* | .26554 | .000 | 1.2960 | 2.7667 |
| | | 2 | 1.6877* | .31225 | .000 | .8230 | 2.5525 |
| | | 4 | 1.8319* | .30004 | .000 | 1.0010 | 2.6628 |
| | | 5 | -.2333 | .31606 | .947 | -1.1086 | .6419 |
| | 4 | 1 | .1995 | .22707 | .904 | -.4293 | .8283 |
| | | 2 | -.1442 | .28027 | .986 | -.9203 | .6320 |
| | | 3 | -1.8319* | .30004 | .000 | -2.6628 | -1.0010 |
| | | 5 | -2.0652* | .28450 | .000 | -2.8531 | -1.2773 |
| | 5 | 1 | 2.2647* | .24785 | .000 | 1.5783 | 2.9511 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 | 1.9211* | .29736 | .000 | 1.0976 | 2.7445 |
| | | 3 | .2333 | .31606 | .947 | -.6419 | 1.1086 |
| | | 4 | 2.0652* | .28450 | .000 | 1.2773 | 2.8531 |
| **Enabler 4** | 1 | 2 | .0506 | .21608 | .999 | -.5478 | .6490 |
| | | 3 | .2471 | .23614 | .833 | -.4069 | .9010 |
| | | 4 | .4442 | .20193 | .187 | -.1150 | 1.0034 |
| | | 5 | -.0196 | .22041 | 1.000 | -.6300 | .5908 |
| | 2 | 1 | -.0506 | .21608 | .999 | -.6490 | .5478 |
| | | 3 | .1965 | .27768 | .954 | -.5725 | .9655 |
| | | 4 | .3936 | .24924 | .514 | -.2966 | 1.0838 |
| | | 5 | -.0702 | .26443 | .999 | -.8025 | .6621 |
| | 3 | 1 | -.2471 | .23614 | .833 | -.9010 | .4069 |
| | | 2 | -.1965 | .27768 | .954 | -.9655 | .5725 |
| | | 4 | .1971 | .26682 | .947 | -.5418 | .9360 |
| | | 5 | -.2667 | .28106 | .877 | -1.0450 | .5117 |
| | 4 | 1 | -.4442 | .20193 | .187 | -1.0034 | .1150 |
| | | 2 | -.3936 | .24924 | .514 | -1.0838 | .2966 |
| | | 3 | -.1971 | .26682 | .947 | -.9360 | .5418 |
| | | 5 | -.4638 | .25300 | .360 | -1.1644 | .2369 |
| | 5 | 1 | .0196 | .22041 | 1.000 | -.5908 | .6300 |
| | | 2 | .0702 | .26443 | .999 | -.6621 | .8025 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3 | .2667 | .28106 | .877 | -.5117 | 1.0450 |
| | | 4 | .4638 | .25300 | .360 | -.2369 | 1.1644 |
| **Enabler 5** | 1 | 2 | -.1476 | .26121 | .980 | -.8710 | .5758 |
| | | 3 | .0980 | .28546 | .997 | -.6925 | .8886 |
| | | 4 | .1270 | .24410 | .985 | -.5490 | .8030 |
| | | 5 | -.5131 | .26645 | .309 | -1.2510 | .2248 |
| | 2 | 1 | .1476 | .26121 | .980 | -.5758 | .8710 |
| | | 3 | .2456 | .33568 | .949 | -.6840 | 1.1752 |
| | | 4 | .2746 | .30130 | .892 | -.5598 | 1.1090 |
| | | 5 | -.3655 | .31967 | .783 | -1.2508 | .5198 |
| | 3 | 1 | -.0980 | .28546 | .997 | -.8886 | .6925 |
| | | 2 | -.2456 | .33568 | .949 | -1.1752 | .6840 |
| | | 4 | .0290 | .32255 | 1.000 | -.8643 | .9222 |
| | | 5 | -.6111 | .33977 | .379 | -1.5520 | .3298 |
| | 4 | 1 | -.1270 | .24410 | .985 | -.8030 | .5490 |
| | | 2 | -.2746 | .30130 | .892 | -1.1090 | .5598 |
| | | 3 | -.0290 | .32255 | 1.000 | -.9222 | .8643 |
| | | 5 | -.6401 | .30584 | .230 | -1.4871 | .2069 |
| | 5 | 1 | .5131 | .26645 | .309 | -.2248 | 1.2510 |
| | | 2 | .3655 | .31967 | .783 | -.5198 | 1.2508 |
| | | 3 | .6111 | .33977 | .379 | -.3298 | 1.5520 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 | .6401 | .30584 | .230 | -.2069 | 1.4871 |
| **Enabler 6** | 1 | 2 | .1166 | .26600 | .992 | -.6200 | .8533 |
| | | 3 | -2.0588* | .29070 | .000 | -2.8639 | -1.2538 |
| | | 4 | .2745 | .24858 | .804 | -.4139 | .9629 |
| | | 5 | -2.2255* | .27133 | .000 | -2.9769 | -1.4741 |
| | 2 | 1 | -.1166 | .26600 | .992 | -.8533 | .6200 |
| | | 3 | -2.1754* | .34183 | .000 | -3.1221 | -1.2288 |
| | | 4 | .1579 | .30682 | .986 | -.6918 | 1.0076 |
| | | 5 | -2.3421* | .32553 | .000 | -3.2436 | -1.4406 |
| | 3 | 1 | 2.0588* | .29070 | .000 | 1.2538 | 2.8639 |
| | | 2 | 2.1754* | .34183 | .000 | 1.2288 | 3.1221 |
| | | 4 | 2.3333* | .32846 | .000 | 1.4237 | 3.2429 |
| | | 5 | -.1667 | .34600 | .989 | -1.1249 | .7915 |
| | 4 | 1 | -.2745 | .24858 | .804 | -.9629 | .4139 |
| | | 2 | -.1579 | .30682 | .986 | -1.0076 | .6918 |
| | | 3 | -2.3333* | .32846 | .000 | -3.2429 | -1.4237 |
| | | 5 | -2.5000* | .31145 | .000 | -3.3625 | -1.6375 |
| | 5 | 1 | 2.2255* | .27133 | .000 | 1.4741 | 2.9769 |
| | | 2 | 2.3421* | .32553 | .000 | 1.4406 | 3.2436 |
| | | 3 | .1667 | .34600 | .989 | -.7915 | 1.1249 |
| | | 4 | 2.5000* | .31145 | .000 | 1.6375 | 3.3625 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| Enabler 7 | 1 | 2 | .0444 | .23261 | 1.000 | -.5998 | .6885 |
| | | 3 | -.4784 | .25420 | .333 | -1.1824 | .2255 |
| | | 4 | -.2668 | .21737 | .735 | -.8688 | .3351 |
| | | 5 | .0327 | .23727 | 1.000 | -.6244 | .6898 |
| | 2 | 1 | -.0444 | .23261 | 1.000 | -.6885 | .5998 |
| | | 3 | -.5228 | .29892 | .408 | -1.3506 | .3050 |
| | | 4 | -.3112 | .26830 | .774 | -1.0542 | .4318 |
| | | 5 | -.0117 | .28466 | 1.000 | -.8000 | .7766 |
| | 3 | 1 | .4784 | .25420 | .333 | -.2255 | 1.1824 |
| | | 2 | .5228 | .29892 | .408 | -.3050 | 1.3506 |
| | | 4 | .2116 | .28722 | .947 | -.5838 | 1.0070 |
| | | 5 | .5111 | .30256 | .444 | -.3268 | 1.3490 |
| | 4 | 1 | .2668 | .21737 | .735 | -.3351 | .8688 |
| | | 2 | .3112 | .26830 | .774 | -.4318 | 1.0542 |
| | | 3 | -.2116 | .28722 | .947 | -1.0070 | .5838 |
| | | 5 | .2995 | .27235 | .806 | -.4547 | 1.0538 |
| | 5 | 1 | -.0327 | .23727 | 1.000 | -.6898 | .6244 |
| | | 2 | .0117 | .28466 | 1.000 | -.7766 | .8000 |
| | | 3 | -.5111 | .30256 | .444 | -1.3490 | .3268 |
| | | 4 | -.2995 | .27235 | .806 | -1.0538 | .4547 |
| **Enabler 8** | 1 | 2 | -.2714 | .24252 | .796 | -.9430 | .4002 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 3 | -.6118 | .26503 | .149 | -1.3457 | .1222 |
| | | 4 | .0375 | .22663 | 1.000 | -.5901 | .6651 |
| | | 5 | -.3007 | .24738 | .742 | -.9857 | .3844 |
| | 2 | 1 | .2714 | .24252 | .796 | -.4002 | .9430 |
| | | 3 | -.3404 | .31165 | .810 | -1.2034 | .5227 |
| | | 4 | .3089 | .27973 | .804 | -.4657 | 1.0836 |
| | | 5 | -.0292 | .29679 | 1.000 | -.8511 | .7927 |
| | 3 | 1 | .6118 | .26503 | .149 | -.1222 | 1.3457 |
| | | 2 | .3404 | .31165 | .810 | -.5227 | 1.2034 |
| | | 4 | .6493 | .29946 | .199 | -.1800 | 1.4786 |
| | | 5 | .3111 | .31545 | .861 | -.5625 | 1.1847 |
| | 4 | 1 | -.0375 | .22663 | 1.000 | -.6651 | .5901 |
| | | 2 | -.3089 | .27973 | .804 | -1.0836 | .4657 |
| | | 3 | -.6493 | .29946 | .199 | -1.4786 | .1800 |
| | | 5 | -.3382 | .28395 | .757 | -1.1245 | .4482 |
| | 5 | 1 | .3007 | .24738 | .742 | -.3844 | .9857 |
| | | 2 | .0292 | .29679 | 1.000 | -.7927 | .8511 |
| | | 3 | -.3111 | .31545 | .861 | -1.1847 | .5625 |
| | | 4 | .3382 | .28395 | .757 | -.4482 | 1.1245 |
| **Enabler 9** | 1 | 2 | -.0351 | .21874 | 1.000 | -.6409 | .5707 |
| | | 3 | -.4000 | .23905 | .454 | -1.0620 | .2620 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 | -.6232* | .20441 | .023 | -1.1893 | -.0571 |
| | | 5 | -.5000 | .22312 | .172 | -1.1179 | .1179 |
| | 2 | 1 | .0351 | .21874 | 1.000 | -.5707 | .6409 |
| | | 3 | -.3649 | .28110 | .693 | -1.1434 | .4135 |
| | | 4 | -.5881 | .25231 | .142 | -1.2868 | .1106 |
| | | 5 | -.4649 | .26769 | .416 | -1.2062 | .2764 |
| | 3 | 1 | .4000 | .23905 | .454 | -.2620 | 1.0620 |
| | | 2 | .3649 | .28110 | .693 | -.4135 | 1.1434 |
| | | 4 | -.2232 | .27010 | .922 | -.9712 | .5248 |
| | | 5 | -.1000 | .28452 | .997 | -.8879 | .6879 |
| | 4 | 1 | .6232* | .20441 | .023 | .0571 | 1.1893 |
| | | 2 | .5881 | .25231 | .142 | -.1106 | 1.2868 |
| | | 3 | .2232 | .27010 | .922 | -.5248 | .9712 |
| | | 5 | .1232 | .25612 | .989 | -.5861 | .8325 |
| | 5 | 1 | .5000 | .22312 | .172 | -.1179 | 1.1179 |
| | | 2 | .4649 | .26769 | .416 | -.2764 | 1.2062 |
| | | 3 | .1000 | .28452 | .997 | -.6879 | .8879 |
| | | 4 | -.1232 | .25612 | .989 | -.8325 | .5861 |

Based on observed means.

The error term is Mean Square (Error) = .662.

*. The mean difference is significant at the .05 level.

**APPENDIX XII**

**Post-HOC Analysis for Hypothesis 4 (Question 2.4)**

**Post-HOC Test**

**Multiple Comparisons**

| Dependent Variable | (I) Group | (J) Group | Mean Difference (I-J) | Std. Error | Sig. | 95% Confidence Interval Lower Bound | 95% Confidence Interval Upper Bound |
|---|---|---|---|---|---|---|---|
| Barrier 1 | 1 | 2 | -.0640 | .23590 | .999 | -.7173 | .5893 |
| | | 3 | -3.0745* | .25780 | .000 | -3.7884 | -2.3606 |
| | | 4 | -.6223* | .22045 | .043 | -1.2328 | -.0118 |
| | | 5 | -2.8856* | .24063 | .000 | -3.5520 | -2.2192 |
| | 2 | 1 | .0640 | .23590 | .999 | -.5893 | .7173 |
| | | 3 | -3.0105* | .30315 | .000 | -3.8500 | -2.1710 |
| | | 4 | -.5584 | .27210 | .248 | -1.3119 | .1952 |
| | | 5 | -2.8216* | .28869 | .000 | -3.6211 | -2.0222 |
| | 3 | 1 | 3.0745* | .25780 | .000 | 2.3606 | 3.7884 |
| | | 2 | 3.0105* | .30315 | .000 | 2.1710 | 3.8500 |
| | | 4 | 2.4522* | .29129 | .000 | 1.6455 | 3.2588 |
| | | 5 | .1889 | .30684 | .972 | -.6609 | 1.0386 |
| | 4 | 1 | .6223* | .22045 | .043 | .0118 | 1.2328 |
| | | 2 | .5584 | .27210 | .248 | -.1952 | 1.3119 |
| | | 3 | -2.4522* | .29129 | .000 | -3.2588 | -1.6455 |
| | | 5 | -2.2633* | .27620 | .000 | -3.0282 | -1.4984 |
| | 5 | 1 | 2.8856* | .24063 | .000 | 2.2192 | 3.5520 |
| | | 2 | 2.8216* | .28869 | .000 | 2.0222 | 3.6211 |
| | | 3 | -.1889 | .30684 | .972 | -1.0386 | .6609 |
| | | 4 | 2.2633* | .27620 | .000 | 1.4984 | 3.0282 |
| Barrier 2 | 1 | 2 | -.0867 | .20060 | .993 | -.6422 | .4688 |
| | | 3 | -.5569 | .21922 | .089 | -1.1640 | .0502 |
| | | 4 | -.1279 | .18746 | .960 | -.6470 | .3913 |
| | | 5 | .0098 | .20461 | 1.000 | -.5568 | .5765 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 2 | 1 | .0867 | .20060 | .993 | -.4688 | .6422 |
| | | 3 | -.4702 | .25778 | .365 | -1.1841 | .2437 |
| | | 4 | -.0412 | .23138 | 1.000 | -.6819 | .5996 |
| | | 5 | .0965 | .24548 | .995 | -.5833 | .7763 |
| | 3 | 1 | .5569 | .21922 | .089 | -.0502 | 1.1640 |
| | | 2 | .4702 | .25778 | .365 | -.2437 | 1.1841 |
| | | 4 | .4290 | .24769 | .418 | -.2570 | 1.1149 |
| | | 5 | .5667 | .26092 | .198 | -.1559 | 1.2892 |
| | 4 | 1 | .1279 | .18746 | .960 | -.3913 | .6470 |
| | | 2 | .0412 | .23138 | 1.000 | -.5996 | .6819 |
| | | 3 | -.4290 | .24769 | .418 | -1.1149 | .2570 |
| | | 5 | .1377 | .23487 | .977 | -.5128 | .7881 |
| | 5 | 1 | -.0098 | .20461 | 1.000 | -.5765 | .5568 |
| | | 2 | -.0965 | .24548 | .995 | -.7763 | .5833 |
| | | 3 | -.5667 | .26092 | .198 | -1.2892 | .1559 |
| | | 4 | -.1377 | .23487 | .977 | -.7881 | .5128 |
| Barrier 3 | 1 | 2 | .1816 | .24572 | .947 | -.4989 | .8621 |
| | | 3 | .1255 | .26853 | .990 | -.6182 | .8692 |
| | | 4 | -.4774 | .22963 | .236 | -1.1133 | .1585 |
| | | 5 | -.2190 | .25065 | .906 | -.9131 | .4752 |
| | 2 | 1 | -.1816 | .24572 | .947 | -.8621 | .4989 |
| | | 3 | -.0561 | .31577 | 1.000 | -.9306 | .8183 |
| | | 4 | -.6590 | .28343 | .144 | -1.4439 | .1259 |
| | | 5 | -.4006 | .30071 | .672 | -1.2333 | .4322 |
| | 3 | 1 | -.1255 | .26853 | .990 | -.8692 | .6182 |
| | | 2 | .0561 | .31577 | 1.000 | -.8183 | .9306 |
| | | 4 | -.6029 | .30342 | .279 | -1.4432 | .2374 |
| | | 5 | -.3444 | .31962 | .818 | -1.2296 | .5407 |
| | 4 | 1 | .4774 | .22963 | .236 | -.1585 | 1.1133 |
| | | 2 | .6590 | .28343 | .144 | -.1259 | 1.4439 |
| | | 3 | .6029 | .30342 | .279 | -.2374 | 1.4432 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 5 | .2585 | .28771 | .897 | -.5383 | 1.0552 |
| | 5 | 1 | .2190 | .25065 | .906 | -.4752 | .9131 |
| | | 2 | .4006 | .30071 | .672 | -.4322 | 1.2333 |
| | | 3 | .3444 | .31962 | .818 | -.5407 | 1.2296 |
| | | 4 | -.2585 | .28771 | .897 | -1.0552 | .5383 |
| Barrier 4 | 1 | 2 | .5315 | .25997 | .251 | -.1885 | 1.2514 |
| | | 3 | -.1843 | .28410 | .967 | -.9711 | .6025 |
| | | 4 | .5200 | .24294 | .210 | -.1528 | 1.1928 |
| | | 5 | -1.4510* | .26518 | .000 | -2.1854 | -.7166 |
| | 2 | 1 | -.5315 | .25997 | .251 | -1.2514 | .1885 |
| | | 3 | -.7158 | .33408 | .209 | -1.6410 | .2094 |
| | | 4 | -.0114 | .29986 | 1.000 | -.8419 | .8190 |
| | | 5 | -1.9825* | .31814 | .000 | -2.8635 | -1.1014 |
| | 3 | 1 | .1843 | .28410 | .967 | -.6025 | .9711 |
| | | 2 | .7158 | .33408 | .209 | -.2094 | 1.6410 |
| | | 4 | .7043 | .32101 | .189 | -.1846 | 1.5933 |
| | | 5 | -1.2667* | .33815 | .003 | -2.2031 | -.3302 |
| | 4 | 1 | -.5200 | .24294 | .210 | -1.1928 | .1528 |
| | | 2 | .0114 | .29986 | 1.000 | -.8190 | .8419 |
| | | 3 | -.7043 | .32101 | .189 | -1.5933 | .1846 |
| | | 5 | -1.9710* | .30439 | .000 | -2.8140 | -1.1281 |
| | 5 | 1 | 1.4510* | .26518 | .000 | .7166 | 2.1854 |
| | | 2 | 1.9825* | .31814 | .000 | 1.1014 | 2.8635 |
| | | 3 | 1.2667* | .33815 | .003 | .3302 | 2.2031 |
| | | 4 | 1.9710* | .30439 | .000 | 1.1281 | 2.8140 |
| Barrier 5 | 1 | 2 | -.5108 | .26634 | .313 | -1.2484 | .2268 |
| | | 3 | -.1529 | .29107 | .985 | -.9590 | .6531 |
| | | 4 | -.1790 | .24890 | .952 | -.8683 | .5103 |
| | | 5 | -.2974 | .27168 | .809 | -1.0498 | .4550 |
| | 2 | 1 | .5108 | .26634 | .313 | -.2268 | 1.2484 |
| | | 3 | .3579 | .34227 | .834 | -.5900 | 1.3058 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 | .3318 | .30721 | .816 | -.5190 | 1.1826 |
| | | 5 | .2135 | .32594 | .965 | -.6892 | 1.1161 |
| | 3 | 1 | .1529 | .29107 | .985 | -.6531 | .9590 |
| | | 2 | -.3579 | .34227 | .834 | -1.3058 | .5900 |
| | | 4 | -.0261 | .32888 | 1.000 | -.9369 | .8847 |
| | | 5 | -.1444 | .34644 | .994 | -1.1039 | .8150 |
| | 4 | 1 | .1790 | .24890 | .952 | -.5103 | .8683 |
| | | 2 | -.3318 | .30721 | .816 | -1.1826 | .5190 |
| | | 3 | .0261 | .32888 | 1.000 | -.8847 | .9369 |
| | | 5 | -.1184 | .31185 | .996 | -.9820 | .7453 |
| | 5 | 1 | .2974 | .27168 | .809 | -.4550 | 1.0498 |
| | | 2 | -.2135 | .32594 | .965 | -1.1161 | .6892 |
| | | 3 | .1444 | .34644 | .994 | -.8150 | 1.1039 |
| | | 4 | .1184 | .31185 | .996 | -.7453 | .9820 |
| Barrier 6 | 1 | 2 | .1445 | .23326 | .972 | -.5015 | .7905 |
| | | 3 | .4392 | .25492 | .424 | -.2667 | 1.1452 |
| | | 4 | .1262 | .21798 | .978 | -.4775 | .7298 |
| | | 5 | -.2941 | .23793 | .730 | -.9530 | .3648 |
| | 2 | 1 | -.1445 | .23326 | .972 | -.7905 | .5015 |
| | | 3 | .2947 | .29976 | .862 | -.5354 | 1.1249 |
| | | 4 | -.0183 | .26905 | 1.000 | -.7634 | .7268 |
| | | 5 | -.4386 | .28546 | .541 | -1.2291 | .3519 |
| | 3 | 1 | -.4392 | .25492 | .424 | -1.1452 | .2667 |
| | | 2 | -.2947 | .29976 | .862 | -1.1249 | .5354 |
| | | 4 | -.3130 | .28803 | .813 | -1.1107 | .4846 |
| | | 5 | -.7333 | .30341 | .118 | -1.5736 | .1069 |
| | 4 | 1 | -.1262 | .21798 | .978 | -.7298 | .4775 |
| | | 2 | .0183 | .26905 | 1.000 | -.7268 | .7634 |
| | | 3 | .3130 | .28803 | .813 | -.4846 | 1.1107 |
| | | 5 | -.4203 | .27312 | .539 | -1.1766 | .3361 |
| | 5 | 1 | .2941 | .23793 | .730 | -.3648 | .9530 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 2 | .4386 | .28546 | .541 | -.3519 | 1.2291 |
| | | 3 | .7333 | .30341 | .118 | -.1069 | 1.5736 |
| | | 4 | .4203 | .27312 | .539 | -.3361 | 1.1766 |
| Barrier 7 | 1 | 2 | .3808 | .32258 | .762 | -.5125 | 1.2741 |
| | | 3 | -.0157 | .35252 | 1.000 | -.9919 | .9606 |
| | | 4 | -.0563 | .30145 | 1.000 | -.8911 | .7786 |
| | | 5 | -.2712 | .32904 | .923 | -1.1825 | .6400 |
| | 2 | 1 | -.3808 | .32258 | .762 | -1.2741 | .5125 |
| | | 3 | -.3965 | .41454 | .874 | -1.5445 | .7515 |
| | | 4 | -.4371 | .37208 | .766 | -1.4675 | .5933 |
| | | 5 | -.6520 | .39476 | .468 | -1.7453 | .4412 |
| | 3 | 1 | .0157 | .35252 | 1.000 | -.9606 | .9919 |
| | | 2 | .3965 | .41454 | .874 | -.7515 | 1.5445 |
| | | 4 | -.0406 | .39832 | 1.000 | -1.1437 | 1.0625 |
| | | 5 | -.2556 | .41959 | .973 | -1.4175 | .9064 |
| | 4 | 1 | .0563 | .30145 | 1.000 | -.7786 | .8911 |
| | | 2 | .4371 | .37208 | .766 | -.5933 | 1.4675 |
| | | 3 | .0406 | .39832 | 1.000 | -1.0625 | 1.1437 |
| | | 5 | -.2150 | .37769 | .979 | -1.2609 | .8310 |
| | 5 | 1 | .2712 | .32904 | .923 | -.6400 | 1.1825 |
| | | 2 | .6520 | .39476 | .468 | -.4412 | 1.7453 |
| | | 3 | .2556 | .41959 | .973 | -.9064 | 1.4175 |
| | | 4 | .2150 | .37769 | .979 | -.8310 | 1.2609 |
| Barrier 8 | 1 | 2 | .1785 | .31959 | .981 | -.7065 | 1.0636 |
| | | 3 | .5294 | .34926 | .554 | -.4378 | 1.4966 |
| | | 4 | -.0503 | .29866 | 1.000 | -.8774 | .7768 |
| | | 5 | -.0261 | .32600 | 1.000 | -.9289 | .8767 |
| | 2 | 1 | -.1785 | .31959 | .981 | -1.0636 | .7065 |
| | | 3 | .3509 | .41070 | .913 | -.7865 | 1.4883 |
| | | 4 | -.2288 | .36863 | .972 | -1.2497 | .7920 |
| | | 5 | -.2047 | .39111 | .985 | -1.2878 | .8784 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 3 | 1 | -.5294 | .34926 | .554 | -1.4966 | .4378 |
| | | 2 | -.3509 | .41070 | .913 | -1.4883 | .7865 |
| | | 4 | -.5797 | .39463 | .585 | -1.6726 | .5132 |
| | | 5 | -.5556 | .41570 | .669 | -1.7068 | .5957 |
| | 4 | 1 | .0503 | .29866 | 1.000 | -.7768 | .8774 |
| | | 2 | .2288 | .36863 | .972 | -.7920 | 1.2497 |
| | | 3 | .5797 | .39463 | .585 | -.5132 | 1.6726 |
| | | 5 | .0242 | .37420 | 1.000 | -1.0121 | 1.0604 |
| | 5 | 1 | .0261 | .32600 | 1.000 | -.8767 | .9289 |
| | | 2 | .2047 | .39111 | .985 | -.8784 | 1.2878 |
| | | 3 | .5556 | .41570 | .669 | -.5957 | 1.7068 |
| | | 4 | -.0242 | .37420 | 1.000 | -1.0604 | 1.0121 |
| Barrier 9 | 1 | 2 | -.3550 | .31721 | .796 | -1.2335 | .5235 |
| | | 3 | .3608 | .34666 | .836 | -.5992 | 1.3208 |
| | | 4 | -.2131 | .29643 | .952 | -1.0341 | .6078 |
| | | 5 | -.3170 | .32357 | .864 | -1.2131 | .5791 |
| | 2 | 1 | .3550 | .31721 | .796 | -.5235 | 1.2335 |
| | | 3 | .7158 | .40764 | .404 | -.4131 | 1.8447 |
| | | 4 | .1419 | .36589 | .995 | -.8714 | 1.1551 |
| | | 5 | .0380 | .38819 | 1.000 | -1.0370 | 1.1131 |
| | 3 | 1 | -.3608 | .34666 | .836 | -1.3208 | .5992 |
| | | 2 | -.7158 | .40764 | .404 | -1.8447 | .4131 |
| | | 4 | -.5739 | .39169 | .587 | -1.6586 | .5108 |
| | | 5 | -.6778 | .41261 | .473 | -1.8204 | .4649 |
| | 4 | 1 | .2131 | .29643 | .952 | -.6078 | 1.0341 |
| | | 2 | -.1419 | .36589 | .995 | -1.1551 | .8714 |
| | | 3 | .5739 | .39169 | .587 | -.5108 | 1.6586 |
| | | 5 | -.1039 | .37141 | .999 | -1.1324 | .9247 |
| | 5 | 1 | .3170 | .32357 | .864 | -.5791 | 1.2131 |
| | | 2 | -.0380 | .38819 | 1.000 | -1.1131 | 1.0370 |
| | | 3 | .6778 | .41261 | .473 | -.4649 | 1.8204 |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | 4 | .1039 | .37141 | .999 | -.9247 | 1.1324 |
| Barrier 10 | 1 | 2 | .2518 | .28756 | .905 | -.5446 | 1.0482 |
| | | 3 | -.0078 | .31426 | 1.000 | -.8781 | .8625 |
| | | 4 | .2038 | .26873 | .942 | -.5405 | .9480 |
| | | 5 | -.2190 | .29333 | .945 | -1.0313 | .5934 |
| | 2 | 1 | -.2518 | .28756 | .905 | -1.0482 | .5446 |
| | | 3 | -.2596 | .36954 | .956 | -1.2830 | .7637 |
| | | 4 | -.0481 | .33169 | 1.000 | -.9666 | .8705 |
| | | 5 | -.4708 | .35191 | .668 | -1.4453 | .5038 |
| | 3 | 1 | .0078 | .31426 | 1.000 | -.8625 | .8781 |
| | | 2 | .2596 | .36954 | .956 | -.7637 | 1.2830 |
| | | 4 | .2116 | .35508 | .975 | -.7718 | 1.1949 |
| | | 5 | -.2111 | .37405 | .980 | -1.2470 | .8247 |
| | 4 | 1 | -.2038 | .26873 | .942 | -.9480 | .5405 |
| | | 2 | .0481 | .33169 | 1.000 | -.8705 | .9666 |
| | | 3 | -.2116 | .35508 | .975 | -1.1949 | .7718 |
| | | 5 | -.4227 | .33670 | .719 | -1.3551 | .5097 |
| | 5 | 1 | .2190 | .29333 | .945 | -.5934 | 1.0313 |
| | | 2 | .4708 | .35191 | .668 | -.5038 | 1.4453 |
| | | 3 | .2111 | .37405 | .980 | -.8247 | 1.2470 |
| | | 4 | .4227 | .33670 | .719 | -.5097 | 1.3551 |

The error term is Mean Square (Error) = 1.145.

*. The mean difference is significant at the .05 level.

## PAPERS PUBISHED FROM THIS RESEARCH

### 1. International Journal:

1. Thakur, V., and Ramesh, A. (2015) "Healthcare Waste Management Research: A Structured Analysis and Review (2005-14)", *Waste Management & Research*, 1-16. DOI: 10.1177/0734242x15594248. **(SCI; Impact factor: 1.523).**
2. Thakur, V., and Ramesh, A. (2015) "Selection of Waste Disposal Firms Using Grey Theory Based Multi-Criteria Decision-Making Technique", *Procedia - Social and Behavioral Sciences (Elsevier)*, Vol. 189, 81-90.
3. Thakur, V., and Ramesh, A. (2014) "Shift from Product Supply Chain Management to Services Supply Chain Management: A Review*", International Journal of Services and Operations Management*, accepted for publication on Sep. 4, 2014.
4. Thakur, V., and Ramesh, A. (2015) "Management practices and modeling the seasonal variation in healthcare waste at CBWTF: A case study of Uttarakhand, India", *Journal of Modeling in Management*, accepted for publication on Dec. 28, 2015.

### 2. International Conference:

1. Thakur, V., and Ramesh, A. (2015) "Predicting healthcare waste generation rates: A case study of Uttarakhand, India", 19th Annual International Conference of the Society of Operations Management, IIM Kolkata, Dec 11-13, 2015.
2. Thakur, V., and Ramesh, A. (2015) "Choosing healthcare waste disposal strategy", 14th International Conference on IT Applications and Management, Ewha Woman's University, Seoul, Korea, June 24-26, 2015.
3. Thakur, V., and Ramesh, A. (2014) "Selection of Waste Disposal Firms Using Grey Theory Based Multi-Criteria Decision-Making Technique", 18thAnnual International Conference of the Society of Operations Management, Indian Institute of Technology Roorkee, Dec 13-15, 2014.
4. Thakur, V., and Ramesh, A. (2014), "Healthcare Waste Management in India" – in the proceedings of 7th International Conference on Contemporary Business & 14th Global conference on flexible systems management, held at Curtin University, Singapore, during October 15-17, 2014.
5. Thakur, V., and Ramesh, A. (2013) "Services supply chain management: A critical review"- in the proceedings of XVII annual international conference of the society of operations management, held at Indian Institute of Technology Madras, Dec. 2013.

# BIOGRAPHICAL PROFILE OF RESEARCHER

**As on February, 2016**

**VIKAS THAKUR**

Research Scholar

Department of Management Studies

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Roorkee, Uttarakhand, 247667 India.

**Personal Details**

| | | | |
|---|---|---|---|
| (i) | Date of Birth | : | 2nd September, 1985 |
| (ii) | Age | : | 30 Years |
| (iii) | Gender | : | Male |
| (iv) | Marital Status | : | Married |
| (v) | Nationality | : | Indian |

| **Salient Features** |
|---|
| ➢ M.B.A. with specialization in "**Marketing Management & Human Resource Management"** from **IMS, Himachal Pradesh University, Shimla**.<br>➢ B. Tech in "**Electronics & Communications"** from **Green Hills Engineering College, Himachal Pradesh University.**<br>➢ **Net Qualified** in the field of management.<br>➢ **4.0 Yrs**. Experience **(2.6 Years NIT Hamirpur, 6 Months M/s ESC Delhi, 1 Year M/s Elin Electronics Ltd.)** |

| Academic Qualification | | | | | |
|---|---|---|---|---|---|
| *Year* | *Course* | **Univ./Board** | **Institute** | **Aggregate** | **Division** |
| *2013-till date* | *PhD* | IIT Roorkee | IIT Roorkee | 9.5 GPA | First |
| 2008-10 | MBA (Marketing & HR) | Himachal Pradesh University | Institute of Management Study, Shimla | 73.55% | First |
| 2007 | B. Tech (Electronics & Communication) | Himachal Pradesh University | Green Hills Engineering College, Solan | 80.37% | First |
| 2003 | XII$^{th}$ | H.P. Board | Govt. Senior Sec. School, Pragpur | 82.4% | First |
| 2001 | X$^{th}$ | H.P. Board | Govt. High School, Behan | 83.14% | First |

**Work Experience**

- Two and half years of experience in **NIT, Hamirpur** as a lecturer. The subjects taught are: Operations Management, Principles of Management, Marketing Management, Sales and distribution).
- Worked as Marketing Executive in **M/s Electrical Systems & Controls**, Delhi for 6 months.
- Worked as Quality Engineer in **M/s Elin Electronics Ltd.** for 1 year.

**Administrative Experience**

- Worked as **Assistant Warden** in Radhakrishnan Bhawan, at IIT Roorkee from 8/09/2014 to 8/08/2015.

- **Member of organizing committee and group leader** for students' volunteer of SOM International conference 2014 held at DOMS, IIT Roorkee.
- **Member of organizing committee** for THOMSO 2014 at IIT Roorkee.
- **Member of organising** workshops for course curriculum development for MBA course at IIT Roorkee.

**Society Memberships**

- Student membership of Society of Operations Management (SOM).
- Life time membership of Korean Database Management Society.

**Edited Conference Proceedings**

- Associate Editor, XVIII International Conference of SOM 2014 held at Department of Management Studies, IIT Roorkee on 12-14 December, 2014.

**International Visits**

- Paper presented at EWHA Women University, SEOUL, South Korea.

**Training/MDP Programs**

- Conducted session on "Decision Making Skills" for executives of Everest India Ltd. held at Continuing Education Centre, IIT Roorkee on 19 August, 2015.
- Assisted training program conducted for trainees of ISTD, Dehradun Chapter, on 18 March, 2015.

**Workshops Attended**

- Short term course on "Big Data Analysis for Improving Business Performance" organized by DOMS, IIT Roorkee on 17-18 May, 2014.
- One day workshop on "Make in India: Importance of operations and supply chain management", conducted by QIP, IIT Roorkee on $6^{th}$ Feb. 2016.

| Industrial Training | | |
|---|---|---|
| *Company/Institute* | *Area* | *Duration* |
| Punjab Communication Ltd. | Embedded Systems | 6 weeks |
| C-DAC | Networking Technology | 4 weeks |
| Electrical Systems & Controls | Marketing Management | 8 weeks |

**Projects/Consultancy**

- Proposed project entitled "Managerial skills development, IT applications and Operations management in SMEs of Uttarakhand" to Uttarakhand Council of Science & Technology.
- Proposed project entitled "Applications of Big Data Analysis in Healthcare" to DST.
- Proposed the project entitled "Healthcare waste management practices in India and gap analysis" ICMR.

**Projects Supervised for Post Graduate students**

- Project entitled "Healthcare waste management practices and analysing the bio-medical waste generation rates at various healthcare facilities at Uttarakhand" supervised for B. Tech students at IIT Roorkee.
- Project entitled "Bio-medical waste management practices at Jolly Grant Hospital, Dehradun" **sponsored by U-COST.**
- Project entitled "Marketing challenges for the growth of MSME'S in Himachal Pradesh" supervised for MBA students (Batch 2011-13) at NIT Hamirpur.
- Project entitled "Factors affecting the brand loyalty of a brand" supervised for MBA students (Batch 2011-13) at NIT Hamirpur.
- Project entitled "Cognitive dissonance: Post purchase behaviour in Automobile Industry" supervised for MBA students (Batch 2011-13) at NIT Hamirpur.

**Projects Undertaken**

- Project entitled "Effect of advertisement on college going students" completed during MBA course (2008-10) at IMS, Shimla University.
- Project entitled "Temperature sensor with digital output" completed during B. Tech course (2003-2007) at Green Hills Engineering College, Solan Himachal Pradesh.
- Project entitled "Serial communication using microprocessor" completed during B. Tech course (2003-2007) at Green Hills Engineering College, Solan Himachal Pradesh.
- Project entitled "PC/MC based remote control for software's" completed during B. Tech course (2003-2007) at Green Hills Engineering College, Solan Himachal Pradesh.

**Awards and Achievements**

- Net Qualified.
- Was 23$^{th}$ rank holder in XII$^{th}$ at State level.
- Was 29$^{th}$ rank holder in X$^{th}$ at State level.
- Was 2$^{nd}$ rank holder in B.Tech at University level.
- Received scholarships and awards from Government of Himachal Pradesh for 4 years (2001, 2003, 2004-05)

VIKAS THAKUR