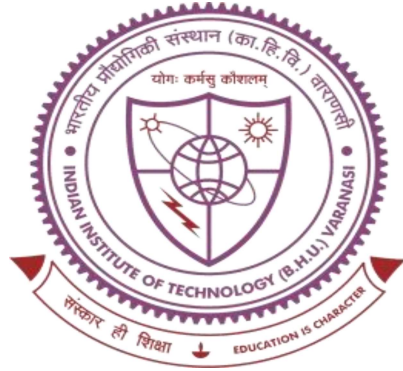


Analysis of Barriers to Healthcare Waste Management: A Case of an Indian City



**Thesis submitted towards the partial fulfillment
for the Award of Degree
*Doctor of Philosophy***

by

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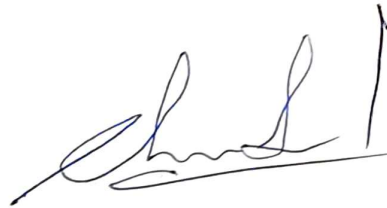
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DECLARATION BY THE CANDIDATE

I, **ABHISHEK RAJ**, certify that the work embodied in this thesis is my own a bona fide work carried out by me, under the supervision of **Dr. CHERIAN SAMUEL** from December 2017 to December 2022, at the Department of Mechanical Engineering, Indian Institute of Technology (BHU) Varanasi. The matter embodied in this thesis has not been submitted elsewhere for any other degree or diploma award. I declare that I have faithfully acknowledged and given credits to the research workers wherever their works have been cited in my work in this thesis. I further declare that I have not wilfully copied any other's work, paragraphs, text, data, results, etc., reported in journals, books, magazines, reports, dissertations, theses, etc., or available on websites and have not included them in this thesis and have not cited as my work.

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It is certified that the statement made above by the student is correct to the best of my knowledge.


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Abhishek Raj

DEDICATED TO
My Father
Mr. SIYARAM SRIVASTAVA
&
My Mother
Mrs. ASHA SRIVASTAVA

TABLE OF CONTENTS

ACKNOWLEDGEMENTS	V
TABLE OF CONTENTS	vii
LIST OF FIGURES	xiii
LIST OF TABLES	xv
LIST OF ABBREVIATIONS	xvii
LIST OF INDICES AND PARAMETERS	xxi
PREFACE	xxvii
1. INTRODUCTION	1
1.1. Prologue	1
1.2. Background and Motivation	8
1.3. Objective of research work	9
1.4. Novelty of research work	10
1.5. Organization of Thesis	10
2. LITERATURE REVIEW	15
2.1. Healthcare waste	15
2.2. HCWM in Various countries	15
2.3. Healthcare waste generation and Management Challenges	17
2.3.1. Integrated solid waste management	21
2.3.2. Existing approaches for SWM	22
3. TOOLS, TECHNIQUES AND METHODOLOGY	30

3.1. Total Interpretive Structural Modelling	30
3.1.1. Identification and Finalization of Items	31
3.1.2. Establish the contextual Relationship and develop SSIM	32
3.1.3. Develop Reachability Matrix	32
3.1.4. Partition of Reachability Matrix	33
3.1.5. Developing Canonical Matrix	34
3.1.6. Formation of Model	34
3.1.7. MICMAC Analysis	34
3.2. DEMATEL	35
3.2.1. Direct Relationship Matrix	36
3.2.2. Development of Normalized Relationship Matrix	36
3.2.3. Development of Total Relationship Matrix	36
3.2.4. Degree of Influence	37
3.2.5. Set up threshold and plot digraph	37
3.3. Quality Function Deployment	38
3.4. Analytical Hierarchy Process	42
3.4.1. Steps Involved in AHP	42
3.4.2. Basic Principle of AHP	47
3.4.3. Test of Consistency	45
3.5. Fuzzy Theory and Decision Making	46
3.5.1. Fuzzy Numbers	47
3.5.2. Triangular Fuzzy Number	47
3.5.3. Linguistic Variables	48
3.5.4. Ranking of Generalized Triangular Fuzzy Number	48
3.6. Two Echelon Location Routing Problem	49

4. Understanding the Interrelationship of HCWM Barriers	53
4.1. Identification and definition of barriers	53
4.2. Total Interpretative Structure Modeling	53
4.3. Interpretive matrix	64
4.4. Total interpretive structural model	66
4.5. MICMAC Analysis	67
4.6. DEMATEL	69
4.7. Results and Discussions	76
4.8. Concluding Remark	77
4.9. Theoretical and Managerial Implications	77
5. Finding Customer's Requirements and selecting important activities for their fulfillment	78
5.1. Introduction	78
5.2. Methodology	79
5.3. Discussion	84
5.4. Conclusion	84
5.5. Theoretical and Managerial Implications	84
6. Allocation of weight to HCWM barriers and policy recommendations to overcome barriers	86
6.1. AHP Method	86
6.2. Results of AHP	88
6.3. Strategies to overcome Barriers	95

6.4. Fuzzy TOPSIS Method	97
6.5. Results of Fuzzy TOPSIS	98
6.6. Conclusion	100
6.7. Theoretical and Managerial Implications	100
7. To Solve Hospital Waste Management Conundrum in an Unplanned City -A Case of Varanasi	101
7.1. Demographic of City	101
7.2. Healthcare Infrastructure	101
7.3. Hospital Waste Management	102
7.4. Research Objective	104
7.5. Problem Introduction	104
7.6. Healthcare Condition in Varanasi	105
7.7. Proposed IHWM system	106
7.8. Mathematical model formulation	107
7.9. Results and Discussion	111
7.10 Optimal waste Collection between Processing facility (PF) and Collection center (CC)	112
7.11. Optimal waste Collection between Collection centers and Hospitals	115
7.12. Conclusion	119
7.13. Managerial Implications	120
8. Conclusion and Future Scope	121
8.1. Introduction	121

8.2. Summary of Findings	121
8.3. Managerial Implications	123
8.4. Limitation of Present Work	124
8.5. Scope for Future Work	124

References

Appendix A

Appendix B

List of papers published/accepted for publication

LIST OF FIGURES

Figure 1.1	Healthcare Waste	6
Figure 1.2	Structure of Thesis	11
Figure 2.1	Hospital Waste Management Hierarchy	19
Figure 2.2	Hospital Waste Management Cycle	20
Figure 2.3	Integrated Solid Waste Management Model	21
Figure 3.1	Flow of Work	30
Figure 3.2	MICMAC Results	34
Figure 3.3	Flow Chart for DEMATEL	37
Figure 3.4	House of Quality	39
Figure 3.5	Analytic Hierarchy Process	42
Figure 3.6	Triangular Fuzzy number	47
Figure 3.7	Two Echelon	49
Figure 4.1	Flow Chart for TISM	54
Figure 4.2	Digraph representing Dependence Relationships	63
Figure 4.3	TISM MODEL	65
Figure 4.4	MICMAC	68
Figure 4.5	Causal Diagram	74
Figure 5.1	Flow Chart for QFD	79
Figure 5.2	Correlation Matrix	81
Figure 5.3	House of Quality	82
Figure 6.1	Flow Chart for AHP	86
Figure 6.2	Proposed Strategies	98
Figure 7.1	Government Healthcare Facilities in Varanasi	106

Figure 7.2	Location of Processing Facilities	113
Figure 7.3	Location of Collection Centers	115
Figure 7.4	Location of Hospitals	116
Figure 7.5	Connection between PF, CC and Hospitals	119

LIST OF TABLES

Table 2.1	Relevant Barriers with Description and supporting References	24
Table 3.1	Structural Self Interaction Matrix	31
Table 3.2	Thomas Saaty's nine-point scale for making the judgment	43
Table 3.3	Random Index	45
Table 4.1	Structural Self-Interaction Matrix	55
Table 4.2	Initial Reachability Matrix	57
Table 4.3	Final Reachability Matrix	58
Table 4.4	Level Partitioning	59
Table 4.5	Level Partitioning of Barriers	64
Table 4.6	Direct Relationship Matrix	69
Table 4.7	Normalized Relation Matrix	70
Table 4.8	Total Relation Matrix	72
Table 4.9	Degree of Influence	73
Table 4.10	Comparison of TISM and DEMATEL Analysis	75
Table 5.1	User Need with Rating	80
Table 6.1	Priority ranking of barriers	88
Table 6.2	Categorization of Barriers	89
Table 6.3	Pairwise matrix and ranking of Organizational barriers	91
Table 6.4	Pairwise matrix and ranking of Waste Handling barriers	92
Table 6.5	Pairwise matrix and ranking of Human Resource barriers	92
Table 6.6	Pairwise matrix and ranking of technical barriers	93
Table 6.7	Overall Weight and Ranking of barriers	94

Table 6.8	Strategies to Overcome HCWM Barriers	95
Table 6.9	Linguistic Variables and TFNs	97
Table 6.10	Ranking of Various Strategies	99
Table 7.1	Common Biomedical Waste Treatment Facilities Near Varanasi	103
Table 7.2	Description about processing and collection center	112
Table 7.3	Distance between processing facilities	112
Table 7.4	PF and CC	114
Table 7.5	Distance between Collection centers	114
Table 7.6	CC and Hospitals	116
Table 7.7	CC with amount of waste Collection	117
Table 7.8	Vehicle route form PF to CC	117

ABBREVIATIONS

HCW	Healthcare Waste
HCWM	Healthcare Waste Management
HCF	Healthcare Facility
CBWTF	Common Bio-medical Waste Treatment Facility
WHO	World Health Organization
SWM	Solid Waste Management
HIV	Human Immunodeficiency Virus
AIDS	Acquired Immunodeficiency Syndrome
EPI	Environmental Performance Index
CWM	Controlled Waste Management
TISM	Total Interpretive structural modeling
DEMATEL	Decision-making trial, and evaluation laboratory
MICMAC	Cross-impact matrix multiplication applied to classification
QFD	Quality Function Deployment
MCDM	Multi-Criteria Decision-Making
AHP	Analytic Hierarchy Process
COVID	Corona Virus Disease
MSW	Municipal Solid Waste
HTA	Health Technology Assessment
GDP	Gross Domestic Product
ISWM	Integrated Solid Waste Management
TSP	Traveling salesman Problem
VRP	Vehicle Routing Problem

NP	Non-Deterministic Polynomial-Time
MADM	Multi-Attribute Decision-Making
SSIM	Structural Self-Interaction Matrix
HOQ	House Of Quality
MILP	Mixed-Integer Linear Programming
FPI	Fuzzy Performance Index
2E-MOLRPM	Two-Echelon Multi-Objective Location Routing Problem Model
BHU	Banaras Hindu University
FST	Fuzzy Set Theory
TFN	Triangular Fuzzy Number
CPC	Centre for Pollution Control
CRs	Customer Requirements
ISM	Interpretative Structural Modeling
CR	Consistency Ratio
CI	Consistency Index
RI	Radom Index
TQM	Total Quality Management
ANP	Analytic Network Process
KMO	Kaiser–Meyer–Olkin
EFA	Exploratory Factor Analysis
TOPSIS	Technique for Order of Preference by Similarity to Ideal Solution
OB	Organizational Barrier
WHB	Waste Handling Barrier
HRB	Human Resource Barrier
TB	Technical Barrier

SEM	Structural Equation Modeling
SC	Supply Chain
SCM	Supply Chain Management
PIS	Positive Ideal Solution
NIS	Negative Ideal Solution
CCi	Coefficient Of Closeness
PF	Processing Facility
CC	Collection Center
PPE	Personal Protective Equipment

LIST OF INDICES AND PARAMETERS

Indices and Parameters for Chapter 4

- B1 Lack of Awareness
- B2 Lack of Training
- B3 Insufficient staff working in HCWM
- B4 Unavailability of segregation bins
- B5 Lack of top Authority dedication towards HCWM
- B6 No segregation and collection center
- B7 The Incineration plant is not within the hospital
- B8 Lack of Government support and Policies
- B9 Lack of handling tools and Precautions
- B10 Reluctance to change and Adoption
- B11 No coordination between the municipality, Pollution Control Board, and hospital authorities
- B12 Lesser Prioritization of Waste Management issues in policies of Health Care Units
- B13 No Strict implementation of disinfectant techniques
- B14 No adequate information regarding waste quantity and compositions
- B15 Lack of Recycling Centers

<i>Y</i>	Yes
<i>N</i>	No
<i>1*</i>	Transitive relationship
<i>D_p</i>	Dependence power
<i>D_r</i>	Driving power
<i>i</i>	Index for barriers row wise
<i>j</i>	Index for barriers column wise
<i>K</i>	Direct Relation Matrix
<i>Y</i>	Normalized Relation Matrix
<i>T</i>	Total Relation Matrix
μ	Mean
σ	Standard Deviation

Indices and Parameters for Chapter 6

<i>A_j</i>	Set of Criteria
<i>a_{ij}</i>	Quotient of weights
<i>W_i</i>	Relative weights
λ_{\max}	Largest Eigenvalue
<i>WSV</i>	Weighted Sum Value
<i>OB1</i>	Lack of coordination of hospitals with other authorities
<i>OB2</i>	No priority to waste management issues
<i>OB3</i>	No strict implementation of control measures
<i>OB4</i>	No information regarding waste quantity and compositions
<i>OB5</i>	No availability of recycling centers in Hospitals
<i>OB6</i>	Lack of regular monitoring of healthcare waste

WHB1	Lack of Govt. support and policies
WHB2	No availability of segregation bins
WHB3	No place for temporary storage and segregation
HRB1	Lack of Qualification and awareness of employees
HRB2	Lack of support from Management
HRB 3	People do not want to change their thinking
TB1	Poor training of staffs
TB2	Lack of intelligent waste management techniques
TB3	No tools and precautions to handle healthcare waste
Xij	Fuzzy Decision Matrix
aj	Normalized Fuzzy Decision Matrix
Vij	Weighted Normalized Fuzzy Decision Matrix
A*	Positive Ideal Solution (PIS)
A ⁻	Negative Ideal Solution (NIS)
D(x,y)	distance between each alternative to PIS and NIS.
<i>a</i>	Lower number of triangular fuzzy numbers (<i>a, b, c</i>)
<i>b</i>	Middle number of triangular fuzzy numbers (<i>a, b, c</i>)
<i>c</i>	Upper number of triangular fuzzy numbers (<i>a, b, c</i>)

Indices and Parameters for Chapter 7

P	Set of Processing Centers
C	Set of Collection centers
H	Set of Hospitals
V	Set of all nodes
A	Set of all arcs
(i,j)	To indicate decision variables

q_h	Demand of hospitals
DT1	Distance to cover in tier1
DT2	Distance to cover in tier2
W_p	Capacity of truck at Processing center P
W_C	Capacity of truck at Collection center C
d_{ij}	Transportation cost on arc i, j
F_p	Fixed cost of locating Processing center P
F_C	Fixed cost of locating Collection center C
Cap_processing	Capacity of Processing Centers
Cap_collection	Capacity of Collection Centers
Y_p	Processing center is located
Y_C	Collection center is located
Z_{ij}^P	Arc(i, j) is travel in first echelon
X_{ij}^C	Arc(i, j) is travel in second echelon
V_{pc}	Collection center C is assigned to Processing Plant P
V_{ch}	Hospital h is assigned to Collection center C
Q_{ij}^P	Load on the vehicle on arc(i, j) in first echelon
Q_{ij}^C	Load on the vehicle on arc(i, j) in second echelon
U_C	Total waste collected at Collection center

PREFACE

Healthcare waste is a global waste that is rapidly expanding. The rise in healthcare waste is caused by various pandemics and an increase in hospitals. Another issue of concern is the volume of garbage produced. Assume that the hospital only produces a little amount of garbage. A waste audit is one way to quantify the trash and determine carbon emissions in that situation because it will lower the disposal costs (Hsu *et al.*, 2021). Environmentally friendly methods and cost-effective pathways are needed for proper waste management in the healthcare industry. The most important aspect of waste management in the healthcare industry is collection and segregation. The correct segregation of many healthcare wastes is required to prevent the needless expense of their treatment because they are not all dangerous. Waste in the healthcare industry is a problem in both developed and developing nations. Reducing the amount of healthcare waste can also be accomplished by recycling and reprocessing it. Stainless-steel debris from three hospitals was gathered for a case study, and a repair and recycling strategy was used. As a result, the instrument's life cycle was lengthened and waste disposal expenses were reduced (Van *et al.*, 2021). It is a recommended practice to do this if the healthcare waste is within the acceptable range. The hospital's staff has to be informed and properly trained. Another excellent choice is to use green purchasing providers (Zamparas *et al.*, 2019). After reviewing a variety of literature, it has been determined that healthcare waste management is a critical problem for all nations and that its disposal is difficult. Because of several obstacles, it is difficult for healthcare organisations to manage healthcare waste. Healthcare waste management is a problem in several healthcare sectors throughout the world. The COVID-19 pandemic is currently posing a

threat to the world because of global trade. The effects of healthcare waste on the environment and society are severe. Healthcare waste has been treated using a variety of treatment technologies (Aung et al., 2019).

This study offers a more comprehensive viewpoint on healthcare waste management. It is carried over into the four objectives, taking into account one of the following case studies of an Indian city:

1. To find the relationship among barriers to the healthcare waste management sector:
2. Finding Customer's Requirements and selecting essential activities for their fulfillment:
3. Allocation of weight to HCWM barriers and policy recommendations to overcome barriers:
4. To Solve Healthcare Waste Management Conundrum -A Case of Varanasi: