A Rational Approach for Assessment of Waste Management in Indian Construction Industry

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by

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CERTIFICATE

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Dedicated To

My

Daughter - Sri Sasya Gokul Venigalla

and Family members

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ABSTRACT

Construction industries are bulk generators of waste globally. Construction waste needs to be managed in order to minimize environmental burden in India and conserve existing natural resources. Despite numerous policies and guidelines there is improper construction waste management in India. Towards addressing this issue, a novel framework is presented to unravel waste management in India. Therefore, the current study- (i) quantifies the waste generated at construction sites; (ii) Identifies and models the causes along with their individual impacts on construction waste generation; (iii) evaluates barriers, potential benefits and enforcement measures for implementing SWMP and recycling of construction waste;(iv) Investigates attitude & behavioural intentions of the construction workforce towards implementation of construction waste management and (v) develops onsite tools to monitor, assess construction waste management and establish an e-commerce store for marketing of construction waste. To achieve the desired objectives case studies, questionnaire surveys are performed to gather the required data from various construction professionals. The data collected is analysed using various statistical theories, models, tools and techniques.

Based on which- (i) a revenue generation based solution- online facility/Android application (waste alley) is developed for trading construction waste; (ii) A index based tool is developed which aids in estimating the onsite WM performance of the construction project; (iii) various sources of CW generation are identified and the impact of each individual cause on CW generation is modeled using SEM to develop a guide for engineers to identify and reduce the areas of waste generation; (iv) The barriers, benefits for implementing CWM as well as for recycling of construction waste are identified; based on which, actionable enforcement measures are recommended for mitigating observed barriers; (v) The effects of attitude & behavior of construction work force towards implementation of CWM are quantified, which enables HR managers to sensitize the work force and (vi) a framework is developed based on process flow models of onsite CW work flow -which enables quantification of optimal work flows developed for individual projects.

The proposed framework is pertinent to: (i) policy makers –for establishing regulations & practices; (ii) corporates –for devising effective approaches; (iii) academia- for encouraging attitude and behavioral changes towards implementation of CWM.

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ABBREVIATIONS

Symbols

%	Percentage
*	Multiplication
R^2	Correlation Coefficient
***	Statistical significance

Weight and Measures

m^3	Cubic metre
w	Weight assigned to each attribute by the respondents,(values
A	Highest weight (i.e., 7 in this case), and
N.	Total number of respondents
n	Number of factors
m	Number of groups
J	The factors 1,2…. N
W	Concordance
Df	Degrees of freedom
Sig	Significance
Cα	Cronbach’s alpha
STD	Standard Deviation
(χ^2):	Chi square test
P	Significance
Ho	Null Hypothesis
H1	Alternate Hypothesis
RS_{ijk}	Score of kth response for jth factor in ith category;
RW_{ijk}	Weight of kth response for jth factor in ith category
CW_i	Weight of ith category
FW_{IJ}	Weight of jth factor in ith category.
L	Number of factors in ith category
M	Number of responses for jth factor in ith category.

µm	Micrometer (micron)
kN	Kilo Newton
kg	Kilogram
kg/m^3	Kilogram per cubic meter
A	Highest weight
N	Total number of respondents.

Text Abbreviations

AII	Analogous importance index
BBM	Barriers, benefits and measures
SWMP	Site waste management Plan
CWM	Construction Waste Management
CW	Construction Waste
SEM	Structural equation modelling
BIV	Beneficial index value
RMA	Relative mapping approach
ETPB	Extended theory of planned behaviour
OCWMPA	Onsite construction waste management performance assessment index
MT	Million tonnes
CWG	Construction waste generation
SPSS	Statistical package for social sciences-
TPB	Ajzen's theory of planned behaviour
BNA	Bayesian Network analysis
SEM	Structural equation modelling
PLS-SEM	Partial least squares structural equation modelling
GIS	Geographic Information System.
WGR	Waste Generation Rate
GFA	Gross Floor Area
ANN.	Artificial neural network
KMO	Kaiser Meyer Olkin
CB-SEM	Covariance Based SEM
VB SEM	Variance Based SEM

AMOS	Analysis of moment of structures
GFI	Goodness of fit index
IFI	Incremental Fit index
TLI	Tucker-Lewis Index.
RMSEA	Root mean squared error of approximation
ECVI	Expected cross validation index
CR	Convergent validity
AVE	Average variance Extracted
RFID	Radio frequency identification tags
GRIHA	Green rating for integrated habitat assessment
LEED	Leadership in energy and environmental design
CPCB	Central pollution control board
WMPFM	Waste Management process flow models

CHAPTER 1

Introduction

1.0 Research Background

The rapid urbanization has led to social and economic developments which contribute to global economic prosperity. The increase in financial opportunities has attracted and motivated individuals to migrate to urban regions. The gradual increase in the proportion of migrants has significant influence on building and infrastructure projects. Inappropriate organisation of the building sector consequently results in unsustainable habitats. Therefore, there is a need for assessing the economic and environmental impacts of the urbanisation process to ensure sustainable development.

Coupled with the benefits of the urbanization and extensive infrastructure, reconstruction and building projects led to a momentous increase in construction and demolition (C&D) waste generation in the last few years (Jain et al.,2020a). Construction waste management (CWM) became one among the major environmental concerns in most of the municipalities as landfilling is dominant practice for waste disposal in both developed and developing nations (Bolyard et al.,2016; Ghanimeh et al., 2016). However, these landfills need post closure care which is usually 30 years in developed countries (Zheng et al., 2015). Hence there is an emerging need in choosing alternative solutions for managing construction waste (KolaventiSS et al.,2017). Developed nations generate tremendous amount of waste in comparison to developing nations (Das et al., 2019).

Despite possessing potential waste management infrastructure and policies on waste management, they struggle with enforcement of waste recycling procedures (Haas et al., 2015; Pires & Martinho, 2019). Whereas, in developing nations, attainment of circular economy is arduous in nature, due to lack of documentation associated with construction waste (CW) (Koutamanis et al., 2018; Zhang et al., 2019; Yuan, 2017; Islam et al., 2019). The C & D waste generated in various countries is presented under Table 1.1**.**

Table 1.1 C & D waste generated in various countries

Country	Waste generation (MT /year)	Year	Reference
USA	569	2017	(Menegaki and Damigos 2018)
UK	136.2	2016	(Department for environment food and rural
Australia	67	2017	(Departmenkt of the Environment and Energy
Brazil	45	2015	(De Magalhaes et al. 2017)
Germany	209	2015	(Federal Ministry for the Enviornment Nature Conservation and Nuclear Safety 2018))
Australia	20.4	2017	(S. Shooshtarian et al., 2019)
China	1130	2014	(Lu et al. 2017)
Hong Kong	58	2014	(Hossain et al. 2017)
UAE	4.5-6.35	2014	(Ouda et al. 2018)
Japan	77	2012	(Harish. P. Gayakwad 2015)
South	61.1	2013	
Germany	86	2014	(Aliferova and Ncube 2017; Kabirifar et al. 2020)
Netherlands	22	2014	
Italy	39	2014	
Malaysia	28.6 Ton Daily	2015	
France	65	2014	

Construction waste(CW) is originated during new construction, renovation as well as demolition (Kofoworola OF and Gheewala SH 2009). Compared to any other waste, CW are tougher to handle as well as recycle due to heterogeneity. An increase in construction activities brings about the enormous need of raw materials such as sand, soil, stone, and limestone. The extraction of these raw materials has harsh ecological impact. It is estimated that, construction industry generates about 35% of waste to landfill globally (Ghaffar et al., 2020) and rapidly developing cities are major contributors of C&D waste (Jain et al. 2020b). Sustainable development in building construction is the key to conserve natural resources (Mathiyazhagan et al., 2018b; Blaisi 2019) assure control of pollution and mitigate the hazards in traditional construction activities(Li and Mathiyazhagan 2017). This creates an imperative, for invention of sustainable products (Sinakou et al., 2019) which are compatible with the environment , leading to circular economy (Minunno et al., 2018; Luttenberger 2020).

Construction industries occupy preeminent share in India's economy and play a dominant role in environmental degradation (Mathiyazhagan et al., 2018a). *'The housing for all'* a mission launched in June 2015 to achieve the construction of housing units by 2022, thus escalating the generation of CW (BMTPC 2018). In India, the amount of solid waste generated is 960 million tons (MT) out of which, the CW is 100-400 MT in 2017(Central Pollution Control Board 2017; Gupta 2018; Kolaventi et al., 2019). At present, the annual consumption of the construction materials are- sand: 750 million tons; soil-350 million tons; stone -2 billion tons; lime stone-242 million tons (Ipsita Satpathy et al., 2016). However, the number is inaccurate due to non-documentation of the material deposited on the sides of the roads, open plots, etc. C&D waste generation rates for few Indian cities daily and annually are shown in (Table 1.2). I12n accordance with Building Materials & Technology Promotion Council (BMTPC) (Sekhar et al., 2015;BMTPC 2018).

Table 1.2 C&D waste generation in Indian cities (BMTPC 2018, Sekhar et al. 2015)

City	Population(Census 2011)	Daily CDW (tons/day)	Annual CDW(Million
Mumbai	12,442,373	2,500	0.75
Delhi	16,787,941	4,600	1.38
Bangalore	8,443,675	875	0.26
Chennai	6,500,000	2500	0.75
Kolkata	4,496,694	1600	0.48
Jaipur	3,471,847	200	0.06
Patna	2,514,590	250	0.08
Ahmedabad	6,063,047	700	0.21
Bhopal	1,917,051	50	0.02
Coimbatore	2,618,940	92	0.03

India has the relevant regulations for waste management, but due to their weak enforcement, construction firms place waste management and reduction at the bottom of their agenda due to the complexity of incorporating these within the existing system (Ayarkwa.J et al. 2000). Existing research indicates that waste management is effective if it is integrated with management functions and is considered as the major research directions (Yuan and Shen 2011). An effective management system constitutes realistic awareness of environmental sustainability(Madani et al., 2017). The expanding deliberation on sustainability plays a major role in advancing the construction sector by amending policies, rules, laws and regulations to favour sustainable alternatives globally (Raharjana 2011).

Therefore, there is an emerging need in managing the waste originated during construction. Construction waste management (CWM) can control the release of pollutants, waste generation and therefore need an immediate attention by policy makers to amend the existing policies (Kolaventi SS et al., 2017; Ragossnig A and Tunesi S 2018). GRIHA (Green Rating for Integrated Habitat Assessment) and LEED (Leadership in Energy and Environmental Design) are the tools which are used to assess the performance of buildings during their entire lifecycle by means of providing ratings. In these tools, segregation, reuse and disposal of construction waste altogether are given one point under criteria 22 (Reduction in waste during construction). The Brundtland report of 1987 titled 'Our Common Future' proposed sustainable development merged with ecological, economic & social systems (Sinakou et al. 2019). However, it creates challenges for practical implementation (Berglund et al. 2019).

Despite the schemes and guidelines available in India regarding waste management, illegal dumping is the most common practice for disposal of waste. The existing practices dealing with construction waste in India are: dumping in empty plots, landfills, water sources or incineration of the wastes. The methods provide a temporary solution by only postponing the problem. Implementing strategies such as 3R, circular economies (Ghosh SK and Agamuthu P 2018; Campbell 2019; Charlson and Hons 2019; Hopkinson et al. 2019) is practically challenging in most of the Indian construction sites.

Therefore, in order to achieve sustainable development by reducing wastes, the adoption of construction waste management in construction sites is paramount (Crawford et al., 2011). To delve into implementation, the current study focusses on construction waste management –Identification of factors influencing CWM, modelling the causes of waste generation, assessment of barriers, benefits and corresponding measures for implementing site waste management plan and attitude, behaviour parameters associated for implementing CWM in India. Furthermore, the study analysed real time waste flow at construction sites using process flow models, and developed prototypical Android application and index based system for marketing and performance assessment of CW and its management.

1.1 Problem Statement:

"As there is an augmentation in today's consumer society, so is the usage of resources and the waste it generates. The people of the European Union (EU) dispose 2.7 billion tonnes every year (Domestic and industrial waste etc.) of which 98 million tonnes are hazardous. Amongst them, Construction and demolition waste occupies the greatest share.(European Comission 2016)

The above statement indicates C&D waste is a global issue. In India for the past few years, construction industry served as a vital catalyst for expansion of economy development. Whilst propelling the engine of the expansion, the dependency on the labour inclusive methods is a major problem associated with the Indian construction industry. These (labour inclusive methods) are influential for the waste generation at construction sites & need to be controlled at the production stage by means of cleaner production process which aid in waste reduction at source.

An inefficient waste management system directs C&D waste to landfills excessively, along with the waste which can be recycled. CWM is a challenging issue in most of the developing countries like India, where CWM lacks priority. The increase in population leads to an increase of construction activities thus making CWM not a necessity but an option. Indian government in principle encourages sustainable practices in managing different waste including C&D waste. The literature review highlights the following issues, which need to be addressed for proper implementation of C&D waste management system.

- Effective resource consumption procedures, causes and the individual impact on waste generation need to be analyzed (Luangcharoenrat et al. 2019)
- The lack of industrial norms, quantification data and implementation strategy on construction waste create uncertainty in managing the waste generated. (Ram and Kalidindi 2017)
- The barriers and contemporary measures need to be identified to accelerate the implementation of site waste management plan (Mahpour 2018).
- The incorporation of CWM during execution phase is barely practiced. Hence alternative solutions such as optimum process flow models and strategies which have benefits of waste minimization, effective management along with revenue generation need to be developed (Adedeji et al. 2017)

- Integration of attitudinal and behavioural factors is equally important to enhance the efficiency and effectiveness of CWM system in India (Jain et al. 2020a).

1.2 Thesis organization

The thesis is organized as:

Chapter 1 of the thesis focus on**,** background and the necessity of the study, introduction to CWM and developing of the problem statement.

Chapter 2 of the thesis reviews the literature on, CW quantification, modelling causes of CW generation, barriers, benefits, measures for implementing SWMP and recycling, attitude, behaviour studies on CWM and onsite, marketing strategies for CW management. Based on which, the literature gaps are summarized.

Chapter 3 of the thesis defines aim, objectives, scope and significance of the current study.

Chapter 4 of the thesis details the research methodology used in the study. In this chapter the systematic procedure used for achieving the desired objectives is discussed. Based on this, the research questions and methodology are developed. The current study is categorized under four phases. All the four phases of the project are discussed under subsequent chapters.

Chapter 5 of the thesis presents- (i) quantification of waste by means of wastivity, identification of CWM influence factors and measurement of concordance among engineers, academia and contractors; (ii) modelling the causes which influence the waste generation at construction site using structural equation modelling.

Chapter 6 of the thesis investigates the impact of various causes on waste generation using structured interviews, surveys and identifies the individual impact on CW generation using structural equation modelling.

Chapter 7 of the thesis evaluates, barriers, benefits and enforcement measures for implementing site waste management plan as it is identified as critical factor for waste generation. In addition, comparison of C & D WM practices of European nations with Indian initiatives are presented.

Chapter 8 of the thesis assesses attitude and behavioural parameters, which influence the implementation of CWM in India, using an extended theory of planned behaviour (ETPB) approach. A hypothetical SEM model is developed for assessment of parameters.

Chapter 9 of the thesis explores onsite CWM strategies. For this: (i) a framework (process flow model) is developed to track onsite CW; (ii) marketing strategies are designed to eliminate illegal disposal of CW; (iii) index system to assess onsite CWM performance is developed.

Chapter 10 of the thesis presents brief conclusions from each phase of the project as well as critical conclusions of the study and significant contributions of the current study along with future scope of the investigation.

CHAPTER 2

Literature review

2.0 Introduction

In the current chapter, existing studies on CWM are discussed. CW is defined in existing literature as the difference between the amount of materials delivered and accepted on the site (Pheng LS and Stephanie KLT 1998). Alternatively, a mixture of construction materials such as concrete, steel, rubble, and timber is defined as waste (Dania et al. 2007). Furthermore it is the material loss generated by the activities which do not add any benefit to the project (Koshy R and Apte EMR 2012). The amount of waste generated is dependent on the type of material. Besides, CWM is defined as an comprehensive and rational method to maintain environmental sustainability (Gilpin 1996; Townsend et al. 2004). CWM is an technique to mitigate the cost of disposal and examine alternate methods to reduce, reuse, recovery and recycle of CW which end up in landfill (Mincks 1994). Despite, the existence of waste management systems, they are characterized by low collection rate, recycling, and increased open dumping (Sophia Ghanimeh et al.,2019).

The literature review is organized under different sections as:

- CW quantification and factors influencing CWM.
- Modelling causes of CW generation.
- Barriers, benefits and measures for implementing SWMP.
- Attitude & behaviour studies using extended theory of planned behaviour.
- Onsite and marketing strategies for CWM.

The findings from the literature review help to identify the research gaps and form the basis of the research design in the subsequent chapters. In the initial part of the study, the CWM status in Indian context is assessed using various statistical and theoretical procedures. Based on the assessment, onsite solutions such as real time tracking, performance assessment indexes and marketing strategies for C&D waste are developed.

2.1 Status of C&D waste management system in India

In India, the CW is typically disposed in empty places, water ways, shoulder of the roads and is blended with domestic waste (Sapuay 2016). In contrast to these, procedures such as reuse, recycle are not practiced at most of the Indian construction sites (Gupta 2018). Unlike developed countries, Indian construction companies typically do not incorporate waste management in their construction projects (Irizarry et al. 2013).

The typical approaches employed by the Government of India to manage construction waste are:

- Both construction & municipal wastes are under the control of Panchayat Raj systems.
- Domestic waste is converted into manure & is used effectively.
- An empty plot is allotted by the Government of India to dump the C &D waste generated at construction sites.
- A nominal fee is charged for temporarily storing the CW until a suitable vendor is found.

The challenge for waste management within Panchayat Raj system is that finding suitable vendors is time consuming and there is insufficient space available for storing the CW at the sites allocated by the Government of India. Swachh Bharat Abhiyan launched by the Ministry of Housing and Urban Affairs in 2014 has been developed with an objective of providing clean sanitation facilities (MHUA 2018). Consequently, adequate information on management and disposal methods of CW is not available. Illegal dumping of the waste is the most common disposal method practiced by the waste generators as there is neither regulation nor tracking of the onsite construction waste generated (Sekhar.A et al. 2017).

Existing rules stipulate that, bulk generators of waste need to pay the processing & disposal charges wherein the rates are fixed by the local authorities. The Central Pollution Control Board (CPCB) stipulates that waste generators producing 20 tons in a day or 300 tons in a month for a single project should submit a framed waste management plan to the local authorities (CPCB 2017). The duties of the local authority according to CPCB are:

- Education of the people regarding management of waste at their construction sites.
- Safe disposal of hazardous waste if any observed.
- Placing of appropriate containers for collection of waste with regular maintenance.

- Management of incentive schemes to waste generators if the waste is being onsite.
- Tracking waste generation and disposal methods in their region and annually updating the data base.
- Collaboration with the experts for the efficient usage of recycled material.

In conjunction with the above, there should be waste segregation at each site to ensure other wastes do not get mixed with CW. The following are the key initiatives on C&D waste management in India (Table 2.1).

Table 2.1 Key initiatives on C&D waste management in India (MHUA 2018)

Key Initiatives	Expected outcome
Ministry of Urban Development (MoUD)	Setup ecofriendly C&D waste recycling facilities in each state.
Swachh Bharat Mission	Setup C&D waste recycling points at local level.
Ministry of Environment, Forest & Climate Change (MoEF &CC)	Incorporation of the concept of 3R for construction materials used in projects.
Bureau of Indian Standards(BIS)& Indian Road Congress (IRC)	Preparation of code practices, standards for use of recycled C&D materials in construction activities.
IS 383 : 2016 Indian Standard code for Coarse & fine Aggregate for concrete-(III)	Establish standard for coarse & fine aggregates
National Building Code (NBC- CED 46) of India 2005	Establish standards for usage of recycled materials in construction projects.
Building Material & Technology Promoting Council (BMTPC)	Guidelines on usage of C &D waste in construction of dwelling units & related infrastructure in government” housing schemes.
Central Pubic Works Division (CPWD)& Central Pollution control board (CPCB)	Guidelines on reuse & recycling of C&D waste.

Despite the initiatives and rules framed, there is no appropriate waste management employed at the construction sites in India. Following are the key aspects practically evident:

- Construction sites do not employ waste management
- Submission of documents to local authorities relating to management of waste is neither practiced nor enforced
- There is no practice of waste segregation at the sites.
- There are no incentive schemes for projects practicing reuse.
- Specific containers for collecting construction waste are unavailable onsite.
- Non availability of database for tracking disposal methods.

2.2 Previous studies

2.2.1 Review of literature on CW quantification and modelling factors influencing CWM

CW quantification is defined in previous literatures as estimation of total amount of waste that is being generated from projects. Quantification of CW is crucial for assessing the causes for waste generation, estimation of waste assets, framing of strategies for recycling and disposal etc. Despite its importance, a reliable quantification of C&D waste is not yet available in developing nations like India. Therefore, significant insights into C&D waste quantification are necessary. In addition, to face the challenges related to C&D waste management, it is important to identify various factors influencing CWM. No comprehensive methodology exists to assess the individual impact of these causes on waste generation in India. Therefore, the impact of individual factors needs to be modelled.

Kofoworola et al., (2009), quantified the CW generated in Thailand. The amount of waste generated is assessed using the product of activity area, waste generation rate and waste material percentage. However, the study stated that for an efficient recycling of C&D waste data is necessary. Therefore, the study suggested that for better planning and improvement of CWM, quantification of C&D waste is necessary. Furthermore, the study recommended inventory management for C&D waste generated, which can provide baseline information for recycling large scale construction waste.

Jingru Li (2013), developed an index based system to assess construction waste generation (CWG) from building projects. The study utilized gross floor area based on mass balance principle to estimate building C&D waste. The principle is used for all types of materials in a newly constructed residential building at Shenzhen city of China. The analysis results conclude that concrete is the major contributor of waste. The model is then validated with the existing transportation records in site. The developed strategy can be used as a bench mark for future investigations.

Amal Bakchan (2019), estimated the waste generated in non-residential construction projects based on sampling of 535 waste hauling trucks. Among the various construction materials, concrete and masonry are the highest contributors to wastage. Timber occupies the second place after concrete. In addition, the study quantified the benefits of CW recycling. The study thus aimed at analyzing handling practices of the generated waste and project management processes in institutional projects. Furthermore, the study helps in improving onsite sustainability performance of construction projects.

Ram V.G et al., (2017), estimated C&D waste using waste generation rates in Chennai city using case studies. Waste generation rates and regression analysis is used for quantification of the waste generated. C&D waste debris generated in 2013 is 1.14 MT. Masonry debris occupy 76 % of the total C&D debris. The share occupied by construction debris is 36 % of the solid waste generated in Chennai city. Materials, such as wood, electrical wires, doors, windows and reinforcement steel, were found to be salvaged and sold on the secondary market. Concrete and masonry debris were dumped in either landfills or unauthorized places.

Luiz Mauricio et al., (2020), developed fuzzy based model for estimating CW that is being generated. A three step process is followed for model development, sensitivity analysis, and model validation. A set of IF-THEN rules are developed based on two independent variables, built area and number of floors. A sensitive analysis was conducted to evaluate the influence of the independent variables on waste generation. The model is further calibrated and verified through a case study of 23 residential buildings constructed in the Brazilian Amazon. The developed model has an accuracy of 64% and 67% in development and validation phase which is acceptable. The developed model can be used by waste managers for monitoring of waste in respective building projects.

Ning Zhang,(2019), compared three C&D waste quantification techniques i.e weight-per-construction-area method (WAM), building life span-based method, and weight-per-capita method in China. Among the three methods weight-per-construction-area is appropriate because of the data availability and accuracy at a city or national level.

The results of WAM indicate that a total of 4.1 billion metric tons (Bt) of CDW were generated in China in 2016, mainly from demolition waste (85%). Taking the changes of building life span into account, a projection analysis reveals that the cumulative CDW generation will be 50 Bt between 2017 and 2040 in China (equal to approximately 38 years' cumulative generation of global municipal solid waste).

Chakkrit Luangcharoenrat (2019), identified 28 causes for construction waste generation and grouped them into four categories i.e. design and documentation, material and procurement, construction method and planning, and human resources. To determine the significant level of each factor, a questionnaire survey is conducted among contractors. Among the different factors, changes in design, working attitudes and behaviors, ineffective planning and scheduling, and material storage were among the highest impact factors on construction waste generation in each category. The identified factors aid stakeholders in building suitable strategies to manage construction waste efficiently.

Suaathi Kaliannan (2018), identified the root causes for CWG using triangulation technique. The cross validation of the analysis results is performed using 38 articles and the results are evaluated using practitioners. A total of 80 root causes were identified from 38 articles and the 5 main root causes determined have scored more than 50% out of the total number of articles. Based on the results, 87.5% of construction practitioners agreed that constant design changes, incorrect storage of materials, poor handling of materials, effect of weather and mistakes while ordering from suppliers are crucial causes for CWG.

Roseline Ikau (2016) evaluated the factors which cause CWG in Malaysian construction sites. Contractors are involved in the questionnaire survey to list out the major factors which influence CWG. The causes in design, procurement, material handling and construction stage are assessed. The gathered responses are analyzed using SPSS from which degree of importance is calculated. The analysis results conclude that lack of knowledge or experience in construction waste, purchase of materials contrary to specification and inappropriate storage are among the main factors identified based on degree of importance index (DOI). In addition, lack of regulations, enforcement guidelines in Malaysian construction industry are considered as primary reasons for increase in CWG.

Tareq Khaleel (2018) categorized the causes of CWG into three groups such as (i) materials management and handling, (ii) transportation and storage, (iii) site management and practice stage. Questionnaire survey with 100 engineers are interviewed to assess the construction waste factors. The responses are analyzed using relative importance index.

The analysis results conclude that damage of materials, dual handling and lack of technical staff are the topmost ranked causes with RII of 0.866, 0.844 and 0. 833 respectively. The findings aid engineers in reducing CW quantities and improve WM performance of the respective construction sites.

Jing kuang Liu (2020) used structural equation modelling (SEM), to identify the factors which are significant in reduction of waste at source. A theoretical hypothesis was framed and tested. It was found that among the various parameters, government subsidies have highest path coefficient compared to the remaining influencing factors. Among the different paths, ethics of workforce, attitude and behavior, sustainability, government subsidies, contracts, transportation, operation and storage, SWMP are significant and valid. The aim of the study is to motivate stakeholders to implement CWM in respective projects.

Jiayuan Wang (2019) modelled various factors which affect CW reduction in design stage using SEM. Semi-structured interviews and questionnaires are the survey tools used to identify the influence factors. The analysis results conclude that, social and market environments have higher path coefficients followed by supervision, attitude and behavior parameters. Internal culture has an indirect effect on designer's intentions. In addition, suggestion and strategies are proposed from designer, engineer, government and client perspective. The conclusions from the study aid in developing standards and regulations for designing construction waste minimization.

Hilary Omatule Onubi (2020) compared the green approaches onsite with economic feasibility and environmental standards. The novelty of the study lies in estimation of correlation between onsite sustainable CWM practices with economic performance at corporate level. For which, a theoretical model is framed and tested via 168 projects executed by class-A Nigerian contractors. The gathered data is analyzed using (PLS-SEM) technique. The framed hypothesized model had a good fit, satisfactory measurement and structural model. The analysis results conclude that environmental performance partially mediates between sustainable green practices and economic viability. The results thus indicate that the site conforming to environmental standards tend to achieve fine economic success. The study further concludes that in order to achieve balance between environment and economic performance the contractors need to incorporate flexible approaches.

Konstantyn Povetkin (2020) determined various major causes for waste generation in infrastructure projects and their preventive measures. The major activities that are producing higher quantities of waste and which have greater impact on economy and environment are identified. After which, functional modelling is used for analysis of the causes. The developed model is further integrated in project supply chain for measurable material flow. In addition, the model is applied onsite for practical validation.

Asad Kamal (2021) analyzed the construction material sustainable usage with their performance and supply chain association in Pakistan. The study is conducted using closed ended questionnaire on 300 participants. The gathered responses are evaluated using SEM for which an initial hypothesis has been established. The analysis results thus conclude, there exists statistical significance among the components of supply chain integration with project performance. In addition, there exists statistical significance of mediating factor construction material sustainable usage. However, as the study indicates, the outcomes are limited to the construction industry of Pakistan. The authors suggest that the research work can be extended in future by comparing with construction industries of different countries.

2.2.2 Barriers, benefits and measures for implementing site waste management plan (SWMP) and CW recycling

HongpingYuan (2017) investigated the critical challenges and corresponding counter measures for C&D waste management problems in China. The data is collected from, government and non-government organizations, industrial experts and previous literatures. The data on waste generation, regulations and procedures are gathered and are analyzed. The study identified five drawbacks, among which are- lack of regulatory environment, involvement of several government organizations, lack of WM, ineffectual recycling facilities, lack of basic C&D waste data. The counter measures proposed include, improving C&D waste regulations, accurate and timely C&D waste management estimates, incorporation of CWM, providing efficient recycling facilities and by collecting waste disposal fees.

Saidat Damola Olanrewaju (2020) identified the barriers for reducing construction waste in design phase from architects perspective. Based on which, strategies for reducing onsite CW in design phase has been suggested. The study adopted questionnaire (open and close ended) to gather the data from the architects in Nigeria. The study thus concludes, changes in design by the client, shortage of trained workers, lack of flexibility and adaptability in design are the identified barriers. In accordance with the identified barriers, providing adequate training for the workers regarding policy and regulations, performing market survey on the availability of sustainable materials along with elaborated detailing are suggested measures. In addition, the study suggests that incorporating design checklist with waste minimization criteria will aid in reducing onsite CW at design phase.

Hongping Yuan (2011) explored the barriers for C&D waste management in China. For this, a questionnaire survey with 16 barriers which effect the C&D waste management are identified form previous literatures and interviews. The gathered responses are analyzed using ranking and factor analysis. Based on the analysis results, absence of market for recycled products, lack of attentive waste reduction plans in design phase, lack of regulations, are ranked as the topmost barriers. In addition, the identified barriers are analyzed using exploratory factor analysis (EFA). The analysis results of EFA conclude 16 barriers are grouped into 5 categories (awareness, management support, economic viability, marketing strategies and onsite conditions.

JingLiu (2020) investigated marketing strategies for C&D waste recycling from stakeholders perspective. Therefore, in this study the profits of both stakeholders- waste producer and recycler, are investigated under various marketing scenarios and level of environmental impacts. To achieve this, game theory is used for estimating the decisions between waste producer and recycler and their corresponding profits. The analysis results conclude, the profits of recycler are minimal, when the recycling plant processing capacity is less. In this study the dynamic interactions of waste producer and recycler are analyzed by comparing various market strategies.

Zhikang Bao (2020) reported the barriers for onsite C&D waste recycling at source itself. The study used mixed method approaches i.e. both site visits and interviews to gather data from Hong Kong construction sites. Based on this, lack of enough site space, lack of recycling opportunities, lack of offsite recycling and government policies are the major barriers for onsite C&D waste recycling. The study therefore suggests measures for efficient onsite recycling. Few among them include tailored recycling plant and equipment, improved government support, along with successful offsite recycling. The proposed measures probes into onsite and offsite waste recycling procedures in Hong Kong. The developed system can be used to strengthen recycling techniques in future.

Zeli Wang (2020) used simultaneous localization and mapping (SLAM) technology for successful onsite recycling of C&D waste, where in, a robot is used to deal with complex onsite scenarios. The method developed is effortless and less time consuming. Additionally, SLAM model can overcome the patrolling and picking method failure problems. For this, a system based computer vision model is developed to detect residual pipes and cables and are evaluated with algorithms developed in lab and onsite. The similar approach can be used to detect few other construction materials such as nails, timber, ceramics etc.

Mingxue Ma (2020) identified the challenges associated with C&D waste management in China. The data is collected from ten C&D waste recycling plants which are located in ten different cities. A total number of twenty employers are interviewed to identify and examine the challenges. Among the various challenges, eight challenges are detected. Lack of stable C&D waste recycling facilities, lack of subsidies for C&D waste products, lack of waste management in design specifications, lack of norms at onsite sorting, uncontrolled landfill actions, lack of cooperation among various administrations, lack of quantification and tracking of waste generated. Based on these challenges, the study suggested counter measures for effective management of C&D waste.

Yangyue Su (2020) demonstrated the means of changing strategies for governments, C&D waste recycling plant authorities and contractors working onsite. Game theory is used to assess the decision for efficient waste strategies.to achieve this numerical simulation analysis is utilized to validate the framed model. Further, the key parameters which influence stakeholder's decisions are studied in China. The analysis results indicate that, supervision of recycled market by government regarding purchasing of recycled materials by contractors along with producing superior quality products are the beneficial options. Employing high violation penalties can lead to high quality materials. Stable product prices, taxes and benefits for contractors along with low subsidy rates. The proposed study can be used to understand the behavior and demand of stakeholders to promote sustainable recycling market.

Qingwei Shi (2019) proposed, an multi-objective function optimization model to optimize C&D waste recycling and disposal plant. The model is tailor made with genetic algorithm, and probabilistic robust optimization to achieve the best solution. The major objective of the study is to reduce cost and negative environment effects. To achieve this, genetic algorithm is used to achieve preliminary results after which robust model is used to achieve best solution. The analysis results of the model indicate sites which are cost effective and sustainable compared to the remaining sites. Based on the model, further upgradation of site can be performed. The developed study can be further used for selecting site for C&D waste recycling plant.

Jingru Li (2020) quantified the essential policies for progressing C&D waste recycling industry. The study used, previous literatures to identify the crucial policies which are grouped into three categories: (i) control policies (ii)marketing policies and (iii) information based policies. The study used regression analysis to quantify the interrelation ships between crucial polices and implementation in cities of China. The study collected the data from fifty-two Chinese cities. The analytical results conclude that possessing green product label as well as taxes and standards are crucial constructs to improve C&D waste recycling industry in China. Furthermore, the study suggested that landfill charge can be implemented for further advancements. The developed framework can serve as a guide for the remaining cities of China.

ZhikangBao (2021) devised an model to plan for onsite and offsite CW recycling considering various parameters such as time, marketing, cost and government. The research study used semi-structured interviews onsite to gather the required data. The analysis results conclude, the major parameters for successful recycling are (i) project characteristics such as site space issues and time (ii) industrial and government support which include regulations, marketing strategies, subsidies. Moreover, the study organized the dynamics in CW recycling decision support system to enhance practical implementation of CWM.

LiMa (2020) studied various waste treatment methods used by stakeholders as individual and as a group.Accordingly,the research developed game model to assess symbiotic relationships between recycling and construction industries with or without policies, schemes and incentives. In accordance with the findings, the study investigated the role of incentives in CW recycling. The results of the model indicate that to achieve successful construction waste recycling incentive schemes are mandatory. Additionally, the study suggested counter measures to mitigate the existing barriers and to promote successful waste recycling in China.

2.2.3 Attitude and behavior studies using extended theory of planned behavior

The assorted theories to estimate the association between behavioral variables and green actions include Maslow's hierarchy, norm activation and social cognitive theory of these TPB is adopted in most scenarios (D. Li et al., 2019). Behavioral intention (BI) is combination of three determinants - attitude(ATT), subjective norm (SN), and perceived behavioral control (PBC). The TPB framework links attitude, subjective norms and perceived behavior control to BI and actual behavior of participants.

The prophecy of TPB can be enhanced by using extended theory of planned behavior (ETPB),which includes additional variables such as moral norms (Kaffashi & Shamsudin, 2019), perceived usefulness (Mak et al., 2019a), and knowledge (Taufique & Vaithianathan, 2018). BI is usually endorsed as a proxy of definite activities, as monitoring & reporting of actual behaviors is complex in wide contexts. The items or constructs are used to measure practitioner's planned behavior towards implementation of CWM by using self-reporting. The items selected can aid in promoting CWM through amendments to the existing policies and guidelines (Knoeri et al., 2011). Despite the imposed regulations by the Indian government, CWM is practically nonexistent in most of the construction sites (KolaventiSS et al.,2017).

Several studies are available in India which utilize the TPB framework, few of which are, explanation of multiple behaviors in association with ecotourism in Himalayan region of India. Consequently, studies extended TPB by additional constructs for enhanced prediction. Environmental concern and knowledge are the two additional constructs which are used to study the behavioral intentions of Indian youth to buy sustainable products (Yadav & Pathak, 2016). Similarly, attitude personal norms, environmental concern, and willingness are used to assess intentions to buy products with green packaging (G. Prakash & Pathak, 2017). Few other studies such as exploring sustainable tourism choices of Indian youth using individual morality and righteousness (Verma & Chandra, 2018), consumers involvement in explaining green behavior (Taufique&Vaithianathan, 2018), behavioral parameters to improve recycling and waste management status in India (Singh et al., 2018). Researchers thus conclude that ETPB can result in improved benefits. Various studies in CWM with different behavioral determinants are shown in Table 2.2

Table 2.2 TPB studies on construction waste management

Author	TPB			ETPB					
	ATT	PBC	SN	AW	RK/PR	EV	BF	DG	KN
(G. Zhang et al., 2021)				✓	✓	✓	✓		
(Friedrich, 2021)	✓	✓	✓			✓			
(S. Jain et al., 2020)	✓	✓	✓	✓	✓				
(Yang et al., 2020)	✓	✓	✓				✓		
(Mak et al., 2019a)	✓	✓	✓	✓		✓	✓		
(Wu et al., 2017)	✓	✓	✓		✓	✓			
(J. Li et al., 2015)	✓	✓	✓						
(Teo et al., 2001)	✓	✓	✓	✓					
(Heidari et al., 2018)	✓	✓	✓	✓					
(Yuan et al., 2018)	✓	✓	✓				✓	✓	
(J. Li et al., 2018)	✓	✓	✓	✓			✓		
(Oztekin et al., 2017)	✓	✓	✓					✓	
(Timothy M rose,2016)	✓	✓	✓		✓		✓		
(Kumar et al., 2017)	✓	✓	✓	✓					
(Khan et al.,2019)	✓	✓	✓	✓	✓				
(Singh et al., 2018)	✓	✓	✓		✓	✓			
(Yadav et al.,2017)	✓	✓	✓			✓			
(X. Zhang et al., 2017)	✓	✓	✓	✓					
(Khan et al., 2019)	✓	✓	✓	✓					
(Maichum et al., 2016)	✓	✓	✓						✓
(S. C. Chen et al.,2016)	✓	✓	✓	✓					
(Corsini et al., 2018)	✓	✓	✓	✓					
(M. F. Chen et al.,2010)	✓	✓	✓		✓				
(Janmaimool et al.,2016)	✓	✓	✓					✓	
(Y. Zhang et al., 2018)	✓	✓	✓			✓			
(Y. Zhang et al., 2018)	✓	✓	✓						
(L. Zhang et al., 2018)	✓	✓	✓	✓		✓			✓

JingruLi (2015) examines the role of designers in implementing waste management at design phase. The study employs Ajzen's theory of planned behavior (TPB) to develop a hypothetical model. The developed model is then tested using SEM. The study gathered the responses using questionnaire survey in China. The results conclude that attitude & perceived behavior control has positive effect on designer behavioral intention on waste minimization. Nevertheless, the effect of subjective norm is minimal. In addition, the study suggests policies to reduce waste generation during design phase.

Jingru Li (2018) studied the behavioral factors which influence construction waste reduction, from contractors employees perspective. In this study, two additional parameters (knowledge and personal norms) are added into the conventional TPB model. The data gathered from China is validated using SEM. The evaluation thus concludes that the augmented model has better exploratory power compared to conventional TPB model. Knowledge has highest impact on contractor's employees compared to other TPB parameters.

Binxin Yang (2020) analyzed the waste reduction behavior of construction workforce using TPB. Based on which, simulation model is developed using system dynamics. The analysis results of simulation model indicate, among the various management measures the effect of reactive actions are substantial in early stages of construction. While the effect of preventive actions is prominent in later stages of construction. The study summarizes the effect of reactive actions, prioritization and preventive actions are significant and aid in improving construction workers waste reduction attitude.

Amal Bakshan (2017) used Bayesian Network analysis (BNA) to improve CWM practices. The research method adopted consists of developing and administering the survey to the onsite construction workers. The gathered responses are then evaluated using single and multi-stage factor analysis. Based on which a probabilistic relational model is developed. The investigation findings of the study conclude, the behavior intention is highly influenced by the attitude (21%), previous experience (20%) and societal pressure (10%). Besides this, the possibility of effective CWM increases by 83% when onsite workers developed favorable attitude towards CWM. The developed study can serve as a decision tool for developing viable CWM strategies.

Sourabh Jain (2020) proposed an framework to examine the attitude and behaviors of builders towards C&D WM recycling in Indian construction projects. The study used extended theory of planned behavior (ETPB) with various parameters such as perceive benefits, cost, behavior control, attitude and subjective norm. In addition, various institutional pressures and environmental consciousness are studied. Questionnaire survey is developed for data collection. A total number of 260 responses are recorded. The gathered responses are then evaluated using PLS-SEM. The analysis results of the study indicate that personal motives are the major drivers of behavioral intention towards recycling C&D waste.

Zezhou Wua (2016) examined the contractor's attitude and behavior towards C&D waste management in China. An ETPB is developed using the additional constructs (economic feasibility, government inspections and project limitations). A hypothetical model is framed using additional constructs. A total number of eight constructs are identified, based on which seven hypotheses are framed.

To gather the data from construction sites, questionnaire survey is used. The developed hypothesis is later analyzed using SEM.The evaluation results indicate, the major determinant factor for contractor's C&DWM behavior is economic feasibility in the first place followed by government inspections. While, the impact of project limitation is insignificant for contractor's behavioral implementation of C&DWM. The study further concludes that, the government plays key role in encouraging and directing the contractor towards improved C&D waste management behavior.

2.2.4 Onsite and marketing strategies for CW management

Technological innovations are needed for successful management of C&D waste (Oliveira et al.2019). Earlier studies reported that, the increase in societal development accelerated the usage of software technologies such as BIM (Building information and modelling),GIS (geographic information system), BDA (Big data analytics), RFID (Radio frequency identification tags), which have proven successful in solving C&DWM problems (Huang et al. 2018; Lu 2019).

Software advancements tend to solve C&DWM problems. However, the software extensions at site, which can quantify the onsite waste management performance of construction projects are limited. The assessment of waste management performance onsite, can aid in enhanced benefits like- (i) identification of weak zones in the corresponding projects based on which measures can be proposed at management level (ii) quantification of the total amount of waste that is being generated at their projects(iii) recovery of valuable recyclable material(iii) identification of the effective segregation system(iv) estimation of the alternative methods for material disposal.

Jiayuan Wang (2018) developed a framework to quantify carbon emissions during demolition of a building. High rise residential buildings are used as a case study. The analysis results conclude, the sustainable benefit obtained due to recycling depends on the type of material. Furthermore, metal waste recycling has more sustainable benefits compared to other waste (masonry). In addition, the study identified onsite dealing of C&D waste such as (segregation, collection) producer higher amounts of carbon emissions. While, onsite recycling proved to be best in comparison with offsite recycling plants and landfills regarding carbon emissions. The study thus developed inventories on large scale to manage the C&D waste.

Nissim Seror (2018) used geographic information system (GIS) tools and geo-statistical modelling to locate the regions in Israel, which are highly vulnerable for illegal dumping of C&D waste. The study thus concludes accessible road network, the range of ravine, forest vicinity are the common factors present in existing illegally dumped sites. By using the analysis data, the regions with high potential for illegal dumping are mapped. The mapped data can be used by the official relating to environmental law to help them monitor these high risk zones and imposing penalties.

Xi Chen (2017) identified the factors impacting disaster waste generation in Hong Kong. Big data analytics is used for the quantification. The study identified that, demolition cost and duration of demolition are mutually dependent on each other. In addition, few other factors such as location of the site, building usage, and public- private building projects possess substantial impact on disaster waste generation. The study further indicates, based on the identified correlations, that the stakeholders can initiate policies and managerial actions to reduce disaster waste generation.

Noor Yasmin Zainun (2015) located the illegal disposed C&D waste sites along with assessment of the disposed C&D waste and to formulate GIS based map for illegal disposal of C&D waste in Malaysia. Based on the GIS modeling the study used photographs for recognizing the illegally dumped C&D waste. Based on which, the disposed material is quantified using pyramidal or rectangular shape measure. While for the scattered material, the weight is calculated and later on is converted into volume. The gathered data is thus mapped onto the GIS system. The study is developed with a motive of creating a database for illegal dumping sites in Malaysia.

Bo Yu (2019) developed a mixed trilogy strategy, to estimate demolition waste using WGR and GRA on a massive scale. Primarily, based on available data, WGR are calculated for various types of building. Likely, using a sample size of 200, GFA is calculated based on image recognition technology (IMRT) by setting up the error range within 10 percent. By using both of these methods, estimation of demolition waste on a massive scale is calculated. The test study indicate 49.40 MT of demolition waste is estimated. The study thus states that, the proposed methodology can be used to ameliorate the existing prediction methods.

Francesco Di Maria (2016) estimated the particle size distribution of aggregates using image analysis. The estimation of particle size is crucial, as it predicts the recyclability and the quality of the output material. The existing methods such as sieving or laser diffraction, have several onsite limitations. The particle size is estimated using image analysis and is later compared with manual sieving. The test results indicate 85 percent agreement with conventional sieving approach. The usage of such digital based systems can reduce manual errors and are less time consuming.

Zeli Wang (2019) developed a robotic waste sorter to segregate minute construction materials such as nails and screws. Such minute matters are tough to segregate and causes material loses and violates onsite construction safety. Therefore, the robot is used to track onsite to detect such substances by inspecting the entire working space. The study uses ANN in anonymous sites to detect scattered substances. Computer vision technology and full-coverage path-planning algorithm are the novel advancements used in the study. Similar technologies can be used in future, to identify CW onsite.

2.3 Summary of literature review

The literature review can be summarized with the following key findings:

- Previous studies stated, quantification is crucial for managing construction waste to assess the causes for waste generation, estimating waste asset, along with framing of strategies for recycling and disposal.
- Despite its importance, a reliable quantification of C&D waste is yet not available in developing nations like India. Significant insight into C&D waste quantification is necessary.

- To restrain the amount of waste generated, identification of causes for construction waste generation is crucial.
- There is no cohesive methodology developed to assess the individual impact of the causes of waste generation in India. Therefore, the impact of individual factors needs to be modeled.
- There is a pressing need to promote and implement management SWMP onsite.
- The existing literature indicates that assessment of attitudinal and behavioral parameters are crucial for improving CWM status of India.
- The enforcement measures such as training and supervision an appropriate linkage with attitudinal and behavioural is ill defined in the literature.
- The decision approach from a micro structural perspective is therefore important to assess the determinants which affect the implementation of CWM.
- Therefore, integrating social & behavioural factors are equally important to improve the current WM status in India. Theory of planned behaviour is most widely used in assessing individual intention by using three constructs namely (i) attitude (ii) subjective norms (iii) perceived behavioural control.
- The prediction capability of TPB can be enhanced by using extended theory of planned behaviour (ETPB). ETPB consists of additional variables such as moral norms, perceived usefulness and knowledge.
- Strategies for managing CW, which create revenue generation are ill defined in previous studies.

2.4 Literature gap

- There is a requirement to develop a quantification tool which is convenient and which can act as a sound measure for waste management effectiveness.
- There is a requirement to assess and model the impact of causes on CW generation.
- To identify the barriers and counter measures for implementation of SWMP.
- To assess attitude & behavioural parameters for implementing CWM in Indian context using extended theory of planned behaviour.

- The incorporation of CWM during execution phase is barely practiced and assessment tools are needed to monitor waste management performance of the construction sites.
- Alternative solutions and strategies which can create revenue generation need to be developed for managing CW.

CHAPTER 3

Aim and Objective

3.0 General

It is evident from previous literature, that there are limited studies available in India regarding construction waste management.

Research question

How can we identify and quantify the reasons for improper management of construction and demolition waste in Indian construction industry, despite the various guidelines and rules issued by the Government?

Approach

In this study CWM is addressed in different contexts such as identification of various factors influencing CWM performance along with modelling the causes of CW generation. In addition, the study further assesses barriers, benefits and measures for non-implementation of site waste management plan and attitudinal as well as behavioral studies are evaluated. Furthermore, a framework is suggested to quantify onsite waste management performance by developing process flow models, performance evaluation index and marketing solutions (prototype Android application- Waste alley) is developed to incentivize construction waste.

3.1 Aim and Objectives

3.1.1 Aim

To develop a rational framework for identification and quantification of the reasons for improper management of construction and demolition waste in Indian construction industry, despite the various guidelines and rules issued by the Government.

3.1.2 Objectives

- To quantify the waste generated at construction sites and analyze waste management influence factors at Indian construction sites statistically.
- To assess causes & their individual impacts on construction waste generation.
- To assess barriers, potential benefits and enforcement measures for implementing SWMP and recycling.
- To investigate (Attitude & Behavioural) intention of the individual professionals towards implementation of construction waste management.
- To develop onsite tools to monitor, assess construction waste management and establish an e-commerce store for marketing construction waste.

3.2 Scope and limitations of the present investigation

3.2.1 Scope

- Evaluation of construction waste management performance in India by identifying factors influencing waste management and modelling the causes for waste generation.
- Investigating various barriers, benefits and enforcement measures for implementation of SWMP and recycling.
- Assessment of CWM implementation in projects by attitudinal and behavioural factors.
- Developing onsite tools for monitoring and estimating C & D waste management performance. Suggesting a framework for developing software tools for marketing C & D waste.

3.2.2 Limitations

- The current study quantified waste from construction sites limited to concrete and steel.
- The current study incorporated two additional constructs in TPB model i.e. Knowledge and perceived usefulness.

3.3 Research significance

- Application of structural equation modelling to identify causes for CWG.
- Determination of barriers, benefits and measures for implementing SWMP in specific to Indian construction industry.
- Study of attitudinal and behavioral parameters influencing implementation of CWM.
- Assessment of onsite waste performance using process flow models and index based systems
- Development of a commercial solution to incentivize CW.

CHAPTER 4

Methodology

4.0 Introduction

In this chapter the procedures employed in this study are systematically discussed. In the current work both qualitative and quantitative approaches are used. The thesis is categorized under four phases. ***Phase-1*** of the project work deals with identification of waste management influence factors and modelling the causes for waste generation. ***Phase-2*** of the project deals with assessment of barriers, benefits and enforcement measures for SWMP implementation. ***Phase-3*** of the project deals with attitudinal & behavioural studies on implementation of construction waste management. ***Phase-4*** of the project deals with onsite solutions for CWM which include drafting waste management process flow models, framing an index based system for assessing waste management performance of construction projects and developing an E-Commerce store for marketing of C & D waste. All the four phases of the project (Figure 4.1) are discussed in detail under subsequent sections.

4.1 Phases of the research work

4.1.1 Phase-I

Phase -I of the research work evaluates:

(1) Quantification of CW: Quantification of the construction waste that is being generated from the construction projects – Quantified using wastivity.

(2) Identification of CWM influence factors: Statistical tools are applied such as-

- Analogous importance index (AII) to rank the corresponding variables.
- Various statistical analysis are conducted to check internal consistency, adequacy, elimination of outliers and calibration of questionnaire.
- The degree of concordance among various construction professionals towards waste management is analyzed using Kendall’s coefficient of concordance (W).

(3) Modelling the causes for CW generation: Modelling the causes which influence waste generation at construction site using structural equation modelling.

4.1.2 Phase-II

Phase -II of the research work assesses:

(i)Barriers, benefits and measures for implementing site waste management plan: The BBM for implementation of SWMP is assessed by using Beneficial index value (BIV), for this a questionnaire survey with 64 questions are distributed (online, offline). The relative significance among the variables i.e average significant score (ASS) is calculated by the weighted average model from which (BIV) is calculated**.**

(ii)Barriers & Measures for recycling: There are several barriers associated to recycle construction waste. For this, six active governments as well as private construction sites in India are visited and studied to assess the barriers for recycling of construction waste. The four categories- (i) Behavioural (ii) Technical (iii) Legal and (iv) Marketing barriers (Mahpour, 2018) are used in detailed analysis. Relative mapping approach is used for the assessment of barriers for recycling of construction waste among the construction sites

(iii)Comparison of C & D WM practices of European and Indian nations: The successful C & D WM practices in Europe are compared with Indian initiatives to improve the status of recycling in India.

4.1.3 Phase-III

Phase -III of the research work determines:

(i)Extended Theory of planned behavior (ETPB) to promote implementation of construction waste management in India

The attitudinal and behavioural studies on implementation of construction waste management in India are studied using ETPB. The assorted theories to estimate the association between behavioural variables and green actions include Maslow's hierarchy, norm activation and social cognitive theory of these TPB is adopted in most scenarios(Li et al., 2019). Behavioural intention (BI) is combination of three determinants: attitude (ATT), subjective norm (SN), and perceived behavioural control (PBC).

The TPB framework links attitude, subjective norms and perceived behaviour control to BI and actual behaviour of participants. The prophecy of TPB can be enhanced by using extended theory of planned behaviour (ETPB), which includes additional variables such as moral norms, perceived usefulness and knowledge. BI is usually endorsed as a proxy of definite activities, as monitoring & reporting of actual behaviours is complex in wide contexts. The items or constructs are used to measure practitioner's planned behaviour towards implementation of CWM by using self-reporting. The items selected can aid in promoting CWM through amendments to the existing policies and guidelines.

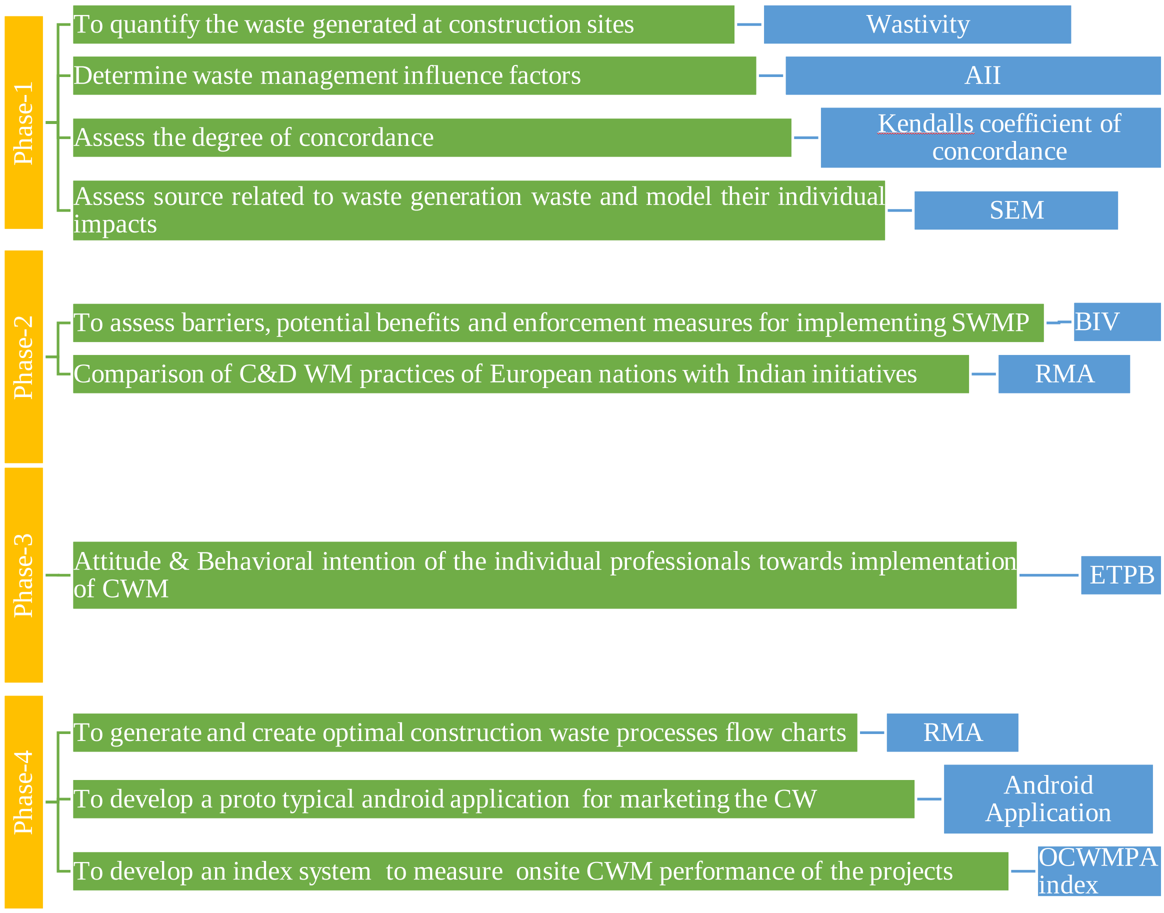


Figure 4.1 Research Methodology

4.1.4 Phase-IV

Phase -IV of the research work develops:

(i) Waste process flow

Waste process flow modelling is utilized in this study to examine the real time waste flow at construction sites. The technique has the advantage of presenting a well-defined process flow in a simple way(Fisher and Shen 1992). Using this technique, six active construction sites in India are studied. The case studies are selected on the basis of ongoing constructions of different sizes (small, medium large) projects. The process flow models are developed based on observations and discussions with the relevant staff at construction sites. The process adopted at each site can be easily represented to enable identification of strengths and weakness in each construction site.

(ii) Development of Android application - "Waste Alley"

A Proto-typical Android Application-***Waste Alley*** is developed for marketing C &D waste**.** Waste Alley provides an e-portal where construction waste can be bought and sold. The user in possession of waste (seller) can post the information on the website along with the photograph, location, type of the material, age of the materials and contact details. A GPS enabled system needs to be associated with the android application to aid in locating the seller or if the seller is unavailable the buyer can simply post/advertise their requirement.

(iii) Developing onsite construction waste management performance assessment (OCWMPA) index

The onsite CWM performance of the companies is assessed by means of an index. For this, 32 OCWMPA variables are selected and are further scrutinized by means of ranking. Finally, top 25 variables are used for further analysis. Later on OCWMPA index is developed. The index ranges from 0 to 1000.Where, 0-250 refereed as poor, 250-500 as fair, 500-750 as good, and 750-1000 as excellent performance towards waste management.

4.2 Research Question

Table 4.1 Research Questions

Main research question		
How can we identify and quantify the reasons for improper management of construction and demolition waste in Indian construction industry, despite the various guidelines and rules issued by the Government?		
Objective 1 To quantify the waste generated at construction sites and analyze waste management influence factors at Indian construction sites statistically	**RQ1:** *How can we quantify the total amount of waste that is being generating from construction projects.* **RQ2:** *What are the various factors which are influencing CWM.*	**PHASE-1** **Wastivity** is used to quantify the total waste that is being generating from the projects. Based on the site visits, the factors which are influencing WM are analysed using various **statistical techniques.** **Exploratory factor analysis** is used to group the variables into corresponding categories and **Structural equation modelling** is used to assess the individual impact of causes on construction waste generation.
Objective 2 To assess causes & their individual impacts on CWG.	**RQ3***: What are the various causes for construction waste generation* **RQ4***:What is the impact of individual causes on construction waste generation*	
Objective 3 To assess barriers, potential benefits & enforcement measures for SWMP implementation	**RQ5:** *What are barriers, benefits and enforcement measures for implementing site waste management plan and recycling in India.*	**PHASE-II** To assess the BBM for implementing SWMP a **weighted average model** and **beneficial index value** is devised**.** To assess the BBM for implementing recycling relative mapping approach is used.
Objective 4 To investigate (Attitude & Behavioural)	**RQ7:** *What are the various attitudinal & behavioural*	**PHASE-III** **Extended theory of planned behaviour** is used to assess the

intention of the individual professionals towards implementation of CWM.	*parameters associated with implementing CWM in India.*	attitudinal & behavioural impacts for implementing CWM in India.
Objective 5 To develop onsite tools to monitor, assess construction waste management and establish an e-commerce store for marketing construction waste.	**RQ8:** *How can we track the onsite waste management process?* **RQ9:** *How can we quantify the performance of waste management system onsite?* **RQ10:** *How can we prevent illegal disposal and landfilling of C & D waste*	**PHASE-IV** To track the real time CW flow **process flow models** are drafted To measure the onsite waste management performance of construction projects an **index system** is formulated. An framework- **E-Commerce store** is suggested to prevent illegal disposal and landfilling of C & D waste.
Establish and assess the status of construction waste management in India by developing a holistic approach for CW management which can benefit both policy developers and industry.		

CHAPTER 5

Construction waste quantification and identification of CWM influence factors

5.0 General

Objective -1 of the research work consists of :

1. Identification of CWM influence factors.
2. Assessment of degree of concordance among the respondents. The methodology for objective-1 is presented under figure 5.1.

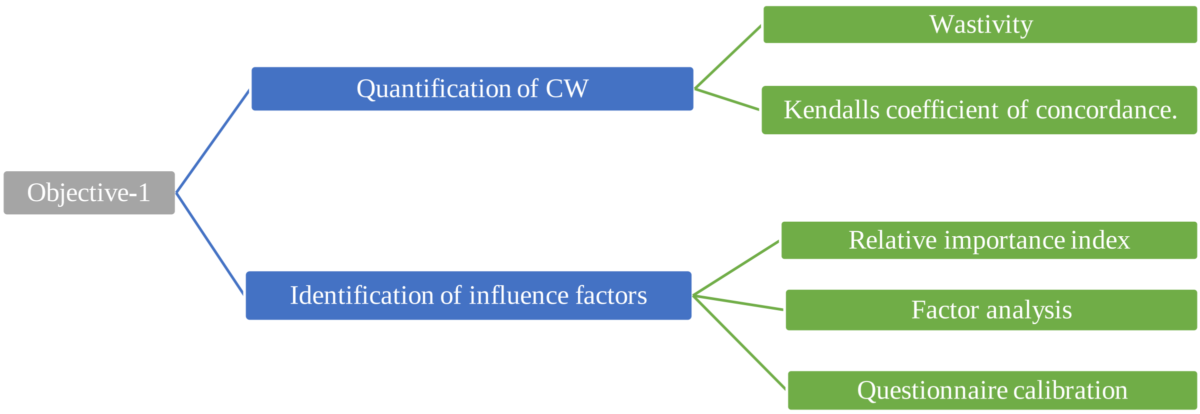


Figure 5.1 Methodology for objective one

5.1 Wastivity, Grouping, ranking and concordance calculation of CWM influence factors

5.1.1 Wastivity

Wastivity is a measure of waste management effectiveness and is represented as a ratio of material wastage to the estimated material consumption (Sushil, 2015). For the calculation of wastivity the current chapter presents two case studies of multi storied RCC buildings located in Telangana State, India. Construction sites are selected on the basis of ease of construction, document management, ease of obtaining the data and logistic feasibility. Steel and concrete are selected for the study because concrete and steel are the major contributions of the waste (Llatas 2011;Poon et al., 2001 ; E. C. et al., 2017).

5.1.2 Identification and grouping of influence factors

As stated earlier there is lack data or documentation relating to CW generated onsite with the construction firms, the selection of the variables is based upon field interviews with site engineers as well as from the existing literature. The opinions of the engineers on the variables selection is justified from the previous research (Assem Al-Hajj, 2011; Osmani et al., 2008; Rawshan Ara Begum et al., 2006). A detailed note of variables and their literature sources are presented in Table 5.1.

Table 5.1 Variables and their literature sources

Category	*Description*	*Source*
1		
CMT1	Wastes are to be placed in an accessible area for easy shipping	(Wang et al. 2010)
CMT2	An index score to define the capability of a firm towards waste management is mandatory	Interview
CMT3	During bidding process additional weightage to be given to contractors having clear plan, schedule and estimates of waste management	Interview.
CMT4	A ranking system to rank firm according to existing plans of towards waste management is mandatory.	Interview
CMT5	Mandatory item of actual cost for waste treatment to be provided in bill along with satisfactory documentation	(Muleya et al. 2017)
CMT6	Workers should be given training in identifying recyclable material	(Wang et al. 2010)
CMT7	Enforce strict punishment for illegal disposal of wastes in violation of EPA regulations	(Shen et al.2002)
CMT8	Waste collectors are to be installed at every floor and a jumbo collector for the entire building	(Wang et al.2010)
CMT9	Site waste management plan (SWMP) should be completed before preconstruction phase	(Muleyaet al.2017)
CMT10	Fragile materials are to be handled carefully in order to reduce wastage during construction.	(Muleya et al.2017)
CMT11	Separation of individual waste from a mixture of wastes	(Wang et al.2010)
2		
DOC1	A Statute on management of waste by the corresponding waste producers is not mandatory	(Wang et al. 2010)
DOC2	Clauses relevant to Quality and safety of recycled material are not necessary to be included in code books	(Muleya et al.2017)
DOC3	Clauses in contract documents specifying waste treatment methodologies and equipment are not mandatory	(Muleya et al.2017)
DOC4	Checklists for waste management need to be verified and enforced by subcontractor alone	(Osmani et al. 2008),
DOC5	Code provisions for construction waste management is not	Interview

DOC6	Documents and records relating to waste management is maintained by subcontractor alone	(Osmani et al. 2008)
DOC7	Transportation and storage of materials need not be specially addressed in SWMPs.	(Muleya et al.2017)
3		
CE1	Installation of equipment's for recycling in construction site is not mandatory as it does not reduce transportation cost	Interview
CE2	Installation of equipment's for recycling in construction site is not mandatory	(Poon et al. 2004b)
CE3	Additional methods need not be informed to site management and workers to treat the materials after recycling	(Poon et al. 2004b)
4		
MAT1	Prefabricated materials and components do not produce less amount of wastage	Interview
MAT2	Fragile materials need not to be replaced in order to reduce wastage during construction.	(Osmani et al. 2008)
MAT3	Individual containers for sorting out of waste is mandatory in construction site	(Wang et al. 2010)
5		
WI1	Separate workers should be appointed at the site for disposing waste.	(Wang et al. 2010)
WI2	There is a need of representative of contractor at the site to enforce waste management	(Wang et al. 2010)

Note: 1- Construction Method **2-**Documentation **3-**Construction Equipment **4-**Materials **5-**Worker Intention

A detailed questionnaire is framed, comprising of 47 variables and distributed to contractors, academicians and engineers throughout India such as New Delhi, Chennai, Bangalore, Cochin, Thiruvananthapuram, Vijayawada etc. Detailed demographics of the respondents are shown in Table 5.2.

Table 5.2 Demographics of the respondents

Respondents Profile	Number of respondents	Percentage of respondents
Academicians	95	52 %
Engineers	42	23%
Contractors	47	25%
Total	184	100%

Variables are grouped under corresponding factors by means of exploratory factor analysis (EFA). It is used to reduce the large number of variables into manageable constructs. Further, it is used to enact grouping of variables with their corresponding factors and to remove the variables which do not explain the constructs (Taherdoost et al., 2014). IBM SPSS(R) statistics 23.0 is used for the analysis. The general descriptive statistics of the variables are computed as per (Manuel Gomez-Soberon et al., 2013) between the three groups of respondents: i) central tendency measures-mean, median, mode, sum; (ii) Dispersion measures-standard error of the mean, standard deviation, variance, range, minimum, maximum; (iii) form of the curve distribution-skewness, standard error of skewness, kurtosis, standard error of kurtosis.

5.1.3 Ranking of Influence factors by means of AII

A ranking analysis has been used to rank the influence factors. Simple mean and standard deviation is not sufficient to assess the overall rankings as they do not present any relationship (Chan et al., 1997). Hence the study utilizes the analogous importance index (AII). Ranking is given on basis of AII. MS-Excel(R) is used for analyzing the ranks. The workforce has been classified into three categories i.e. engineers, academia and contractors and the ranking are performed in two ways. One method is to rank influence factors (IF) by means of consideration of all the variables; the other method is to rank IF within respondent groups. The ranks are allotted by considering AII values. The variable with highest AII is assigned the top most rank (Iyer et al., 2005).

5.1.4 Measurement of concordance among engineers, academia and contractors

Based on field visits and interviews it is observed that management of waste in Indian construction industry is blended with a mixture of attitudes. The attitudes of various construction professionals towards waste management can be analyzed for better waste management practice by means of Kendall's coefficient of concordance (W). This coefficient (W) is used to assess the consistency as well as level of agreement among the respondents. The value of (W) ranges from 0 to 1 where- 0 refers to perfect degree of disagreement and 1 refers to perfect degree of agreement (Chan et al., 2012). The hypothesis is designed as:

Null Hypothesis (H_o): There is insignificant degree of agreement among contractors, academicians and engineers.

Alternate Hypothesis (H_1): There is statistically significant degree of agreement among contractors, academicians and engineers.

5. 2 Analysis results and discussion

5.2.1 Wastivity calculation at construction sites

Wastivity is a measure of waste management effectiveness, represented as a ratio of material wastage to the estimated material consumption. Sites 1 and 2 are G+4 and G+2 commercial complexes with ongoing construction. The wastage is computed for each of the floors and wastivity is thus calculated by using equation (1). Slabs are considered for the study as they are require major amount of raw material and hence they are major contribuitors of waste generation (Gomez-soberon et al. 2014).

$$\textit{Wastage} = \textit{Actual consumption} - \textit{Estimated consumption}$$

$$\text{Wastivity} = \frac{\text{Wastage}}{\text{Estimated consumption}}(100) \qquad (1)$$

The total wastivity share of concrete is 18.28% and steel is 35.7% respectively (Figure 5.2). A similar approach can be used for various materials such as tiles, ceramics, bricks, plastic, timber, cardboards etc.

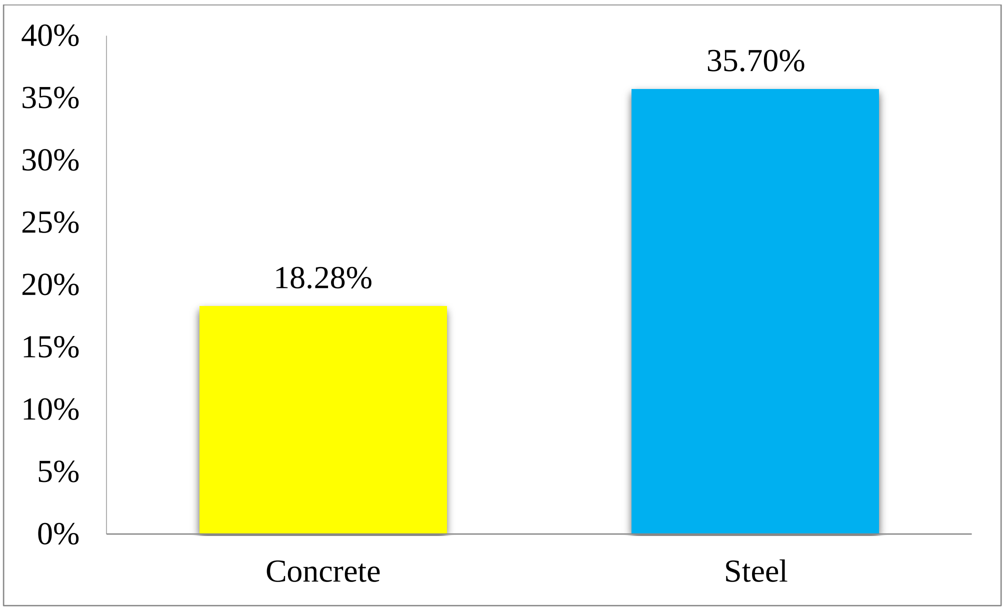


Figure 5.2 Wastivity percentage calculation in construction sites

5.2.2 Factors Influencing Construction Waste Management

A detailed survey is performed in order to examine the influence factors for improper waste management at construction sites. The questionnaire is assembled based on existing literature and communicated through authenticated emails. Respondents are asked to rate their response on a 7 point Likert scale, bench marking 7 as strongly agree to the statement and 1 as strongly disagreeing. A total of 184 professionals were contacted out of which 157 responded, achieving a response rate of 85.3%. The respondents include employees at government and private organizations within India. A sample size of 100 or greater is adequate for running factor analysis (Hair et al. 2009). The assumptions of factor analysis such as multivariate normality, multicollinearity, positive definiteness, homoscedasticity, and variance are checked to delete outliers from the data using statistics. Finally, 152 responses are found suitable for the study out of which 52% are academicians, 23% are engineers, and 25 % are contractors.

Exploratory factor analysis (EFA) enables grouping of the influence factors. Principal component analysis (PCA) is used for factor extraction. It is used when no background data or model exists (Gorsuch et al.2010).The survey consists of 47 questions, each corresponding to a variable. Variables with factor loadings greater than 0.3 (Kline, 1994) are considered for the study. The Kaiser-Meyer-Olkin (KMO) test is used to measure the adequacy of the data and its value ranges from 0 to 1, wherein a value greater than 0.6 is considered adequate for EFA (Taherdoost et al., 2014). Bartlett's Test of sphericity gives a chi-square output ($p<0.05$) which indicates that the matrix is a non-identity matrix (Taherdoost et al., 2014). Results are presented in Table 5.3, and are satisfactory (Taherdoost et al., 2014).

Table 5.3 KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.872
Bartlett's Test of Sphericity	Approx. Chi-Square	2052.995
	Df	325
	Sig.	.000

A total number of 26 out of 47 variables are grouped into five categories which can explain 62.63 % of variance. EFA enables grouping of the variables under five categories: 11 variables are loaded in ***construction method***, 7 variables on ***documents***, 3 variables on ***construction equipment***, 3 variables on ***materials*** and 2 variables on ***worker intention*** (Table 5.4). The loading of the variables is supported by (Gavilan et al., 2006; Cha et al., 2009; Bossink et al., 2002).

Subsequent to factor analysis, the internal consistency of the data is measured by means of Cronbach's alpha using IBM SPSS 23®. The value ranges from 0 to 1. The values closer to 1 indicate higher internal consistency and vice versa. The Cronbach's alpha values for various categories are: construction method (CMT)- 0.918, documentation (DOC)- 0.864, construction equipment (CE)- 0.781, materials (MAT)- 0.723, worker intention (WI)- 0.721. The Cronbach's alpha for all variables is 0.877 and are considered reliable (Hair et al., 2009).

Table 5.4 Factor Extraction

Variables	Factor Loadings	Variance Explained
Construction Method		
CMT1	.769	31.865
CMT2	.753	
CMT3	.749	
CMT4	.741	
CMT5	.706	
CMT6	.701	
CMT7	.682	
CMT8	.637	
CMT9	.628	
CMT10	.538	
CMT11	.372	
Documentation		
DOC1	.774	15.585
DOC2	.761	
DOC3	.750	
DOC4	.744	
DOC5	.726	
DOC6	.707	
DOC7	.701	
Construction Equipment		
CE1	.831	6.238
CE2	.753	
CE3	.603	
Materials		
MAT1	.616	5.184
MAT2	.567	
MAT3	.559	
Worker Intention		
WI1	.873	3.789
WI2	.507	

5.2.3 Central tendency, dispersion measures and form of curve distribution

The general descriptive statistics such as central tendency, dispersion and form of distribution curve for the grouped variables are computed.

(i) Central tendency measures: For the variables of ***construction method*** (Figure 5.3, 5.4, 5.5) the mean of all the three groups ranges from 5.6 to 5.9 which implies there is moderate degree of agreement but not perfect degree of agreement. While for ***documentation*** the mean of contactors and engineers is 4 i.e. (neutral) whereas for academicians is 3 (somewhat disagree) to most of the statements. For the variables in ***construction equipment*** the mean is 2.6 to 2.9 (Disagree) to most of the statements. Similarly, for variables grouped under ***materials*** the mean is in the range of 2.3 to 3.7 (somewhat disagree to disagree) indicating a large variation among academicians (3.7), contractors (2.4) and engineers (2.3). For ***worker intention*** 5.3 to 5.6 indicating there is no strong agreement but there exists moderate agreement in between the groups.

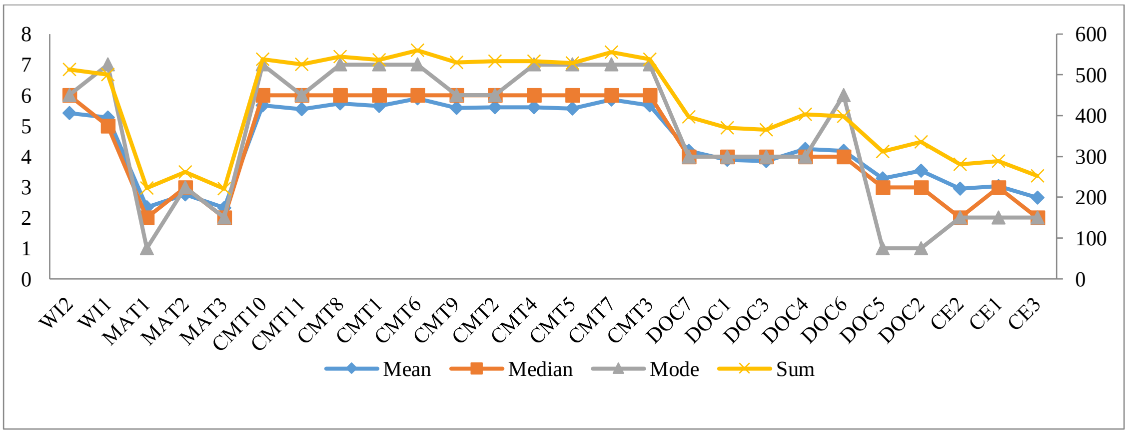


Figure 5.3 Central tendency measures for academia

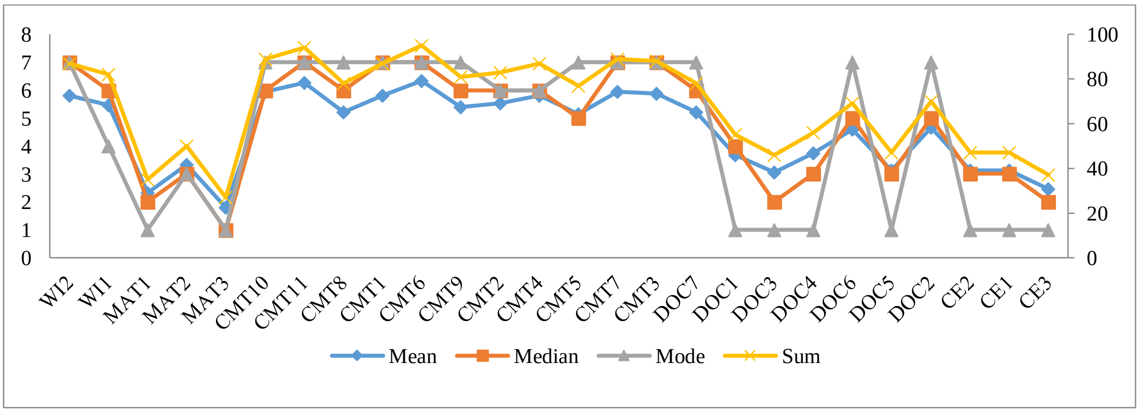


Figure 5.4 Central tendency measures for contractors

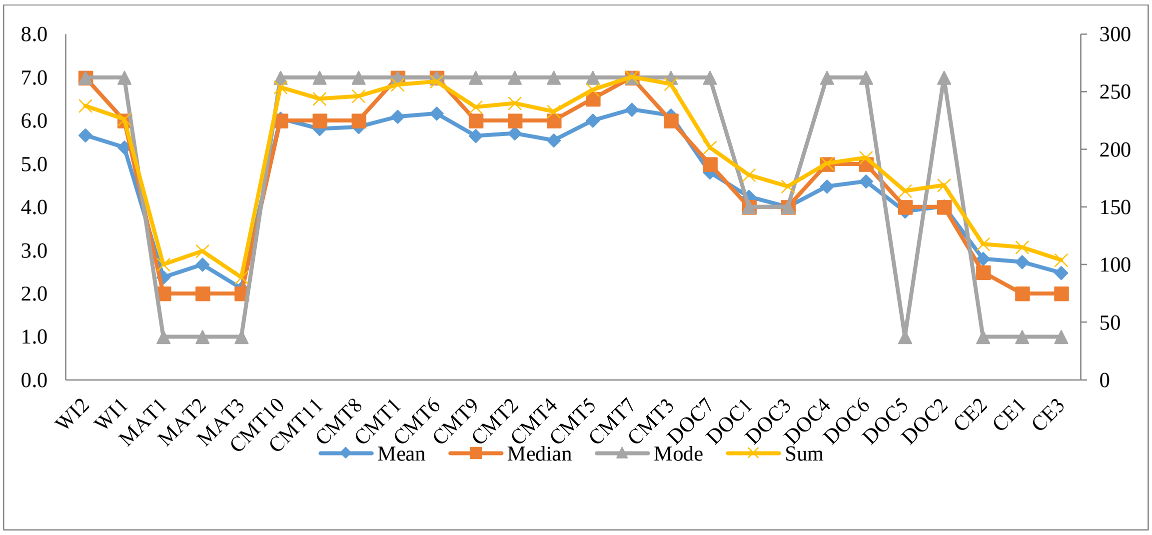


Figure 5.5 Central tendency measures for Engineers

(ii) ***Dispersion measures*** (Figure 5.6, 5.7, 5.8): The range or amplitude for each of the evaluation i.e for ***construction method***-academia-5.09, contractors-4.82, engineer-4.73 which implies 3 groups have different amplitudes. For ***documentation*** all 3 groups have same amplitude i.e. 6.00. Whereas for ***construction equipment*** the amplitude 6 is same for academia, engineer and 5.33 for contractor. The variables in ***material stage*** are 5.33 for academia and engineers and 4.6 to the contactors. For the variables of ***worker intention*** is same academicians and engineers i.e. 6 but for contractors the value is 4.5, which indicates that, in most of the cases the responses of academia and engineer are almost similar compared to contractor's response.

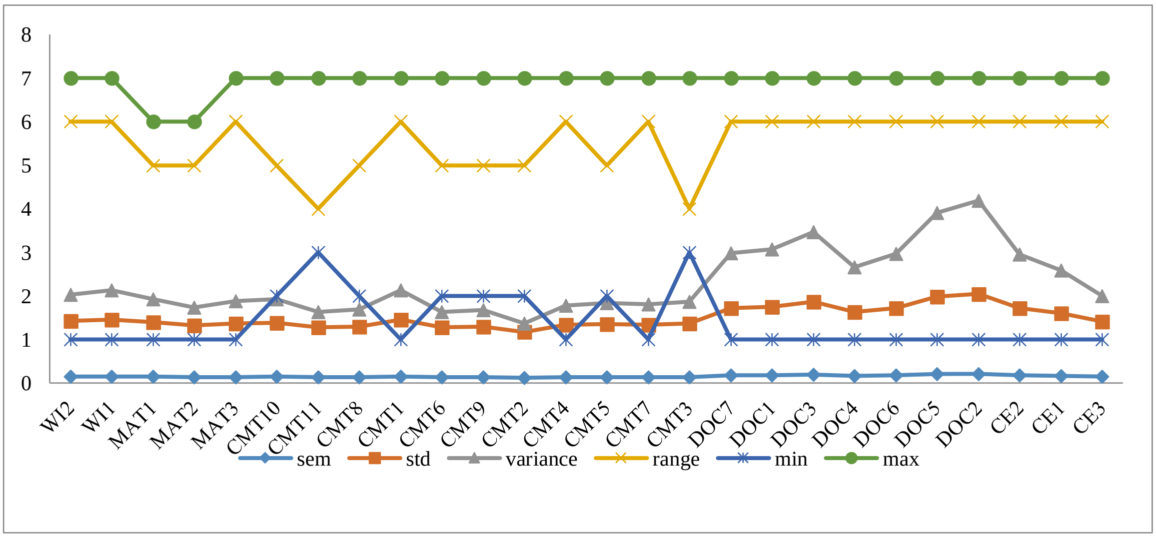


Figure 5.6 Dispersion measures for academics

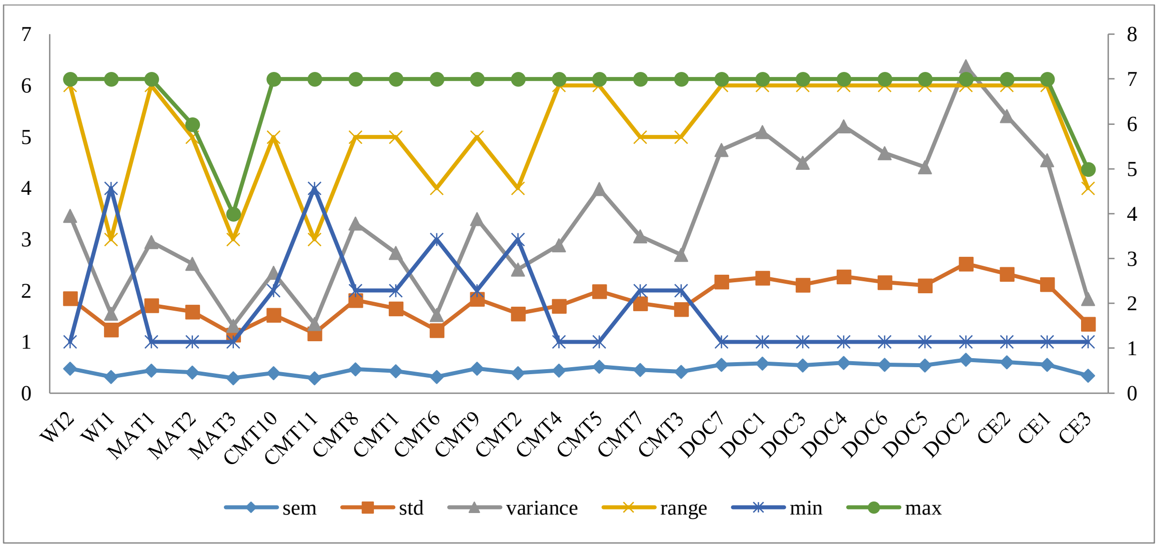


Figure 5.7 Dispersion measures for contractors

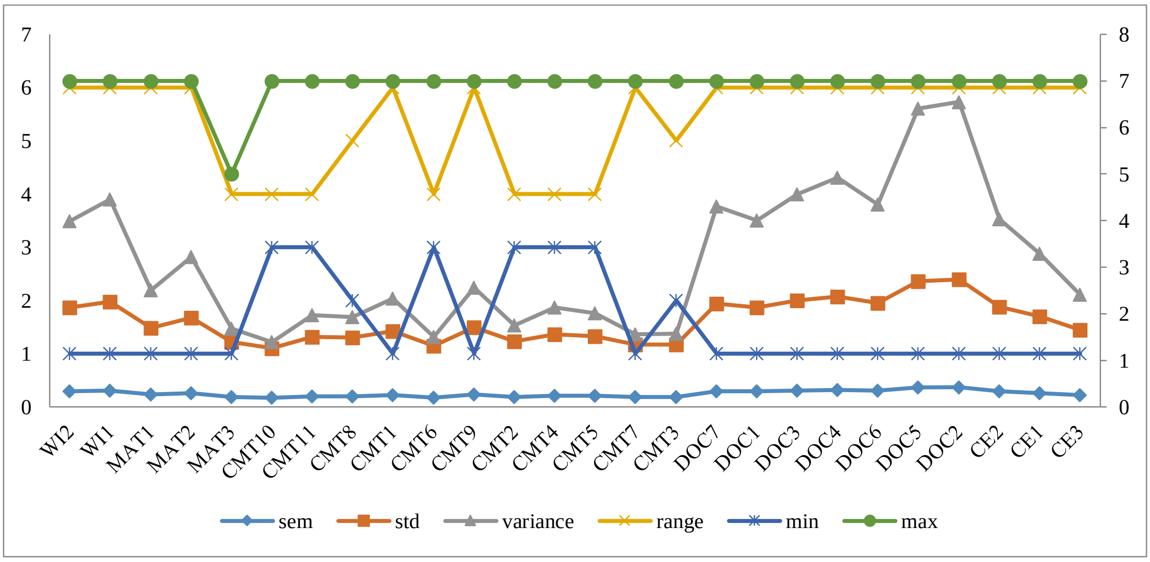


Figure 5.8 Dispersion measures for engineers

(iii)Form of the curve distribution:-The skewness and kurtosis of variables shown in Figure (5.9, 5.10, 5.11) are in the range of -2 to +2 which according to (George et al.,2016) is satisfactory for the analysis.

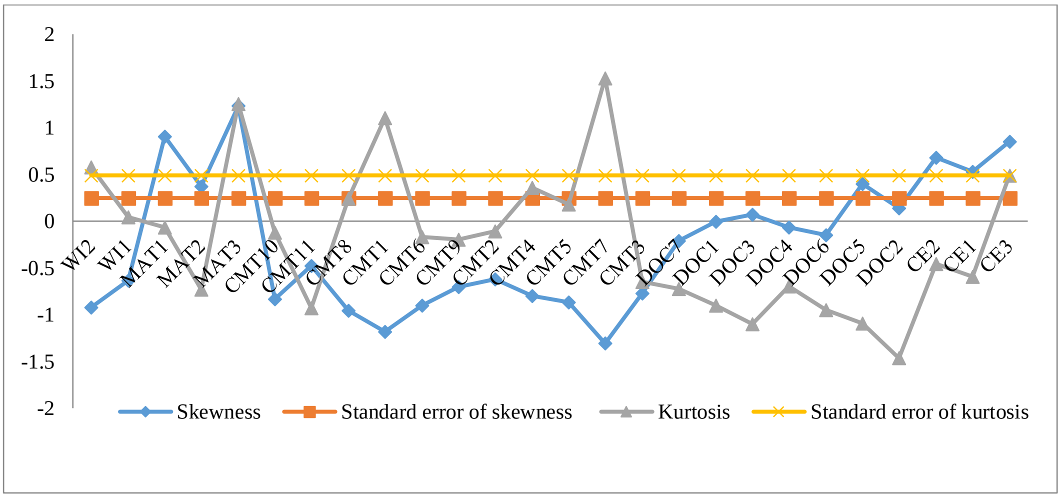


Figure 5.9 Form of the curve distribution for academics

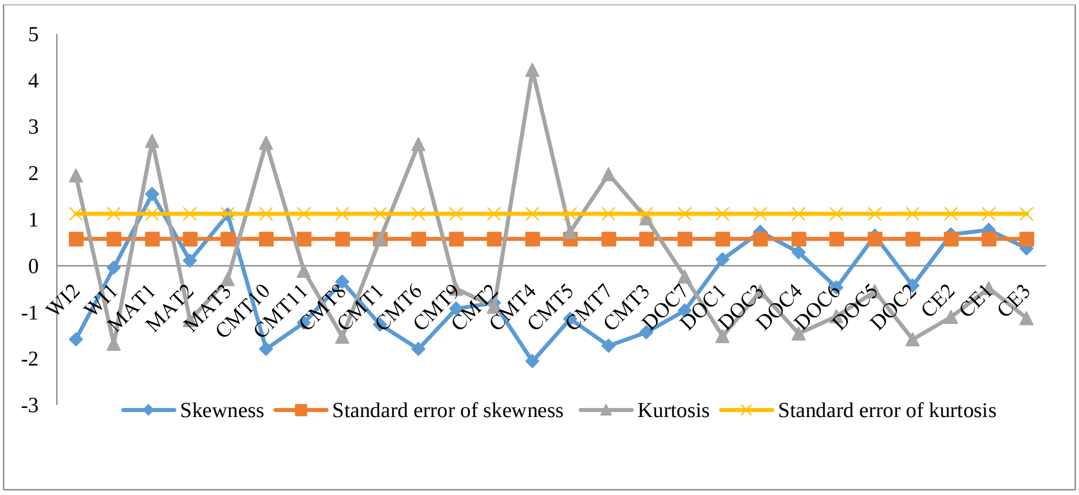


Figure 5.10 Form of the curve distribution for Engineers

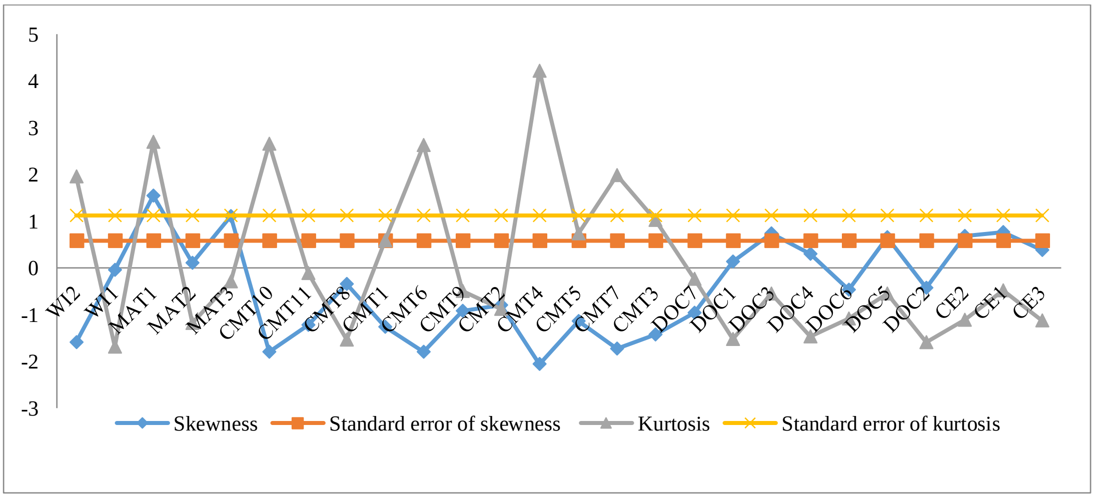


Figure 5.11 Form of the curve distribution for contractors

To rank the top most influence factors analogous importance index (AII) is used and is evaluated using the following expression (Iyer et al., 2005).

$$AII = \sum w/(A * N) \qquad (2)$$

Where, ***w:*** weight assigned to each attribute by the respondents, (values from 1 to 7)

A: Highest weight (i.e., 7 in this case), and

N: total number of respondents.

Table 5.5 Summary of analogous importance index ranking of influence factors

IF	Contractor			Academician			Engineer		
	AII	OR	GR	AII	OR	GR	AII	OR	GR
	Construction method								
CMT10	0.848	3	3	0.811	4	4	0.864	5	5
CMT11	0.895	2	2	0.791	11	11	0.83	8	8
CMT8	0.743	12	10	0.818	3	3	0.837	7	7
CMT1	0.829	6	6	0.806	6	6	0.871	4	4
CMT6	0.905	1	1	0.842	1	1	0.881	2	2
CMT9	0.771	11	9	0.797	9	9	0.806	11	10
CMT2	0.791	9	8	0.802	7	7	0.816	9	9
CMT4	0.829	6	6	0.802	7	7	0.793	12	11
CMT5	0.733	14	11	0.795	10	10	0.857	6	6
CMT7	0.848	3	3	0.836	2	2	0.895	1	1
CMT3	0.838	5	5	0.811	4	4	0.874	3	3
	Documentation								
DOC7	0.743	12	1	0.597	16	3	0.687	14	1
DOC1	0.524	18	5	0.556	17	4	0.605	17	4
DOC2	0.438	23	7	0.55	18	5	0.571	19	6
DOC4	0.533	17	4	0.606	14	1	0.639	16	3
DOC6	0.657	16	3	0.598	15	2	0.656	15	2
DOC5	0.448	20	6	0.469	20	7	0.558	20	7
DOC3	0.667	15	2	0.504	19	6	0.575	18	5
	Construction Equipment								
CE2	0.448	20	1	0.423	22	2	0.401	21	1
CE1	0.448	20	1	0.433	21	1	0.391	22	2
CE3	0.352	24	3	0.38	24	3	0.354	24	3
	Materials								
MAT1	0.333	25	2	0.335	25	2	0.34	25	2
MAT2	0.476	19	1	0.394	23	1	0.381	23	1
MAT3	0.257	26	3	0.332	26	3	0.303	26	3
	Worker intention								
WIM1	0.829	6	1	0.773	12	1	0.81	10	1
WIM2	0.781	10	2	0.753	13	2	0.769	13	2

IF: Influence factors; OR: Overall rank; GR: Group rank.

Contractors and Academicians rank - ***Workers should be given training in identifying recyclable material***, as the top influence factor. Engineers rank the factor- ***Enforcement of strict punishment for illegal disposal of wastes in violation of EPA regulations***, as the top influence factor (Table 5.5).

5.2.4 Measurement of concordance among construction professionals

In conjunction to AII, concordance among the three groups respondents (Contractor, Academia, and Engineer), is checked using Kendall's coefficient of concordance (w). It is a measure to determine agreement among raters (Enshassi et al., 2009). Test statistics measure the concordance on a scale of 0-1. Where, 0- perfect degree of in agreement and 1- strong degree of agreement among professionals. Concordance is computed by the following equation:

$$\mathrm{W} = 12\mathrm{U} - 3\mathrm{m}^2\mathrm{n}(\mathrm{n}-1)^2/\mathrm{m}^2\mathrm{n}(\mathrm{n}-1) \quad (3)$$

Where: $\boldsymbol{U} = \sum_{i=1}^{n}(\sum \boldsymbol{R}^2)$

n: number of factors, ***m:*** number of groups, ***j:*** The factors 1,2…. N

In all the cases the null hypothesis H_0 is rejected and alternate hypothesis H_1 is accepted. However to explore in deep the level of agreement among groups, according to (Lebreton, 2008). Kendall's 'w 'of 0 to 0.3 indicate - no agreement, 0.31 to 0.50- week agreement, 0.51 to 0.70- moderate agreement, 0.71 to 0.90- Strong agreement, 0.91 to 1.0- very strong agreement.

Table 5.6 Concordance

Category	W	Degree of Agreement	Hypothesis
Construction method	0.68	Moderate agreement	H1
Documentation	0.76	Strong agreement	H1
Construction equipment	0.81	Strong agreement	H1
Worker intention	1.00	Very strong agreement	H1
Materials	1.00	Very strong agreement	H1

Analysis results of concordance (Table 5.6) show that there is a moderate degree of agreement among the 3 group respondents for the variables in ***construction method*** and strong degree of agreement amongst the variables grouped in ***documentation***. Strong agreement to the variables under ***construction equipment*** and very strong agreement to variables under ***worker intention*** and ***materials***. Therefore, it is concluded that there is large variation within the variables under ***construction method***. It is thus statistically proved that there is large variation (w=0.68) in the preference of methods adopted at the sites for construction waste management.

5.3 Conclusion

The total wastivity of concrete and steel is found to be 18.28% and 35.7%, respectively, which are one of the major contributors of construction waste (Li et al., 2013). The top most influence factors which can ameliorate waste management performance in Indian construction industry according to analogous importance index (AII) are: (i) Training of workers in identifying recyclable materials by separation of individual wastage from mixture. This finding is in line with the findings Wong et al., 2004 and Poon et al., 2001 who stated that there should be segregation of the waste onsite for better management of the waste. It is also stated by Kulatunga et al., 2006 and Petts,1995 that adequate training of employees help in improved waste management performance. Most of the workers employed at construction sites are uneducated. Therefore, adequate training on identification and separation of recycled materials needs to be given at construction sites for enhancing waste management performance.

(ii) enforcing strict punishments for illegal disposing of wastage. The findings aligns with the conclusions of (Huang et al. 2018 ; Wu et al. 2016) who stated that the probable barriers for successful implementation of construction waste management is lack of strict punishments for illegal dumping of the waste. Therefore, the government should implement strict penalties for illegal dumping of waste along with waste management plans.

Concordance analysis indicates there is a moderate degree of agreement among the Contractors, Engineers and Academicians for the variables grouped under ***construction method*** and strong degree of agreement amongst the variables grouped under ***documentation***. Strong agreement amongst the three groups is found for variables grouped under ***construction equipment*** and very strong agreement is found for variables in ***worker intention*** and ***materials***. This work corroborates the findings that there exist differences among attitudes of professionals towards waste management (Shi et al. 2013). The outcomes from the study enable in depth exploration of the barriers which impede enforcement of waste management policies in Indian construction industry.

CHAPTER 6

Modelling the causes of construction waste generation

6.0 General

Objective -2 of the research work models the causes of CWG. The study uses a five step approach to assess the impact of various causes on waste generation. As there is a severe lack of documentation on construction waste within the construction firms in India, the study has adopted structured interviews as well as surveys for data collection. The methodology for objective-2 is presented under figure 6.1.

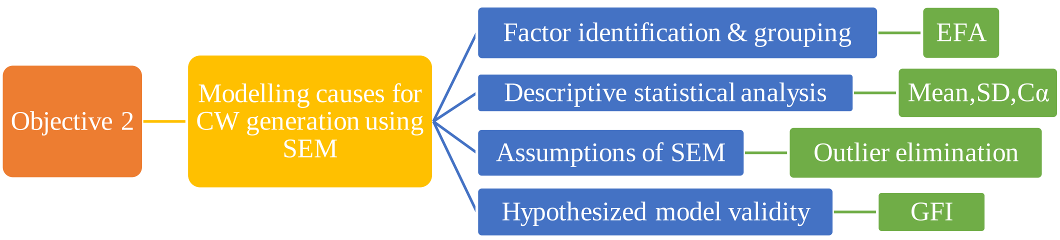


Figure 6.1 Methodology for objective two

6.1 Identification of causes which lead to waste generation

The variables (for causes of construction waste generation) have been identified from existing literature as well as expert survey **(**Figure 6.2). A total of 34 variables are thus identified (Table 6.1). A questionnaire is thus drafted by using a five point Likert scale. A five point Likert scale is used in identification of causes in various studies (Wang J and Zhengdao L, 2014; Tam, 2008; Yuan, 2013). The questionnaire is divided into two sections: respondents profile and causes. The respondents are asked to rank the individual causes with 1 = not important and 5 = extremely important.

Table 6.1 Causes for construction waste generation

No	Causes after factor analysis	Source
D 1	Design changes while construction is in	(Ekanayake LL and Ofori G,2004)
D 2	Complicated design and detailing in drawings	(Osmani et al.,2008)
D 3	Inadequate coordination and communication	(Poon CS and Ann TW,2004)
D 4	Incomplete contract documents and errors in contract documents	(Fadiya O and Georgakis P,2014)
D 5	Unreadable/inapplicable specification	(Nilesh J and Avinash S,2017)
D 6	Contract documents deficient at beginning of construction	(Ekanayake LL and Ofori G,2004)
OS 1	Rework, variation and negligence	(Assem,2011)
OS 2	Time restraint and inclement weather	(Klepa et al.,2019)
OS 3	Unskilled labours and malfunctioning of	(Faniran OO and Caban G,1998)
SMP1	Lack of on-site waste management plans and inadequate strategy for waste minimization	(Adewuyi TO,2013)
SMP2	Improper planning for required quantities and poor site conditions	(Nilesh J and Avinash S,2017)
SMP3	Delays in passing information on types and sizes of materials and lack of supervision	(Wahab A and Lawal A,2011)
MHS1	Materials delivery in improper packing	(Ekanayake LL and Ofori G,2004)
MHS2	Damages during hauling from storage to the point of application	(Wahab A and Lawal A,2011)
MHS3	Inadequate materials handling and use of materials which are close to work place	(Bakr,2019)
OPS1	Ordering errors (too much or too little)	(Fadiya O and Georgakis P,2014)
OPS2	Purchases not complying with specifications	(Ekanayake LL and Ofori G,2004)
OPS3	Over allowance	(Bakr,2019)
OPS4	Suppliers' errors	(Muleya F and Kamalondo H,2017)
C1	Lack of awareness	(Assem,2011)
C2	Lack of Training	(Nilesh J and Avinash S,2017)
C3	Due to vandalism	(Faniran OO and Caban G,1998)
C4	Due to theft	(Faniran OO and Caban G,1998)
C5	Construction site do not produce any wastage	(Interview)
C6	Construction wastage is used in site itself	(Interview)
HHS1	Narrow construction sites	(Interview)
HHS2	Low protection during unloading	(Muleya F and Kamalondo
HHS3	Inefficient methods of unloading	(Bakr,2019)

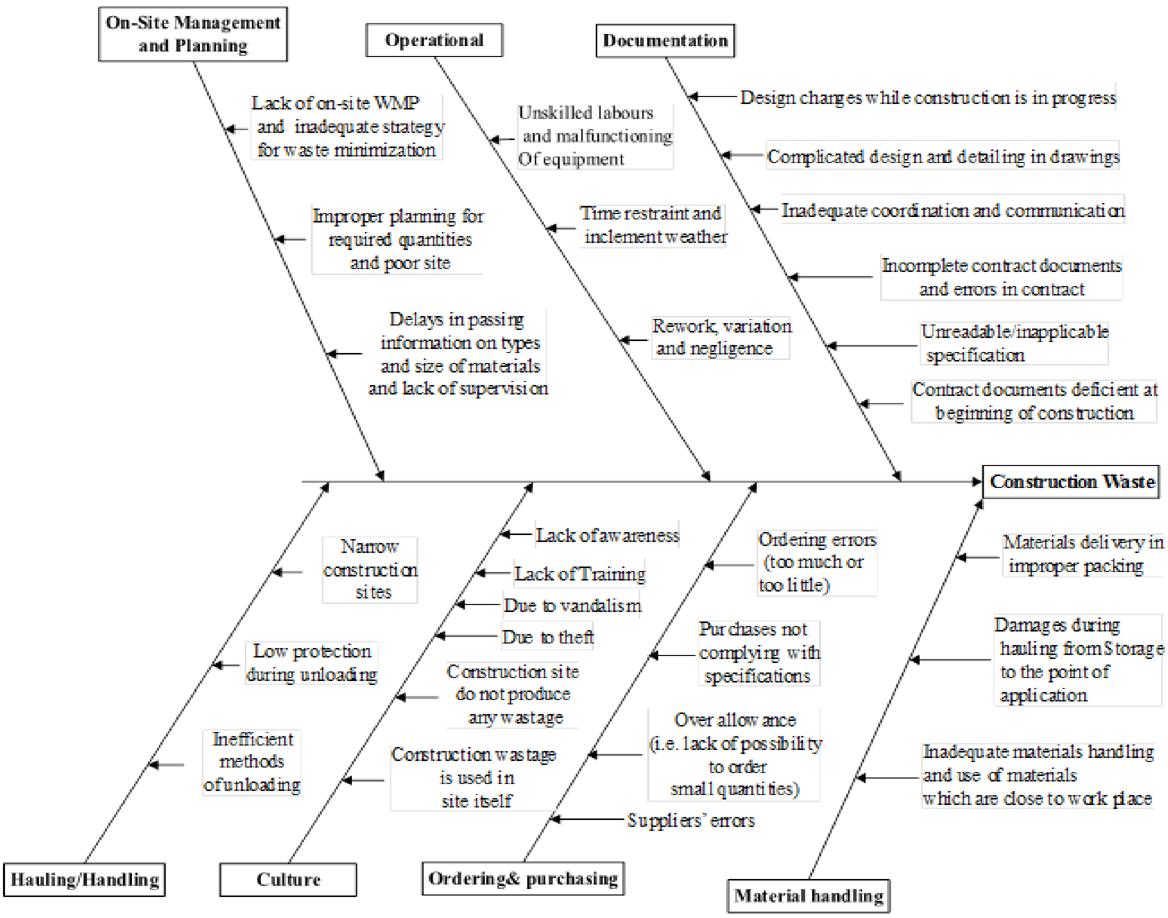


Figure 6.2 Cause and effect diagram of construction waste generation

6.2 Data collection

The survey was conducted in two modes - online and offline. The survey team is divided into two groups. Group 1 was focused on engineers and group 2 was focused on managers and the rest of the staff. A total of 248 questionnaires were distributed out of which 202 responded (81.4 % response rate) which was deemed to be satisfactory (Sekaran, 1984). The demography of respondents is presented in Table 6.2.

Table 6.2 Demographics of the respondents.

Category	Frequency	Percentage (%)
Gender		
Male	176	87.13
Female	26	12.87
Age		
Below 20	2	0.99
20 - 29	164	81.19
30 - 39	22	10.89
40 - 50	12	5.94
Above 50	2	0.99
Designation		
Engineer	148	73.27
Manager	25	12.38
Contractor	7	3.47
Academic faculty	22	10.89
Work Experience		
0-5 years	157	76
6-10 years	24	12
11-15 years	8	5
Above 15 years	14	7

6.3 Statistical analysis of the factors

Various statistical analyses are performed on the variables. Assumptions of structural equation modelling- multivariate normality, multi collinearity, positive definiteness, homoscedasticity and variance are checked to exclude any outliers in the data. Out of 202 responses 5 are identified as outliers and are removed, resulting in a data set of 197 responses, which is used for the further analysis. The sample size 197 responses are found to be adequate to run the factor analysis. According to (Gorsuch, 2010) a minimum number of 100 samples are needed irrespective of the number of variables to run the factor analysis. Exploratory factor analysis is used, to group the variables into responding categories and to reduce the large number of variables into manageable constructs.

Principal component analysis using varimax rotation is used for factor extraction. Varimax reproduces clear loadings by maximizing the variance of squared loadings (Cho K and Hong T, 2009). The variables with factor loadings greater than 0.3 only are considered for the study(Kline, 1994). The Kaiser Meyer Olkin (KMO) value is 0.8 indicating that the sample is adequate for running factor analysis (Kline, 1994) Bartlett's test of sphericity is used to check whether the variables in the correlation matrix are correlated significantly different than zero and whether the significance value is less than 0.05 (Hemanta D and Anil S, 2012) is shown in Table 6.3

Table 6.3 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy		0.884
Bartlett's Test of Sphericity	Approx. Chi-Square	2845.306
	df	378
	Sig	.000

The number of factors to be extracted is based on eigenvalues visualized using scree plot (Kline, 1994). From the above process seven categories are identified- documentation stage (DS); operation stage (OS); onsite management and planning (SMP); material handling stage (MHS); ordering and purchasing stage (OPS); culture (CS); hauling and handling stage (HHS). Of these, six variables are loaded onto (DS), three variables onto (OS), three variables onto (SMP), three variables onto (MHS), four variables onto (OPS), six onto (CS), and 3 onto (HHS) Table 6.4.

The internal consistency of the data is measured by Cronbach's alpha using IBM SPSS® 23 software. The value of Cronbach's alpha range in between 0 to 1 with values closer to one indicating higher internal consistency and vice versa. The values of Cronbach's alpha for various factors are- documentation (D) 0.841; operation (OS) 0.723; onsite management and planning (SMP) 0.823; material handling (MHS) 0.776; ordering and purchasing (OPS) 0.815; culture (C) 0.809; hauling and handling (HHS) 0.766. The Cronbach's alpha for the entire set of variables is 0.929 and hence the variables considered are reliable for further analysis (Hair et al., 2010).

Table 6.4 Descriptive Statistics

SI number	Factors	Variables	Descriptive Statistics		
			Mean	**STD**	**cα**
1	Documentation (D)	D1	3.99	1.20	.841
		D2	3.04	1.12	
		D3	3.39	1.09	
		D4	3.11	1.19	
		D5	3.11	1.11	
		D6	3.16	1.21	
2	Operation (OS)	O1	3.20	1.13	.723
		O2	2.99	0.97	
		O3	3.45	0.96	
3	Onsite management and planning (SMP)	SMP1	3.4	1.10	.823
		SMP2	3.46	1.06	
		SMP3	3.33	1.00	
4	Material Handling (MHS)	MHS1	3.02	1.07	.776
		MHS2	3.18	0.97	
		MHS3	3.17	0.99	
5	Ordering and Purchase (OPS)	OPS1	2.95	1.14	.815
		OPS2	3.28	1.11	
		OPS3	3.06	1.03	
		OPS4	2.95	1.04	
6	Culture (C)	C1	3.01	1.09	.809
		C2	3.16	1.22	
		C3	3.08	1.02	
		C4	2.74	0.95	
		C5	2.87	1.20	
		C6	3.29	1.18	
7	Hauling and Handling (HHS)	HHS1	3.20	1.01	.766
		HHS2	3.25	1.10	
		HHS3	3.32	1.06	

6.4 Framework of structural equation modelling

Structural equation modelling (SEM) is a multivariate statistical tool that consists of two components: a measurement model and an structural model (Yong QC and Yang BZ, 2012). The measurement model (confirmatory factor analysis) measures reliability and how well the observed variables correlate with the latent variables, while the structural model (regression analysis) assesses the relation among latent variables (Molenaar K and Simon W, 2000). The benefit of using SEM is that it enables simultaneous assessment of interrelationships between numerous independent and dependent variables (Ozorhon et al., 2007)**.**There are two types of SEM: covariance based SEM (CB-SEM) explains the relationship among observed, latent variables and variance based SEM (VB-SEM) considers the amount of variance (Davcik NS, 2014).

SEM has previously been applied to CWM for- analysing factors that affect stakeholder's intention in promoting disaster waste management (Maryono N and Hirofumi S, 2015); modelling CWM by AMOS-SEM and waste efficient materials procurement influence factors (Ajayi SO and Oyedele L, 2018); investigating factors influencing waste management (Manowong, 2012).

An appropriate sample size is important to run analyses as it effects the establishment of parameter estimates. Sample size proposed in various studies ranges from 100 to 400 (Molwus JJ and Erdogan B, 2013). The sample size of between 50-100 is barely adequate (Iacobucci, 2010) while a sample size of 200 is ideal (Kamalendra KT and Jha KN , 2017). Therefore, a sample size of 197 is found to be satisfactory for this study. Mean and standard deviation are shown in table 6.4. A hypothetic model is developed to test the relationships between various causes of waste generation (Figure 6.3). CB–SEM is used for the analysis and the model is analysed using IBM SPSS Amos 23®. CB–SEM has several statistical advantages over VB-SEM (Schumacker Randall, 2016). Maximum likely hood estimation is used in the study. The hypothesis has been framed as follows:

Null hypothesis (H_o): Path coefficient values of paths relating waste generation factors to waste generation are not significantly different from zero.

Alternate hypothesis (H_1): Waste generation factors have a significant positive influence on the waste generation at construction sites.

6.5 Hypothesized model validity

The validity of the model is then checked by means of various goodness of fit indices (GOF) (Wong PSP and Cheung SO, 2005). Among the different GOF indices available the following are selected to determine the model fit (Molenaar K and Simon W, 2000).

1. **Chi square test (χ^2):** It enables comparison between the observed covariance matrix and the estimated covariance matrix (Yong QC and Yang BZ, 2012).

2. **Goodness of fit index (GFI):** It is one among several absolute fit indices. It clearly represents how the hypothetic theory fits the data. GFI is affected by sample size .The value ranges in between 0 to 1 and the values tend to increase with sample sizes (Coughlan J and Hooper D, 2008).
3. **Incremental Fit index (IFI):** It is also known as relative fit index which compares revised hypothetical model with the statistical base line model (Miles J and Shevlin M, 2007). These fit indices do not use chi-square as such; instead they compare chi-square value with the hypothetical model. Also among such indices is the comparative fit index (CFI) which is effective for smaller sample sizes (Xiong B and Skitmore M, 2015).
4. **Tucker-Lewis Index (TLI):** It usually compares sample size and the complexity of the model (Patel, 2016)**.**
5. **Root mean squared error of approximation (RMSEA):** It usually favours parsimony which means it chooses the model with least number of parameters (Coughlan J and Hooper D, 2008).
6. **Expected cross validation index (ECVI):** It tests the stability of the model (Schreiber et al., 2006).

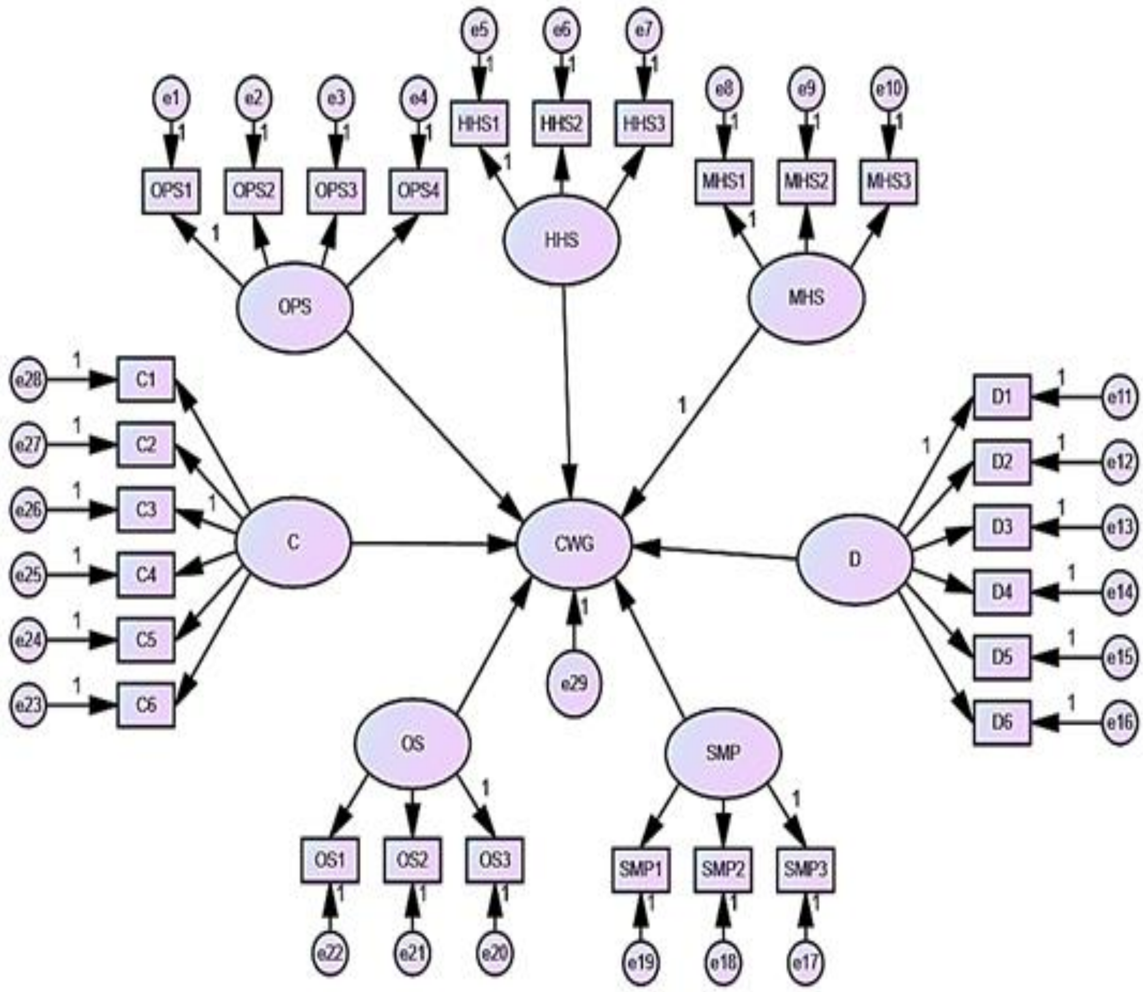


Figure 6.3 Hypothesized Model for modelling the causes of construction waste generation

The acceptable values of these fit measures are presented in Table 6.5 (Hemanta D and Anil S, 2012). The GOF values of the hypothesized model are as follows. The value of χ^2/dof = 2, GFI = 0.77, IFI = 0.82, TLI = 0.80, CFI = 0.82, RMSEA=0.08, ECVI=4.75. Indicate the hypothesized model (Figure 6.3) cannot clearly explain the effect of various constructs on construction waste generation. This calls for the revision of the hypothesized model. The model can be revised in two ways - (i) deleting the path with the lowest path coefficients (ii) adding casual relationships (Molenaar K and Simon W, 2000). The first method was used in the present case and the model is revised for the better model fit.

Table 6.5 GOF Measures (Wong PSP and Cheung SO, 2005;Jing et al., 2019;Schreiber et al., 2006; Hemanta D and Anil S, 2012;Cho K and Hong T, 2009)**.**

SI .No	GOF measure	Acceptable limit	Hypothesized model	Revised model
1	X^2/DOF	1-3	2	1.6
2	GFI	0 (no fit)-1(Absolute fit)	0.77	0.88
3	IFI	0 (no fit)-1(Absolute fit)	0.82	0.94
4	TLI	0 (no fit)-1(Absolute fit)	0.80	0.93
5	CFI	0 (no fit)-1(Absolute fit)	0.82	0.94
6	RMSEA	<0.05(good)0.1(threshold)	0.08	0.05
7	ECVI	Lower value	4.75	1.69

The revised model, amended by means of deleting the paths with low path coefficients, is shown in Figure 6.4. Hence the alternate hypothesis (H1) – "causes have a significant positive influence on the waste generation at construction sites", is accepted based on figure 6.4 and the null hypothesis is rejected.

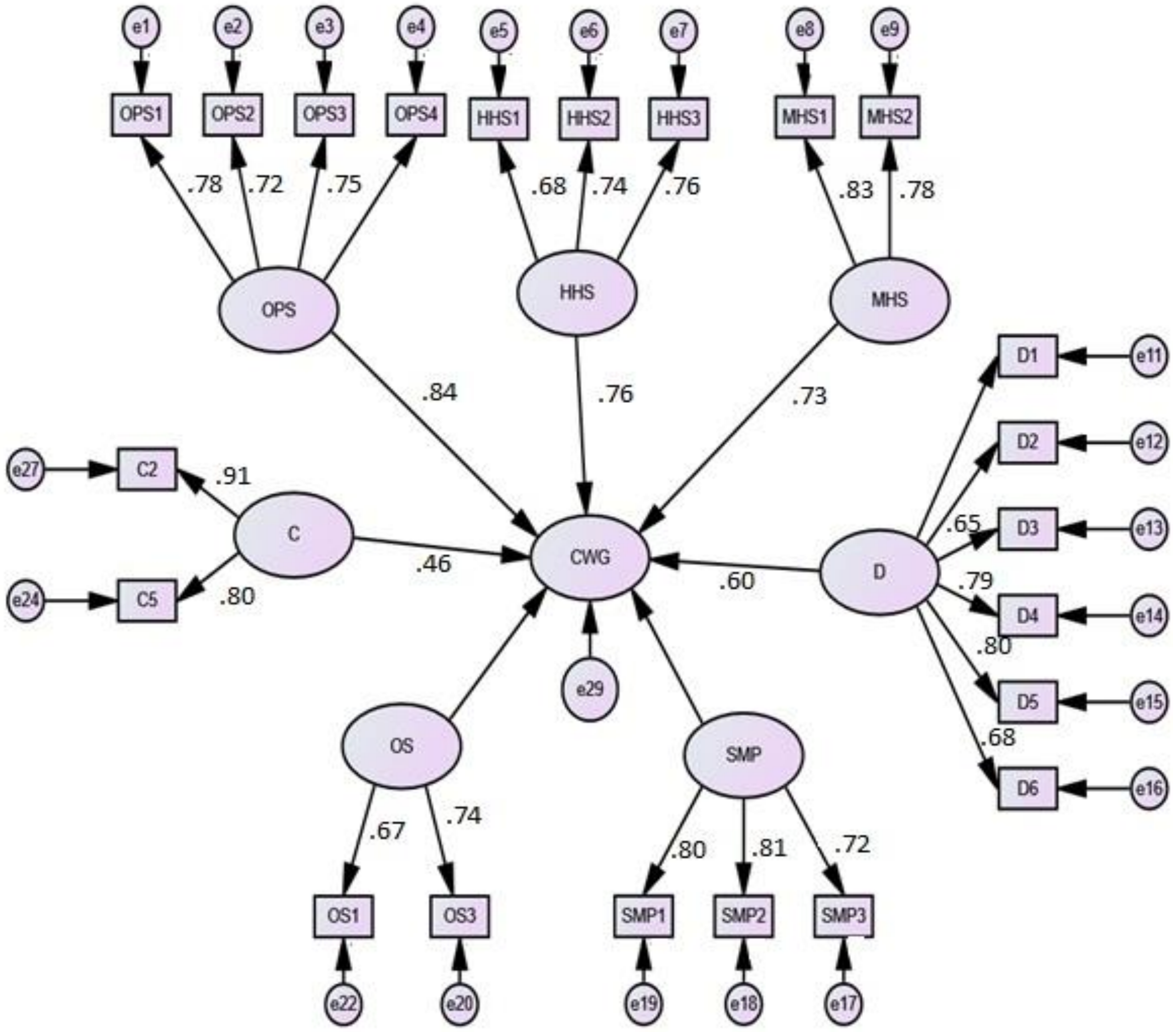


Figure 6.4 Revised model for modelling the causes of construction waste generation

The convergent validity (CR) of the revised model is tested by means average variance (AVE). The AVE of all the variables in this study range between 0.5 to 0.64 which is above the recommended value of 0.5 (Michael T, 1998).

In this study the CR ranges between 0.7 to 0.9 which corresponds to the acceptable value of ≥ 0.7 (Jing et al., 2019). Hence it is indicated that the variations of *dependent variables* predicted by *independent variables* are lesser compared to the variations in *errors* (Table 6.6). This implies that the average explanatory power of each item in the *construct* is appropriate.

Table 6.6 Path coefficient and its significance of the structural model and measurement model

Relationship			Estimate	P	AVE	CR
Structural Model						
OPS	<---	CWG	0.836	***		
HHS	<---	CWG	0.758	***		
MHS	<---	CWG	0.734	***	0.589	0.905
D	<---	CWG	0.598	***		
SMP	<---	CWG	0.956	***		
Measurement model						
OPS1	<---	OPS	0.783	***		
OPS2	<---	OPS	0.717	***	0.56	0.79
OPS3	<---	OPS	0.745	***		
HHS1	<---	HHS	0.676	***		
HHS2	<---	HHS	0.741	***	0.52	0.77
HHS3	<---	HHS	0.762	***		
MHS1	<---	MHS	0.833	***	0.64	0.78
MHS2	<---	MHS	0.776	***		
C2	<---	C	0.906	***	0.73	0.84
C5	<---	C	0.800	***		
D3	<---	D	0.649	***		
D4	<---	D	0.794	***	0.53	0.82
D5	<---	D	0.801	***		
D6	<---	D	0.677	***		
OS1	<---	OS	0.674	***	0.50	0.71
OS3	<---	OS	0.738	***		
SMP1	<---	SMP	0.803	***		
SMP2	<---	SMP	0.814	***	0.61	0.82
SMP3	<---	SMP	0.723	***		

*** indicates statistical significance at 0.001 level of confidence.

The *discriminant validity* is verified by comparing AVES of the constructs and the squared multiple correlations between two constructs of interest. From the results it is clearly indicated that all AVE are greater than squared correlations. The diagonal values (in bold) of Table 6.7

represent AVEs of the constructs and the remaining values indicate correlations between the constructs.

Table 6.7 Results of discriminant validity test

	MHS	HHS	C	OPS	D	OS	SMP
MHS	**0.555**						
HHS	0.365	**0.531**					
C	0.214	.0.333	**0.52**				
OPS	0.397	0.482	0.267	**0.528**			
D	0.245	0.215	0.194	0.430	**0.51**		
OS	0.457	0.389	0.283	0.424	0.371	**0.509**	
SMP	0.526	0.494	0.341	0.514	0.378	0.487	**0.611**

6.6 Results and discussion

The last column in Table 6.5 lists the GOF results of the revised model. The value of χ^2/dof =1.6, GFI = 0.88; IFI = 0.94; TLI = 0.93; CFI = 0.94, RMSEA = 0.05, and ECVI = 1.69. It can be clearly seen that the revised model gives a better fit. Larger value of the path coefficient indicates the importance of the factor which leads to construction waste generation. The most significant factor which contributes to construction waste generation is SMP with path coefficient of 0.96. The rest of the factors and their attributes emerging from the SEM output are explained in the subsections below.

6.6.1 Onsite Management and planning (SMP)

SMP is the most significant factor with a path coefficient of 0.96. The attribute under this factor are: SMP1- Lack of on-site waste management plans and inadequate strategy for waste minimization with a path loading 0.80; SMP2- Improper planning for required quantities and poor site conditions with a path loading 0.81; SMP3- Delays in passing information on types and sizes of materials and lack of supervision with a path loading 0.72. Among the three attributes the SMP2 has the highest path coefficient with a value of 0.81.

Majority of the construction professionals responded that lack of proper planning of quantities of the materials would lead to increase in construction waste generation. Excess planned material may finally end up as waste. In addition to this, industry conditions such as non-availability of skilled labour and working practices such as negligence by the workers or the attitudes of the individuals toward waste reduction are some of the attributes which a need drastic revision for reduction of waste in Indian construction industry. The findings from the analysis of SMP variables revealed that despite the policies and guidelines framed by the government at national, regional and local levels (CPCB, 2017) site waste management documentation is not maintained at the construction sites or corporate offices. This is primarily because of lack of enforcement by the government. Appropriate inspections of verifiable documentation will form the basis on which the government can impose fines or taxes.

6.6.2 Operation (OS)

OS is the next significant factor with a path coefficient of 0.84. The attributes under this factor are: OS1-Rework, variation and negligence with a path loading 0.67; OS3-Unskilled labours and malfunctioning of equipment with a path loading 0.74. Among the attributes OS3 has the highest path coefficient with a value of 0.74. In the Indian construction sector most of the workforce is uneducated. The labourers who deal with the construction material are completely unaware of the consequences to nature, if waste is not treated or disposed properly. This is because they are guided towards profit rather than sustainability. Most of the companies are much concerned about the completion of projects on time than disposing the construction waste efficiently. There is a strong urgency for orienting the companies towards proper reuse, recycle of the material to mitigate the problem. The government of India needs to levy taxes for setting up of recycling plants to manage C&D waste. This approach creates additional employment opportunities as well as fulfilling the goal of sustainability.

6.6.3 Ordering and Purchase (OPS)

Ordering and purchase is yet another factor, with a path coefficient of 0.96, which contributes to increased waste generation. The attributes under this factor are: OPS1- Ordering errors (too much or too little), (path coefficient 0.780); OPS2- Purchases not complying with specifications with a path loading 0.72; OPS3- Over allowance (i.e. lack of possibility to order small quantities) with a path loading 0.75. Among these attributes OPS 1 has the highest path coefficient with a value of 0.78. Proper estimation of the required materials and double checking of the quantities can help in solving over-ordering errors. In addition to that, adequate storage of the materials can help in reducing the damage of materials in stock. This aids in reducing construction waste as well as indirect costs of the project.

6.6.4 Hauling (H) / Material Handling (MHS)

The next most significant factor is HHS with a path coefficient of 0.76. The attributes under this factor are: HHS1-Narrow construction sites (path coefficient 0.68); HHS2- Low protection during unloading (path coefficient 0.74); HHS3- Inefficient methods of unloading (path coefficient 0.76). Among the three attributes HHS3 has the highest path coefficient with a value of 0.76. Next to hauling is material handling which occupies fifth place with a path coefficient of 0.73. The attribute under this factor are- MHS1- Materials delivery in improper packing with a path loading of 0.83; MHS2- Damages during hauling from storage to the point of application with a path loading of 0.78. The loading and unloading operations are yet another attribute which need a serious consideration through appropriate handling of the material during loading and unloading operations which generate a significant amount of waste. Fragile materials need to be safely delivered by means of protective packaging. Narrow construction sites are yet another attribute where the movement of the material is tough and hence leading to damage/spilling of the material. The only alternative is to efficiently plan the work space. Monitoring the real time movement of materials onsite by means of GPS, information and communication technology (ICT) such as RFID tags (Radio Frequency Identification tags) and barcoding can enable logistical planning for efficient usage of the material as well as reduction of waste at construction sites.

6.6.5 Documentation (D)

Documentation stage is next most significant factor with a path coefficient of 0.6. The attributes are as following: D3-Inadequate coordination and communication with a path loading of 0.65; D4- Incomplete contract documents and errors in contract documents with a path loading of 0.79; D5- Unreadable/inapplicable specification with a path loading of 0.80; D6- Contract documents deficient at beginning of construction with a path loading of 0.68. Documentation is an important factor. It is observed in most Indian construction companies that despite the rules and policies framed by the government of India, companies fail to maintain documentation. Appropriate documentation has benefits such as: timely checks can be maintained on the amount of material getting wasted and the material procurement and handling procedures can be revised. The documentation on site waste management plan should contain items such as quantification of waste, method of disposing waste, treatment of waste. The government should conduct inspections and submission of waste management report before, during and after construction project need to be made mandatory. This reinforces the analysis results of SMP variables.

6.6.6 Culture (C)

The factor that is loaded the least is the culture with a path coefficient of 0.46. The attributes under this factor are: C2- Lack of Training 0.91; C5- Construction site do not produce any wastage 0.80. Most of the respondents agree to the fact that imparting proper training on managing waste at construction sites would resolve the problem. The massive construction has a workforce with diverse mind sets which need to be trained on managing waste efficiently and effectively. Schemes such as pep talks are organized in multinational companies where the authorities discuss and conduct meetings with the co-workforce (labours). Awareness programs are not observed in smaller firms. The commitment to construction waste management plans within major construction companies is unclear due to lack of verifiable documentation.

6.7 Conclusion

The construction industry is one of the bulk generators of the waste globally. There is a wide range of factors which contribute to the generation of waste at construction sites. This study examines the effect of various factors on construction waste generation in order to identify the significant factors. Due to lack of site waste management plans within many Indian organizations it is a challenge to identify the factors which effect waste generation at construction sites. Structural equation modeling is used to assess the parametric effects of various factors along with their attributes. Thus a novel causal relationship of various factors which lead to waste generation at construction sites is developed by means of structural equation modeling. The revised model concludes that the most important factor is SMP with a path coefficient of 0.96 followed by O (0.91), OPS (0.84), HHS (0.76), MHS (0.73), D (0.60) and C (0.46). Hence the alternate hypothesis that waste generation factors have a significant positive influence on the waste generation at construction site is accepted. The study indicates that with an efficient site waste management plan, the generation of construction waste could be reduced. The finding aligns with the findings of (Lau HH and Whyte A, 2008; Florence YYL and Mark CHL, 2002; Mincks, 1994; Brouwers HJH and Bossink BAG, 2002) who stated that SWMP needs to be enforced in all the construction sites irrespective of the size of the construction site. With an efficient SWMP the amount of waste generated:

- Can be audited
- Can be minimized
- Can be prevented and,
- Waste collection, segregation and disposal can be efficiently managed
- Assessment of material waste reuse can be achieved
- Efficient record system can be achieved.

In addition, financial losses due to wastage can be tracked and quantified, enabling policy makers to amend the existing policies. Usage of RFID tags and barcoding system for material management may reduce waste generation due to handling procedures.

Appropriate documentation provides the framework for SWMP on which basis other mitigation measures may be enforced. The documentation on site waste management plan should prescribe items to be tracked in detail such as: waste quantity, method of disposing waste and treatment of waste. The government should conduct inspections and submission of waste management report by contractors before, during and after construction project need to be made mandatory. This reinforces the analysis results of SMP variables. Standardized documentation procedures for SWMP may also be initiated and incentivized within existing green building performance rating frameworks such as GRIHA and LEED-India. The attributes involved in the study and the outcomes are applicable within the context of the Indian construction industry. However, the methodology for identifying and quantifying the causes of C& D waste presented in this study is general and scalable to other regions.

CHAPTER 7

Barriers, potential Benefits and enforcement measures for implementing site waste management plan and recycling

7.0 General

Objective -3 of the research work consists of two core sections i.e. identification of -

a) Barriers, benefits & measures (BBM) for implementation of SWMP and recycling.
b) Comparison of C & D WM practices of European nations with Indian initiatives.

(a) A list of barriers, benefits and measure are collected from literature. Collected variables are further scrutinized with the help of experts i.e. academia, experts (more than 15 years of industrial experience) then a questionnaire survey with 64 questions are distributed. Questionnaire survey and case studies are the research tools used as either appropriate documentation nor data is available with the organizations. The research methodology is explained under subsequent sections. The analysis of BBM include four sections-

1. statistical analysis (to eliminate outliered responses, to assess internal consistency in data)
2. relative significance among the variables (average significant score (ASS) is calculated by the weighted average model from which beneficial index value (BIV) calculated).
3. gathered questionnaire responses are calibrated to check validation among the respondent groups
4. degree of concordance among respondent groups is measured using Kendall's coefficient of concordance- to assess the level of agreement between respondent groups**.**

(b) Comparison of C & D WM practices of European nations with Indian initiatives. The successful C & D WM practices in Europe are compared with Indian initiatives to improve the status of recycling in India. The methodology for objective 3 is presented under figure 7.1.

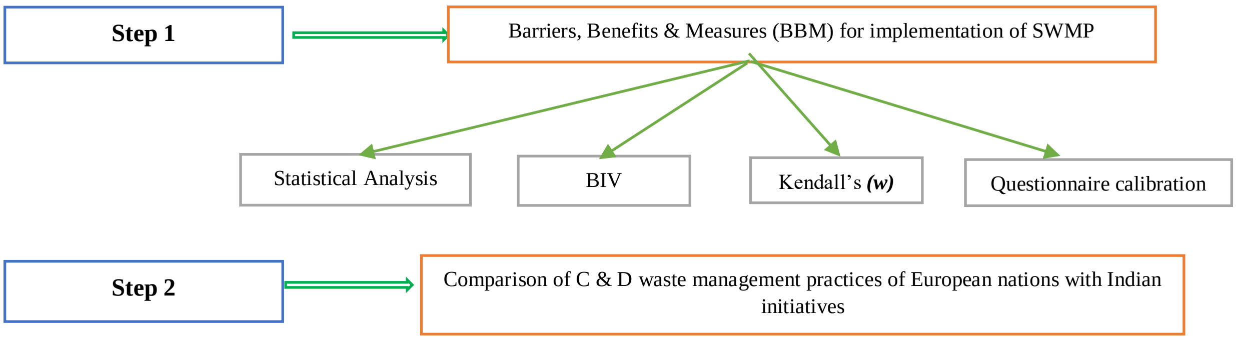


Figure 7.1 Methodology for objective three

7.1 Statistical Analysis / BIV / Kendall's (w) / and Questionnaire calibration for BBM of SWMP

7.1.1 Statistical Analysis

The variables (BBM) for SWMP are chosen from the existing literature sources (Yuan, 2017; Plochl et al., 2008; Shen LY, 2002; Yuan et al., 2011) as well as interviews with the experts in the field. Factors and their corresponding coding is shown in Table 7.1 and 7.2. Data is collected by means of drafting a questionnaire which is divided into two sections- (i) An introductory section – collecting data about respondents (ii) section two consists of 64 questions (factors) on barriers, benefits and measures.

Table 7.1 Coding and explanation of Barriers, Benefits(Yuan 2017; Plochl et al. 2008;Shen LY 2002;Yuan et al. 2011)

Coding	Explanation	Coding	Explanation
B_1	Lack of awareness	BF_1	Reduces payment of penalties
B_2	I do not see waste management as an major issue	BF_2	Increase chance of selection during bidding
B_3	Wastage is not measured at site.	BF_3	Improves waste management standards
B_4	No guidelines are available with company.	BF_4	Leads to environmental protection by conserving resources
B_5	Clients do not take it seriously	BF_5	Increase business competitiveness
B_6	Government do not concern about the place where I dispose wastage	BF_6	Helps in reduction of payment of taxes
B_7	Waste management does not create profit	BF_7	Increase profits

B_8	My senior officer do not care about implementing of waste management so why should I	BF_8	Helps in efficient use of materials
B_9	Waste management do not add any hike in my profile	BF_9	Reduction of environmental pollution
B_{10}	Following waste management does not help me getting promotions	BF_{10}	Develops Positive attitude among staff in conserving environment
B_{11}	No punishment for avoiding waste management	BF_{11}	Helps to prevention of natural disasters and injuries
B_{12}	Increase in additional costs	BF_{12}	Nullifies pollution relating to air, water, and land.
B_{13}	Lack of experienced staff		
B_{14}	Lack of coordination among workforce employed in a project		
B_{15}	Lack of supplier co-operation		
B_{16}	Consume additional time (Records, efforts, manpower)		
B_{17}	Heavy documentation load as appropriate data not available		
B_{18}	Difficulty in acquiring data from field		
B_{19}	Loopholes in gathered data		
B_{20}	Lack of equipment availability on site for measuring wastage		
B_{21}	Change of existing practice of company structure and policy		
B_{22}	Lack of technological support within organization.		
B_{23}	Implementation of waste management is not my work.		
B_{24}	Waste is reused at my site.		
B_{25}	Lack of awareness of law regarding illegal dumping.		
B_{26}	It is easier/cheaper to dump.		

Table 7.2 Coding and explanation of Measures(Yuan 2017;Plochl et al. 2008; Shen LY 2002;Yuan et al. 2011)

Coding	Explanation
MI_1	Implementation of software technology
MI_2	Increase in awareness
MI_3	Enforcement of punishments for illegal dumping of wastage
MI_4	User friendly technology
MI_5	Availability of recycling equipment on the site
MI_6	Increasing market value for waste materials
MI_7	Providing incentives to workers for implementing waste management
MI_8	Legal requirements on environmental protection

MI_9	RRR strategy of construction waste onsite
MI_{10}	Imposing responsibilities of protecting environment of management staff
MI_{11}	Applying environmentally friendly technology
MI_{12}	Workshops on waste management and separate training for workers on waste
MI_{13}	Adopting waste management plan
MI_{14}	Continuous efforts in improving waste management
MI_{15}	Collecting suggestions for improving waste management
MI_{16}	Inclusion of waste management in tendering requirements
MI_{17}	Effective communication on waste management among workforce
MI_{18}	Close supervision at site level
MI_{19}	Concessions on recycling equipment
MI_{20}	Reduction of taxes on recycled materials.
MI_{21}	Separate team for waste management
MI_{22}	Creating awareness about the misconceptions on using recycled materials among
MI_{23}	Designs for recycled aggregate.
MI_{24}	Competitiveness among workers regarding CWM is the only way to improve
MI_{25}	Terminating contract for contactors not implementing CWM.
MI_{26}	Advertisements through media/social network is necessary to improve CWM

Five-point Likert scale is used in the survey ranging from 1- Not important to 5-Extremely important. The survey is conducted online as well as offline. The survey is conducted on engineers, contractors, managers and academician's. A total of 248 questionnaires are distributed out of which 202 responded with a response rate of 81.4 %, which deemed to be satisfactory for further analysis (Sekaran, 1984).

The respondents are chosen based on - (i)Experience (one year of minimum experience in the construction sector; (ii)educational qualification (minimum qualification required is Bachelors of Engineering); (iii)expertise in the field (aware of C & D practices); (iv) policy amenders (within system); (v)Government organizations and (vi) Licensed contractors. Detailed demographics of the respondents are shown in Table 7.3.

IBM SPSS(R) 23 is used for the descriptive statistical analysis (Table 7.4). Outlier responses in the data are deleted by statistical tests such as multivariate normality, homoscedasticity, multicollinearity, positive definiteness and variance. Five among 202 responses are identified as outliers and are eliminated for further analysis. The internal consistency of the data is checked by using Cronbach's alpha. The values of Cronbach's alpha range from 0 to 1, with values closer to one indicating higher internal consistency and vice versa. The values of Cronbach's alpha for various factors are: barriers (B) 0.912, benefits (BF) 0.857, and measures (M) 0.962. The Cronbach's alpha for the entire set of variables is 0.975. Hence the variables considered are reliable for further analysis (Hair et al., 2010).

Table 7.3 Detailed demographics of the respondents

Category	Frequency	Percentage (%)
Gender		
Male	176	87.13
Female	26	12.87
Age		
Below 20	2	0.99
20 - 29	164	81.19
30 - 39	22	10.89
40 - 50	12	5.94
Above 50	2	0.99
Designation		
Engineer	148	73.27
Manager	25	12.38
Contractor	7	3.47
Academic faculty	22	10.89
Work Experience		
1-5 years	157	76
6-10 years	24	12
11-15 years	8	5
Above 15 years	14	7

7.1.2 Beneficial Index value

To examine the relative significance among the variables, average significant score (ASS) is calculated by the weighted average model (Shen LY and Vivian WYT, 2002). However, the Average significant score (ASS_i) used in the model does not consider the degree of variation among the individual responses, and is given by:

$$\mathbf{ASS_i} = \frac{\sum_{i=1}^{5} X_j N_{ij}}{N} \qquad \text{............ (1)}$$

Where:

ASS_i - Average significant score of the factor i

X_j- Factor score assigned (on a Likert scale of 1 to 5).

N_{ij}- Number of respondents who assigned the score X_j for the factor i

N- Total number of respondents.

Thus, merging both weighted average and coefficient of variation can mitigate the corresponding weakness of ranking the variables. The coefficient of variation is calculated by dividing weighted average with standard deviation. The combined weighted average and coefficient of variation value is indicated as beneficial index value (BIV), is shown below.

Based on the BIV the rankings for individual variables are given (Shen LY and Vivian WYT, 2002).

$$BIV_i = ASS_i + \frac{ASSi}{\sigma i} \quad \text{………. (2)}$$

Where:

ASS_i - Average Significant score of the variables.

$\frac{ASSi}{\sigma i}$ - Coefficient of Variation.

BIV- Beneficial index value.

Table 7.4 Descriptive Statistics

V	M	S	BIV	R	V	M	S	BIV	R	V	M	S	BIV	R
Barriers					**Benefits**					**Measures**				
Cα=0.912					Cα=0.857					Cα=0.962				
B1	3.7	1.2	6.4	9	BF1	3.0	0.9	5.7	12	MI1	3.4	1.1	5.8	26
B2	3.5	1.3	5.5	25	BF2	3.4	1.0	6.2	10	MI2	4.0	1.0	6.8	14
B3	3.4	1.2	6.2	12	BF3	3.6	1.0	6.8	5	MI3	4.0	1.1	6.7	20
B4	3.8	1.0	6.7	1	BF4	4.1	1.0	7.4	1	MI4	3.9	1.1	7.0	6
B5	3.8	1.1	6.4	6	BF5	3.3	1.0	6.8	4	MI5	4.0	1.0	7.1	3
B6	3.4	0.9	6.6	2	BF6	3.1	1.2	5.9	11	MI6	3.9	0.9	7.0	9
B7	3.5	1.1	5.9	19	BF7	3.4	1.1	6.4	8	MI7	3.6	1.1	6.7	18
B8	3.0	1.3	5.7	22	BF8	3.9	1.1	7.2	2	MI8	4.0	0.9	7.3	1
B9	3.0	1.4	5.7	24	BF9	3.9	1.2	7.2	3	MI9	3.6	1.2	6.7	21
B10	3.1	1.0	5.7	23	BF10	3.8	1.0	6.8	6	MI10	3.7	1.0	6.7	17
B11	3.3	1.3	5.8	20	BF11	3.2	1.4	6.4	9	MI11	3.8	1.0	6.8	12
B12	3.4	1.2	6.4	8	BF12	3.5	1.2	6.6	7	MI12	3.8	0.9	7.1	4
B13	3.0	1.2	6.5	3						MI13	4.0	0.8	7.2	2
B14	3.4	1.2	6.4	7						MI14	4.0	0.9	7.1	5
B15	3.3	1.2	6.2	14						MI15	3.8	0.9	6.9	10
B16	3.1	1.2	6.1	16						MI16	4.0	1.1	7.0	8
B17	3.3	1.2	6.2	15						MI17	3.5	1.0	6.8	13
B18	3.1	1.4	5.8	21						MI18	3.5	1.2	7.0	7
B19	3.2	1.4	5.9	18						MI19	3.7	1.0	6.7	16
B20	3.5	1.1	6.2	13						MI20	3.9	0.9	6.6	22
B21	3.1	1.1	6.4	10						MI21	3.9	0.9	6.9	11
B22	3.1	1.1	6.5	4						MI22	3.5	1.0	6.8	15
B23	3.0	1.5	5.4	26						MI23	3.6	1.1	6.7	19
B24	3.2	1.2	6.3	11						MI24	3.5	1.1	6.4	25
B25	3.7	1.3	6.5	5						MI25	3.3	0.9	6.5	23
B26	3.4	1.4	6.0	17						MI26	3.6	1.1	6.4	24

V: Variables; M: Mean; S: Standard Deviation; BIV: Beneficial Index Value; R: Rank

7.1.3 Questionnaire calibration

The questionnaire used for the analysis is calibrated statistically to check the validation among the respondent groups according to (Manuel Gomez-Soberon et al., 2013). Among them are: (i) central tendency measures such as -mean, median, mode and sum; (ii) dispersion measures-standard error of the mean, standard deviation, variance, range, minimum and maximum; (iii) form of the curve distribution-skewness, standard error of skewness, kurtosis and standard error of kurtosis etc.

7.1.4 Concordance among Managers, Contractors, Engineers and Academics

The diverse attitudes on the factors is assessed by using Kendall's coefficient of concordance (w). It is used to measure the consistency as well as level of agreement between respondent groups. Kendall's 'w' ranges from 0-1 , where 0 refers to perfect disagreement and 1 refers to perfect agreement between respondent groups(Chan and Chan, 2012). The null and alternate hypothesis are defined as:

Null Hypothesis (H0): There is disagreement between the respondent groups.
Alternate Hypothesis (H1): There exists agreement between the respondent groups.

7.1.5 Barriers and Enforcement Measures for implementing recycling of construction waste

The barriers in implementing recycling of CW are identified from the literature sources (Table 7.5). The barriers are categorized into four categories-

(i) Behavioural- Attitude and human behaviour;

(ii) Technical- lack of technical knowledge, standards for recycling;

(iii) Legal- lack of policies and

(iv) Marketing- lack of market for recycled material (Mahpour 2018).

Six active government as well as private construction sites (Table 7.6) in India are visited and studied to assess the recycling procedures adopted at these construction sites.

Table 7.5 Barriers for recycling

Barrier	Coding	Explanation	Literature Source
Behavioural	BR1	Not practicing waste management	(Jin R and Yuan H 2019)
	BR2	Lack of ethics in waste generation as well as segregation	(Yuan,2017)
	BR3	Lack of awareness on waste management	(Bakshan et al. 2016)
Technical	BR4	No waste segregation	(Vegas et al.,2015)
	BR5	No supervision for waste generation calculation	(Jin et al. 2017); Udawatta N et al.,2015)
Legal	BR6	Dumping of waste in low area and later disposing them by means of hauling through trucks.	(Balaguera et al.,2018; (DeMelo AB and Gonalves AF 2011)
Marketing	BR7	No materials recovery for recycling at construction sites	(DeMelo AB and Gonalves AF 2011)

Table 7.6 Details of the case studies

S. No	Storeys	Project	Structure
Project 1	G+8	Residential building	RCC
Project 2	G+12	Residential township	RCC
Project 3	G+4	Residential project	RCC
Project 4	G+3	Residential project	RCC
Project 5	Pipeline	Irrigation Project	Precast, RCC
Project 6	G+2	Government office	RCC

7.2 Comparison of C & D waste management practices in European nations with Indian initiatives

Successful environmental management practices (SEMP) for C & D waste:

The successful practices of C&D WM in European nations are selected in the current study for comparative analysis (Table 7.7). The peculiar properties of these practices include visualized environmental benefits, affordable and reproducible nature for waste authorities, best environmental performance under specific economic & technical situations.

Table 7.7 Successful environmental management practices (SEMP) of C & D waste in Europe (Ref *).

SEMP in Europe	Explanation	Impact on cost	Sustainable benefit
C& D waste management strategies	***Motive:*** To advance in CDW management plans at local, regional & national level in association with stakeholders. ***Core criteria:*** • Establishment of minimal sorting & management functions • Waste prevention and re-use is top priority. • Identification & quantification of C &D waste and corresponding solutions • Propel innovative recycling opportunities. • Standardizing management of hazardous materials.	Low	Landfill diversion of C&D waste is achieved.
Economic tools	***Motive:*** To use economic tools for encouraging and maximizing environmental performance of waste management systems. ***Core criteria:*** • Driving cost savings to recycling (landfill tax), • Use of recycled materials (aggregates levy) • Business to business refund systems	High	Landfill diversion of C&D waste is achieved.
Site Waste Management Plans (SWMP)	***Motive:*** To reduce & manage waste ***Core criteria:*** • Defining standards for CW generation. • Management of SWMP by specifying necessary actions for each waste. • Estimate amount of waste generated. • Administrative alternatives • Resources allocation. • Define duties.	Medium-High	95% recycling of C&D waste can be achieved

Prevention, Collection & Designing out waste	***Motive:*** To prevent & minimize waste during entire life cycle of a building and during specification, design phase. ***Core criteria:*** • Identifying probabilities for the usage of prefabricated elements, • Contemporary construction process. • Reuse of auxiliaries • Reduction of onsite cutting practices. • Organized buildings disassembling • Maximize reuse & recycle of recovered materials.	Low	75% waste reduction can be achieved
Onsite waste management & prevention	***Motive:*** To prevent & manage waste. ***Core criteria:*** • Monitoring on waste generation. • Establishing waste segregation, collection strategies • Update SWMP on regular basis.	Medium	99% of waste can be diverted from landfill
Material use efficiency & reuse	***Motive:*** To prevent material loss and to harvest materials, auxiliaries at C & D sites such as bricks, beams, slabs, tiles, pallets, formworks, auxiliary structures, etc. ***Core Criteria:*** • Improving material logistics. • Management of material remains. • Applying innovative storage facilities • Effective handling practices.	Low-Medium	15 % of material savings is observed
Reuse building deconstruction &material recovery	***Motive:*** To evaluate the recovery of materials from buildings which are ready for destruction. ***Core Criteria:*** • Principles of transparency (visibility of elements), • Regularity (similar materials are used for same applications). • Simplicity (limited number of materials & components, easy to segregate materials). • Maximize the production of high-quality recycled aggregates.	High	95-99% of material recovery rates can be achieved

Quality assurance schemes	***Motive:*** To involve industries to improve status of recycled materials ***Core Criteria:*** • Quality of recycled products. • Increase the usage of recycled products. • Encourage waste segregation and landfill diversion.	High	Improved recycling market

* Ref : (ISWA, 2012; Waste and Resources Action Programme, 2012; Central; Gálvez-Martos et al., 2018).

7.3. Results and Discussion

7.3.1 Beneficial index Value

Beneficial index Value (BIV) values are computed based on the frequency of the items for each of the variables, and the ranks are given correspondingly as shown in Table 7.4 and figure 7.2. Tableau® software is used for data visualization of Gantt percentage and average score of barriers, benefits and measures.

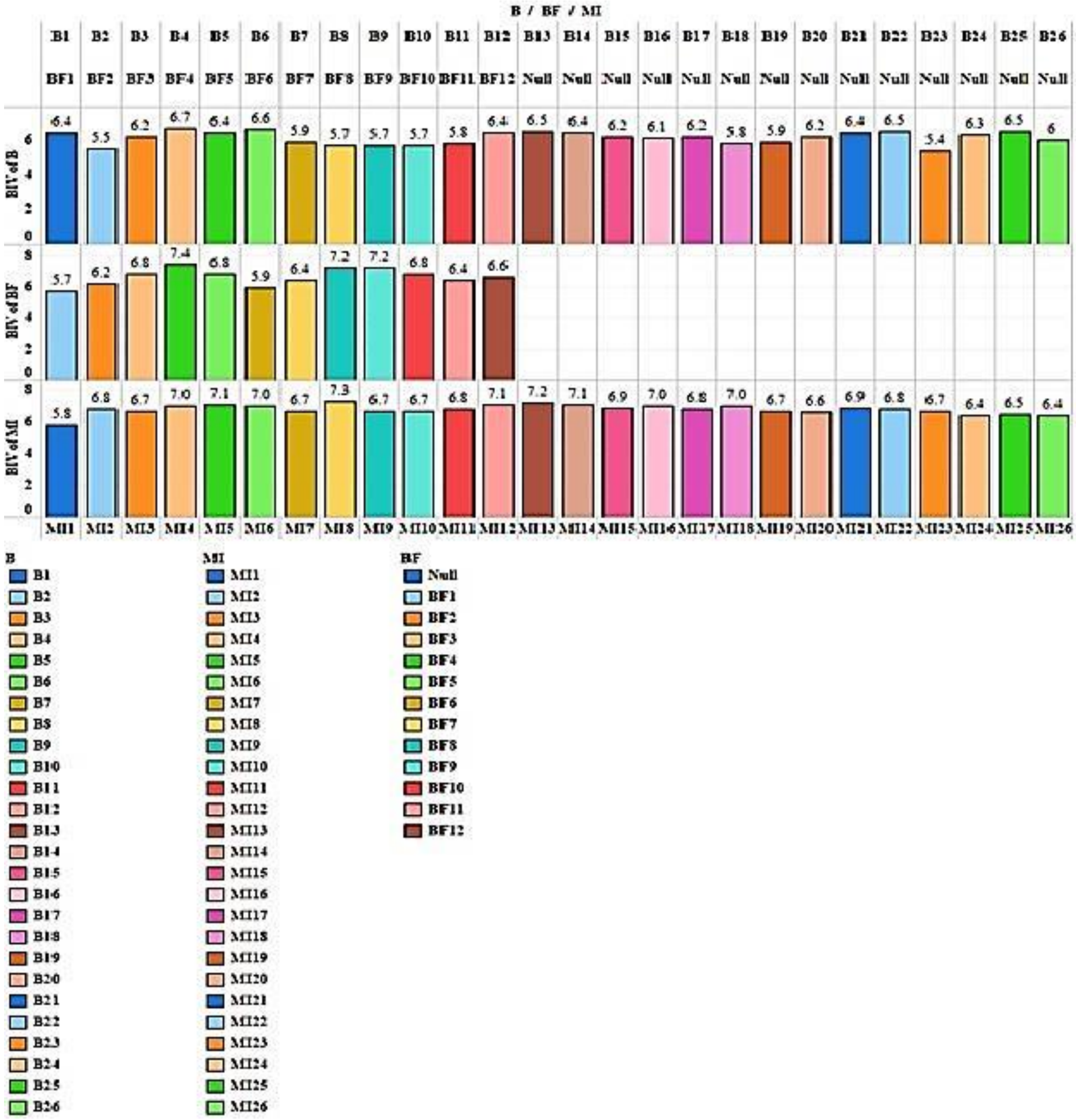


Figure 7.2 BIV values of barriers, benefits and measures

From Figure 7.2, B4- *"No guidelines are available with company"* is ranked as the highest parameter with a beneficial index value (BIV) of 6.70; B6- *"Government is not concerned about the place where I dispose wastage"* with BIV of '6.63' is ranked second; B13 - *"Lack of experienced staff"* (BIV-6.59) ranked third, B22*"Lack of technological support within organization*" (BIV-6.50) and B25 "*Lack of awareness of law regarding illegal dumping"* (BIV-6.50) are ranked fourth. The Gantt percentage and average score of the individual barrier is calculated using Tableau® is shown in Figure 7.3. The Gantt percentage reveal, among the different barriers B4 has got the highest Gantt percentage of importance 81.2 % and 18.9% (Low importance).

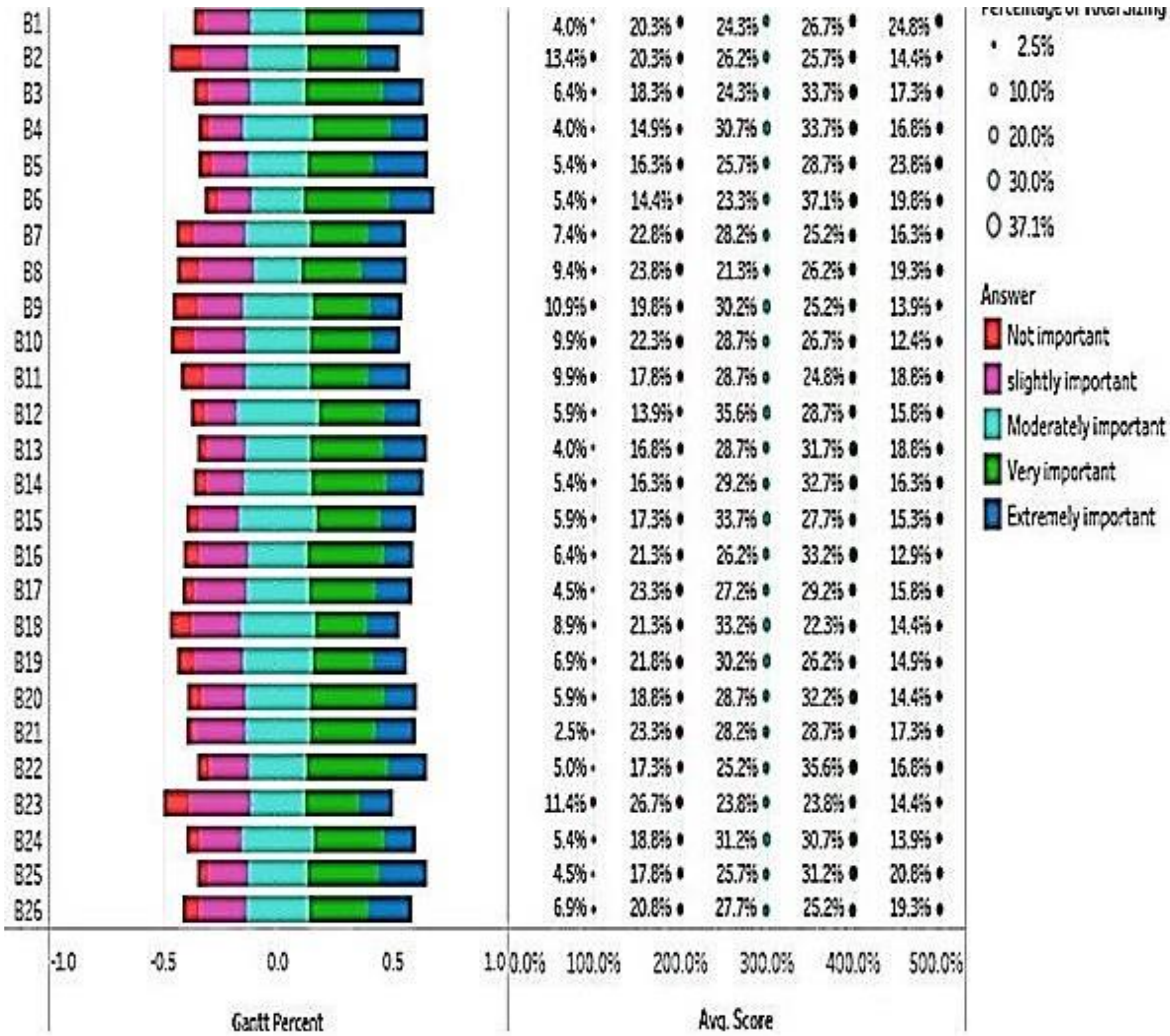


Figure 7.3 Gantt percentage and average score of barriers

BF4- "*environmental protection by conserving resources"* is ranked as the highest parameter among benefits with a beneficial index value of (7.42); BF8 (7.24)- *"Helps in efficient use of materials"* ranked second; BF9 (7.24) - "Reduction of environmental pollution ranked third, BF5 (6.86)- Increase business competitiveness ranked fourth; BF3 (6.85)- Improves waste management standards is ranked fifth. The Gantt percentage and average score of the individual benefit is shown in Figure 7.4. The Gantt percentage reveal, among the different benefits BF4 has got the highest Gantt percentage of importance 86.1 % and 13.9 % (Low importance).

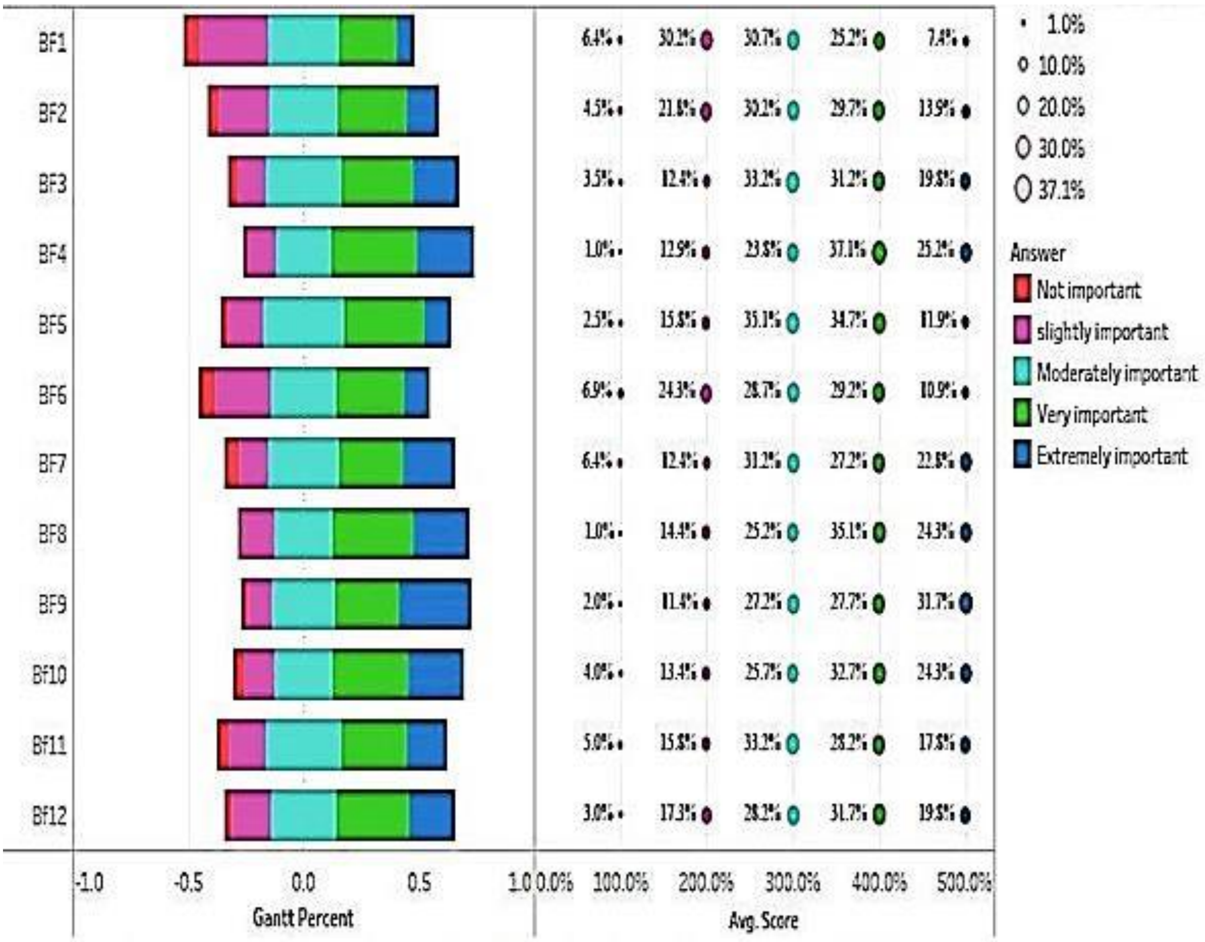


Figure 7.4 Gantt percentage and average score of benefits

MI8- *Legal requirements on environmental protection* is ranked as the highest parameter with a beneficial index value of (7.32); MI13 (7.22) - *Adopting waste management plan* is ranked second; MI5 (7.14) *Collecting suggestions for improving waste management* ranked third, MI12 (7.10), MI14 (7.10)- *Workshops on waste management with separate training for workers on waste management* and *continuous efforts in improving waste management* are ranked fourth.

The Gantt percentage and average score of the individual measure is shown in Figure 7.5. The Gantt percentage reveal, among the different measures MI8 has got the highest Gantt percentage of importance 84.2 % and 14.9 % (Low importance)

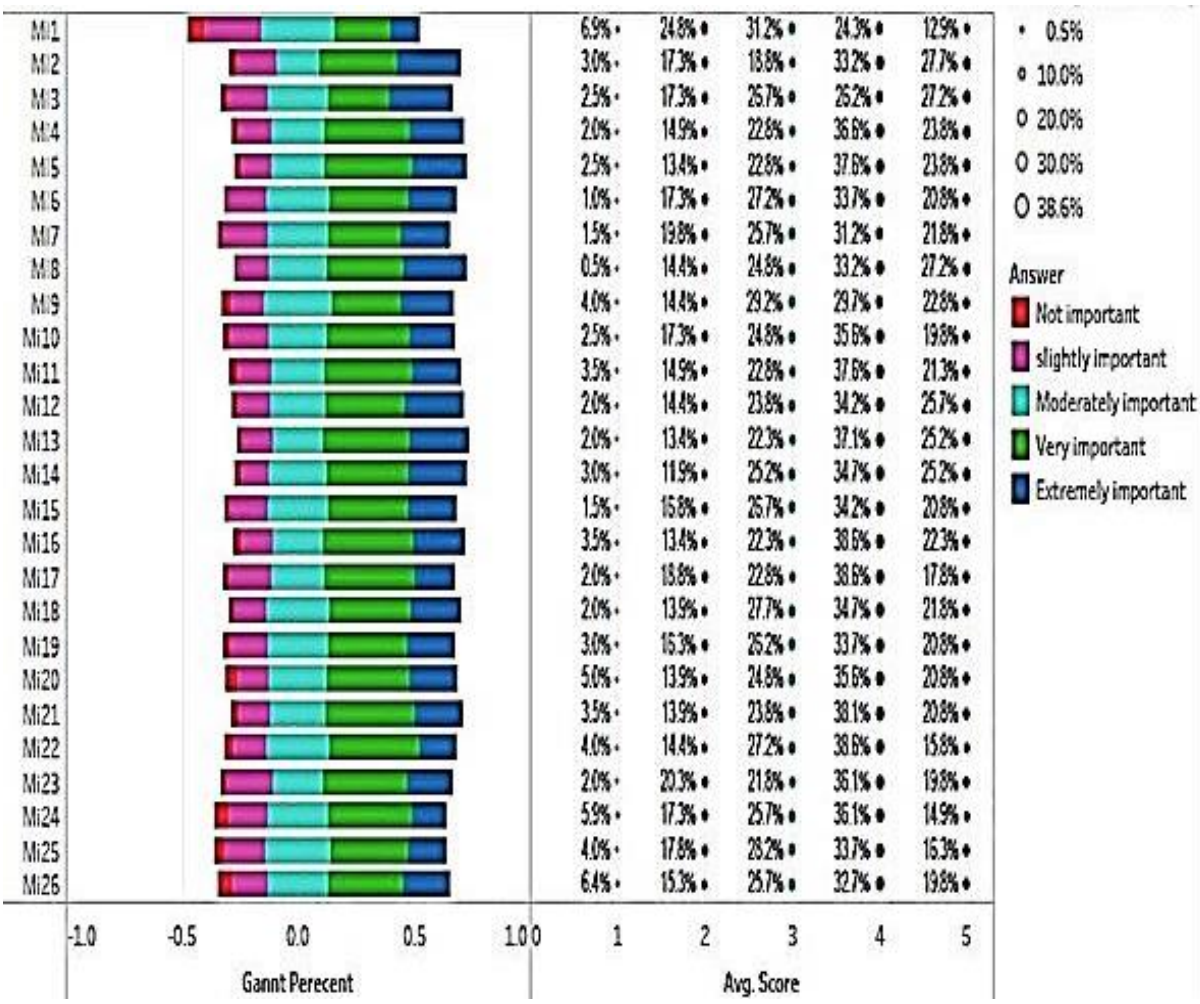
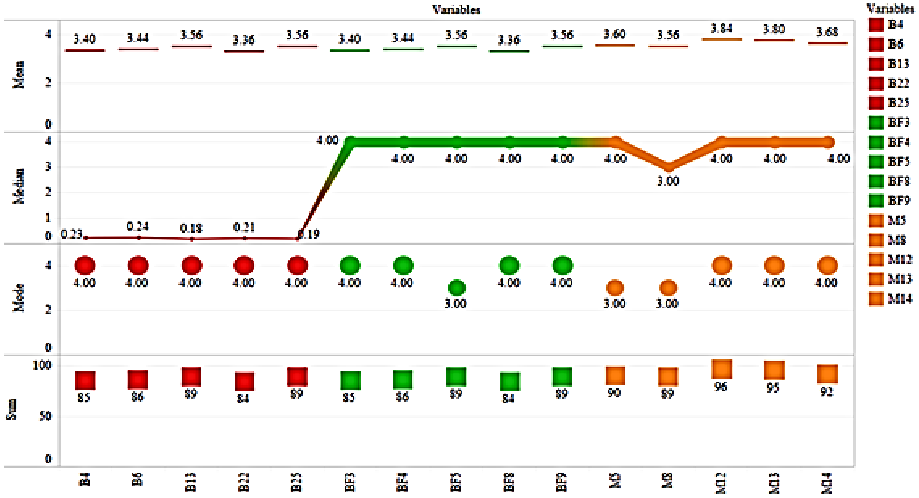


Figure 7.5 Gantt percentage and average score of measures

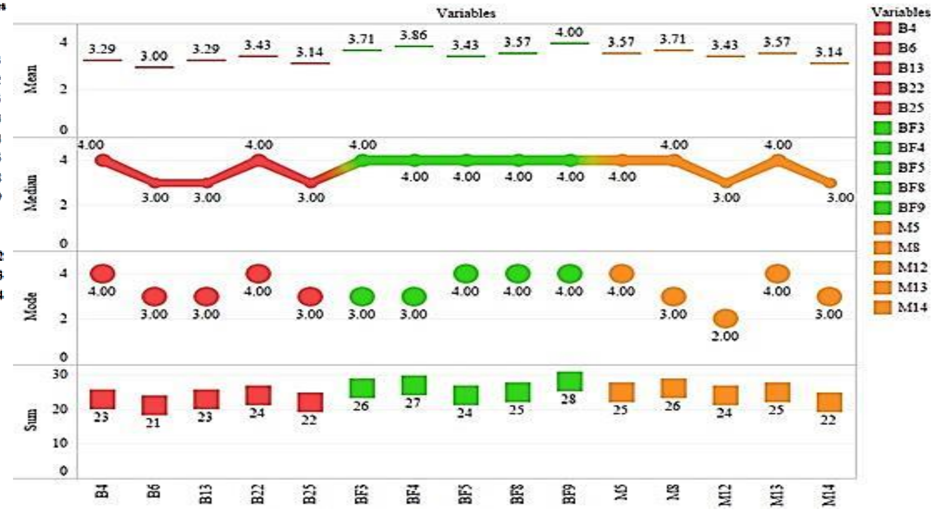
7.3.2 Questionnaire calibration

The descriptive statistics- central tendency measures, dispersion measures, form of the curve distribution for variables (barriers, benefits and measures for implementing SWMP are calibrated to check the validation among respondent groups (Manuel Gomez-Soberon et al., 2013). Sample descriptive statistics for top 5 ranked variables is shown below.

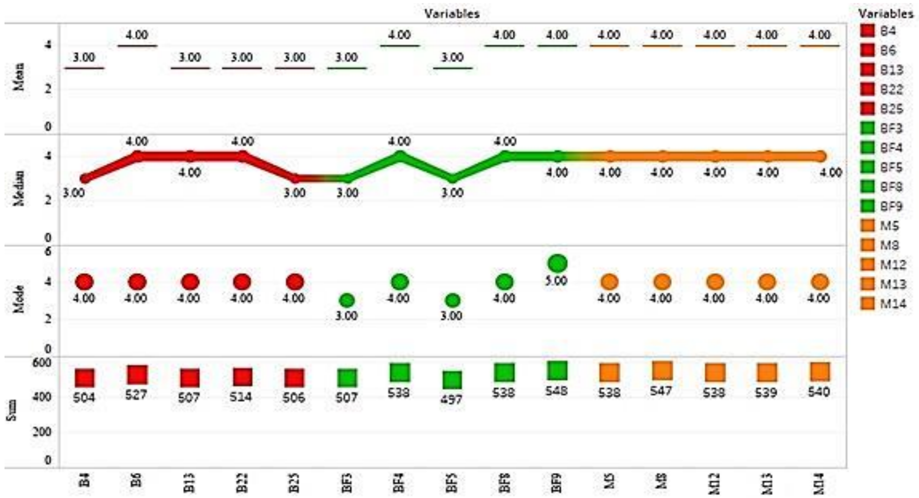
(i) Central tendency measures: Variables from top five rankings in barriers, benefits and measures are chosen for calculation of central tendency measures. The results indicate to the factor group *barriers* the mean of all the four respondent groups range from 3.00 to 4.00 and for *benefits* ranges from 3.00 to 4.00, *measures* ranges from 3.14 to 4.00. The analysis results of median, mode and sum are shown in Figure 7.6.



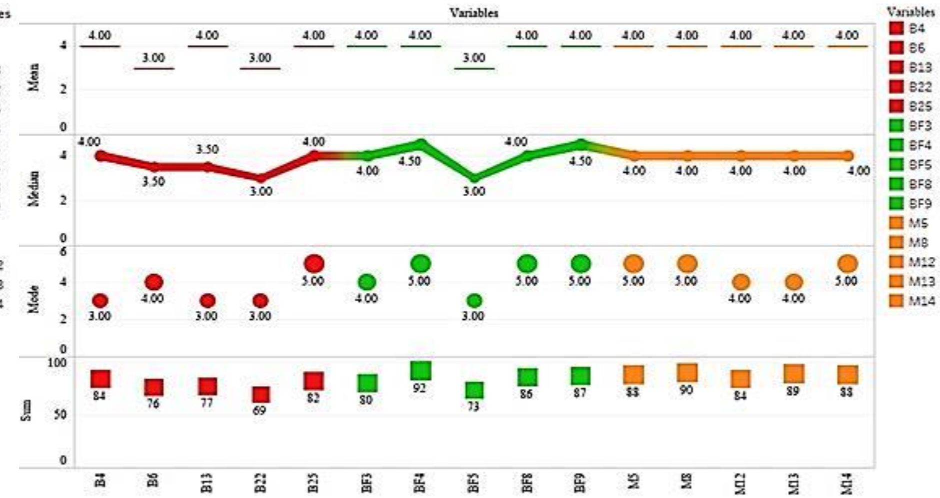
(a)



(b)



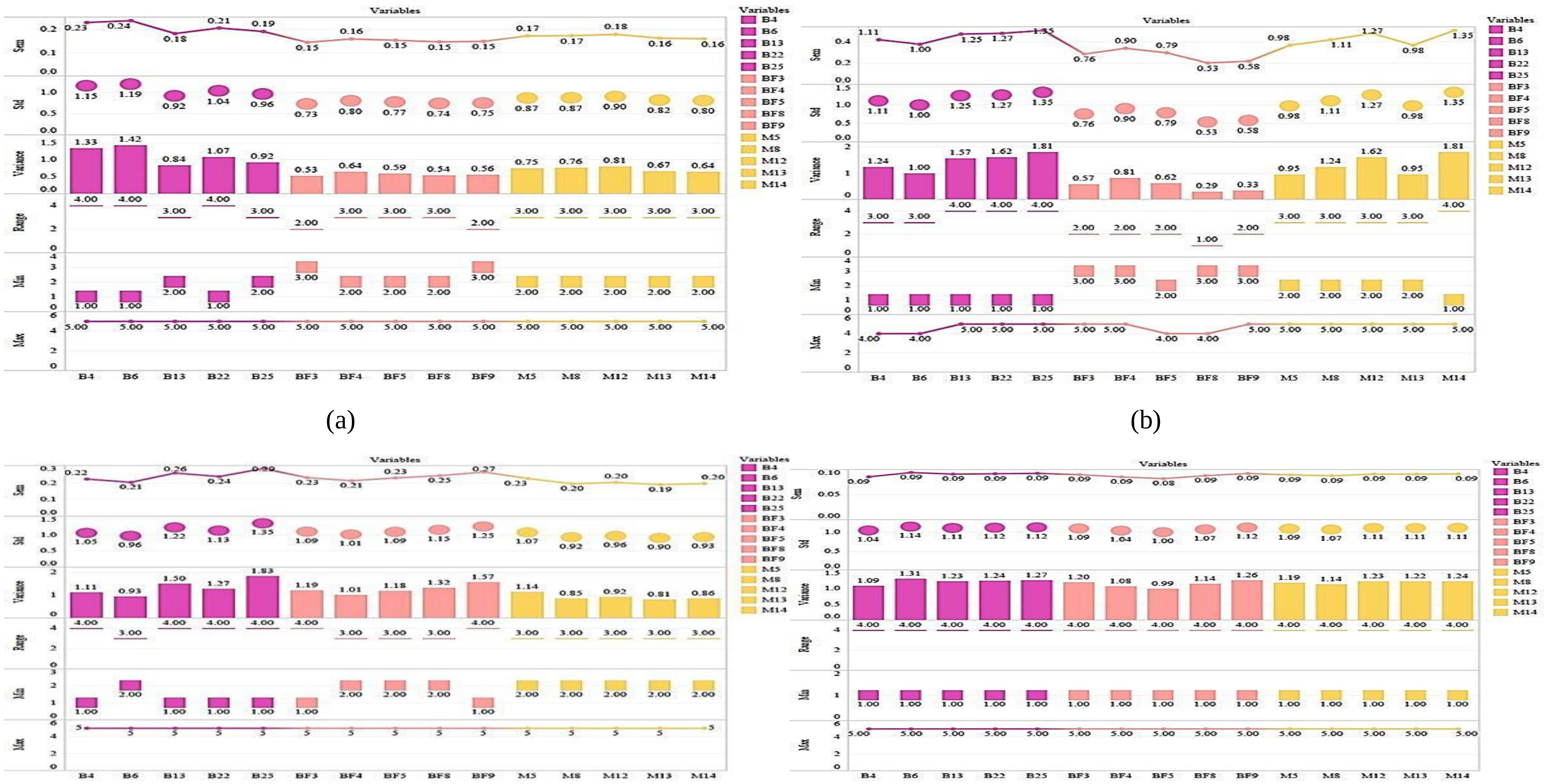
(c)



(d)

Figure 7.6 **Central tendency measures for Managers (a) Contractors (b) Engineers(c) Academics (d)**

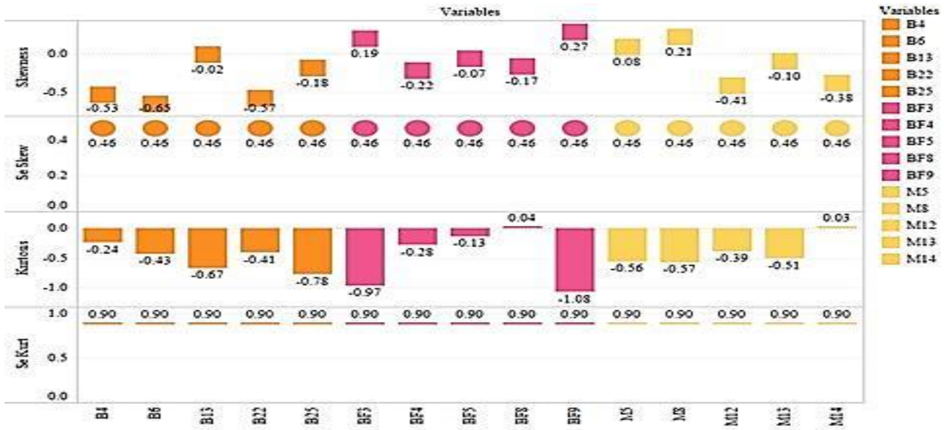
(ii) ***Dispersion measures***: The range or amplitude for each of the evaluation i.e. for *barriers range* from 3.00 to 4.00, benefits 2.00 to 4.00, measures 3.00 to 4.00. Similar comparative results are shown in Figure 7.7



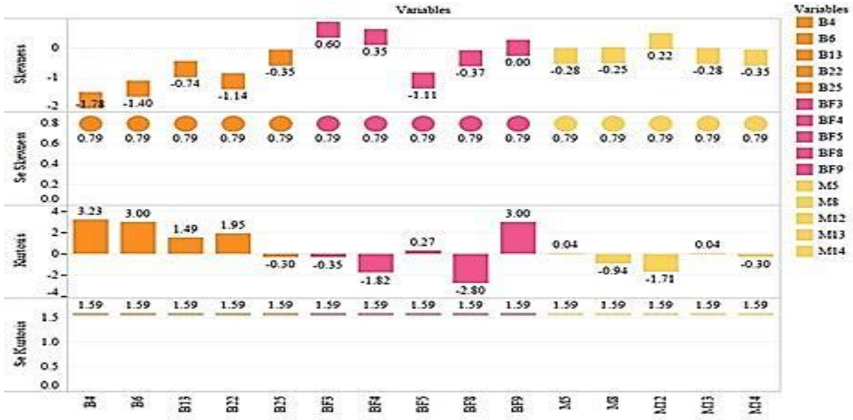
(a) (b) (c) (d)

Figure 7.7 Dispersion Measures for Managers (a) Contractors (b) Engineers(c) Academics (d)

(iii)***Form of the curve distribution***-The skewness and kurtosis of variables under barriers, benefits and measures shown in Figure 7.8 are in the range of -3 to +3.

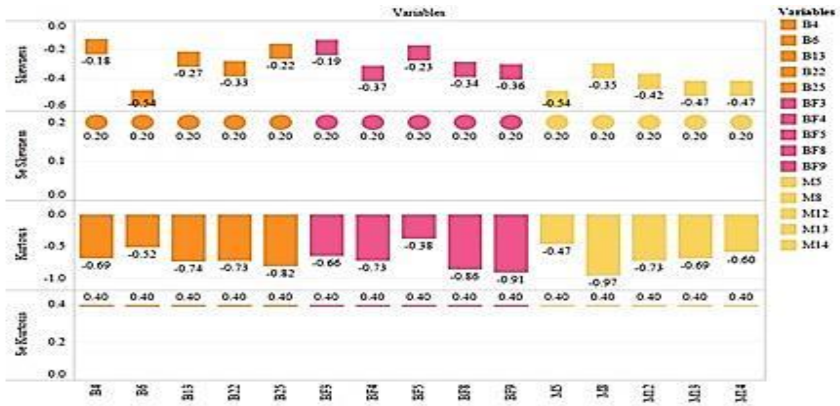


(a)



(b)

(c)



(d)

Figure 7.8 Form of the curve distribution for Managers (a) Contractors (b) Engineer(c) Academics (d).

7.3.3 Measurement of concordance among construction professionals

The degree of concordance between the respondent groups i.e. (Managers , Contractors , Engineer and Academics) for BBM is calculated using Kendall's coefficient of concordance (w) (Enshassi A and Sherif M, 2009).The level of concordance is measured on a scale of zero to one. Where '0' indicate perfect disagreement with the statements and '1' indicate perfect agreement to the statements. Kendall's (w) is calculated using (1). Null and alternate hypothesis is framed.

$$W = 12U - 3m^2n(n-1)^2/m^2n(n-1) \ldots\ldots.. (3)$$

$$\text{Where:} U = \sum_{i=1}^{n}(\sum R^2)$$

n: number of factors, m: number of groups, j: The factors 1,2…. N

Null Hypothesis (H_0): There is disagreement between the respondent groups

Alternate Hypothesis (H_1): There exists agreement between the respondent groups.

Table 7.8 Kendall's (w) among -Manager, Contractor, Engineer & Academics

Category	*Kendall coefficient of concordance*	*Degree of Agreement*	*Hypothesis*
Barriers	0.478	Week	H0
Benefits	0.722	Strong	H1
Measures	0.481	Week	H0

The range of Kendall's w is as follows (i) 0-0.3—Disagreement between respondents (ii) 0.31-0.50 week agreement (iii) 0.51-0.70 Moderate agreement (iv) 0.71-0.90-strong agreement (v) 0.91-1.0 very strong agreement (Lebreton, 2008).Analysis results of concordance (Table 7.8) indicate there is week agreement among manager, contractor, engineer and academics for the factors grouped under barriers & strong agreement to the factors under benefits and week agreement to the factors under measures. This clearly shows there exists diverse mind-sets between the respondents among the barriers and measures; however, all the respondents have strong agreement on benefits inferred by implementing SWMP.

7.3.4 Barriers and Enforcement Measures for recycling of construction waste

Relative mapping approach on six case studies(Table 7.9) indicate three out of six projects are not implementing WM at construction sites; three out of six projects do not segregate the waste produced; all six projects dump the waste in a specified area and remove them when there is a space constraint at construction sites (no planned disposal of waste); all six projects have no recycling procedures adopted at their sites; four out of six projects have no supervision on waste generation and calculation; three out of six projects lack of ethics in waste generation and two out of six projects are unaware of waste management. The results indicate the barriers for practice of recycling at construction sites are (open dumping, Lack of segregation, lack of knowledge on recycling, lack of quantification of data). Each of them are explained in detail.

Table 7.9 Relative mapping of practicing recycling between construction projects

Coding	Barrier	Project 1	Project 2	Project 3	Project 4	Project 5	Project 6
BR1	Not practicing waste management	X	Y	X	X	Z	Z
BR2	Lack of ethics in waste generation as well as segregation	X	Y	X	X	Y	Y
BR3	Lack of awareness on waste management	X	Y	X	X	X	Z
BR4	No waste segregation	X	Y	X	X	Y	Z
BR5	No supervision for waste generation calculation	X	Y	Z	X	Y	Y
BR6	Dumping of waste in low area and later disposing them by means of hauling through trucks.	Z	Y	Y	Z	Y	Y
BR7	No materials recovery for recycling at construction sites	Y	Y	Y	Y	Y	Y

Note: X: Insignificant Y: Significant Z: Strong

7.3.4.1 Measures against behavioral barriers:

Several attitude and behavioral barriers hinder the implementation of recycling, the most prevalent perception that usage of recycled materials leads to poor quality, spreads misleading information. This can be overcome through:

- Adequate training of workforce and supervision of construction waste generation.
- Enhancement of sustainable policies in companies.
- Increase government funded constructions using recycling materials.

7.3.4.2 Measures against technical barriers:

Absence of technical knowledge such as standards, guidance on effective usage of C & D waste in construction, hinders the implementation of recycling. This can be overcome through:

- Government and industry funded research and development on C & D recycling.
- Code provisions such as acceptable limits of recycled materials in various building components.
- Collaboration and outsourcing of small-scale industries which suffer low financial capabilities.

7.3.4.3 Measures against legal barriers:

Lack of policies, regulations for recycling of CW and supervision on dumping of CW. This can be overcome through:

- Increased landfill charges.
- Strict supervision to avoid illegal dumping.
- Exemptions from taxes such as GST for using recycled materials.
- Including additional points for using recycled products within existing green building rating systems.

7.3.4.4 Measures against marketing barriers:

Absence of demand i.e. undeveloped market for recycled products and immense cost for recycling and finite support from government are major barriers. The measures to increase the marketing of recycled materials include:

- Usage of mobile crushers at demolition sites aid onsite recycling and reduce transportation costs.
- Granting best waste utilization certificates for companies utilizing recycled products.
- Increasing recycling plant outlets.
- Association with local manufactures.
- Tax incentives and providing advanced equipment at cheaper rates etc.

7.3.5 Discussion on comparison of C & D waste management practices in European nations with Indian initiatives

Construction & demolition waste management plans (C&DWM) or strategies:

- The C&DWM plans & strategies is a regular approach in European nations. Key criteria of best practice strategic plan at national, regional and local level is shown in Table 7.10. Strategies are effective, if they are accompanied by regulation, enforcement practices, or economic indicators (taxes, levies). However, the degree of implementation & consequences varies extensively. C&DWM is routine in countries which have.
    - Restriction on supply of natural raw materials,
    - Significant environmental awareness and,
    - Established C&DW recycling facilities.
- In UK, environment policies and strategies are framed using '***Waste Resources Action Programme'***(WRAP) which lead to:
    - Increased recycling rate i.e. up to 90 % (DEFRA, 2017)
    - Landfill diversion of concrete and metal wastes.
    - Savings beyond 200 kg CO2 per GBP 100,000 construction value
- Stakeholder involvement is the key aspect in developing C&DWM plans & strategies. Stakeholder involvement was made through ***"Halving Waste to Landfill Commitment"*** campaign, which includes 750 supply chain construction organizations (Waste and Resource Action programme, 2011).
- The ***International Solid Waste Association*** established in 2012 (ISWA, 2012) established practices for active involvement of stakeholders. Highlights of ISWA include:
    - Consultation, communication & user contribution.
    - Participatory inclusive planning.
    - Assess performance of the framed system.
    - Define & update objectives.
    - Monitor progress towards milestones.
    - Establishment of local waste platforms.

Table 7.10 Key criteria of best practice strategic plan at national, regional and local level

S.No	National	Regional	Local
1.	Identification, quantification of CDW management options	Implement national strategies	Involves local industries
2.	Involvement of stakeholders from construction organizations	Measure the need of collection, treatment & recycled material.	Establishing environmentally-friendly public procurement policies at local level
3.	Establish CDW management targets & policies	Setup investment plans for R & D.	Establishes building reuse strategies, waste sorting requirements
4.	Prioritizes waste prevention	Quality assurance schemes	Establish guidance for small waste producers
5.	Provide standard code of practice	Defines a performance baseline	Establishes communication economic instruments,
6.	Provides realistic regulatory strategy for construction firms	Identification of future flow of waste	Establish municipal collection points to prevent sorting issues, low collection rates & illegal

Status in India: Abundant policies corresponding to frequent amendments are available in India, few among them are Swachh Bharat mission, Page 227- C&D waste, National Environment Policy of 2006- concept of 3R, Central pollution control board (CPCB)-2017 – Guidelines of environmental management of C &D waste. C&DWM rules 2016 by ministry of environment, forest and climate change (MoEF&CC). However, Participatory inclusive planning, performance assessment of the framed system, progress monitoring towards milestones are barely implemented in India.

Economic tools:

- In European nations economic tools have stronger impact than regulatory systems. Economic tools are designed with a motive of (i) diversion of waste from landfills (ii) Increase recycling of waste and (iii) optimum usage of resources.
- Among them are ***business to business, B2B***, schemes in Europe are particularly noteworthy. The scheme is routine for reusable packaging materials such as pallets, drums, cardboards etc. (Waste and Resource Action programme 2011)
- Deposit-refund schemes are yet other powerful economic tools practiced in Spain municipalities. Nominal amount is charged on the estimated amount of wastes documented in SWMP as part of the essential licensing requirement. The deposit is refunded to the

contractor when "waste management certificates" are submitted to the corresponding authorities.

Status in India: Economic tools are merely available in India, however schemes such as Swachh Bharat Abhiyan are well established for domestic waste such as waste to compost etc. While in case of C &D waste, CPCB mandated the usage of recycled products up to 20 per cent lower in comparison with conventional products for Government projects. The probable barrier for involvement is that, there is no materials recovery for recycling at construction sites. However, amalgamation of B2B along with deposit refund schemes can motivate stakeholders towards implementation of C&D WM.

Site waste management plans:

The formulation of SWMP is a legal requirement in most of the European countries. The SWMP consists of two phases such as SWMP design & SWMP implementation.

SWMP design: The following are the core criteria involved in SWMP design

- Scope of SWMP need to be formulated such as identification of materials which need to be recovered, reused, recycled & disposed.
- Defining waste management responsibilities.
- Identification of instruments for monitoring, collecting & promoting correct waste management practices.
- Defining waste types, estimation of wastes
- Cost estimation & potential savings identification.
- Defining procedures for segregation, storage, removal and transportation.
- Communication strategy needs to be defined.
- Identification of waste prevention techniques, reuse & recycling opportunities for individual waste streams.
- Evaluate potential onsite applications.

SWMP implementation: The following are the core criteria involved in SWMP implementation

- Communication & explanation of SWMP onsite.
- Identification of available waste storage areas & resources onsite.
- Placing of waste sorting containers near waste generation sources.
- Onsite training & promotion of SWMP to new staff.
- Regular documentation update.

Status in India: According to construction and demolition waste management rules 2016, waste generator who produces more than 20 tons in a day or 300 tons per project in a month shall produce SWMP. However, it is not enforced nationally this is due to - *"No guidelines are available with company"; "Government is not concerned about the place where I dispose wastage"*; *"Lack of experienced staff"; "Lack of technological support within organization*"; *"Lack of awareness of law regarding illegal dumping"* (Figure 7.2).

Onsite waste prevention & collection:

It is estimated that 33% of waste generation in construction site is due to failure of implementation of waste prevention measures in design phase (Osmani et al., 2008).The following are the few of the modern techniques (Figure 7.9) widely used in UK .The incorporation of these methods has led to a waste reduction potential of approximately 90% (Waste and Resources Action Programme, 2012).

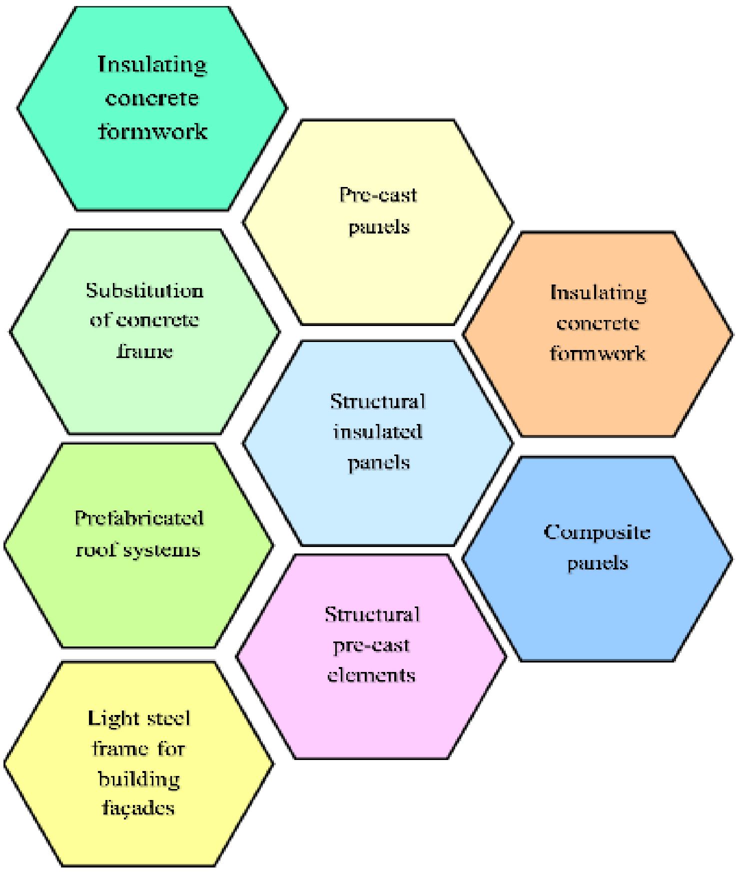


Figure 7.9 Modern methods of construction

European nations formulated onsite waste prevention into four major waste management activities which involves:

(i) **Estimation of onsite waste generation & resources provision –** Waste estimation is tailor made estimation i.e. which can be optimized based on past experiences of the working professionals.

(ii) **Collection & segregation techniques-**The following are the standardized techniques which are adopted widely in UK

- Waste collection bins are identified for individual waste; the size of bin is selected based on estimated amount of waste.
- To collect the waste onsite eco points, recycling points are implemented.
- Temporary waste collection points are placed to improve waste segregation efficiency.
- Hazardous wastes are collected and placed separately with utmost care.
- Onsite training of the laborers on CWM.
- Easily accessible site area for the movement of trucks etc.

(iii) **Procedures & methodologies to ensure best management options:** The techniques involve visual inspections, symbols, waste management certificates, registers, documentation, signs, portable crushers, wood shredders etc.

(iii) **Establishment of waste logistics:** In UK nations two collections methods are usually employed ***(i) Reactive:*** Usually adopted for large fractions of waste (automatic replacement of containers) ***(ii) Scheduled:*** Usually adopted for constant generation of waste such as municipal wastes.

Status in India: Onsite waste prevention & collection is partially adopted in Indian construction sites. However, waste segregation, collection is observed in well-established sites operated by first class contractors. Therefore, for practical enforcement contractor, client, designer etc. play a key role.

Materials Re-use

Factors such as aesthetics, space, and client satisfaction play a key role in reuse of materials. ***Selective building deconstruction (SBD)*** is the widely adopted procedure in most of the European nations. It involves methodical disassembling procedures with an aim of optimizing reuse, recycling & landfill diversion. The following are the steps involved in selective building deconstruction:

- Audit on hazardous substances
- Identify the need for specialized stripping (asbestos etc.).
- Manual dismantling of sensitive units (sanitary ware, glass, wood etc.).
- Removal of direct reusable items such as ceilings, floorcoverings, combustible and non-combustible elements are stripped and segregated correspondingly.
- Removal of steel frames, wooden beams etc.

Concrete buildings are usually demolished and the material is crushed to produce aggregates. The method (SBD) has several advantages over conventional building deconstruction such as increased landfill diversion, direct reuse of building elements etc. Moreover, it is estimated that approximately 40 % of embodied energy and 60% carbon foot print of concrete structure can be saved using SBD.

Status in India: Indian standard code IS 383-2016 – revision III, established specifications on usage of RA, NBC- CED 46 of India 2005 established standards on usage of RA i.e. 30 % replacement of natural CA and up to 50 % for pavements. In addition, guidelines for sustainable habitat part (IV) established guidelines on reuse & recycling of C &D waste and central public works department (CPWD) and national building construction company (NBCC) established rules mentioned in BIS 383-2016. Furthermore, BMTPC 2016 has established guidelines on usage of C & D waste in construction of dwelling units and infrastructure constructed by government. However, the probable barriers for usage of recycled materials, in the Indian context, include various behavioural, technical, legal and marketing barriers.

Material recovery

- High quality aggregates are produced from well segregated waste & has higher applicability in comparison with mixed crushed concrete aggregates.
- The standard code of practice for recycled aggregates usually adopted in Germany is DIN standard 4226-100.
- Berlin and Baden of Wurttemberg in Germany is setup with well-defined recycling standards and is estimated to have higher recycling rates up to 90 %.
- It is estimated that nearly 20-25% of the recycling dust consists of particle size less than 10 μm hence their release is duly controlled by de-dusting devices.
- The European committee of standardization (CEN) established (CEN/TC 351) a technical committee to assess the release of construction products release into soil, water and air.

Status in India: SBD for recovering valuables from construction sites (for reuse and recycling), which are ready for demolition, is rarely practiced in India. This is because of the misconception that reuse, and recycling of materials leads to decrease in material strengths and quality. Government of India should substantiate the adequate research on usage of recycled C & D materials.

Quality assurance schemes (QAS):

- The schemes are mandatory for better marketing of recycled construction materials.
- The quality assurance schemes usually establish unified rules and regulations for producers as well as for manufactures.
- In Germany quality of recycled aggregates is established based on (i) Leaching characteristics (ii) application suitability for each type.
- The QAS schemes usually adopted in Europe are Austrian construction materials recycling association.
- Finland SFS standard 5884 and ***Programme agre gain*** in UK maintained by WRAP are few of the QAS
- In addition, European EN 12620 - to assess the performance of recycled aggregates, EN 13242 - roads and EN 13043- asphalt are the vital standards adopted in European nations.

Status in India: The Bureau of Indian Standards (BIS) and Indian Roads Congress (IRC) shall be responsible for preparation of code, practices, standards and products of C &D waste in India.

7.4 Conclusion

The barriers, benefits and enforcement measures in implementing SWMP at construction sites are identified and analysed. Beneficial index value is used to rank the variables in corresponding categories. The results conclude among the barriers; **B4-** "*No guidelines are available with company"* is ranked as the highest parameter with a beneficial index value of (6.70)(Udawatta N et al., 2015); **B6 (6.63***)*- *"Government is not concerned about the place where I dispose waste"* ranked second (Vegas et al., 2015); **B13 (6.59)- "***Lack of experienced staff ranked third* (Bakshan et al., 2016), **B22 (6.50) and B25 (6.50***)- "Lack of technological support within organization* "and "*Lack of awareness of law regarding illegal dumping* "are ranked fourth(Ranta et al., 2018; Udawatta N et al., 2015).

Among benefits **BF4 (7.42)-** *environmental protection by conserving resources* is ranked as the highest parameter (Shen and Tam, 2002); **BF8 (7.24)** - *Helps in efficient use of materials* ranked second(Tam, 2008); **BF9 (7.24)**-*"Reduction of environmental pollution*" ranked third(Zhen C et al., 2000), **BF5 (6.86)** –"*Increase business competitiveness"* ranked fourth (Tam et al., 2014); **BF3 (6.85)**- *Improves waste management standards* is ranked fifth (Jasch, 2000).

Measures **MI8 (7.32)-** *Legal requirements on environmental protection* is ranked as the highest parameter (Weisheng L and Yuan H, 2010); **MI13 (7.22)**- *Adopting waste management plan* is ranked second (Lau HH and Whyte A, 2008); **MI5 (7.14)** *Collecting suggestions for improving waste management* ranked third (Udawatta N et al., 2015), **MI12 (7.10) and MI14 (7.10)**- *Workshops on waste management with separate training for workers on waste management and Continuous efforts in improving waste management* are ranked fourth (Kulatunga U and Amaratunga D, 2006 ; Petts, 1995). It is therefore concluded that, most of the respondents believe with an efficient waste management system construction waste can be reduced. However irrespective of the respondent's intention there are no guidelines available with the company. This clearly indicates lack of interest in implementing waste management system. Most of the respondents agreed for an effective waste management implementation legal enforcement is mandatory i.e. through penalties, taxes etc. Furthermore, analysis results of concordance indicate there is ***week agreement*** among manager, contractor, engineer and academics for the factors grouped under barriers, strong and weak agreement to the factors under benefits and measures. This clearly shows there exists diverse mind-sets between the respondents among the barriers and measures; however, all the respondents have strong agreement on benefits inferred by implementing SWMP.

Recycling studies on the six active projects indicate Barriers i.e. (behavioural, legal, technical, marketing) to enforce recycling are (i) non-implementation of SWMP(ii) illegal dumping (iii) lack of segregation(iv) ethics and supervision on recyclable materials. Suggested measures for efficient recycling are (i) ***Behavioural***-*Government projects construction using recycled materials, adequate training and supervision* (KolaventiSS et al., 2019).(ii) ***Technical***- *code provisions of acceptable quality for various building components* (Kleemann et al., 2017) (iii) ***legal***- *Higher landfill charge with strict penalties for illegal dumping*(Rodríguez et al., 2017) (iv) **Marketing** – *Mobile crushers at demolition sites and increasing recycling material sale outlets* (Gangolells et al., 2014;Shi et al., 2013).

Suggestions for better management of C & D waste based on comparison with European nations.

The following are the suggestions for better performance of CWM.

- ***Association of building approval*** with CWM documentation.
- Onsite CWM performance assessment using ***index system***
- ***Eco points establishment*** for collection of construction waste.
- Usage of ***android applications for CW*** marketing.
- Maintenance of ***CWM check list.***
- ***Mandatory recycled material usage*** in Government construction projects.
- ***Incentive sche***mes for construction projects which performs best in CWM (usage of recycled materials, storage etc.)
- ***Tax levies*** on recycling equipment.
- ***Mobile recycling plants.***

The above suggestions can improve the status of CWM and recycling in India. The study can thus provide guidance in developing company policies, laws and regulations to improve C & D recycling status of Indian construction industry while aiming for sustainability.

CHAPTER 8

Attitude & behavioural studies on implementation of construction waste management

8.0 General

Objective - 4 of the research work consist of assessing attitude and behavioural parameters which influence implementation of construction waste management in India. The study utilised an extended theory of planned behaviour (ETPB) approach by developing a hypothesized structural equation modelling (SEM) model for assessment of parameters. The methodology for objective 4 is presented under figure 8.1.

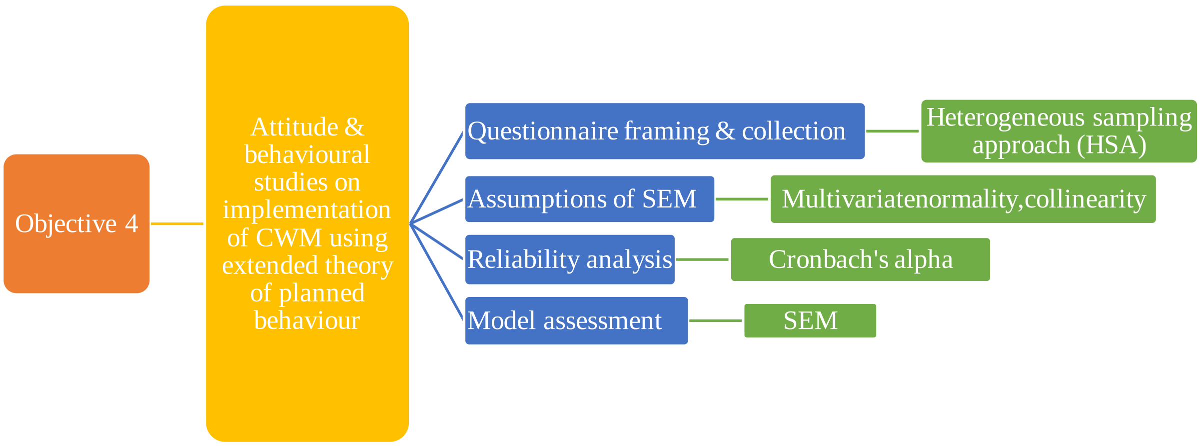


Figure 8.1 Methodology for objective four

8.1 Theoretical background and ETPB studies in Indian context

8.1.1 Theoretical background of ETPB

The various theories to estimate the association between behavioural variables and green actions include Maslow's hierarchy, norm activation and social cognitive theory. Of these, TPB is adopted in most scenarios (Li et al., 2019). Behavioural intention (BI) is a combination of three determinants- attitude (ATT), subjective norm (SN) and perceived behavioural control (PBC). The TPB framework links attitude, subjective norms and perceived behaviour control to BI and actual behaviour of participants. The prophecy of TPB can be enhanced using extended theory of planned behaviour (ETPB), which includes additional variables such as moral norms (Kaffashi and Shamsudin, 2019), perceived usefulness (Zhang et al., 2021), knowledge (Mak et al., 2019), government norms (Mak et al., 2019), economic viability (Friedrich, 2021), awareness (Khan et al., 2019), technology developments (Kaffashi and Shamsudin, 2019), demographics (Yuan et al., 2018), pressure and consciousness (Jain et al., 2020a).

Additionally, TPB & ETPB are used to assess individual environment behaviours in various sectors (Table 8.1). For instance, household food waste generation (Yuan et al., 2018), plastic waste (Khan et al., 2019), environmental practices (Betts et al., 2018), recycling (Botetzagias et al., 2015), sustainable materials (Friedrich, 2021), autonomous vehicles (Jing et al., 2019; Kaffashi and Shamsudin, 2019), waste prevention & recycling behaviour (Oztekin et al., 2017), circular economy (Singh et al., 2018), green purchase behaviour (Yadav and Pathak, 2017).

Similarly, ETPB is applied in various domains of C&D waste management such as assessment of behaviour to promote CW recycling (Botetzagias et al., 2015); assessment of contractors (Li et al., 2018), project manager (Yuan et al., 2018) and designers intention on CW reduction (Li et al., 2015), assessment of attitudes which influence WM (Jain et al., 2020a).Therefore it is evident from the previous literature that, the complex nature of the individuals cannot be assessed using one model. Therefore, the conventional TPB model needs to be modified according to the specific purpose for enhanced reliability.

The quality perceptions of the consumer has, a significant impact on the purchasing behaviour (Li et al., 2018). Similarly, the recycled products purchase behaviour is interconnected with their quality specifications. Low quality of the recycled products can prevent the construction workforce from its usage. It is evident from the study conducted by (Teo and Loosemore, 2001) subordinates attitude towards CWM implementation has substantial impact on perceived usefulness and costs. In the same manner, workforce knowledge on WM can improve and develop positive attitude towards its implementation (Khan et al., 2019).

Table 8.1 TPB studies on construction waste management

Author	TPB			ETPB					
	ATT	PBC	SN	AW	RK/PR	EV	BF	DG	KN
(Zhang et al., 2021)				✓	✓	✓	✓		
(Friedrich, 2021)	✓	✓	✓			✓			
(Jain et al., 2020a)	✓	✓	✓	✓	✓				
(Yang et al., 2020)	✓	✓	✓				✓		
(Mak et al., 2019)	✓	✓	✓	✓		✓	✓		
(Khan et al.,2019)	✓	✓	✓	✓	✓			✓	✓
(Yuan et al., 2018)	✓	✓	✓				✓	✓	
(Li et al., 2018)	✓	✓	✓	✓			✓		
(L. Zhang et al., 2018)	✓	✓	✓	✓		✓			✓
(Singh et al., 2018)	✓	✓	✓		✓	✓			
(Wu et al., 2017)	✓	✓	✓		✓	✓			
(Oztekin et al., 2017)	✓	✓	✓					✓	
(Yadav et al.,2017)	✓	✓	✓			✓			

***ATT- Attitude, PBC- Perceived behavioural control, SN- Subjective Norm, AW- Awareness, RK, PK- Risk and Pressure, EV- Economic viability, BF- Benefits, DG- Demographics and KN- Knowledge.

8.1.2 TPB studies in Indian context

The intention to implement CWM at construction site is influenced by non-fiscal motives such as attitudinal and behavioural parameters. Several studies are available in India which utilize the TPB framework. Environmental concern and knowledge are the two additional constructs which are used to study the behavioural intentions of Indian youth to buy sustainable products (Yadav and Pathak, 2016). Attitude, personal norms, environmental concern, and willingness are used to assess intentions to buy products with green packaging (Prakash et al., 2020). Individual morality and righteousness are used for exploring sustainable tourism choices among Indian youth (Verma and Chandra, 2018). In a similar manner, involvement of consumers in explaining green behaviour, behavioural parameters to improve recycling and waste management status in India (Singh et al., 2018; Verma and Chandra, 2018) are studied.

In addition there are limited studies available which explore the association between behavioural intention in implementing waste management at Indian construction sites (Mak et al., 2019). In summary, a combination of theory of planned behaviour (ATT, SN and PBC) and institutional theory (KN and PU) together tend to provide a broader perspective on implementation of CWM. Therefore, the current work identifies the factors driving construction professionals towards implementation of CWM.

8.2 Hypothesis Development

The hypothesis in the current study is framed based on attitude and behavioural aspects of construction workforce, towards implementation of CWM in India. The causal relationships among the predictor variables is presented in figure 8.2.

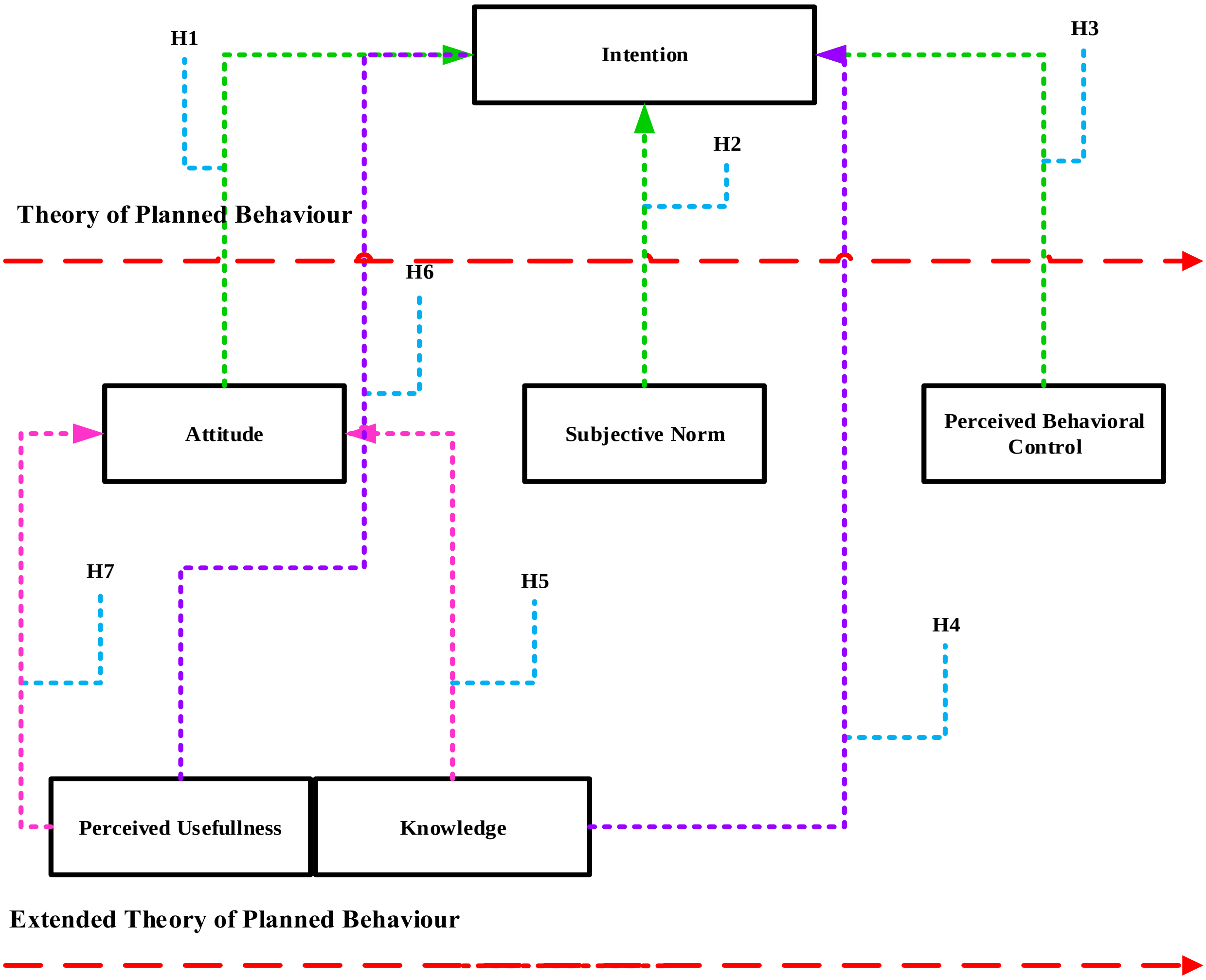


Figure 8.2 Extended theory of planned behaviour for CWM.

8.2.1 Attitudes (ATT)

Attitude refers to the positive or negative evaluation of the behaviour corresponding to an individual person (Teo and Loosemore, 2001). Jain et al., 2020a, determined that construction workforce has developed positive attitudes towards C & D waste recycling. In a similar manner (Wu et al., 2017) concluded that contractors displayed positive attitudes towards implementing C & D waste management. Yuan et al., (2018), stated that project managers tend to exhibit positive attitudes towards reducing construction waste. Thus the following hypothesis is proposed in accordance with the previous literature:

H1: *Favourable attitude towards construction waste has a positive effect and significant impact on intention to adopt CWM.*

8.2.2 Subjective Norms (SN)

SN refers to: (i) The influence of external pressure on individual's behaviour; (ii) Seeking opinions from others such as higher authorities, friends; (iii) The extent to which others approve or disapprove for a specific situation (Wu et al., 2017). Similarly, Li et al., 2018 found that subjective norms reinforce behaviour analysis of CWM and have direct and significant effects on future implementation of CWM. A previous study by Wu et al. (2017) concluded that subjective norms encourage CWM implementation. It is further stated that SN plays an ancillary role in alleviating designers intention towards CW reduction (Li et al., 2015). Therefore, it is evident from previous literature, that SN is successful in predicting the behaviour intentions towards implementing CWM. Thus, the following hypothesis is proposed:

H2: *SN has a positive and significant impact on the intention to adopt CWM.*

8.2.3 Perceived behaviour control (PBC)

PBC refers to the individual's perception of the difficulty of enacting a behaviour. Ajzen (1991), argued that PBC comprised of two highly related and correlated variables such as perceived self-efficacy and perceived controllability. The former explains one's belief about their own ability, while the later indicates the belief that one's behaviour is volitional. Both of these variables combined together, refer to PBC (Teo and Loosemore, 2001). Wu et al., (2017) stated that PBC emboldens individuals in construction sector to incorporate CWM. Subsequently, it is reported by (Verma and Chandra, 2018) that PBC has a significant impact on visitors to green hotels. Furthermore, Li et al. (2018) concluded that PBC has an significant effect on waste reduction. Thus in association with the past literatures the hypothesis is framed as:

H3: *PBC has a positive and significant impact on the intention to adopt CWM.*

8.2.4 Knowledge (KN)

KN is yet another important parameter in assessing BI and occupies a vital role in individual decision making (Teo and Loosemore, 2001). Behavioural knowledge refers to performing the intended behaviour to evaluate responsibility as well as perceived effectiveness of the act (Jing et al., 2019). It is illustrated by L. Zhang et al., (2018) that the individual's *knowledge* plays a crucial role in assessing intentions towards following environmental regulations. It is indeed concluded by Khan et al., (2019) that *knowledge* plays a key role in assessing attitudes towards managing plastic waste. In a similar manner, *knowledge* has a positive relationship with behaviour regarding reducing CW (Li et al., 2018). Additionally Tam (2018) stated that , knowledge play crucial role in determining recycling intentions. Based on previous literature the following research hypotheses are proposed:

H4: *KN has a positive and significant impact on intention to adopt CWM.*

H5: *KN has a positive and significant impact on attitude to adopt CWM.*

8.2.5 Perceived usefulness (PU)

PU is correlated with a positive attitude towards implementation of CWM and plays a crucial role in assessing intention (Jain et al., 2020a). Previous literature includes- PU components such as benefits to environment (Mak et al., 2019), commercial acquisition (Tam, 2018), corporate image (Yuan et al., 2018). Unless there is perceived usefulness (financial gain), stakeholders are hesitant to develop a positive attitude towards incorporating CWM (Ghaffar et al., 2020).Thus, based on previous literature the following hypotheses are proposed:

H6: *PU has a positive and significant impact on intention to adopt CWM.*

H7: *PU has a positive and significant impact on attitude to adopt CWM.*

8.3 Attitude & behavioural factors

The study consists of assessing the impact of attitudinal & behavioural parameters on implementation of CWM using extended theory of planned behaviour. Data collection in Indian construction industry is challenging due to dearth of documentation. Hence the data, in the thesis is compiled using surveys & structured interviews. A questionnaire is developed from the tested and validated scales of the concepts. The target sampling frame in this work includes practitioners from the construction sector, which captured individual attitude, belief system and behavioural intention towards implementation of CWM. The opinions of construction sector practitioners and experts reflects the perceptions in the industry (Ghaffar et al., 2020).

8.3.1 Questionnaire preparation

Prior to data collection an iterative procedure - heterogeneous sampling approach (HSA), is used for drafting the questionnaire. HSA is used for achieving the diverse characteristics of expert interviewees (Mak et al., 2019). The opinions of subject matter experts (SME) are used to assess the content validity of the variables gathered from previous literatures (Table 8.2). The SME are queried regarding the variables used & their relevance in the study with Yes or No options. A total of 15 SME (5 academicians, 5 structural engineers and 5 site managers) are selected as suggested by (Gilbert and Prion, 2016). They are selected on the basis of- (i) knowledge on CWM; (ii) implementation of CWM; (iii) respondents experience greater than 5 years and (iv) companies greater than 10 years of service life. Basic demonstration of the variables is given to the experts, who are asked to determine- (i) the salient beliefs that come to mind while implementing CWM onsite and (ii) comment on the contents as well as phrasing of the variables. Furthermore, to evaluate the gathered responses, Lawshe's content validity test is used.

$$CVR = [(ne - N)-N/2] / 2 \qquad - (1)$$

where CVR = content validity ratio, ne = number of experts in the panel answered "Yes, relevant"; and N = total number of experts in the panel.

The CVR for all the variables is calculated from which critical CVR (mean value of CVR) is calculated. The results indicate the critical CVR value of 0.62. Based on Lawshe's CVR critical table, for the panel size of 15, the acceptable limit is 0.49 (Gilbert and Prion, 2016). Hence the content validity of the items is verified and are acceptable.

The feedback from SME is "positive" and suggested to incorporate the following changes- (i) provide basic introduction of the survey and (ii) rephrase few variable statements, for which, the changes are made correspondingly. The adopted procedure can reduce both acquiescence and extreme response biases (Meisenberg and Williams, 2008).

Table 8.2 Attitudinal & Behavioural parameters literature sources

Coding	Explanation	Source
KN1	I think incorporation of CWM cost additional resources, manpower, and time.	
KN2	I am not aware of any government/municipal polices regarding WM at construction site.	(Jing et al., 2019)
KN3	I do not think site waste management plan can be practically enforced at construction sites.	
IN1	I am willing to implement CWM during every stage of construction in future.	
1N2	I am willing to incorporate, CWM at construction waste.	(J. Li et al., 2015)
IN3	I am willing to propose amendments to while adapting CWM.	
PU1	Site waste management plans do not increase profits for the company.	
PU2	CWM do not add any hike in my profile.	(Hwang et al, 2011)
PU3	Following CWM does not help me getting promotions.	
ATT1	Implementation of CWM helps in reduction of waste.	(Osmani et al., 2008)
ATT2	Incorporation of CWM in the early stage of construction can help in reducing the messiness at construction site.	(Lingard H et al.,2000)
ATT3	Implementation of WM enhances the environmental friendly images corporate.	(Saez et al., 2013)
SN1	My contractor approves my implementation of WM at site.	
SN2	My co-worker reminds me to implement WM at site.	
SN3	My client agrees that, incorporation of WM is must.	(J. Li et al., 2015)
SN4	MY suppliers agree to my implementation of WM at site.	
SN5	My co-workers are not used to manage waste at construction sites so as I.	
PBC1	I trust myself in implementing WM at site.	
PBC2	I believe that without strict rules we cannot implement WM.	
PBC3	If none reminds me I cannot incorporate WM.	(Davies et al., 2002)
PBC4	I think there is no enforcement of CWM by government agencies.	

8.3.2 Data collection

A three step thematic analysis is conducted to refine the similarities and for investigating unpredicted insights for studying social behaviour:

(i) Open coding method is used to develop initial codes, where appropriate keywords are identified from the variables and grouped accordingly (Mak et al., 2019). For example, hikes, profits and promotions are grouped and coded under perceived usefulness.

(ii) subsequently, the dependent variables are labelled by identifying the common codes.

(iii) reviewing the coded, labelled independent and dependent variables.

A detailed description of the variables & coding is presented under Table 8.3. The questionnaire is thus framed which is divided into two sections. The first section deals with basic demographics of the respondents and the next section consists of primary study with 21 variables (close ended questions anchored on a five-point Likert scale ranging from "1 strongly disagree" to 5 strongly agree). Snowball sampling approach (SSA) is used to gather the data in both online and offline mode. The SSA is a rapid and inexpensive method to obtain substantial number of questionnaires (Gilbert and Prion, 2016). A total of 400 questionnaires are circulated amongst employees of several large and established construction companies of which 242 responded (60.5 % response rate) which is proved to be satisfactory (Sekaran, 1984). The demographical statistics of the respondents are- Engineer (50%), labour 28.69%, academia and manager (21.07%). Among the total number of respondents, 67% of the respondents have experience less than 5 years and 33% of the respondents have experience greater than 5 years. The non-formal segment of the industry, which consists of small contractors who typically do not implement CWM in their projects, is excluded from the survey.

Adequate sample size (SS) is crucial for analyses as it affects parameter estimates. The sample size collected is justified using two methods- (i) a priori power analysis using G*power software and (ii) Heuristics approach. A statistical power analysis is conducted using G*Power software to estimate the sample size suitability for this study. When f^2 *effect size* is 0.15, *alpha* is 0.05, *power* is 0.95, and the number of predictors is 5, then the projected sample size required is approximately 89. Several studies have proposed sample size ranges from 50-100 is barely acceptable and 200 is ideal (Kamalendra KT and Jha KN, 2017). Therefore, the sample size of 242 is deemed sufficient (Jing et al., 2019).

Table 8.3 Descriptive statistics (Jing et al., 2019; Li et al., 2015)

Code	Explanation	Mean	STD	Cα
KN1	I think incorporation of WM cost additional resources.	3.06	1.39	0.714
KN2	I am not aware of any polices regarding WM at construction site.	2.86	1.38	
KN3	I do not think SWMP is practically possible onsite	2.49	1.30	
I1	I am willing to implement WM during every stage of construction in future.	3.57	1.47	0.896
12	I am willing to incorporate, WM onsite	3.43	1.41	
I3	I am willing to propose amendments to while adapting WM.	3.42	1.41	
PU1	SWMP do not increase profits for the company.	2.54	1.29	0.704
PU2	WM do not add any hike in my profile.	2.80	1.36	
PU3	Following WM does not help me getting promotions.	2.77	1.31	
A1	Implementation of CWM helps in reduction of waste.	3.41	1.52	0.904
A2	Incorporation of CWM in preconstruction can help in reducing the messiness.	3.37	1.52	
A3	Implementation of WM enhances the environmental friendly	3.62	1.45	
SN1	My contractor approves my implementation of WM onsite.	2.97	1.31	0.903
SN2	My co-worker reminds me to implements WM onsite	2.94	1.30	
SN3	My client agrees that, incorporation of WM is must.	2.97	1.31	
SN4	My suppliers agree to my implementation of WM	2.99	1.33	
SN5	My co-workers are not used to manage waste so as I.	2.81	1.30	
PBC1	I trust myself in implementing WM at site.	3.45	1.45	0.810
PBC2	I believe that without strict rules we cannot implement WM.	3.53	1.41	
PBC3	If none reminds me I cannot incorporate WM.	2.89	1.39	
PBC4	I think there is no enforcement of CWM by government	2.92	1.33	

8.3.3 Post data statistical analysis

Assorted statistical tests such as multi collinearity, multivariate normality, variance, positive definiteness and homoscedasticity, are conducted to eliminate outliers from the data (Hair et al., 2010). IBM SPSS 23® is used for data analysis. From which, 5 responses are declined as they contain insufficient information and are excluded from further analysis. A total number of 237 responses are included in descriptive statistics (corresponding variable means, standard deviations and reliability statistics) & SEM.

The consistency in the data is assessed using Cronbach's alpha (Cα). Cα ranges from 0 to 1 with values closer to one indicate higher consistency and vice versa. The Cα for the constructs ranges from 0.7 to 0.9. In psychological research (Cα) greater than 0.7 is acceptable (Hair et al., 2010).The Cα for the constructs are: Attitude (ATT) - 0.904, Perceived usefulness

(PU) - 0.810, Subjective Norm (SN) - 0.903, Perceived behaviour control (PBC) - 0.776, Intention (IN) - 0.896, Knowledge (KN) - 0.714 hence variables are adequately internally consistent.

8.3.4 Statistical tool

The data is then analysed using structural equation modelling (SEM) as suggested by (Anderson and Gerbing, 1988). SEM is used widely for assessing various dependent and independent relationships (Wu et al., 2017). The inter-relationship among variables, the hypothesis testing and model fit are analysed using AMOS V 23.0 respectively.

8.3.5 Framework of structural equation modelling (Model validity)

Structural equation modelling (SEM)is the commonly used tool to analyse developed TPB and ETPB models (Teo and Loosemore, 2001). SEM is a multivariate statistical approach which consists of measurement and structural model i.e. confirmatory factor analysis & regression analysis. The measurement model assesses reliability and correlation of observed variables with the latent constructs. While, the structural model analyses the association between latent constructs. The benefit of SEM is that, it facilitates concurrent relationship estimates of diverse dependent and independent constructs (Hair et al., 2010). Covariance (CB-SEM), and variance based (VB-SEM) are the common approaches used in SEM. The former explains the relation among latent & observed variables while the latter considers measure of variance.

Covariance based SEM with maximum likely hood estimation is used in the analysis as it has several benefits compared to variance based SEM. The hypothesized model is evaluated using IBM SPSS Amos 23® (Figure 8.3). The model efficiency is validated using distinct goodness of fit indices (GOF). The following are the fit indices commonly used to determine model fit Chi square test ($\chi 2$), Goodness of fit index (GFI), Incremental Fit index (IFI), Tucker-Lewis Index (TLI), Root mean squared error of approximation (RMSEA), Expected cross validation index (ECVI).

The GOF values of the hypothesized model failed to clarify the impact of the constructs on CW generation. Thus, the hypothesized model is revised by either - (i) removing the path with least coefficients or (ii) adding additional relationships to the variables. Therefore, in this study the model is revised by adding casual relationships (Figure 8.4).

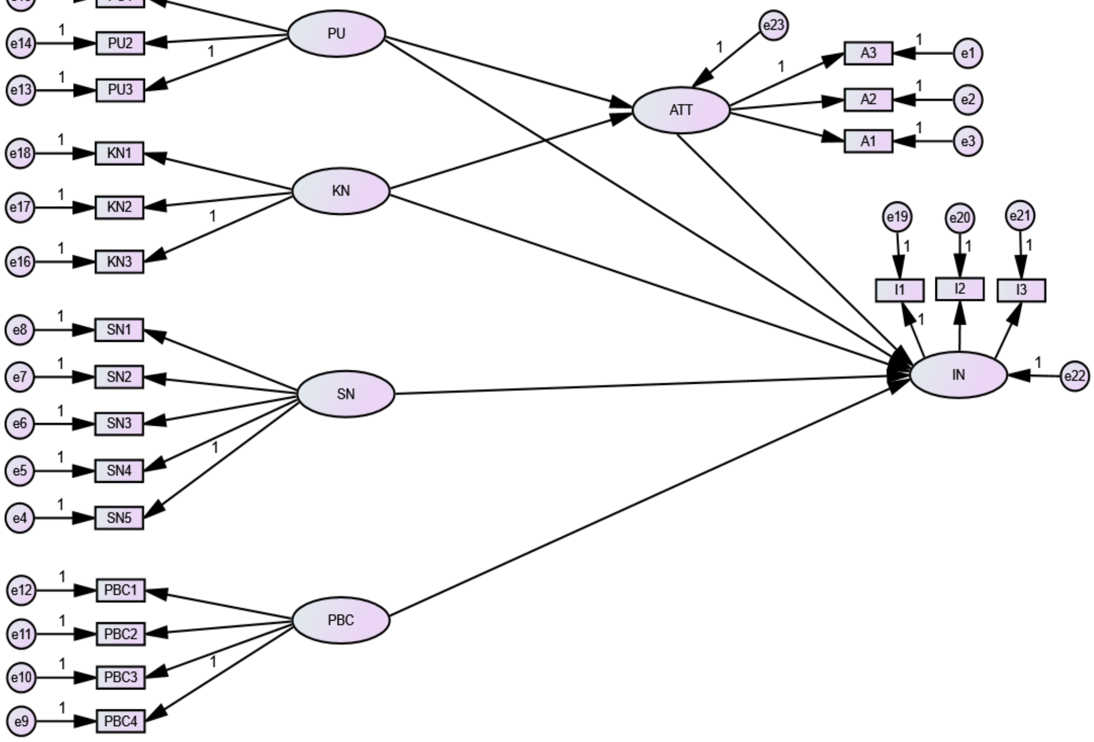


Figure 8.3 Hypothesized SEM model

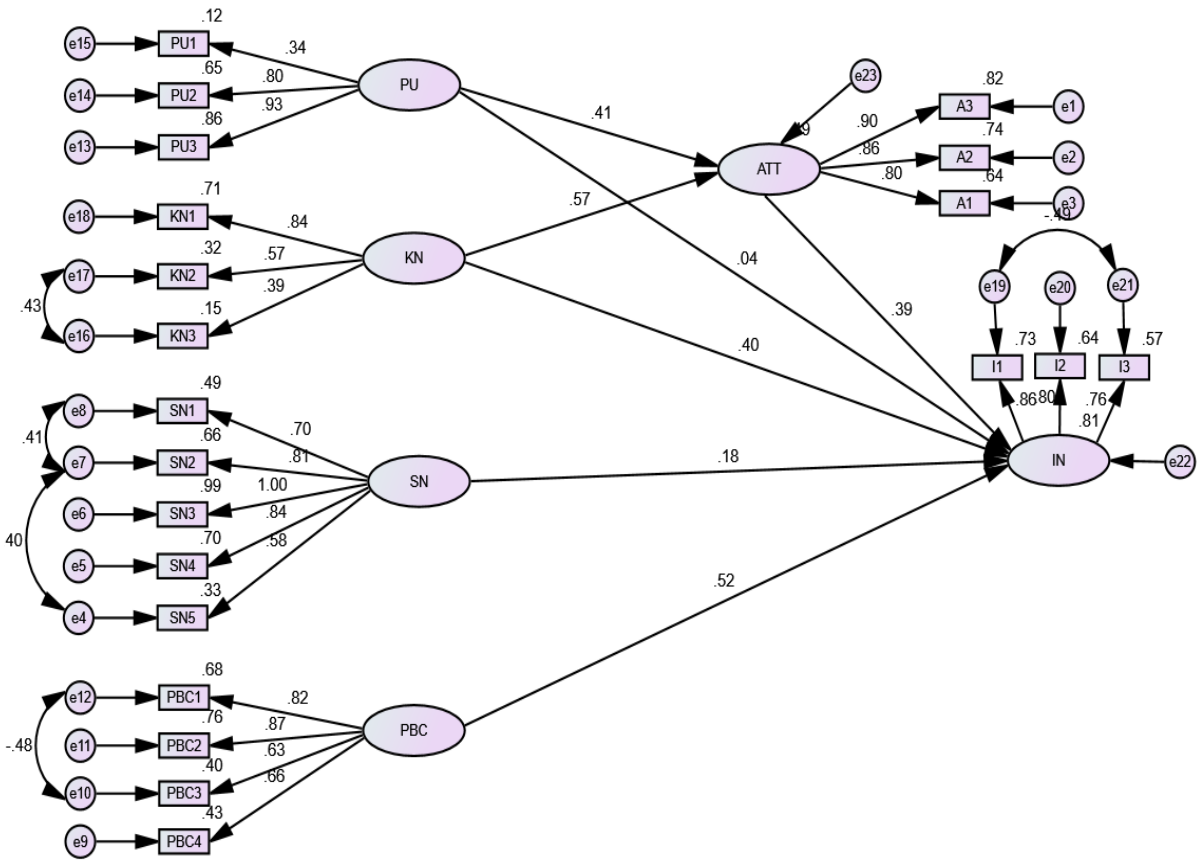


Figure 8.4 Revised SEM model

8.4 Analysis results

8.4.1 Measurement model: validity & reliability

The Confirmatory factor analysis (CFA) indicate that the hypothesized model has poor fit based on GOF values i.e. $\chi 2$/dof =4; Goodness of fit index = 0.70; Incremental Fit index = 0.74; Tucker-Lewis Index = 0.72; Confirmatory fit index = 0.74, root mean squared error of approximation = 0.10, and expected cross validation index = 4.75. Therefore, the model is revised i.e. model fitness is improved by adding covariance's based on modification indices. The revised model indicates better GOF i.e. $\chi 2$/dof =2, Goodness of fit index = 0.76; Incremental Fit index = 0.83; Tucker-Lewis Index = 0.80; Confirmatory fit index = 0.83, root mean squared error of approximation = 0.08, and expected cross validation index = 2 (Table 8.4).

Table 8.4 GOF Measures (Jing et al., 2019)

S.No	GOF	Acceptable fit limit	Hypothesized	Revised model
1	$\chi 2$/dof	1-3	4	2
2	GFI	0 (poor)-1(Good)	0.70	0.76
3	IFI	0 (Poor)-1(Good)	0.74	0.83
4	TLI	0 (Poor)-1(Good)	0.72	0.80
5	CFI	0 (Poor)-1(Good)	0.74	0.83
6	RMSEA	<0.05(good)0.1(threshold)	0.10	0.08
7	ECVI	Lower value	4.75	2

.

8.4.2 Structural model: Hypothesis Testing

The structural path coefficients or standardized estimates are shown in Table 8.5. Based on the level of significance i.e. $p<0.001$ the following conclusions are drawn. Five out of seven paths had significance level less than 0.001, which indicates statistically significant relationships. The paths H1, H3, H4, H5, & H7 are statistically significant while H2, H6 are not statistically significant at 0.001 level. Therefore, the hypothesis H2 and H6 are rejected. The standardized estimates in Table 8.5 indicate the degree of correlation among variables. The path coefficients reveal that the construct PBC has greatest effect on behaviour intention (0.521), followed by

KN (0.403) and ATT (0.385). Among the additional constructs i.e. KN and PU; KN has greater effect on ATT (0.569).

Table 8.5 Standardized estimates & significance level of the revised ETPB

Hypothesis	Path	Indirect effect	Direct effect	Standardized estimate or Total effects	S.E	P	Hypothesis
H1	ATT → IN	-	0.385	0.385	0.072	***	Accepted
H2	SN → IN	-	0.180	0.180	0.073	0.001	Rejected
H3	PBC → IN	-	0.521	0.521	0.101	***	Accepted
H4	KN → IN	0.184	0.219	0.403	0.209	***	Accepted
H5	KN → ATT	-	0.569	0.569	0.298	***	Accepted
H6	PU → IN	0.157	-0.116	0.041	0.047	0.486	Rejected
H7	PU → ATT	-	-	0.407	0.081	***	Accepted

***p <0.001.

8.4.3 Construct validity ---Convergent and discriminant validity

Construct validity is the degree to which the test actually measures what the theory claims and is usually assessed using convergent and discriminant validity. The tests are- (i) *construct reliability* analyzed using composite reliability (CR), (ii) *convergent validity* using average variance extracted (AVE) (with an acceptable value of 0.5) and (iii) *discriminant validity* using squared correlations and AVE are assessed. The composite reliability ranges from 0.63 - 0.90 which indicates the values exceed recommended level i.e. 0.6 (Bagozzi and Youjae Yi, 1988). The statistics denote, that the variations of dependent variables predicted by independent variables are lesser in comparison with variation in errors. Therefore, the average explanatory power of the items in the construct is appropriate. Hence the construct reliability is established. The AVE of the variables in the study ranges from 0.50 - 0.73. The discriminant validity is established when the AVE of the constructs are higher in comparison with the squared multiple correlations. The values represented in bold indicate AVEs of the constructs and the remaining values indicate construct correlations (Table 8.7). Based on these results (*reliability, convergent validity, discriminant validity*) of the revised model is valid (Table 8.6 and 8.7).

Table 8.6 Path coefficient & significance of the measurement model.

Path			Estimate	P	AVE	CR	Cα
A1	<---	ATT	0.797	***			
A2	<---	ATT	0.863	***	0.733	0.891	0.904
A3	<---	ATT	0.905	***			
SN1	<---	SN	0.699	***			
SN2	<---	SN	0.810	***			
SN3	<---	SN	0.997	***	0.635	0.894	0.903
SN4	<---	SN	0.839	***			
SN5	<---	SN	0.576	***			
PBC1	<---	PBC	0.822	***			
PBC2	<---	PBC	0.869	***	0.564	0.836	0.810
PBC3	<---	PBC	0.629	***			
PBC4	<---	PBC	0.656	***			
KN1	<---	KN	0.843	***			
KN2	<---	KN	0.569	***	0.504	0.642	0.714
KN3	<---	KN	0.843	***			
PU1	<---	PU	0.928	***			
PU2	<---	PU	0.343	***	0.542	0.758	0.704
PU3	<---	PU	0.805	***			
I1	<---	IN	0.857	***			
I2	<---	IN	0.797	***	0.648	0.846	0.896
I2	<---	IN	0.757	***			

Table 8.7 Results of discriminant validity test

	ATT	SN	PBC	KN	PU	IN
ATT	**0.733**					
SN	0.492	**0.635**				
PBC	0.628	0.509	**0.564**			
KN	0.531	0.342	0.492	**0.496**		
PU	0.390	0.338	0.469	0.459	**0.542**	
IN	0.797	0.535	0.440	0.467	0.418	**0.648**

8.5 Discussion and implications

8.5.1 Discussion of the analysis results

The analysis results conclude that, intention to implement CWM can be predicted by ATT, PBC and KN. PBC has a positive and high impact on IN to adopt CWM (H3). It is expected that constraints perceived by users for implementation of CWM affect the behaviour during execution. For example- (i) lack of standards on usage of CW products, (ii) increased recycled products price in comparison with conventional materials, (iii) lack of standard documentation, higher goods service tax (GST)i.e. 18% on recycled products, (iv) non-user friendly setup might increase the degree of perceived external constraints of a user thereby decreasing the willingness to implement CWM onsite. This is consistent with the research findings derived from (Mak et al., 2019), who reported that for construction companies in real estate and infrastructure domains looking to implement C&D waste management. These results suggest that PBC can be an important skill.

Furthermore, the additional construct KN (H4) is the second most influential construct which impacts implementation of CWM in India. The direct effect and indirect effect via ATT on IN is 0.219 & 0.184 respectively, with a total effect of 0.403, which is significant. This indicates that KN determines the implementation of CWM behaviour directly rather than indirectly through the other constructs. This indicates that the implementation of CWM is solely depend on the individual's knowledge of CWM. In India, the majority of the construction participants are unaware of the current C & D WM rules. Mega projects incorporate C & D WM as part of their environmental clearance requirements. However, most of the project owners are unaware of waste disposal methods. These findings are consistent with the results of Li et al. (2018) who stated that, KN play crucial role in CWM implementation such as drafting waste management plans, purchasing sustainable materials etc. The managerial implications include training programs which address the adverse effects of CW on environment, the benefits associated with reuse, innovative methods for CW reduction, employment of low budget waste technologies blended with onsite sorting of CW promote awareness and implementation of SWMP (Ghaffar et al., 2020).

In terms of influential predictors of BI, the analysis results indicate that ATT is the third most influential construct (0.385). This is slightly different from the findings of Yuan et al. (2018), who stated clearly that ATT is the critical factor for predicting successful solid waste management. However, house waste management is associated with individual behaviour, while CWM is collective in nature, for which implementation is dependent on others (Botetzagias et al., 2015). Thus construction companies need to focus on policies which can enhance attitude of workforce towards waste reduction, and strategies for efficient CWM implementation. The positive attitudes of workforce tend to increase the chances for CWM implementation.

The impact of SN (H2) was rather insignificant and therefore did not have an positive influence on behavioural intention regarding implementation of CWM, which is consistent with previous findings (Jain et al., 2020a). The possible explanation of this is that in India, social awareness, economic and environmental benefits specific to CWM implementation are limited. The limited awareness results in reclined social expectations, minimum or non-existent social norms on CWM. Unless there is an increase in societal awareness, SN cannot positively relate with the behavioural intention.

The impact of PU on IN (H6) is insignificant while its impact on ATT (H7) is significant (0.407). This indicates that the people perceive that costs associated for implementation of CWM are higher in comparison to the benefits. A plausible explanation for the above is that *perceived usefulness* influences *intention* through the mediator of *attitude*. Moreover, the context of this study is focused on the stage of initial adoption and voluntary implementation of CWM (without rewards). One possible solution is to incorporate economic incentive schemes (Mak et al., 2019). Currently, public has minimal knowledge of the benefits, legislations in comparison with the corporates therefore providing financial benefits such as goods service tax (GST) waiver, achievement awards for CWM could increase the corporate image, awareness and help in decision making regarding implementation of CWM. The positivity of users towards *perceived usefulness* of CWM may not immediately lead to behavioural intention to implement, but rather to initially form a favourable attitude toward establishing CWM onsite. In other words, potential users such as engineers, contractors, architects would need substantial time period to thoroughly change their psychological state to regulate the adoption of CWM.

8.5.2 Implications of the study

8.5.2.1 Theoretical implications

In specific, social awareness towards sustainable environment is crucial in Indian context. Through command (rules, regulations) & control instruments (strict penalties) there will be perceptible changes in attitudes of workforce associated with C &D WM in India. The finding aligns with the verdict of (Betts et al., 2018) which explained the role of organisations, in adopting sustainable supply chain and processes. Realistically, the C &D waste in India intensifies with increase in infrastructure, population and income, which ultimately leads to an upsurge in open dumping and landfilling. The meagre implementation of CWM escalates material shortages, human health hazards etc. The CWM sector need to be popularized among researchers, corporates, government and society towards resource efficiency. Efficient collaborators are the key to progression of sustainable environment (Ghaffar et al., 2020).

The usage of decision making tools at various levels is the appropriate solution to assess hidden issues, frame and incorporate evidence based policies on CWM. Among them are the SEM (Kolaventi et al., 2020), game theory (He and Yuan, 2020), application driven programmes (Mak et al., 2019).

8.5.2.2 Practical implications

The findings of the present study indicate three effective implications for CWM implementation. Firstly, framing of strict rules for CWM implementation is found to be a significant and highly loaded factor (0.87), which can be achieved with the following steps - (i) including C & D WM in air action programmes; (ii) inclusion of state govt and urban local bodies (ULB) for proper disposal of C &D waste; (iii) standardisation of CWM practises along with an administrative head specifically for C &D waste; (iv) adapting process flow monitoring of waste generation, collection, transport at onsite; (v) establishing check-up points for illegal transportation of C & D waste; (vi) providing barcode or QR coding system and enrouting GIS tracking system for C & D waste to document hauling routes and final destinations to prevent illegal disposal; (vii) Penalizing contractors without site waste management plans can improve CWM implementation.

Along with the strict rules, providing adequate knowledge (path loading- 0.84) on the costs associated for CWM implementation is yet other core criteria for successful implementation of CWM. Creating awareness among regarding negative effects such as loss of valuable recyclable material due to illegal disposal of the C & D waste. Digitalization of C & D WM is necessary for easy accessibility of the data. Therefore, providing training on usage of latest techniques such as Integrated Project Delivery (IPD), Virtual Prototyping, and CAD are successful global strategies for improving C&D WM. Implementing CWM can preserve raw materials and ensure numerous environmental and social benefits.

Finally, enhancing the attitudes (0.90) associated for implementing WM by - (i) creating market of recycled products; (ii) addition of financial drivers; (iii) marketing recycled products at a lower price in comparison with the conventional products can improve the C & D WM status in India.

8.5.2.3 Implication of the research on academia, industry and policy developers

The current article theoretically explores the intention to implement CWM onsite. The study has implications for Indian construction industry thus making a first step for an era of onsite CWM. *Knowledge* has a direct and indirect effect on onsite CWM implementation. While *perceived usefulness* has an indirect significant effect on *behavioural intention*. The industries should look forward to host several campaigns to increase awareness on CWM. It is further highlighted by research that workforce are focussed on individual capability in implementing CWM. Therefore, it is evident that conducting seminars, workshops on CWM onsite and effective solutions such as including wall of fame and shame boards onsite, assessment of WM performance of construction sites can reduce illegal disposal of CW.

The findings from the study, provide a basis for the government as well as regulators to establish enhanced strategies towards sustainable C&D waste management in India. Which includes - (i) establishment of contractual clauses which are requisites for implementing CWM; (ii) Framing of legislations which includes deconstruction plan at planning phase; (iii) amendments in existing green building rating systems such as GRIHA, LEED and BREEAM ; (iv) recruiting and training workforce; (v) setting up of recycling target for every project; (vi) framing of GST tax waiver policies; (vii) creation of societal awareness and (viii) improving employee motivation for implementing CWM.

By expanding this line of research to other CW oriented guidelines, researchers and practitioners may design more effective and human- oriented CWM programmes. Specifically, the proposed extensive framework aids in improved insights of individual, corporate, and regulatory factors which governs individual behaviour towards material efficiency and sustainability.

8.6 Conclusion

The existing programmes implemented by the Government of India have a minimal focus on behavioural aspects for implementing CWM. Therefore, the present article attempts to analyse various attitudinal and behavioural factors associated for implementing CWM in India. The major contribution of the article is the application of psychological theories - the notion of theory of planned behaviour (ATT, SN and PBC) and institutional theory (KN and PU), to provide a clear picture of associated factors for non-implementation of CWM in Indian construction projects. As partial mediating factors, perceived usefulness and knowledge explain the complex and evolving decision-making process behind implementation of WM under conflicting environments. Based on which, a theoretical model with seven hypotheses is developed using Ajzen's TPB and is analysed using SEM.

The analysis results indicate that five out of seven paths have significant influence on implementation of CWM. Perceived behaviour control (0.52), knowledge (0.40) and attitude (0.38) are three significant factors influencing the intention to adopt CWM. The impact of subjective norm and perceived usefulness is insignificant. This is due to the fact that, in India, social awareness and environmental benefits specific to CWM implementation are limited. The limited awareness results in lower social expectations, minimal or non-existent social norms on CWM. Furthermore, people perceive that costs associated with implementation of CWM are higher in comparison to the benefits.

Based on the results, it is evident that the following conditions may increase the degree of perceived external constraints by a user, thereby decreasing the willingness to implement CWM onsite:

- lack of availability of standards on usage of CW products,
- increased recycled products price in comparison with conventional materials
- lack of standard documentation,
- higher goods service tax (GST)i.e. 18% on recycled products,
- non-user friendly setup.

Based on the above conditions, the following measures can provide better chances for onsite implementation of CWM:

- Providing training on usage of latest techniques such as BIM, GPS, GIS and Big Data, Integrated Project Delivery (IPD), Virtual Prototyping, and CAD.
- Establishment of contractual clauses which are requisites for implementing CWM.

- Framing of legislations which includes deconstruction plan at planning phase.
- Setting up of recycling target for every project.
- Framing of GST tax waiver policies.
- Employment of low budget waste technologies blended with onsite sorting of CW.
- Implementation of SWMP and associated checklists can improve the implementation of CWM at management level.

In this study the TPB model incorporates two additional constructs namely *knowledge* and *perceived usefulness*. Further studies can strengthen the findings by including constructs such as socio economic factors, moral norms etc. The moderating effect of such extrinsic factors on standard or extended TPB model requires further investigation.

CHAPTER 9

Construction waste processes flow models and possible solutions for efficient CWM

9.0 Introduction

Objective-5 of the research work focusses on onsite CWM. For this- (i) a framework for developing process flow models are developed to track onsite CW; (ii) marketing strategies are designed to eliminate illegal disposal of CW; (iii) index based system is developed to assess onsite CWM performance. The methodology of objective 5 is organized under subsequent sections (Figure 9.1).

(i) Construction waste process flow modelling: The following procedure is used in the study of onsite CW process.

Step 1: Construction waste process flow models for six ongoing construction sites are drafted.

Step 2: Relative mapping approach is used to assess strengths and weakness at corresponding construction sites.

Step 3: An optimum process flow model for selected construction sites is developed in accordance with identified strengths & weakness.

***(ii) Development of Android application - "Waste Alley*"**:** A proto typical Android application for marketing of C& D waste is developed to eliminate illegal dumping of CW along roads, empty plots etc.

(iii) Developing onsite CWM performance assessment (OCWMPA) index: The onsite WM of the construction sites is assessed by using an index. The developed index can be used as a bench mark to identify the weak links at construction sites and further strengthening them by providing amendments in the companies CWM policies.

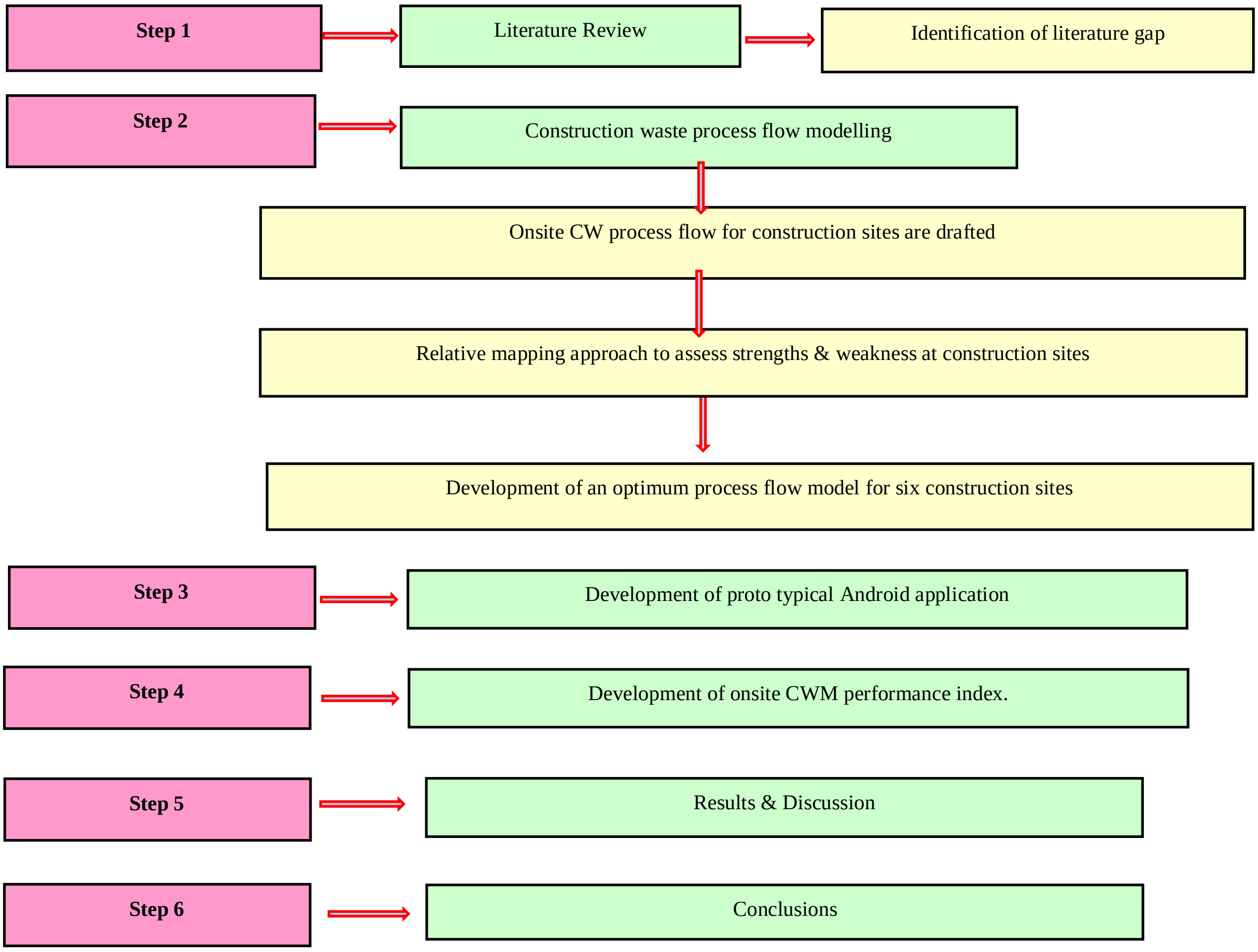


Figure 9.1 Methodology for objective five

9.1 Construction waste process flow modelling

Waste process flow modeling is utilized in this study to examine the real time waste flow at construction sites. The technique has the advantage of presenting a well-defined process flow in a simple way. Using this technique, six active construction sites in India are studied. The case studies and corresponding respondents are selected on the basis of- (i) Different sizes of ongoing construction projects (small, medium and large); (ii) Awareness and minor implementation of construction waste management practices; (iii) Awareness of government norms, regulations on C&D waste; (iv) site engineers with experience of greater than 20 years and (v) Availability & accessibility of the data. The findings are presented for each of the six case studies. The details of the case studies in shown in Table 9.1.

Table 9.1 Details of the case studies

Project	Project Type	Organization
Project 1	G+8 residential building	Private
Project 2	High rise residential township	Private
Project 3	G+4 residential project	Private
Project 4	G+3residential project	Private
Project 5	Precast pipeline project	Government
Project 6	G+2 government office	Government

9.1.1 Terminology used in construction waste process flow modelling

The information presented in process flow models for the six case studies includes four key components namely waste generator, waste organizer, waste processing, waste terminal etc. To enable comparison between the six case studies, consistent terminology, symbols are used. Table 9.2 & Figure 9.2.

- Waste generator indicate, the source as well as the province of waste generation.
- Waste collector, delivery and loading indicate the means of collection, hauling & shipment of waste.
- Waste organizer denote, the tools used for waste handling activities (manpower, machinery, both)
- Waste terminal denote the ultimate status of waste i.e. reuse, recycle or dumping.

The process flow models are developed based on observations, discussions with the relevant staff at construction sites. The process adopted at each site can be easily represented to enable identification of strengths and weakness at each construction site. The findings therefore, can be used to establish customized and effective waste management process flow models which can mitigate the weakness in handling waste at construction sites.

Figure 9.2 Symbols representing various waste organizers in process flow

Table 9.2 Terminology, explanation and representation of waste process flow symbols

Terminology	Explanation	Process flow symbols
Waste generator	Waste source	Waste Generation
Waste collector	Collection of waste	Waste Collection
Waste delivery	Delivery of waste	Waste delivery
Waste loading	Loading of waste	Waste Loading
Waste organizer	Gunny bag, trolley, bin, waste container, truck, man force, mechanized tool	Waste organizer
Waste terminal	Reuse, dumping, marketing,	Waste terminal

9.1.2 Drafting construction waste management process flow

The research crew consists of two teams. The first team drafted onsite waste management processes while, the second team conducted interviews with the relevant professionals onsite. The data gathered from both of the teams is combined and presented as waste management process flow models The process flow models are created using Microsoft Visio®.

The data gathered is used in identifying the strengths as well as weaknesses in managing waste at construction sites are shown in Table 9.3 & 9.4.

Table 9.3 Strengths of waste management process observed at construction sites

Notation	Description of strengths
S1	Practice of waste management
S2	Additional labors employed for cleaning waste
S3	Waste segregation practiced at site.
S4	Waste reusing.
S5	Waste recycling.
S6	Site supervision on waste generation.
S7	Site supervision on waste disposal.
S8	Generation of revenue from waste
S9	Usage of mechanized equipment for waste handling
S10	Documentation management and maintenance on CW
S11	Maintenance of bins for collection of waste.
S12	Safe handling procedures.

Table 9.4 Weakness of waste management process observed at construction sites

Notation	Description of weakness
W1	Not practicing waste management
W2	No waste segregation
W3	Dumping of waste in specified location onsite and later disposing them by means of trucks
W4	No materials recycling at construction sites
W5	Not practicing reuse at sites
W6	Noise and dust pollution during transportation of waste
W7	No mechanized procedures during waste transportation
W8	Employing additional labors to clean the set waste due to delays in collection of waste periodically
W9	High amount is paid for disposing waste by means of transportation
W10	No supervision for waste generation and calculation
W11	Lack of ethics in waste generation as well as segregation
W12	lack of awareness on waste management

9.2 Development of Android application- "Waste Alley"

9.2.1 Prototype of Seller and Buyer Portal

A Proto-typical Android Application- Waste Alley is developed. Waste Alley provides an E-portal where construction waste can be purchased and traded. The user in possession of waste (seller) can post the information on the Android application along with the photograph, location, type of the material, age of the materials and contact details (Figure 9.3).

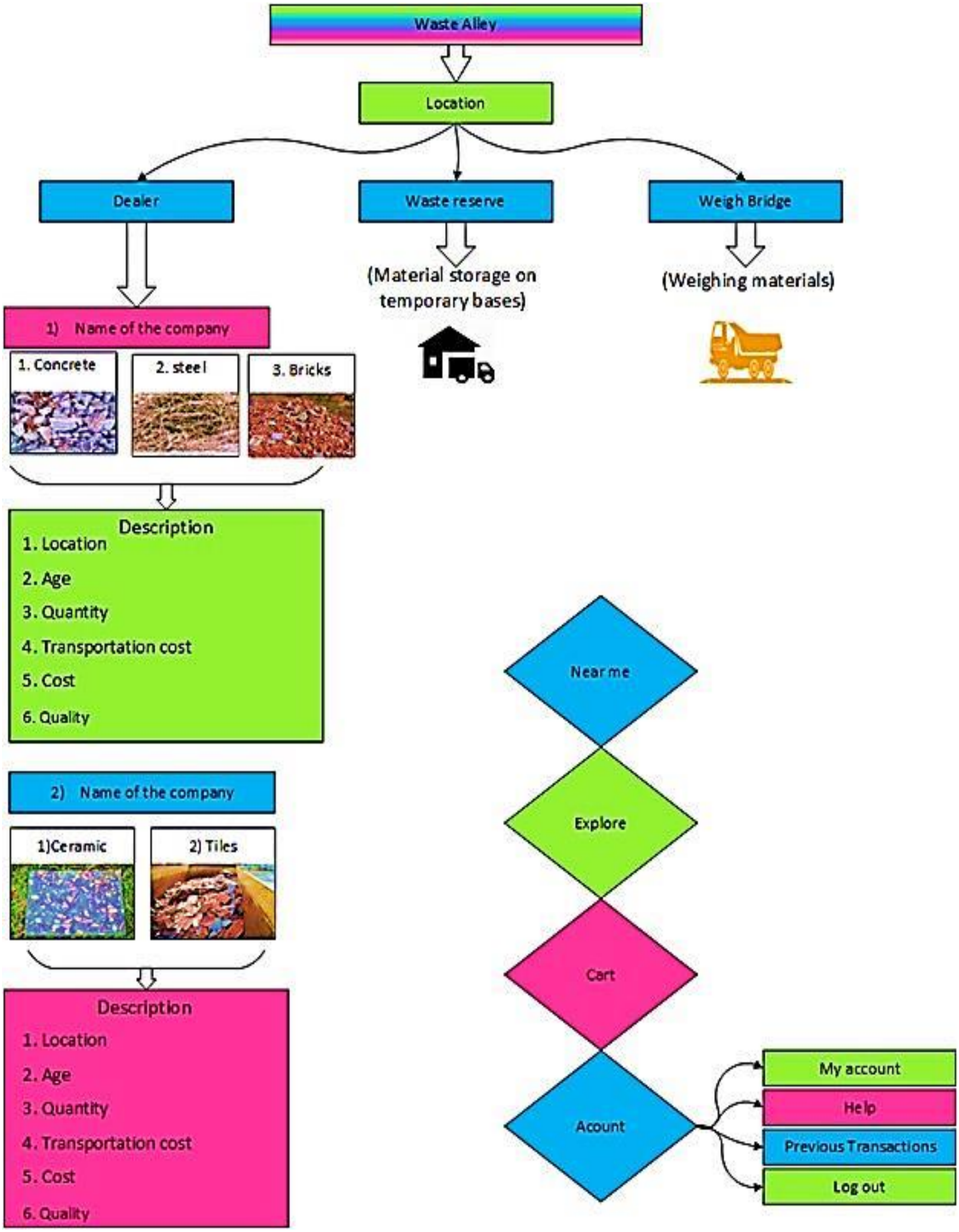


Figure 9.3 **Workflow for Proto-typical Android Application-Waste Alley**

9.3 Developing onsite construction waste management performance assessment (OCWMPA) index

The onsite CWM performance of the companies is assessed by means of an index. For this, 32 OCWMPA variables are selected and are further scrutinized by means of ranking. Finally, top 25 variables are used for further analysis. Later on OCWMPA index is developed. The index ranges from 0 to 1000. Where, a score of 0-250 is poor, 250-500 is fair, 500-750 is good, and 750-1000 is excellent in terms of performance towards waste management. The procedure is explained in detail in following steps:

The following are the steps executed to collect OCWMPA variables:

Step 1:

At first a list of top ranked variables (which are used to assess the CWM performance) are selected from previous literature.

Step 2:

The variables are further scrutinized by expert professionals (academicians, engineers with experience greater than 20 years) prior to drafting of questionnaire.

Step 3:

Thus a questionnaire is drafted with 32 variables (Table 9.5). Seven-point Likert scale is used in the survey ranging from (1) strongly disagree to (7) strongly agree. The questionnaire is divided into two sections. The first part gathers the background data of the respondents. The second part focuses on the respondent's opinion on the level of significance of OCWMPA variables.

Step 4:

Google Forms are used to collect information from engineers, contractors, architects, and construction managers. The survey is conducted online (Google form) as well as offline (Onsite visits). The respondents are selected based on three factors -(i) Academic background (minimum B-tech); (ii) Knowledge (basic knowledge of CWM) and (iii) experience (minimum of two years of field experience). Both government and private organizations are involved in the survey. The completed questionnaires are then exported to MS Excel and later to IBM SPSS 20.0 for further analysis. A total of 177 responses received of which 154 are online and 23 offline.

Table 9.5 OCWMPA variables

Factor category	Factor	Factor Name
	H1	Contractor involvement in construction waste management
	H2	Client involvement in construction waste management
	H3	Education of staff working on the construction site
Human Resources	H4	Training programs at the construction site
	H5	Appointment of workers especially for separation of waste
	H6	Supplier's involvement in construction waste collection
	H7	The management team for managing construction waste
	C1	Supervision and control of the amount of construction waste
	C2	The practice of segregation i.e. maintenance of separate bins for
	C3	Cleaning up the site on a daily basis
Construction Methods	C4	Quantification of the amount of construction waste generated
Planning	C5	RRR (reduce, reuse, recycle) strategy
	C6	Installation of information boards for segregation of construction
	C7	Allocation of separate space for material sorting at initial stages of
	C8	Informing methods to deal with rest of construction waste after
	C9	Disposal of construction waste periodically by open dumping,
	M1	Installation of recycling equipment at construction sites
	M2	Installation of equipment for waste sorting
Materials& Equipment	M3	Installation of mobile recycling plant at the construction site
	M4	Usage of recycled material at the construction site
	M5	Material transportation system for construction waste
	D1	Separate documentation (records) on recycling waste
	D2	Checklist on the execution of waste management plan
Design &Documentation	D3	Database management system or any software technology for
	D4	Maintenance of record on training programs i.e. past, present and
	D5	Changing of the design
	I1	Awareness of government policies on construction waste generated
	I2	Following government norms on dealing with construction waste
	I3	Incentive in binding for a contractor having a plan about decreasing
Industry Policy	I4	Establish criteria for the quality and safety of recycled materials
	I5	Documentation of payment of taxes and penalties if the waste
	I6	Practice of making money out of waste i.e. selling etc.

9.4. Results and Discussion

9.4.1 Discussion on construction waste process flow modelling

A comparative analysis reveals that amongst the six cases, the existing waste management process in four of the sites is unquantifiable due to open dumping of the waste (Figure 9.4 to 9.6). This is because there exists no evidence of supervision or enforcement by the management or local authorities. Strengths and weakness with respect to CW processing of the six case studies are analyzed using relative mapping approach presented in Tables 9.6 & 9.7.

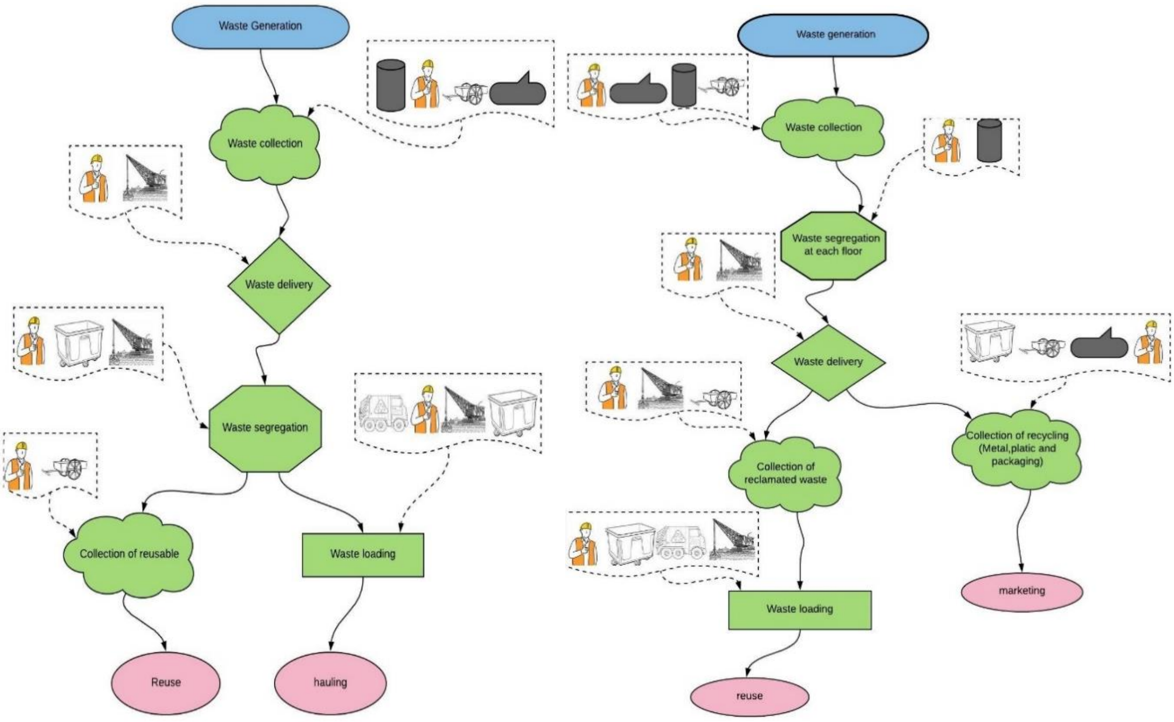


Figure 9.4 WMPFM for a G+8 residential building and high rise residential township –Project 1,2

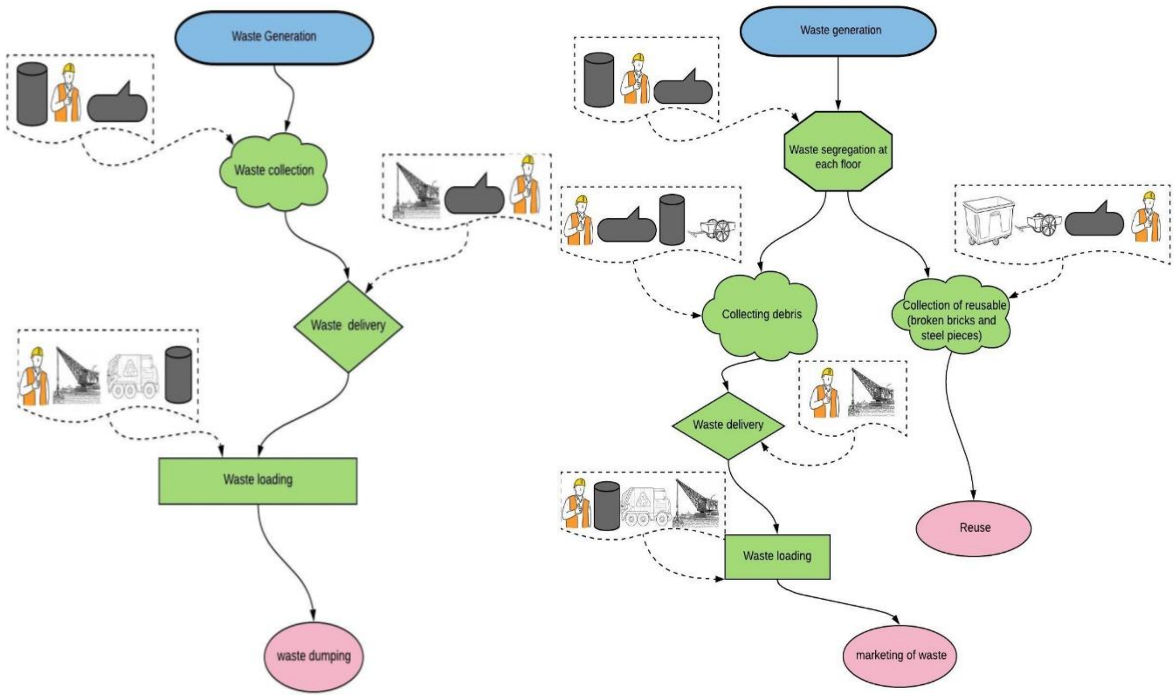


Figure 9.5 WMPFM for a G+4 and G+3 residential project –Project 3,4

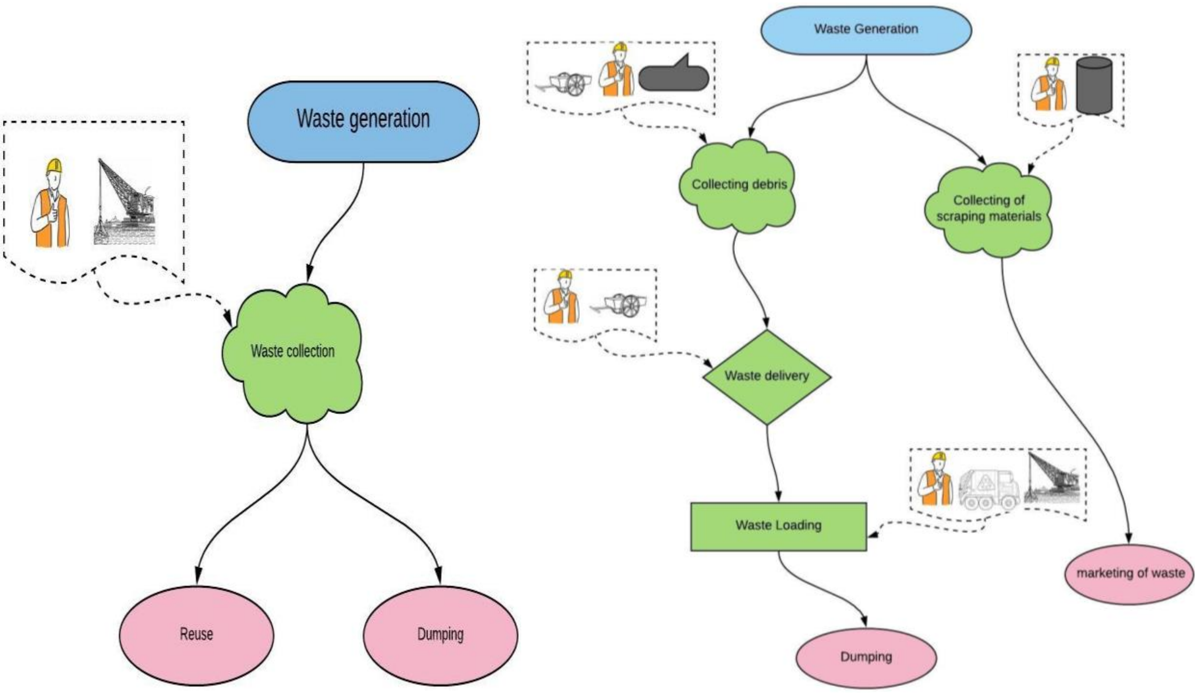


Figure 9.6 WMPFM for a precast pipeline project and G+2 government office – Project 5,6

Table 9.6 Relative Assessments on weaknesses in practicing waste management

Weakness	P- 1	P-2	P-3	P-4	P-5	P-6
W1	X	Y	X	X	Z	Z
W2	X	Y	X	X	Y	Z
W3	Z	Y	Y	Z	Y	Y
W4	Y	Y	Y	Y	Y	Y
W5	X	Z	Z	Y	Z	Z
W6	Z	Z	Z	X	Y	Y
W7	Y	Y	Z	Z	X	Y
W8	X	Y	Y	X	Z	Z
W9	X	Y	Z	X	X	Z
W10	X	Y	Z	X	Y	Y
W11	X	Y	X	X	Y	Y
W12	X	Y	X	X	X	Z

Note: - X- Insignificant; Y- Significant; Z- Strong; P- Project

Table 9.7 Relative assessment of strengths in practicing waste management

Strengths	P -1	P-2	P- 3	P- 4	P- 5	P-6
S1	Y	X	Y	Y	X	X
S2	X	Y	Y	Y	X	Z
S3	Y	X	Y	Y	X	X
S4	Y	Z	Y	Y	Z	Z
S5	X	X	X	X	X	X
S6	Y	X	Z	Z	X	X
S7	Y	X	Z	Y	Z	Y
S8	Z	X	Z	Y	Z	X
S9	X	Z	Y	Y	Y	X
S10	Y	X	Z	Z	X	X
S11	Y	X	Z	Y	X	X
S12	Y	Z	Y	Y	Z	Z

Note: - X- Insignificant; Y- Significant; Z- Strong; P- Project

It is observed that sites P-2, 3, 5, and 6 poorly enforce supervision of waste generation and estimation, while sites 2, 3, 4, 5 and 6 practice negligible reuse. Sites 1, 2, 3, 4 and 6, do not use any mechanized procedure for dealing with waste, which in turn leads to additional time in dealing with waste. It is also observed that projects 2, 3, and 6 pay an additional amount to local contractors/vendors for disposing waste from the construction sites. Projects 1,2 and 6 also have greater likelihood of safety issues such as accident, noise and dust pollution during transportation of waste as there is involvement of manual labor in collecting and transportation of waste. The typical method employ dropping debris from higher floors to the ground floor which in turn leads to several safety issues. In project 3 & 4 multiple handling of the waste is observed at sites which involve double screening of the waste. The open dumping of the waste induced severe air pollution at project 5.

The analysis concludes the presence of the following weaknesses in most of the case studies- W3- Dumping of waste in low area and later disposing them by means of hauling through trucks; W4- No materials recycling at construction sites; W5- Not practicing reuse at sites; W6: Noise and dust pollution during transportation of waste; W7- No mechanized procedures during waste transportation. It is evident that four out of six projects dispose waste by means of dumping in low lying areas. Recycling is not practiced in any of the cases and reuse is given low priority in almost all the cases. It is also noted that lack of mechanized procedures consumes a lot of time while dealing with waste.

The above mentioned issues in these particular projects are caused due to lack of organization policies, non-involvement of local authorities, lack of awareness of government policies, lack of training of the construction crew, lack of standardized waste handling procedures, lack of review exercise on the efficient waste handling practice and lack of awareness amongst crew members that construction waste could lead to safety risk and environment catastrophe if not properly handled and treated. This was in line with the previously reported conclusions of (Kabirifar et al., 2020; Ranta et al., 2018). It is therefore not surprising that four out of six projects studied end up disposing waste by means of dumping in low lying areas. It is further noted, that lack of mechanized procedures causes delays while dealing with waste. Recycling is not practiced in any of the cases and reuse is given insignificant importance in almost all the cases. These findings resonate with the findings of (Huang et al., 2018; Kleemann et al., 2017; Rodríguez et al., 2017; C. Zhang et al., 2020) .

9.4.2 Developing an effective waste management process flow model (WMPFM)

An optimum model is proposed on the basis of incorporating best practices from the results of the six case studies. The combined model proposes commercialization of the waste using an online sales platform and disincentivizes the traditional method of open dumping.

The review of six case studies highlights three basic components namely, waste generation, collection and destination. Initially, the mixed waste is segregated by laborers and placed temporarily in an easily accessible area and then transported to other locations where further segregation takes place. The best practice is to sort out the waste as soon as it is generated. It is observed from the case studies that a parallel process of waste management is not enforced. The waste is placed within the construction site, and later on if it interferes with the site activities it is either segregated or disposed away from the site. Considerable reduction in open dumping of the waste is likely if there is proper sorting at the waste generation stage. Effective reuse of the material can avoid extra capital being invested.

Moreover, it is observed that the site engineers do not consider WM to be a high priority activity as they are not required to submit any documentation to higher authorities and in addition to that, most of them are unaware of the economic and environment cost of waste. To avoid multiple handling of waste and for better waste management, the following practices need to be enforced:

- Establishing collection points and a central staging area within the site, this reduces continuous supervision and increases precision of waste management practice.
- Sorting and packing the materials in gunny bags or containers with RFID tags at the earliest, this increases the ease of mobility & reduces disorganization of waste.

The proposed waste management model (Figure 9.7) is created in view of the following:

- Reduction of overhead charges used for implementing better waste management.
- Reduction of labor hours for dealing with waste.
- Avoiding multiple handling of waste.
- Preference for energy efficient equipment for dealing with waste.
- Reduction of air and noise pollution at the site.
- Minimization of additional time for waste management.
- Maintenance of hygienic site conditions.

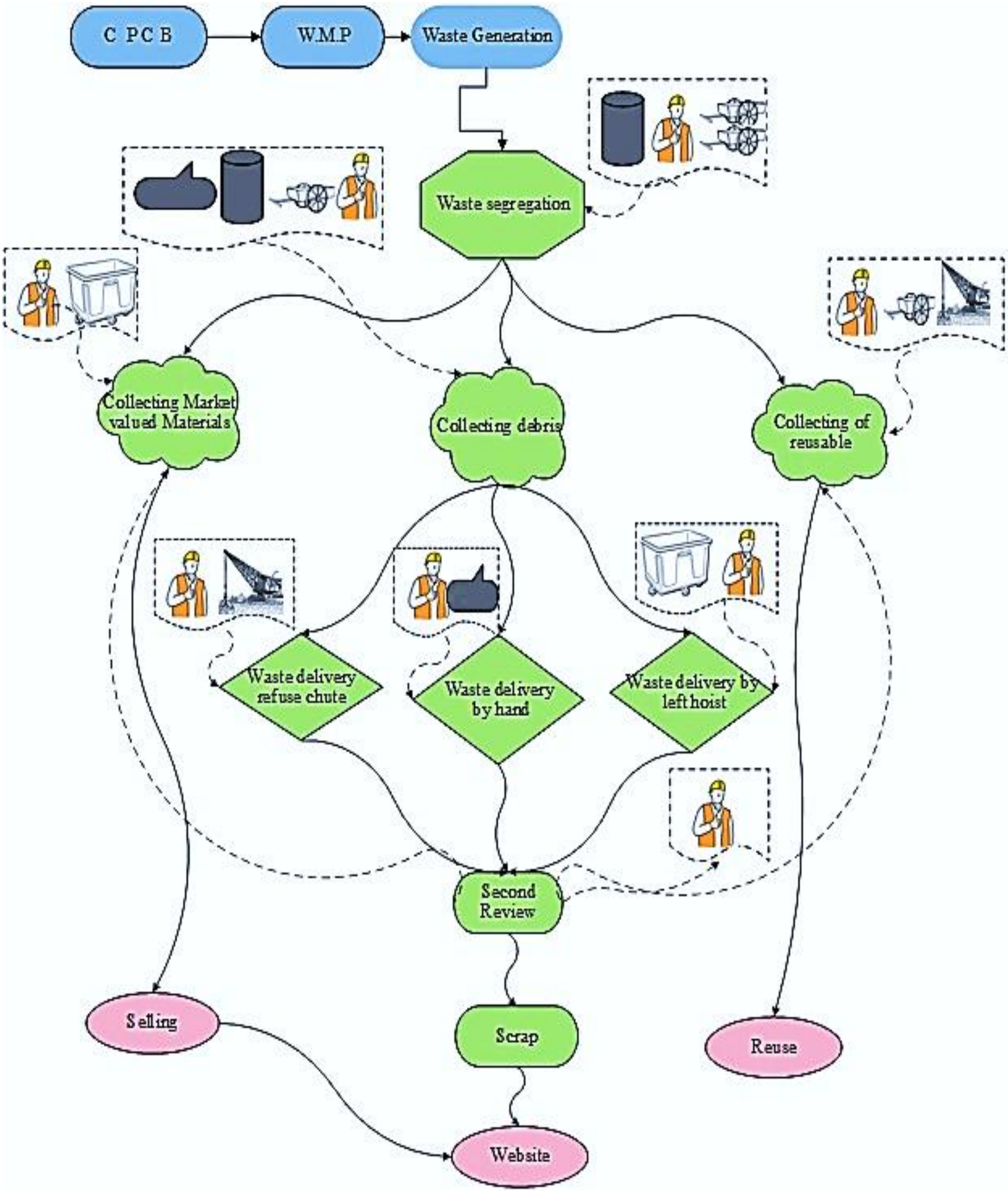


Figure 9.7 Proposed WMPFM

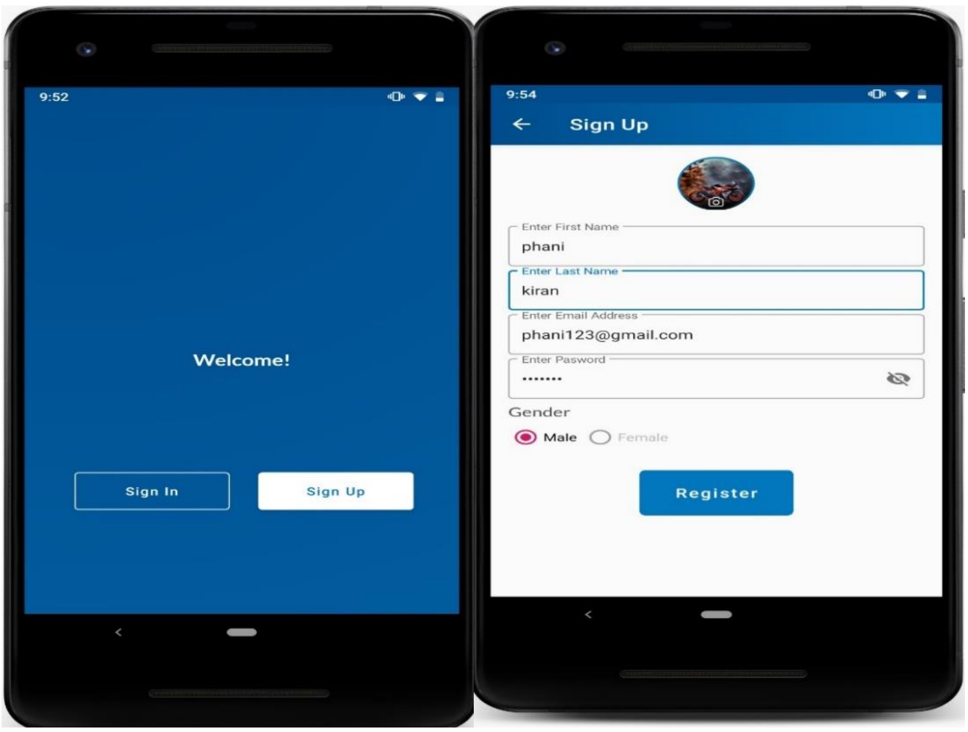
In view of the above aspects, a novel methodology has been devised to significantly reduce illegal dumping of construction waste and to generate wealth from construction waste in India. The problem observed in the Indian construction industry is that, despite rules and policies framed by the Government, waste management is not enforced at construction sites. To address the above problem a framework is set up commercialize CW and develop wealth from waste.

Both sellers and buyers are brought onto a common platform. A proto-typical Android application (Waste Alley) is presented for marketing construction waste.

9.4.3 Development of Android application- "Waste Alley"- Prototype of Seller and Buyer Portal

A Proto-typical Android Application-Waste Alley is developed. Waste Alley provides an e-portal where construction waste can be purchased and traded. The user in possession of waste (seller) can post the information on the Android application along with the photograph, location, type of the material, age of the materials and contact details. A service specific to C & D waste, along the lines of existing platforms such as OLX, is envisioned.

The prototypical Android application developed is user friendly & self-explanatory (Figure 9.8). The general framework described here in can commercialize the C&D waste generated.



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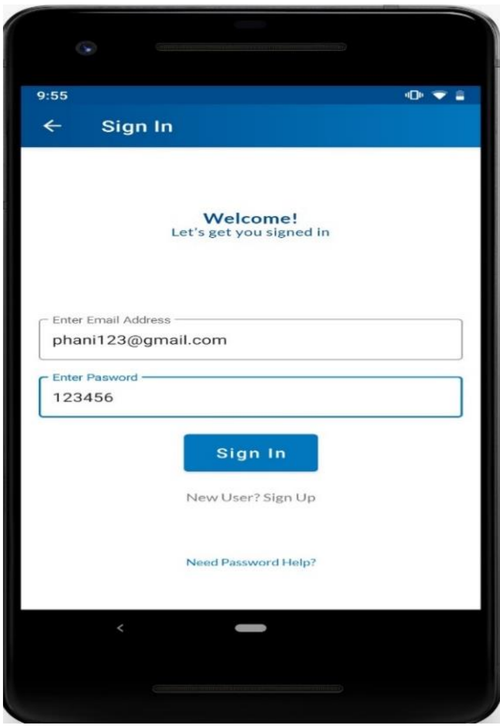
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Welcome!
Let's get you signed in
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New User? Sign Up
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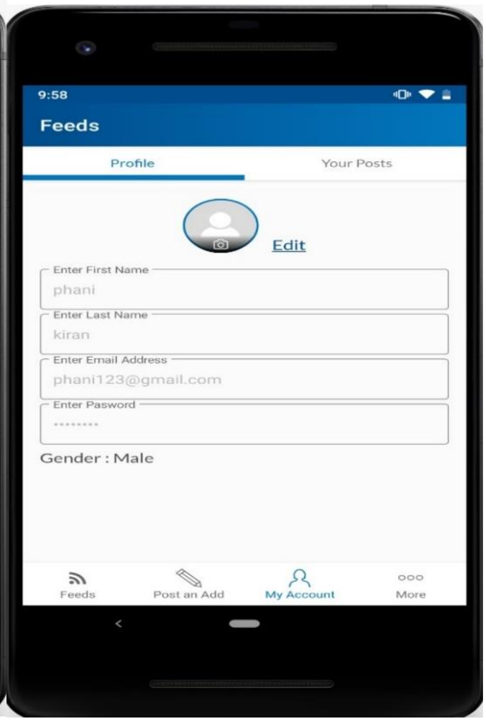
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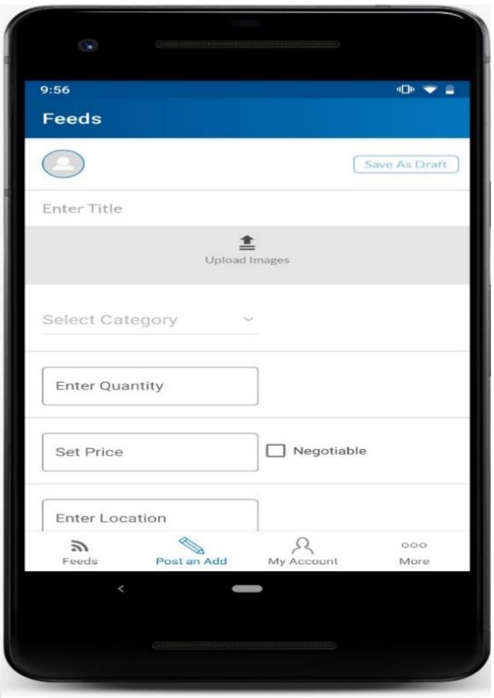
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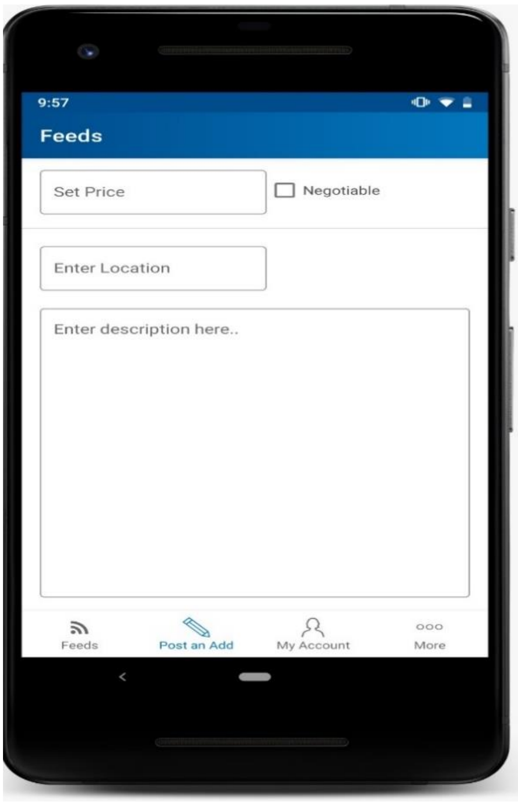

Figure 9.8 User-Interface for Proto-typical android application (Waste alley)

At present, the android application is limited to prototype, because waste reserves need to be set up (location for temporary storage of C &D waste). A GPS enabled system needs to be associated with the Android application to locate the seller or if the seller is unavailable the buyer can simply post/advertise their requirement. Additional factors such as temporary waste storage facility i.e. nearest weigh bridge need to be associated within the application to improve the performance for which the support from the government is demanding.

9.4.4 Development of onsite construction waste management performance assessment (OCWMPA) index

Step 1: Outlier elimination

Multivariate Normality: It usually checks for any outliers in a data. Multivariate Normality is usually calculated using Mahalanobis distance. The Mahalanobis distance is a measure of the distance between a point P and a distribution D. The Mahalanobis value is calculated by using IBM SPSS statistics. The Mahalanobis distance for the total 32 variables is 106.001 which is high. To eliminate this probability values are created and checked, the responses with probability values less than 0.01 are deleted. A total of 10 responses were deleted. The Mahalanobis value after deletion is 71.083.

Homoscedasticity:

If all random variables in the sequence or vector have the same finite variance is known as homogeneity of variance or homoscedasticity. Homoscedasticity is calculated using IBM SPSS, the results are shown below. A Loess line has been added to determine homoscedasticity of the data. From the scatter plot it can be seen that the Loess line is free from sharp curves, hence, the data did not violate the assumption of homoscedasticity (Figure 9.9).

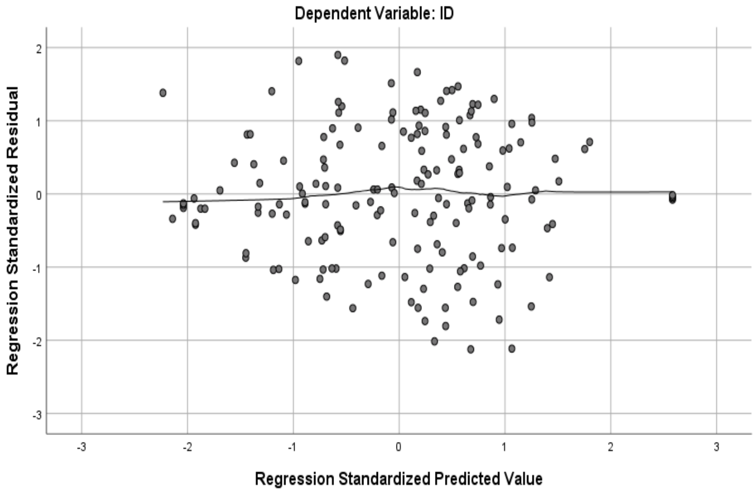

Figure 9.9 Scatterplot

Step 2: Reliability analysis

The internal consistency of the data is measured by using Cronbach's alpha. The value ranges in between 0 to 1. The value closer to one indicate higher internal consistency and vice versa (Olaniyi, 2019). The Cronbach's alpha for the entire variables is 0.929. Therefore, the variables considered are reliable for further analysis (Hair et al., 2010). This is in line with the recommendation stating Cronbach's alpha determination is important, especially when using Likert scale on a questionnaire (Hafiz et al., 2013). Cronbach's alpha ranges from 0 to 1, a value of 0.7 represents an acceptable consistency, 0.8 indicates a good internal consistency, while a value of 0.9 demonstrates an excellent consistency of measurement (Tavakol and Dennick, 2011). Therefore, a value of 0.929 indicates excellent consistency in the measurement.

Step 3: Relative importance index (RII)

Relative importance index (RII) is used to rank the corresponding OCWMPA variables. RII importance index ranges from 0 to 1. The variables with highest RII is given first priority (Table 9.8). In addition, the individual category weightage is calculated in comparison with the remaining categories.

Table 9.8 Ranking of OCWMPA variables

OCWMPA	Coding	RII	Rank
RRR (reduce, reuse, recycle) strategy	C5	0.78	1
Supervision and control of the amount of construction waste	C1	0.78	2
Practice of making money out of waste i.e. selling.	I6	0.77	3
Documentation of payment of taxes and penalties if the waste	I5	0.76	4
The practice of segregation i.e. maintenance of separate bins for	C2	0.76	5
Usage of recycled material at the construction site	M4	0.76	6
Training programs at the construction site	H4	0.76	7
Contractor involvement in construction waste management	H1	0.75	8
Cleaning up the site on a daily basis	C3	0.75	9
Allocation of separate space for material sorting at initial stages of	C7	0.75	10
Incentive in binding for a contractor having a plan about decreasing	I3	0.75	11
Education of staff working on the construction site	H3	0.75	12
Following government norms on dealing with construction waste	I2	0.75	13
Awareness of government policies on construction waste generated	I1	0.74	14
A management team for managing construction waste	H7	0.74	15
Quantification of the amount of construction waste generated	C4	0.74	16
Material transportation system for construction waste	M5	0.74	17
Appointment of workers especially for separation of waste	H5	0.73	18
Establish criteria for the quality and safety of recycled materials	I4	0.73	19
Checklist on the execution of waste management plan	D2	0.72	20
Installation of information boards for segregation of construction	C6	0.72	21
Informing methods to deal with rest of construction waste after	C8	0.71	22
Maintenance of record on training programs i.e. past, present and	D4	0.71	23
Database management system or any software technology for	D3	0.70	24
Installation of recycling equipment at construction sites	M1	0.70	25
Installation of mobile recycling plant at the construction site	M3	0.70	26
Client involvement in construction waste management	H2	0.70	27
Installation of equipment for waste sorting	M2	0.69	28
Disposal of construction waste periodically by open dumping,	C9	0.69	29
Changing of the design	D5	0.69	30
Separate documentation (records) on recycling waste	D1	0.69	31
Supplier’s involvement in construction waste collection	H6	0.63	32

Among various categories construction method and planning occupies highest weightage of 0. 286. Human resources with 0.216, materials & equipment with 0.154, design & documentation with 0.151 and industry policy with 0.193 (Figure 9.10).

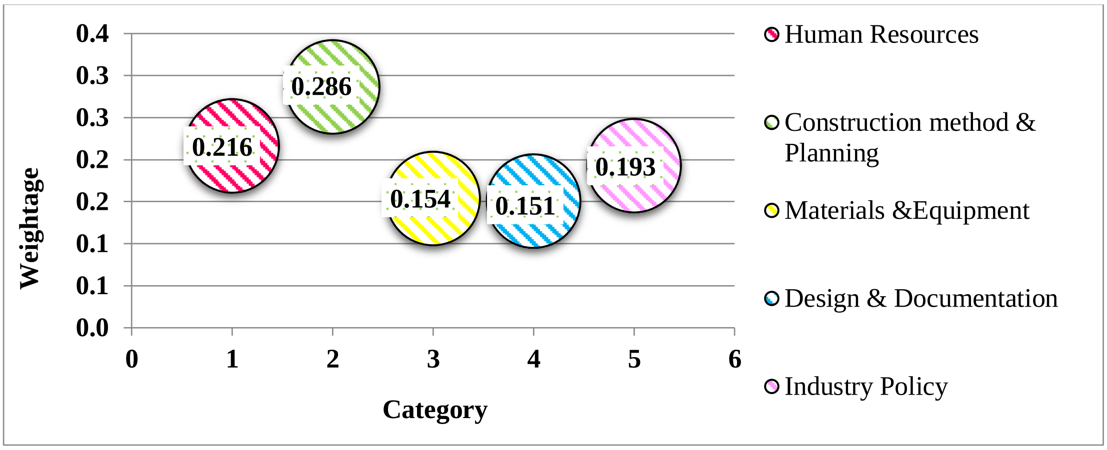

Figure 9.10 Factor weightage

Step 4: Developing an OCWMPA index for construction organizations

The level of CWM performance of the individual organizations can be assessed by utilizing the OCWMP variables. To delve into implementation, top 25 ranked OCWMPA variables (based on RII values) are selected for the study to assess project specific performance. In order to assess the degree of agreement on the finalized factors, the selected factors are converted into a question response format and the user is requested to select the most appropriate response for each question. For example, the question is framed as *"we have controlled supervision and quantification of the construction waste generated"*. In this case, there are five options based on the degree of agreement, i.e., strongly disagree (1) to strongly agree (5). The options have scores ranging from 0 (strongly disagree) to 1 (strongly agree) with intermediate scores of 0.25, 0.50, 0.75 etc. The scores are awarded with the help of experts. Infact, score converting methodology is vital to quantify hard to measure variables in the field of project management. Likewise, all the 25 questions are converted to a question response format and distributed online.

Five construction organizations consisting of five respondents in each organization are used in the present study. The organizations are selected on the basis of the following parameters- (i) Knowledge on CWM; (ii) Implementation of CWM; (iii) Respondents experience greater than 5 years and (iv) with companies greater than 10 years of service life. Both government and corporate organizations are involved in the present study. A sample question response format for five questions is presented in Table 9.9.

Table 9.9 Question–Response Format

Variable	Question	Response option	Score
C5	We adopt RRR strategy at construction sites	A. Strongly agree	1.00
		B. Somewhat agree	0.75
		C. Moderate	0.50
		D. Somewhat disagree	0.25
		E. Strongly disagree	0.00
C1	We have controlled supervision and quantification of the construction waste generated	A. Strongly agree	1.00
		B. Somewhat agree	0.75
		C. Moderate	0.50
		D. Somewhat disagree	0.25
		E. Strongly disagree	0.00
I6	We have a practice of making money out of waste i.e. selling etc.	A. Strongly agree	1.00
		B. Somewhat agree	0.75
		C. Moderate	0.50
		D. Somewhat disagree	0.25
		E. Strongly disagree	0.00
I5	We maintain documentation regarding Construction waste management (on payment of taxes, penalties) if the waste exceeds permitted limits based on government norms	A. Strongly agree	1.00
		B. Somewhat agree	0.75
		C. Moderate	0.50
		D. Somewhat disagree	0.25
		E. Strongly disagree	0.00
C2	We practice waste segregation at the construction site	A. Strongly agree	1.00
		B. Somewhat agree	0.75
		C. Moderate	0.50
		D. Somewhat disagree	0.25
		E. Strongly disagree	0.00

The (OCWMPA) index indicates the level of waste management performance for individual construction project. The equation (4) is used to assess the performance of the construction firm towards CWM (Cha et al., 2009).

$$\text{OCWMPA index} = \sum_{i=4}^{4}\left(\sum_{j=1}^{1}\left(\sum_{k=1}^{m}\left(RS_{ijk}\times RW_{ijk}\right)\times FW_{ij}\right)\times CW_{i}\right) \quad (4)$$

Where RS_{ijk}=score of k^{th} response for jth factor in ith category; RW_{ijk}= weight of k^{th} response for jth factor in i^{th} category $0<RW_{ijk}\leq1$; CW_i = weight of i^{th} category $0<CW_i \leq 7$; FW_{ij} = weight of j^{th} factor in i^{th} category $0<FW_{ij} \leq 1$; l = number of factors in i^{th} category; and m = number of responses for j^{th} factor in i^{th} category. The index ranges from 0 to 1000 and is further classified as (OCWMPA) index ranging from 0-250 as poor, 250-500 as fair, 500-750 as good, and 750-1000 as excellent. The details of the case studies are shown in Table 9.10.

Table 9.10 Details of the case studies

Case study	OCWMPA index	Performance assessment
1	496	Fair (400-600)
2	847	Excellent (>800)
3	513	Fair (400-600)
4	496	Fair (400-600)
5	520	Fair (400-600)

9.5 Conclusion

9.5.1 Construction waste process modelling

The study qualitatively assesses the waste management practices in India and compares the prevalent waste processing practices at six typical construction sites located in three cities - Bangalore (tier-1 metropolitan), Warangal (tier-11) and Amaravati (tier-11) in southern India. The research outcomes demonstrate that-

(i) Waste management plans are virtually non-existent in several companies regardless of the size of the organization;

(ii) Majority of the construction companies are unaware of waste management best practices, leading to severe lack of data associated with quantification of construction waste;

(iii) Four out of six projects studied end up disposing waste by means of dumping in low lying areas;

(iv) Recycling and reuse is not practiced in any of the cases and is given insignificant importance in almost all the cases;

(v) Non availability of mechanized procedures causes delays while dealing with waste.

These findings resonate with the recent research on C & D waste management which illustrate that incorporation of an advanced waste management plan can aid in effective quantification of the waste generated; and in sorting the valuable materials which can be recycled and can reduce illegal dumping of waste.(Jain, et al., 2020a; Kabirifar et al., 2020; Kolaventi et al., 2019; Zhang et al., 2020) .Therefore a novel approach is suggested in this study in view of the depicted outcomes, from which a comprehensive waste management process flow model (WMPFM) is developed by means of incorporating best practices from various case studies. This WMPFM can act as a guide in controlling waste management procedures onsite.

9.5.2 Android Application

The output of the model suggests incentivization as an alternative to illegal dumping, which aligns with the findings of Mak et al., (2019). Towards this end, a proto-typical Android application ***(Waste alley)*** is developed, wherein, either the requirement or existence of waste is advertised online. The approach is consistent with the findings of (Adedeji et al., 2018; Chowdhury et al., 2019), which indicate that developing Android applications or web based solutions for construction waste leads to improved financial benefits. Waste Alley or similar solutions are expected to clear the pathway with the following enforceable actions:

- Integration of waste management in contractual document.
- Permissions for construction with site waste management plan (SWMP).
- Providing CWM certification courses in institutes, organizations etc.
- Inter-state competitive schemes to build awareness and popularize CWM.
- Implementation of permits for C&D waste transportation with radio frequency identification tag (RFID) tracking system.
- Practice manuals or codal provisions on how to use recycled concrete in the new constructions.
- Strict punishments for illegal disposing of wastes and regular monitoring
- Awareness programs on how to gain wealth from waste
- Promotion and marketing of recycled material
- Remove misconceptions on usage of recycled material.

Any such software application needs to link with the existing waste reserves established and managed by the Panchayat Raj systems of Government of India. Location capabilities for identifying weigh bridges will enable accurate monitoring. Online tenders can be called out for setting up waste reserves where the seller could temporarily store the material by paying a nominal charge. The suggested framework can create revenue while providing a practical solution for promoting environment sustainability.

9.5.3 OCWMPA index for construction organizations

- The CWM performance levels of the individual organizations can be assessed by utilizing the OCWMP variables.
- The index ranges from 0 to 1000 and is further classified as (OCWMPA) index ranging from 0-250 as poor, 251-500 as fair, 501-750 as good, and 751-1000 as excellent.
- The results of five construction projects indicate that one out of five projects (Project 4) has excellent performance i.e. OCWMPA index of 847 and the remaining projects perform weakly in terms of CWM, with index value between 400 to 600.
- The OCWMPA index helps the project managers or engineers to infer the CWM performance of their respective projects along with identification of weak areas which need improvement.

CHAPTER 10

Conclusions

10.0 Brief conclusions from each phase of the project

Phase-I of the research work consist of- (i) Quantification of Construction waste; (ii) identification of CWM influence factors and assessment of degree of concordance among respondent groups; (iii) modelling the causes which influence the waste generation at construction site using structural equation modelling. Based on the causes lack of site waste management plan is identified as top most parameter influencing construction waste management performance in India.

Phase–II of the research work focussed on identification of barriers, benefits, and measures for implementation of site waste management plan and construction waste recycling. While pursuing the above research in India, we discovered attitude & behavioural parameters play key role in construction waste management (CWM)implementation.

Phase –III of the research consists of attitude and behavioural studies on implementation of construction waste management in India using extended theory of planned behaviour approach.

Phase –IV of the research assesses- (i) real time waste flow at construction sites using waste process flow models. From which, onsite solutions for effective construction waste management are established; (ii) Development of Android application- “Waste Alley”- for marketing of construction waste and (iii) onsite construction waste management performance assessment (OCWMPA) index- to assess waste management performance of various construction sites.

10.1 Conclusions from Phase 1

The following conclusions are drawn from phase -1 of the project

10.1.1 Identification and grouping of influence factor

The top-most influence factors which can ameliorate waste management performance in Indian construction industry, according to the analogous importance index (AII) are:

(i) Training of workers in identifying recyclable materials by segregation of individual waste from mixed C & D waste;

(ii) enforcing strict punishments for illegal disposal of C & D waste.

10.1.2 Measurement of concordance among Engineers, Academia and Contractors

Kendall's coefficient of concordance indicates there is a moderate degree of agreement among the contractors, engineers and academicians for the variables grouped under construction method (0.68). Hence it is concluded that, there is large variation within the items grouped under *construction method*.

10.1.3 Modelling the causes of construction waste generation

A novel causal relationship of various factors in the revised SEM model reveal, the most important factor is SMP with a path coefficient of 0.96 followed by *O (0.91), OPS (0.84), HHS (0.76), MHS (0.73), D (0.60) and C (0.46)*. Hence the alternate hypothesis that waste generation *factors* have a significant positive influence on the waste generation at construction site is accepted. The study indicates that with an efficient site waste management plan, the generation of construction waste can be reduced. SWMP needs to be enforced in all the construction sites irrespective of the size of the construction site.

10.2 Conclusions from Phase II

The following conclusions are drawn from phase -II of the project

10.2.1 Barriers, Benefits, and Measures for implementation of CWM

The major barriers which hinder the implementation of SMP; *B4-"No guidelines are available with company"* is ranked as the highest parameter with a beneficial index value of (6.70); *B6 (6.63)-"Government is not concerned about the place where I dispose waste"* ranked second (Vegas et al., 2015). Measures *MI8 (7.32) - Legal requirements on environmental protection* is ranked as the highest parameter. It is therefore concluded that, most of the respondents believe that with an efficient waste management system construction waste can be reduced. However, irrespective of the respondent's intention, *there are no guidelines available with the company*. This clearly indicates lack of interest in implementing waste management system at various administrative levels within the companies. Most of the respondents agreed that effective legal enforcement of waste management is mandatory through penalties, taxes etc. Among benefits, *BF4(7.42) - environmental protection by conserving resources* is ranked as the highest parameter (Shen and Tam, 2002); *BF8 (7.24) - Helps in efficient use of materials* ranked second (Tam, 2008).

10.2.2 Barriers and Enforcement Measures for recycling construction waste

Recycling studies on the six active projects indicate Barriers i.e. (behavioural, legal, technical, marketing) to enforce recycling are (i) non-implementation of SWMP(ii) illegal dumping (iii) lack of segregation(iv) ethics and supervision on recyclable materials. Suggested measures for efficient recycling are (i) ***Behavioural****-Government projects construction using recycled materials, adequate training and supervision* (KolaventiSS et al., 2019).(ii) ***Technical****- code provisions of acceptable quality for various building components* (Kleemann et al., 2017) (iii) ***legal****- Higher landfill charge with strict penalties for illegal dumping*(Rodríguez et al., 2017) (iv) **Marketing** – *Mobile crushers at demolition sites and increasing recycling material sale outlets* (Gangolells et al., 2014;Shi et al., 2013).

10.3 Conclusions from Phase III

The following conclusions are drawn from phase -III of the project. Here, extended theory of planned behaviour is used to assess the behavioural intention regarding implementation of construction waste management at construction sites.

10.3.1 Extended Theory of planned behaviour to promote implementation of construction waste management

- The major contribution of the study is use of a behavioural approach i.e. the notion of *theory of planned behaviour* (ATT, SN and PBC) and *institutional theory* (KN and PU) to provide a clear picture of associated factors for non-implementation of CWM in Indian construction projects.
- As a partial mediating factor, perceived usefulness and knowledge provide an explanation of the complex and evolving decision-making process behind implementation of WM under conflicting environments.

- The analysis results conclude that, PBC has greater impact in comparison with attitude and subjective norm. The finding reinforces the observation that inclusion of perceived behavioural control significantly improves the prediction of intentions (Ajzen, 1991).
- Following TPB, therefore, it is expected that management's perception of constraints in implementation of CWM affects whether or not that behaviour will occur. Examples of a few perceived external constraints are:
  - (i) lack of standards in usage of CW products,
  - (ii) Increased recycled products price in comparison with conventional materials,
  - (iii) lack of standard documentation,
  - (iv) Higher goods service tax (GST) i.e. 18% on recycled products,
  - (v) Non-user friendly setup.
- The above perceived external constraints might also form a cycle, which may increase the résistance to implement CWM onsite.
- The additional construct *Knowledge* has significant behavioural impact on implementation of CWM. Whereas, the impact of *subjective norm* and *perceived usefulness* is insignificant, on the behavioural intention to implement CWM.
- A plausible explanation is that *perceived usefulness* might often indicate its influence on the intention through the mediator of *attitude*. Moreover, the context of this study is focused on the stage of initial adoption and voluntary implementation of CWM (without rewards).
- The perceived usefulness of CWM may not immediately lead to a behavioural intention to implement, but rather to firstly form a favourable attitude towards establishing CWM onsite.
- In other words, a period of time is needed to change the psychological state of decision makers such as engineers, contractors, architects, in order for them to adopt CWM.

10.4 Conclusions from Phase IV

10.4.1 Construction Waste Process Flow Modelling

Phase –IV of the project deals with onsite construction waste performance which can be monitored, managed, commercialized, improved using process flow models, internet based applications and by using an indexing system.

- The prevalent waste processing practices at six typical construction sites reveal that in four out of the six projects studied waste is disposed by means of dumping in low lying areas.
- Recycling is not practiced in any of the cases and reuse is given insignificant importance in almost all the cases.
- Waste management plans are virtually non-existent in many companies regardless of the size of the company.
- It is also noted that lack of mechanized procedures causes delays while dealing with waste.
- Most of the construction companies are unaware of waste management best practices leading to severe lack of data associated with quantification of construction waste
- There is lack of effective enforcement of rules to prevent illegal disposal of the waste.

10.4.2 Development of Android application- "Waste Alley"

Either requirement or existence of waste is advertised online. This resonates with the findings that developing Android applications or web based solutions for construction waste reduction and sustainable material management, aid in improved financial benefits (Adedeji et al., 2018 ; Chowdhury et al., 2019). The study revealed that the use of web-based technologies in the construction industry can empower efficient recording benefits, optimized production benefits and effective information processing. The framework suggested can generate revenue while providing a practical solution for promoting environment sustainability.

10.4.3 OCWMPA index for construction organizations

Most of the existing CWM performance assessment methods focus on either the design or planning phase, with minor emphasis on construction phase. To improve the existing system a novel methodology i.e. OCWMPA index is proposed. The index quantifies the performance level of individual project in terms of CWM. The results of five construction projects conclude one out of five projects *(Project 4)* has excellent performance i.e. OCWMPA index of 847 and the remaining projects perform weak towards CWM i.e. with index value between 400 to 600. The OCWMPA index helps the project manager or engineers to infer CWM performance of their respective projects along with identification of weak areas which need improvement.

10.5 Key conclusions

- The causes for CW generation are identified and the impact of individual cause on CW generation is modelled. Thus the model proposed can be used as a guide for engineers to identify the areas of waste generation and decrease the recurrence thereof.
- The barriers, benefits and measures for implementing CWM as well as for recycling of construction waste are identified. The observed barriers are mitigated through enforcement measures. The government bodies or policy framing authorities can use the results of the work to amend existing policies.
- Attitudinal and behavioural studies on implementation of CWM are studied. The framework developed help in assessing various attitudes associated in implementation of CWM.
- The onsite CW flow is assessed by using process flow models from which an effective model is developed by considering existing weakness and strengths of the projects.
- Revenue generation based solution such as, proto typical android application (waste alley) is developed with an aim of incentivizing the CW.
- An index system is developed (OCWMPA index), which aid in estimating the onsite WM performance of the construction project.

10.6 Significant contributions of the current study

The study has developed a rational methodology for identifying, quantifying and modelling:

- Waste generated from construction projects.
- Factors influencing construction waste management.
- Causes and their individual impact on construction waste generation
- BBM for implementing SWMP and recycling.
- Attitude and behavioural factors towards implementing CWM.

Tools developed:

- Onsite waste process flow models to identify weak zones in construction projects regarding CWM performance.
- Android application for marketing CW.
- Index system for assessment of onsite waste management performance.

10.7 Future scope of the investigation

Further study may be attempted in the following regions:

- The current study quantified waste from construction sites limited to concrete and steel. A similar approach can be used for quantification for the other construction materials.
- The current study incorporated two additional constructs in TPB model i.e. Knowledge and perceived usefulness. Future studies can strengthen the findings by including constructs such as socio economic factors, moral norms etc. The moderating effect of such extrinsic factors on standard or extended TPB model require future investigation.
- The developed Android application is limited to virtual prototype model, the functionality of which can be further expanded.
- The developed index system can be enhanced with the help of software packages to reduce manual errors and for better database management.

CHAPTER 11

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APPENDIX

Appendix-A

Part A

* Required

1. Email address* *
2. Name *
3. Gender *
    - Male
    - Female
4. Age *
    - Below 20.
    - 20-29
    - 30-39
    - 40-50
    - Above 50.
5. Education back ground *
    - Below and equal to tenth.
    - Intermediate.
    - B.Tech.
    - M-Tech.
    - Above M-Tech.
6. Name of the company *
7. Designation *
    - Engineer
    - Contractor
    - Academic
    - Faculty
    - Client

- Manager
- Labor

8. Years of experience in construction industry *

- 0-5 years.
- 6-10 years.
- 11-15 years.
- 16-20 Years.
- 20 Years.

Part- B

What is the contribution of the following factors, to waste production on a scale of 1 to 7. Bench marking 7 as strongly agree to the statement and 1 as strongly disagreeing.

1. There is a need of representative of contractor at the site to enforce waste management.
2. Separate workers should be appointed at the site for disposing waste.
3. Support from subcontractors is mandatory for implementing waste management.
4. There should be a separate work break down structure for waste management.
5. Highly qualified engineers are not mandatory for implementing waste management.
6. Education of laborers is not mandatory for waste management.
7. Supervisor to worker ratio will not affect the implementation of waste management.
8. Collection of material packaging waste by their respective suppliers will reduce wastage
9. Revamping will not reduce wastage
10. Usage of good quality materials will not reduce wastage.
11. Prefabricated materials and components will produce less amount of wastage
12. Usage of recycled material is not supported by majority of clients.
13. Fragile materials are to be replaced in order to reduce wastage during construction.
14. Fragile materials are to be handled carefully in order to reduce wastage during construction.
15. Transportation and storage and of materials need not be specially addressed in SWMPs.

16. Preparation of excess perishable material before execution should be strictly avoided to prevent wastage.
17. Excess prepared material enables less delays during execution of tasks.
18. Individual containers for sorting out of waste is mandatory in construction site
19. individual waste from a mixture of wastes should be made a must do option in construction site
20. Waste storage sites design need not be included in design documents.
21. Waste collectors are to be installed at every floor and a jumbo collector for the entire building.
22. Wastes are to be placed in an accessible area for easy shipping.
23. Equip subcontractors with bins for waste collection.
24. Workers should be given training in identifying recyclable material.
25. Installation of equipment's for recycling in construction site is mandatory.
26. A mixture of soil and waste is not taken into consideration
27. Installation of equipment's for recycling in construction site is mandatory as it reduces transportation cost
28. Additional methods have to be informed to site management and workers to treat the materials after recycling.
29. A Statute on management of waste by the corresponding waste producers is not mandatory.
30. Clauses should be incorporated in contractual documents for subcontractor alone.
31. Awards are mandatory for a contractor who produces less amount of wastage.
32. Document management is must for tacking and classifying wastes and quantities
33. Clauses in contract documents specifying waste treatment methodologies and equipment are not mandatory.
34. Site waste management plan (SWMP) should be completed before preconstruction phase.
35. Checklists for waste management need to be verified and enforced by subcontractor alone.
36. An index score to define the capability of a firm towards waste management is mandatory.
37. A ranking system to rank firm towards waste management is mandatory.

38. Documents and records relating to waste management is maintained by subcontractor alone
39. Analyzing alternative route for waste transportation and determining the ideal route is unproductive work
40. Mandatory item of actual Cost for waste treatment to be provided in bill along with satisfactory documentation
41. Enforce strict punishment for illegal disposal of wastes in violation of EPA regulations.
42. During bidding process additional weightage to be given to contractors having clear plan, schedule and estimates of waste management.
43. Code provisions for construction waste management is not mandatory.
44. No GST (State and central tax) on waste treatment equipment’s.
45. Reduce legal procedures for installation of waste management equipment’s.
46. Clauses relevant to Quality and safety of recycled material are not necessary to be included in code books.
47. Government should create separate market for recyclable materials.

Appendix-B

Causes for construction waste

Part-A

1. Email address*
2. Name *
3. Gender *
    - Male
    - Female
4. Age *
    - Below 20.
    - 20-29
    - 30-39
    - 40-50
    - Above 50.
5. Education back ground *
    - Below and equal to tenth.
    - Intermediate.
    - B.Tech.
    - M-Tech.
    - Above M-Tech.
6. Name of the company *
7. Designation *
    - Engineer
    - Contractor
    - Academic
    - Faculty
    - Client
    - Manager

- Labor

8. Years of experience in construction industry *

- 0-5 years.
- 6-10 years.
- 11-15 years.
- 16-20 Years.
- 20 Years.

9. Please rate the best techniques for implementation of waste management*

- Usage of RFID (Bar code) tags for waste management.
- Buying material by the government suppliers. (Announcements, TV, social media).
- Reusing at site itself by making Eco-friendly bricks, path ways, lawns.
- By imposing taxes depending upon the waste generated (high tax---high wastage).
- Building temporary structures.
- Gifts and tender awarding to members Implementing waste management.

10. Are you interested in implementing waste management at your construction site*

- Yes
- No
- Maybe

11. How do you make people enforce waste management*

- by imposing taxes.
- by conducting awareness programs
- I don’t have any authority over it.
- It involves overall involvement of people.
- Other: ------------------

12. Are you aware of the rating systems such as LEED and GRIHA*

- Yes
- No
- Maybe

13. It is easy for me to *

- Dump waste in low lying areas.
- Recycle waste.
- Reuse waste in site itself.
- Market waste(selling)- Government should come forward in purchasing waste.
- Reduce waste.

14. Which of the following materials are major contribution to construction waste*

Not Important (1) Slightly Important (2) Moderately Important (3) Very Important (4) Extremely Important (5).

1. Concrete
2. Timber
3. Metal
4. Bricks
5. Plaster Board's
6. Packaging
7. Tiles
8. Insulation
9. Plastic
10. Cement

Part-B

Causes for construction waste generation

What is the contribution of the following factors, to waste production on a scale of 1 to 5.Not Important (1) Slightly Important (2) Moderately Important (3) Very Important (4) Extremely Important (5).

1. Design changes while construction is in progress
2. Complicated design and detailing in drawings
3. Inadequate coordination and communication (latte information,, last minute client
4. Design changes while construction is in progress
5. Complicated design and detailing in drawings
6. Inadequate coordination and communication (latte information, last minute client
7. Incomplete contract documents and errors in contract documents
8. Unreadable/inapplicable specification
9. Contract documents deficient at beginning of construction
10. Rework, variation and negligence
11. Time restraint and inclement weather
12. Unskilled labors and
13. Delays in giving data to contractual workers with respect to types and sizes of items
14. Required quantity unclear due to improper planning
15. Lack off on-site waste management plans and inadequate strategy for waste
16. Improper planning for required quantities and poor site conditions
17. Delays in passing information on types and sizes of materials and lack of supervision
18. Materials delivery in improper packing
19. Damages during hauling from storage to the point of application
20. Inadequate materials handling and use of materials which are close to work place
21. Usage off cheap quality materials
22. Ordering errors (too much or too little)
23. Purchases not complying with specifications
24. Over allowance (i.e. lack of possibility to order small quantities)
25. Suppliers' errors
26. Lack of awareness
27. Lack of awards
28. Lack of Support from senior management

29. Lack off Training
30. Due to vandalism
31. Due to theft
32. Construction site do not produce any wastage
33. Construction wastage is used in site itself
34. Damage during Transportation
35. Narrow construction sites
36. High protection during unloading
37. Inefficient methods of unloading

Appendix-C

Barriers, benefits and Measures for implementing site waste management plan

Among the different barriers, benefits and measures please rank the contribution of individuals for implementation of construction waste management. Not Important (1) Slightly Important (2) Moderately Important (3) Very Important (4) Extremely Important (5).

Benefits of implementing site waste management plan.

1. Reduces payment of penalties
2. Increase chance of selection during bidding
3. Improves waste management standards
4. Leads to environmental protection by conserving resources
5. Increase business competitiveness
6. Helps in reduction of payment of taxes
7. Increase profits
8. Helps in efficient use of materials
9. Reduction of environmental pollution
10. Develops Positive attitude among staff in conserving environment
11. Helps to prevention of natural disasters and injuries
12. Nullifies pollution relating to air, water, and land

Barriers for implementing site waste management plan.

1. Lack of awareness
2. I do not see waste management as an major issue
3. Wastage is not measured at site
4. No guidelines are available with company
5. Clients do not take it seriously
6. Government do not concern about the place where I dispose wastage
7. Waste management does not create profit
8. My senior officer do not care about implementing of waste management so why
9. Waste management do not add any hike in my profile
10. Following waste management does not help me getting promotions

11. No punishment for avoiding waste management
12. Increase in additional costs
13. Lack of experienced staff
14. Lack of coordination among work force employed in a project
15. Lack of supplier co-operation
16. Consume additional time (Records, efforts, manpower)
17. Heavy documentation load as appropriate data not available
18. Difficulty in acquiring data from field
19. Loopholes in gathered data
20. Lack of equipment availability on site for measuring wastage
21. Change of existing practice of company structure and policy
22. Lack of technological support within organizing
23. Implementation of waste management is not my work
24. Waste is reused at my site
25. Lack of awareness of law regarding illegal dumping
26. It is easier/cheaper to dump

Measures to implement site waste management plan

1. Implementation of software technology
2. Increase in awareness
3. Enforcement of punishments for illegal dumping of wastage
4. User friendly technology
5. Availability of recycling equipment on the site
6. Increasing market value for waste materials
7. Providing incentives to workers for implementing waste management
8. Legal requirements on environmental protection
9. 3R strategy of construction waste onsite
10. Imposing responsibilities of protecting environment of management staff
11. Applying environmentally friendly technology
12. Workshops on waste management and separate training for workers on waste
13. Adopting waste management plan
14. Continuous efforts in improving waste management
15. Collecting suggestions for improving waste management
16. Inclusion of waste management in tendering requirements
17. Effective communication on waste management among workforce
18. Close supervision at site level
19. Concessions on recycling equipment
20. Reduction of taxes on recycled materials
21. Separate team for waste management
22. Creating awareness about the misconceptions on using recycled aggregate /materials
23. Designs for recycled aggregate
24. Competitiveness among workers regarding CWM is the only way to improve CWM
25. Terminating contract for contractor’s not implementing CWM
26. Advertisements through media/social network is necessary to improve CWM

Appendix-D

Part A

* Required

1. Email address* *
2. Name *
3. Gender *
   - Male
   - Female
4. Age *
   - Below 20.
   - 20-29
   - 30-39
   - 40-50
   - Above 50.
5. Education back ground *
   - Below and equal to tenth.
   - Intermediate.
   - B.Tech.
   - M-Tech.
   - Above M-Tech.

9. Name of the company *
10. Designation *
   - Engineer
   - Contractor
   - Academic
   - Faculty
   - Client
   - Manager

- Labor

11. Years of experience in construction industry *

- 0-5 years.
- 6-10 years.
- 11-15 years.
- 16-20 Years.
- 20 Years.

Attitude and behavioural studies

Part B

1. Waste management do not add any hike in my profile
2. Following waste management does not help me getting promotions.
3. Implementation of construction waste management helps in reduction of construction waste.
4. Incorporation of waste management in the early stage of construction can help in reducing the messiness at construction site.
5. Implementation of waste management enhance the environment friendly images corporate.
6. Site waste management plans do not increase profits for the company.
7. My contractor approves my implementation of waste management at site.
8. My coworker reminds me to implements waste managements at site.
9. My client agrees that, incorporation of waste management is must.
10. My supplier agrees to my implementation of waste management at site.
11. There is no enforcement of construction waste management by government agencies.
12. I trust myself in implementing waste management at site.
13. My fellow workers and I believe that without strict rules we cannot implement waste management.
14. If none reminds me I cannot incorporate waste management.
15. I am willing to implement waste management during every stage of construction in future.
16. I am willing to incorporate, waste management at construction waste.

17. I think incorporation of waste management cost additional resources, manpower, time.

18. My coworkers are not used to manage waste at construction sites so as I

19. I am not aware of any government/municipal polices regarding waste management at construction site.

20. Mark only one oval.

21. I do not think site waste management plan can be practically enforced at construction sites.

Appendix-E

Part A

Onsite Construction Waste Management Performance Assessment Index

Basic information of the respondent involved in the survey

* Required

1. Email address *
2. Name *
3. Gender *
   - Male.
   - Female.
4. Age *
   - Below 20.
   - 20-29.
   - 30-39
   - 40-50.
   - Above 50.
5. Education back ground *
   - Below and equal to tenth.
   - Intermediate.
   - B.Tech.
   - M.Tech.
   - Above M.Tech.
6. Name of the company *
7. Designation *
   - Engineer
   - Contractor
   - Academic
   - Faculty

- Client
- Manager
- Labor

8. Years of experience in construction industry *

- 0-5 years.
- 6-10 years.
- 11-15 years.
- 16-20 Years.
- 20 Years.

Relative importance of construction waste management influence factors.

Part B

The following are the influence factors of construction waste. Select the best option between 1 to 7 in terms of affecting the construction waste. Where a score of "1" represents "No significant influence on decreasing wastes and increasing recycling" whereas "7" represents "the Strong influence on decreasing waste and increased recycling"

1. Contractor involvement in construction waste management
2. Client involvement in construction waste management *
3. Education of staff working on the construction site*
4. Training programs at the construction site *
5. Appointment of workers especially for separation of waste *
6. Supplier's involvement in construction waste collection *
7. A management team for managing construction waste *
8. Supervision and control of the amount of construction waste generated *
9. The practice of segregation maintenance of separate bins for construction waste segregation
10. Cleaning up the site on a daily basis *
11. Quantification of the amount of construction waste generated *
12. RRR (reduce, reuse, recycle) strategy *
13. Installation of information boards for segregation of construction waste *

14. Allocating separate space for material sorting at initial stages of construction *
15. Informing methods to deal with rest of construction waste after recycling *
16. Disposal of construction waste periodically by open dumping, incineration, etc *
17. Installation of recycling equipment at construction sites *
18. Installation of equipment for waste sorting *
19. Installation of mobile recycling plant at the construction site *
20. Usage of recycled material at the construction site *
21. Material transportation system for construction waste *
22. Separate documentation (records) on recycling waste *
23. Checklist on the execution of waste management plan *
24. Database management system or any software technology for construction waste (BIM, etc.)
25. Maintenance of record on training programs i.e. past, present and future schedules at construction sites *.
26. Changing of the design *.
27. Awareness of government policies on construction waste generated *.
28. Following government norms on dealing with construction waste *.
29. Incentive in binding for a contractor having a plan about decreasing waste and increasing recycling *
30. Establish criteria for the quality and safety of recycled materials *
31. Documentation of payment of taxes and penalties if the waste exceed permitted limits according to government policies *
32. Practice of making money out of waste i.e. selling etc *
33. Any new influence factor you want to suggest, please name it and give a score as above. *
34. Suggest any process for avoiding waste generated at the construction site. *
35. How do you manage construction waste at the site? *
36. Are you interested in selling up construction waste online? *
37. Are you interested in buying online construction and demolition waste? *

Publications related to the work

International Journals

1. KolaventiSS Tezeswi TP and Siva Kumar MVN. (2019). "An assessment of construction waste management in India: A statistical approach". In *Waste Management & Research*, 37(6), 1–16.DOI: 10.1177/0734242X19867754.

2. KolaventiSS Hikmatulla Momand Tezeswi TP Siva Kumar MVN (2020). "Construction waste in India: a structural equation model for identification of causes". In *Proceedings of the Institution of Civil Engineers– Engineering Sustainability*, DOI: 10.1680/jensu.19.00047

3. Kolaventi SS Hikmatullah Momand Tezeswi TP Siva Kumar MVN(2020) "Implementing Site Waste Management Plan And Recycling In Indian Construction Industry: Barriers, Benefits And Enforcement Measures" *Proceedings of the Institution of Civil Engineers– Engineering Sustainability*, DOI: 10.1680/jensu.21.00032.

National Conference

1. KolaventiSS Tezeswi TP and SivakumarMVN. (2017). A Modeling Approach to Construction Waste Management. IN: Proceedings of Urbanization Challenges in Emerging Economies.Cham:ASCE,11-20, Doi:10.1061/9780784482032.002.

Book Chapters

1. Kolaventi SS Tezeswi TP and Siva Kumar MVN (20121). An Index for Assessment of Onsite Waste Management Performance in Indian Construction Sites" In *Advances in Sustainable Materials and Resilient Infrastructure*, Springer nature.