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INSTITUTE OF ENGINEERING
PULCHOWK CAMPUS**

Thesis No.: 079/MSCoM/016

**“Identifying Key Factors and Formulating a Stakeholder-Informed
Framework for Construction Waste Minimization in Building
Projects of Kathmandu Valley”**

By

Neha Mishra

A THESIS

**SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING IN
PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER IN CONSTRUCTION MANAGEMENT**

**DEPARTMENT OF CIVIL ENGINEERING
LALITPUR, NEPAL**

NOVEMBER, 2025

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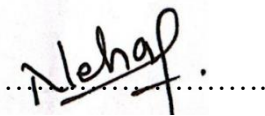
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DECLARATION

I hereby declare that the thesis entitled “**Identifying Key Factors and Formulating a Stakeholder-Informed Framework for Construction Waste Minimization in Building Projects of Kathmandu Valley**”, submitted to the Department of Civil Engineering in partial fulfillment of the requirement for the degree of Master of Science in Engineering in Construction Management, is a record of an original work done under the guidance of Er. Subash Kumar Bhatara. This thesis contains only work completed by me except for the consulted material, which has been duly referenced and acknowledged.

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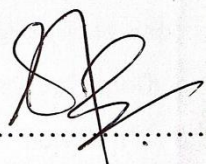
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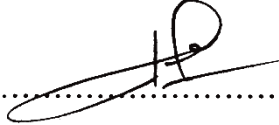
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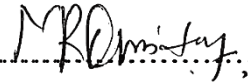

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ABSTRACT

This study investigates the root causes of waste in building projects and develops a stakeholder-informed framework for mitigation. First, the study established a foundational demographic profile of 70 industry professionals (Clients, Contractors, Consultants). It identified and categorized 46 key waste factors using PCA. The analysis distilled these into 11 critical thematic components, with Material Quality & Handling Deficiencies, Inefficient Site Management & Supervision, and Project & Contract Administration Issues emerging as the most significant latent causes, collectively explaining 74.36% of the variance. A comparative analysis of stakeholder perceptions using the RII and Kendall's Tau coefficient revealed both consensus and divergence. While all parties agreed on the high impact of factors like inadequate storage and inappropriate construction methods, perceptions varied by role: Contractors emphasized on-site execution issues, Consultants prioritized design and policy gaps, and Clients focused on managerial and financial controls. Hypothesis testing confirmed no statistically significant difference in rankings between stakeholders for most components, except regarding Project & Contract Administration Issues between Contractors and Consultants, highlighting a key area for improved dialogue. Triangulating quantitative survey data with expert KII validated these findings, confirming the robustness of the identified components. Synthesizing these insights, the study culminates in the development of a proactive, three-phase framework for construction waste management. The framework is built on a foundation of Governance & Stakeholder Alignment and spans: (1) Pre-Construction & Design (prevention), (2) Construction & Execution (minimization and control), and (3) Post-Construction & Closeout (management and improvement). This research provides a validated, actionable roadmap for industry practitioners in Kathmandu Valley. By addressing the root causes of waste through a lens of shared stakeholder responsibility, the proposed framework offers a practical pathway to enhance project efficiency, reduce environmental impact, and promote sustainable construction practices.

Keywords: Construction Waste Management, Principal Component Analysis (PCA), Stakeholder Perception, Relative Importance Index (RII), Kathmandu Valley, Sustainable Construction, Waste Minimization Framework.

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Neha Mishra

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LIST OF ABBREVIATIONS

GDP	Gross Domestic Product
CE	Circular Economy
NBC	Nepal Building Code
JIT	Just-In-Time
BIM	Building Information Modelling
IoT	Internet of Things
PCA	Principal Component Analysis
KII	Key Informant Interview
SPSS	Statistical Package for Social Sciences
AHP	Analytic Hierarchy Process
KMO	Kaiser-Meyer-Olkin
SEM	Structural Equation Modelling
QS	Questionnaire Survey
EFA	Exploratory Factor Analysis
RII	Relative Importance Index
FIFO	First-In-First-out
WMP	Waste Management Plan

CHAPTER 1: INTRODUCTION

1.1 Background

The construction sector serves as a pivotal pillar of economic advancement and national infrastructure, making substantial contributions to GDP growth, employment opportunities, and social development(Cucos & Turcan, 2025). Its role is particularly prominent in developing countries, where it may comprise up to 14% of the GDP and drives economic stability along with wealth generation through ongoing infrastructure investment(Cucos & Turcan, 2025). According to the Economic Survey of Nepal 2021/2022, the construction sector contributed 5.8% to the GDP of Nepal. emphasize that one of the key challenges facing the construction sector is the prevalence of non-value-adding activities and waste, which consume significant time and resources without contributing to the project's final objectives(Aftab et al., 2025). As a matter of fact, Construction activities are one of the major consumers of materials and are responsible for producing a considerable amount of the waste that ultimately affects the success of construction projects and wastes are ended up in landfills(Benfancy Kelechi Enobie et al., 2024). Findings from the study showed that at least one-fifth of construction materials went unused by the end of the project("MATERIAL WASTE IN CONSTRUCTION PROJECTS: CAUSES AND EFFECTS," 2023a).

Although numerous international efforts have been made in the past ten years to enhance sustainable practices and proper waste management in the construction industry(Alazmi et al., 2025), Nepal continues to face challenge in this sector. (Bhatta et al., n.d.). In developing nations, the construction industry's low sustainability performance can be linked to several critical factors, such as the substantial waste produced during construction activities, insufficient awareness among professionals about effective waste management practices, and the limited implementation of formal on-site waste management plans.(Alazmi et al., 2025). Similarly, Design, materials handling, transportation and storage are major contributory activities in generation of construction waste(Khaleel & Al-Zubaidy, 2018a). The case in Nepal is also not any different. The problem is further exacerbated by the absence of adequate construction waste management guidelines (Labra Cataldo et al., 2024). Although Nepal has a Solid Waste Management Act 2068 and Solid Waste Management Rules 2070, the rules and

regulations are outdated and there is a lack of effective legislation and regulatory capacity to manage construction and demolition waste properly (Maharjan et al., 2013). Overall, Nepal's construction industry lacks effective planning and, stakeholder coordination, enforcement of regulations, awareness of sustainable practices and its adoption, and adequate recycling or reuse systems, all of which hinder the minimization of construction waste (Khanal, n.d.).

This research is important as it provides a structured understanding of the key factors driving construction waste in building projects, with a focus on the Kathmandu Valley. By examining the perceptions of different stakeholders and highlighting areas of consensus and disagreement, the study clarifies how clients, consultants, and contractors perceive waste-related challenges. The results are expected to assist industry practitioners and policymakers in formulating effective, targeted strategies to minimize waste, enhance project efficiency, and promote sustainable practices. Furthermore, by integrating quantitative data with qualitative insights, the study addresses a gap in the existing literature and offers a framework to guide future research, informed decision-making, and the adoption of best practices in construction waste management.

1.2 Problem Statement

Globally, construction waste has emerged as a significant environmental challenge, with the sector contributing nearly one-third of total solid waste generated worldwide (Nagapan, Rahman, & Asmi, 2012) (Fitri et al., 2019). Rapid urbanization, infrastructure expansion, and inefficient material use have intensified waste generation, prompting many countries to adopt stringent regulations, recycling targets, and Circular Economy (CE) strategies. While developed nations have made notable progress through advanced technologies, strong policies, and resource-efficient construction practices, developing nations continue to struggle with rising volumes of construction waste and inadequate management systems (Fitri et al., 2019).

Construction waste has become a persistent and growing challenge in Nepal's building sector, particularly in the rapidly urbanizing Kathmandu Valley. The increasing scale of construction activities has led to significant volumes of material waste, resulting in project delays, cost overruns, and negative environmental impacts. Every time when buildings and civil-engineering structures are built, renovated or demolished a sizable

amount of Construction waste is generated(Dhungana et al., 2023) . Despite the scale of the problem, waste management practices within the industry remain largely informal, unstructured, and reactive. At present, most of this waste is managed informally or disposed of in an unplanned and environmentally harmful manner, such as open dumping, roadside accumulation, or illegal landfilling. The practice of dumping Construction in cities leads to river pollution, clogged surface drains, halted traffic, and an unsightly urban landscape (Shajidha & Mortula, 2025).

A major issue contributing to construction waste is the limited understanding of the underlying causes and the lack of reliable data regarding waste-generating factors specific to Nepal's construction context. Design, materials handling, transportation, and storage are major contributory activities in the generation of construction waste (C. Formoso et al., 2002). The case of Nepal is also not so different. Although previous studies conducted in other countries have identified several causes of construction waste, these findings cannot be directly applied to the Kathmandu Valley due to differences in project practices, labor skill levels, design processes, regulatory frameworks, and material handling systems. As a result, practitioners and policymakers lack localized evidence needed to develop context-specific solutions.

The problem is further exacerbated by the absence of adequate construction waste management guidelines(Labra Cataldo et al., 2024) . Although Nepal has a Solid Waste Management Act 2068 and Solid Waste Management Rules 2070, the rules and regulations are outdated, and there is a lack of effective legislation and, regulatory capacity to manage construction waste properly (Maharjan et al., 2013). Similarly, there is no any provision for construction waste management in Nepal Building Code (NBC) for building projects. Overall, Nepal's construction industry lacks effective planning and stakeholder coordination, enforcement of regulations, awareness of sustainable practices, and adequate recycling or reuse systems, all of which hinder the minimization of construction waste.

Furthermore, perceptions of waste-related issues often differ among key stakeholders' clients, contractors, and consultants each of whom experiences construction waste challenges from different perspectives. These divergent perceptions create gaps in communication, responsibility, and decision-making throughout project execution,

resulting in ineffective or fragmented waste management practices. Without understanding the similarities and differences in stakeholder viewpoints, efforts to minimize waste are unlikely to be coordinated or successful. This gap highlights the importance of assessing stakeholder perceptions to ensure that waste management strategies are comprehensive and inclusive.

Despite the recognized importance of effective waste management, there is currently no structured, stakeholder-informed framework tailored for construction projects in the Kathmandu Valley. Existing guidelines are either outdated, limited in scope, or not implemented consistently across the industry. Therefore, there is a critical need to develop a practical and context-appropriate framework that integrates stakeholder input, addresses the identified waste factors, and supports project teams in adopting more efficient and sustainable practices. This thesis seeks to address these gaps by identifying key waste factors, analyzing stakeholder perceptions, and proposing a comprehensive framework for improving construction waste management in Kathmandu Valley's building projects.

1.3 Objectives

The primary objective of this study is to Identify Key Factors and Formulating a Stakeholder-Informed Framework for Construction Waste Minimization in Building Projects of Kathmandu Valley. Whereas, the secondary objectives are as follows:

- To identify and categorize the key factors contributing to construction waste in building projects in Kathmandu Valley.
- To analyze the perceptions among stakeholders regarding the significance of the identified factors causing waste.
- To develop a stakeholder-informed framework for effective construction waste minimization in building projects.

1.4 Scope and Limitation

The study is limited to Kathmandu Valley, so the results may not represent other regions. Stakeholder participation may be uneven, affecting the balance of perceptions collected. Questionnaire-based responses may contain bias or inaccuracies due to self-reporting. Only previously identified factors were studied, so some relevant factors may be missing. The quantitative approach may overlook deeper contextual or behavioral insights. Limited time and resources restricted broader data collection and field validation. Expert-based factor grouping may include some subjective judgment. Rapid changes in construction practices mean findings may not remain fully applicable over time. The proposed framework is conceptual and not practically tested in real projects.

CHAPTER 2: LITERATURE REVIEW

2.1 Concept of Waste

Waste generation persistently leads to environmental problems and exacerbates global warming across the globe. Human activities generate waste, and the methods used to handle, store, collect, and dispose of it can create significant risks to both the environment and public health (Desa et al., 2011). Hence, the establishment of effective waste management rules and strategies is required to manage and minimize wastes. Before doing so, it is important to clarify the concept of “Waste” to provide a foundation and maintain consistency. Below definitions of waste are provided in table form by different authors. Thus, it suggests that there are two methods to minimize waste. One is to improve the efficiency of both value-adding and non-value-adding work, and the other is to eliminate waste by removing non-value-adding activities (Formoso et al., n.d.).

Table 1: Definitions of waste

S.N.	Definitions	Authors
1.	The Germany Waste Act states that waste is any products that have been left by the owner (s) or need to be disposed to protect the environment.	(Ramachandra, n.d.)
2.	Waste is the process and operational concept. The author also added that the definition of waste is resources used to produce a product but at the end has no value.	(Formoso et al., n.d.)
3.	Waste can also be defined as any final products which at the end do not worth to the owner and the owner sees it as a waste.	(Rajendran & Pathrose Gomez, 2012)
4.	Waste is unwanted products or materials.	(Nagapan, Rahman, & Asmi, 2012)
5.	Waste as any human activity that absorbs resources but creates no value, such as mistakes that require	(Womack & Jones, 1996)

	rectification, production of items no one wants, process steps that are not needed, unnecessary movement of employees, and people waiting for the conclusion of upstream activities	
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2.2 Construction Waste

This section presents a review definition of construction waste, the classification of construction waste, and followed by causes of construction waste generation. Experts in the construction industry have been widely discussing about construction waste, for long decades, emphasizing particularly to material waste. Construction waste is defined as “residual material that cannot be used physically or functionally and has a negative impact on the environment (Hadiningrias et al., 2024a). There is a clear linkage between the number of debris removed from the project site and the waste generated during various construction activities (C. Formoso et al., 2002). Researchers have quantified construction waste as the “difference between the materials delivered and approved on-site and those properly used and precisely measured in the executed work (L. Pheng & S. Tan, 1998).

There is generally no accepted definition of construction waste. One common definition of construction waste, as issued by the European Council Directive 91/156/EEC, is “any substance or object which the holder discards or intends or is required to discard” (Directive 91/156/EEC (Osmani, 2012), Article 1, Letter a). This definition applies to all waste irrespective of whether or not it is destined for disposal or recovery operations. However, Skoyles and Skoyles (Skoyles, 1987) defined construction waste as a material “which needed to be transported elsewhere from the construction site or used on the site itself other than the intended specific purpose of the project due to damage, excess or non-use or which cannot be used due to non-compliance with the specifications, or which is a by-product of the construction process” (Tseng & Ming-Lang, 2011). Similarly, the adopted definition of construction waste minimization for this research is “the reduction of waste at source, (i.e. designing out waste) by understanding its root causes and re-engineering current processes and practices to alleviate its generation.

Construction waste is also defined as any “form of inefficiency that leads to the consumption of labor, materials, equipment, or capital in amounts exceeding what is considered necessary for building production” (Chellappa et al., 2023). Conversely, various studies have highlighted that construction waste arises from factors such as expenses related to quality inspections, lack of safety measures, project delays in both progress and completion, rework, transportation and travel time inefficiencies, long distances, adoption of unsuitable management strategies or equipment, and substandard project quality (“MATERIAL WASTE IN CONSTRUCTION PROJECTS: CAUSES AND EFFECTS,” 2023b).

Katz and Baum (Katz & Baum, 2011a) states that the structural phase of the project lifecycle, particularly the initial stage of construction work, generates more waste compared to later stages. In work studies conducted on seven different sites revealed that labourers dedicate about 46% of their time to value-adding activities, while the larger portion is spent on non-value-adding tasks (Christian & Hachey, 1995). Further investigations reported even more critical findings, indicating that only 3% to 20% of the steps generate actual value, representing merely 0.5% to 5% of the overall cycle time (Khaleel & Al-Zubaidy, 2018b). Furthermore, construction waste consists of materials generated during the process and the completion of unnecessary work, which increases the cost of the project without adding any value. Achieving significant improvements in operational processes requires a clear understanding of the concept of construction waste, its categorization and its sources.

2.3 Phases of Construction Waste

Waste from construction is considered high volume when compared with other types of waste, and causes environmental and social problems. The composition of construction waste is often different because it depends on the construction techniques, building types, environment, and other factors. Construction techniques and varying building technologies cause difficulties in determining the type of waste from construction activities. However, there is an ongoing effort to determine the type or classification of construction waste. Katz and Baum (Katz & Baum, 2011b) indicated that the construction work could be divided into three periods according to the nature of waste from the construction such as the structural frame, the early finishing works, and the late finishing works as shown in figure below. The study found the relationship

between the amount of construction waste and the construction period. The amount of waste generated during structural frame construction was less than other periods (Luangcharoenrat et al., 2019).

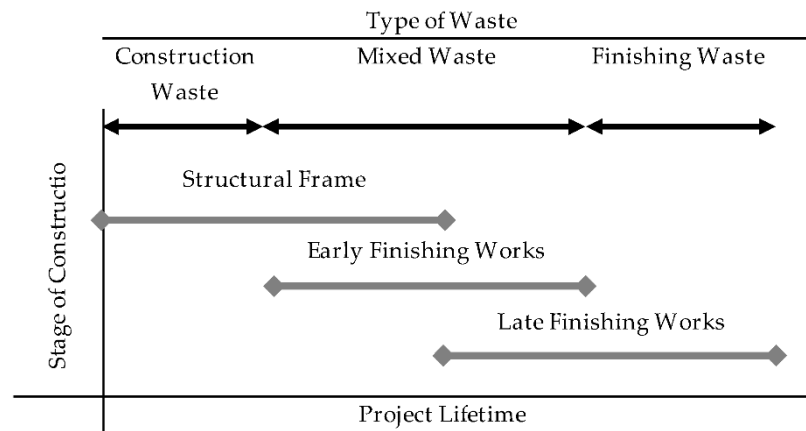


Figure 1: Construction Process and Waste Type

Source: Adapted and modified from Katz and Baum

2.4 Classification of Construction Waste

Construction waste can be classified into two major different categories, namely physical waste and non-physical waste (Hadiningrias et al., 2024b).

2.4.1 Physical Waste

Physical construction waste refers to the waste generated during construction, renovation, and demolition works, encompassing activities such as land excavation or formation, civil and structural construction, site clearance, roadworks, and building refurbishment or demolition (Nagapan, Abdul Rahman, et al., 2012). In simpler terms, physical waste refers to the visible debris present on any construction site, resulting from the depletion of construction materials that become either permanently damaged or lost during the process (Khaleel & Al-Zubaidy, 2018b). Physical waste on construction sites can be categorized into two main types: Natural material waste, which comes directly from raw natural resources without undergoing fabrication processes, such as sand and wood; and fabricated material waste, which results from processed or manufactured materials, including steel bars, steel profiles, concrete, bricks, ceramics, gypsum boards, and glass (Hadiningrias et al., 2024b). The wastage generated during

the construction processes are usually removed from the construction site and dumped for landfilling.

2.4.2 Non- Physical Waste

In contrast, time and cost overruns represent the primary types of non-physical waste commonly arising during the construction process(Nagapan, Abdul Rahman, et al., 2012). Time waste includes factors such as waiting periods, work stoppages, delays in execution, obtaining permits, rework, and performing unnecessary tasks. Cost overrun, also known as "cost increase" or "budget overrun," on the other hand, refers to unforeseen expenses that beyond the allocated sums(Sundarrajan et al., 2008). Numerous academics have noted that material waste creation may result from both time and financial waste (Khaleel & Al-Zubaidy, 2018b). Addressing non-physical construction waste is just as important as managing physical waste. By controlling non-physical waste, construction firms can achieve better cost-effectiveness, reduce unnecessary delays, and contribute to more sustainable and resource-efficient construction practices.

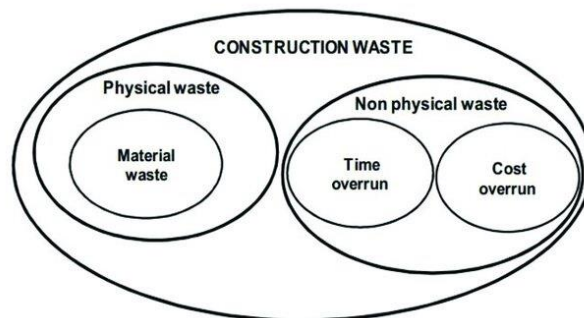


Figure 2: Classification of Construction Waste

Source: Data Adapted from (Khaleel & Al-Zubaidy, 2018)

2.5 Construction Waste in Regional Context

Construction waste has emerged as an emerging challenge in developing countries due to rapid urbanization, poor resource management, and inefficient construction practices. The generation of waste is influenced by project characteristics (size, location, and activities), stakeholder behavior, site management, and environmental conditions(Chellappa et al., 2023). Understanding these factors through previous empirical studies is essential for developing effective waste minimization strategies and enhancing sustainability performance in construction projects. Studies from different

countries such as India, Pakistan, and Jordan provide valuable insight into the diverse yet recurring causes of construction waste across developing regions.

In India, construction waste is primarily driven by a mix of design-related, managerial, and human behavioral factors. The study by (Chellappa et al., 2023) identifies frequent design changes, poor worker behavior, improper planning, weak supervision, and inadequate coordination among project stakeholders as the most critical contributors to material waste generation. Their analysis classifies 36 factors into six major groups: design and drawing, procurement and handling, construction methods and planning, human resources, site conditions, and external factors revealing the multidimensional nature of waste in the Indian construction sector. Improper handling of materials, rework due to errors, and inconsistent implementation of waste management practices further intensify the problem(Chellappa et al., 2023).

Similarly, studies from Pakistan report that construction waste is commonly caused by lack of awareness, inadequate worker training, long project durations, and poor workmanship, which lead to inefficiencies on construction sites. The research also highlights issues such as material price fluctuations, inaccurate estimates, and weak monitoring, all of which contribute to increased wastage. These findings reflect broader structural challenges in Pakistan's construction industry, including poor communication, limited coordination between teams, and insufficient adoption of modern construction practices. Human-related factors such as negligence and lack of skills play a major role, underscoring the critical need for capacity building and improved supervision (Aftab et al., 2025).

Research from Jordan provides further evidence of systematic inefficiencies contributing to waste. The Jordanian study identifies rework, design errors, poor site practices, inadequate supervision, and lack of waste management planning as significant contributors to material waste. In many cases, poor coordination among project stakeholders and limited compliance with construction standards exacerbate waste levels. The absence of structured waste management systems and monitoring mechanisms further weakens efforts to control waste generation in Jordanian construction projects (“MATERIAL WASTE IN CONSTRUCTION PROJECTS: CAUSES AND EFFECTS,” 2023a).

Additional insights from studies in Iraq and Egypt further broaden the understanding of construction waste causes in developing countries. Both studies highlight that ineffective site management, poor supervision, improper storage, and low-skilled workers are recurring challenges contributing to waste. These findings align closely with patterns observed in other developing nations, emphasizing that construction waste is strongly linked to managerial inefficiencies, inadequate planning, and poor resource handling rather than purely technical issues. The major factors identified from literature review are:

Table 2: Factors Identified from Existing Literature

Factors	Derived From
Frequent design changes/ rework caused by design changes	(Chellappa et al.,2023, Al-Btoosh et.al.,2023, Aftaab et. al., 2025)
Design errors	(Chellappa et al.,2023)
Lack of design information	(Chellappa et al.,2023)
Complicated design	(Chellappa et al.,2023, Aftaab et. al., 2025)
Poor design quality	(Chellappa et al.,2023)
Poor product knowledge	(Aftaab et. al., 2025)
Construction drawing errors	(Chellappa et al.,2023)
Inadequate or improper storage / inventory away from site	(Chellappa et al.,2023, Aftaab et. al., 2025)
Poor material and equipment handling	(Chellappa et al.,2023, Aftaab et. al., 2025)
Accidents	(Chellappa et al.,2023)
Damage during transportation	(Chellappa et al.,2023, Al-Btoosh et.al.,2023)
Poor quality of materials	(Chellappa et al.,2023)

Ordering errors/over-ordering/ mistakes in quantity survey	(Chellappa et al.,2023, Al-Btoosh et.al., 2023)
Errors in packing and shipping	(Chellappa et al.,2023)
Defective items	(Chellappa et al.,2023)
Damaged materials	(Chellappa et al.,2023)
Poor planning and scheduling	(Chellappa et al.,2023)
Poor controlling and supervision/ lack of management	(Chellappa et al.,2023, Aftaab et. al., 2025)
Inappropriate construction method	(Chellappa et al.,2023)
Poor co-ordination among parties	(Chellappa et al.,2023)
Misuse or non-availability of tools or equipment	(Chellappa et al.,2023., Aftaab et. al., 2025)
Rework due to poor workmanship	(Chellappa et al.,2023, Aftaab et. al., 2025)
Material misuse	(Chellappa et al.,2023)
Poor team selection	(Chellappa et al.,2023)
Lack of waste minimization /waste management plan	(Chellappa et al.,2023, Aftaab et. al., 2025)
Designer inexperience	(Chellappa et al.,2023)
Incompetent worker/improper worker's skill	(Chellappa et al.,2023, Aftaab et. al., 2025)
Poor attitude & behavior of worker's	(Chellappa et al.,2023)
Lack of incentives	(Aftaab et. al., 2025)
Lack of training and awareness	(Aftaab et. al., 2025)
Lack of supplier involvement	(Chellappa et al.,2023)

Leftover materials on site	(Chellappa et al.,2023)
Poor site condition	(Chellappa et al.,2023)
Site congestion	(Chellappa et al.,2023)
Lightning problem	(Chellappa et al.,2023)
Theft and vandalism	(Chellappa et al.,2023, Aftaab et. al., 2025)
Unpredictable local conditions	(Chellappa et al.,2023)
Error in contract document/poor documentation/lack of documentation	(Aftaab et. al., 2025)
Delay in cash flow/irregular payments	(Aftaab et. al., 2025)
Long project duration leading to change in material price	(Aftaab et. al., 2025)
Poor co-ordination and communication between parties	(Aftaab et. al., 2025)
Waiting resulting from crew interference	(Al-Btoosh et.al)
Inefficient consumption of resources	(Al-Btoosh et.al.,2023)
Waiting due to equipment setup and sharing	(Al-Btoosh et.al)
Composite and building design	(Chellappa et al.,2023)
Waiting due to storage problem and material supplier delay	(Chellappa et al.,2023)

2.6 Construction Waste Minimization and Management Techniques

2.6.1 Waste Prevention and Minimization

Effective construction waste management starts with preventing and minimizing waste at the source, which is the most efficient approach. Reducing waste where it is generated lowers the amount that needs to be handled, recycled, or disposed of later. Careful design and planning play a key role in this process. Architects and engineers can help minimize waste by using standard material dimensions to avoid unnecessary off-cuts, incorporating prefabricated elements to reduce on-site waste, and selecting materials that produce less waste during installation (Ajayi & Oyedele, 2018). Designing buildings for easy dismantling also supports future reuse and recycling of materials (Bertino et al., 2021). The beauty of source reduction lies in waste reduction and the conservation of resources, cost-effectiveness, and a diminished environmental footprint reverberating throughout construction projects.

2.6.2 Lean Philosophy

Another important approach is using Just-In-Time (JIT) delivery, where materials arrive on site only when they are needed. This helps prevent damage and waste caused by storing materials for too long. Proper inventory control and accurate material ordering also reduce the chances of over-purchasing, which is a common cause of waste (Dharmadhikari & Payghan, 2022). Waste prevention measures can be applied more effectively during construction (Liu et al., 2020). PDCA is a continuous improvement cycle that involves planning an action, implementing it, checking the results, and acting to refine or improve the process (Patel & Deshpande, n.d.). Continuous improvement plays a central role by promoting a culture of ongoing refinement, enabling construction teams to detect and eliminate inefficiencies and reduce waste throughout their operations. In addition, educating and training workers and site managers is crucial. When workers understand the importance of reducing waste and follow proper practices (Benfancy Kelechi Enobie et al., 2024)



Figure 3: PDCA Cycle

2.6.3 Sustainable Construction Practices

Adopting sustainable construction practices is an essential strategy for reducing waste and managing resources efficiently. This approach focuses on selecting materials and techniques that minimize environmental impacts throughout the entire building life cycle from initial construction to eventual demolition. A key component of sustainable construction is the use of green building materials. Such materials are derived from renewable sources, produce fewer environmental emissions, and can often be reused or recycled once their service life ends (Benfancy Kelechi Enobie et al., 2024).

2.6.4 Technology Integration

Modern technologies are reshaping how waste is managed in the construction sector, making the process more streamlined and productive. Among these innovations, Building Information Modeling (BIM) and the Internet of Things (IoT) play a major role in minimizing waste. BIM functions as a digital model that captures both the physical and operational aspects of a structure. It enhances planning and material management at every project stage. With BIM, waste can be reduced through more precise material estimation, improved design coordination, and better project oversight. Additionally, BIM supports material reuse and recycling by offering comprehensive details about the types and quantities of materials incorporated into a building. Advanced sorting technologies can improve the efficiency and accuracy of waste segregation and thus increasing recycling rates (Farjana et al., 2023).

2.6.5 Role of Stakeholders in Minimizing Waste

Stakeholders play a vital role in ensuring effective waste management. Each group contractors, government bodies, suppliers, and clients have specific responsibilities.

Contractors need to follow best practices and adhere to waste-related guidelines, while government agencies are responsible for enforcing these rules and offering support through policies, incentives, and resources. Suppliers help by offering eco-friendly materials and products, and clients can promote sustainability by demanding greener approaches in their project specifications (Benfancy Kelechi Enobie et al., 2024).

2.6.6 Waste Management

Effective end-phase waste management at site such as systematic waste sorting, stock clearance, documentation of surplus materials, and conducting waste audits—enable contractors and clients to reduce disposal loads and promote sustainable resource recovery. Studies show that post-construction waste segregation and recycling significantly improve the efficiency of waste-management systems and contribute to circular-economy outcomes by maximizing material recovery and minimizing landfill dependency (Papamichael et al., 2023). Research from China further emphasizes that structured post-construction practices, such as proper segregation, recycling programs, construction permits with waste management plan, technology integration, and clear contractor responsibilities, directly influence the sustainability performance of construction projects (Wu et al., 2025). Similarly, evidence from New Zealand highlights the importance of including waste clauses in contracts conducting final waste audits, and ensuring responsible handover of surplus materials to support environmental compliance and continuous improvement (Gade et al., 2025). Taken together, the literature indicates that end-phase waste-management measures are essential for achieving long-term sustainability in construction projects and ensuring that materials are used efficiently throughout the project life cycle. The European Union promotes a strong framework for construction waste management built around the waste hierarchy, which prioritizes reduction, reuse, recycling, and recovery before considering disposal. EU practices emphasize proper on-site waste segregation to improve recycling quality

and reduce contamination. Construction projects are also required or encouraged to prepare detailed Site Waste Management Plans.

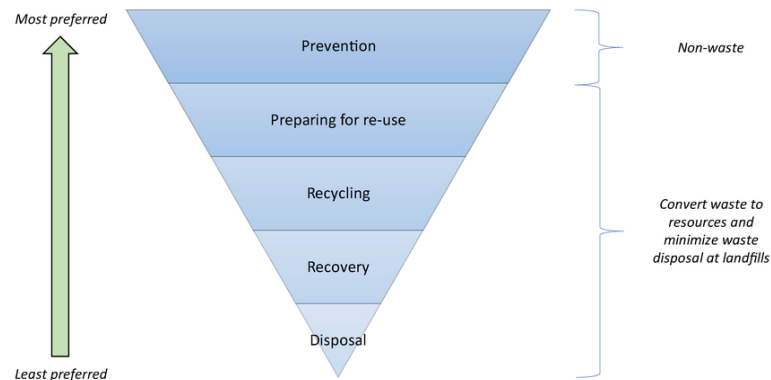


Figure 4: The Five-Step 'Waste Hierarchy' of the European Union;

source: Data Adapted from (Li et al., 2023)

2.7 Policy and Institutional Framework (Implementation Strategies)

A strong regulatory and policy framework is essential for achieving effective construction waste management. These regulations play a key role in establishing standards, ensuring compliance, and encouraging practices that minimize and properly manage waste. Around the world, several policies have been introduced to address the environmental effects of construction waste and to promote more sustainable approaches. Internationally, numerous guidelines support sustainable waste management. A notable example is the European Union's Waste Framework Directive, which forms the basis of waste-related policies across EU countries. The Directive highlights the waste hierarchy giving priority to prevention, reuse, recycling, and recovery before disposal and requires member states to prepare waste management plans and prevention strategies (Benfancy Kelechi Enobie et al., 2024).

CHAPTER 3: METHODOLOGY

This chapter provides a comprehensive overview of the research method followed to achieve the research objectives. Research methodology, research design, study area, population size, sample size calculation, statistical tools and tests, data collecting techniques, data analysis, and research matrix are the subjects covered in this chapter. Figure 5 provides a visual representation of the procedures used to carry out the study approach.

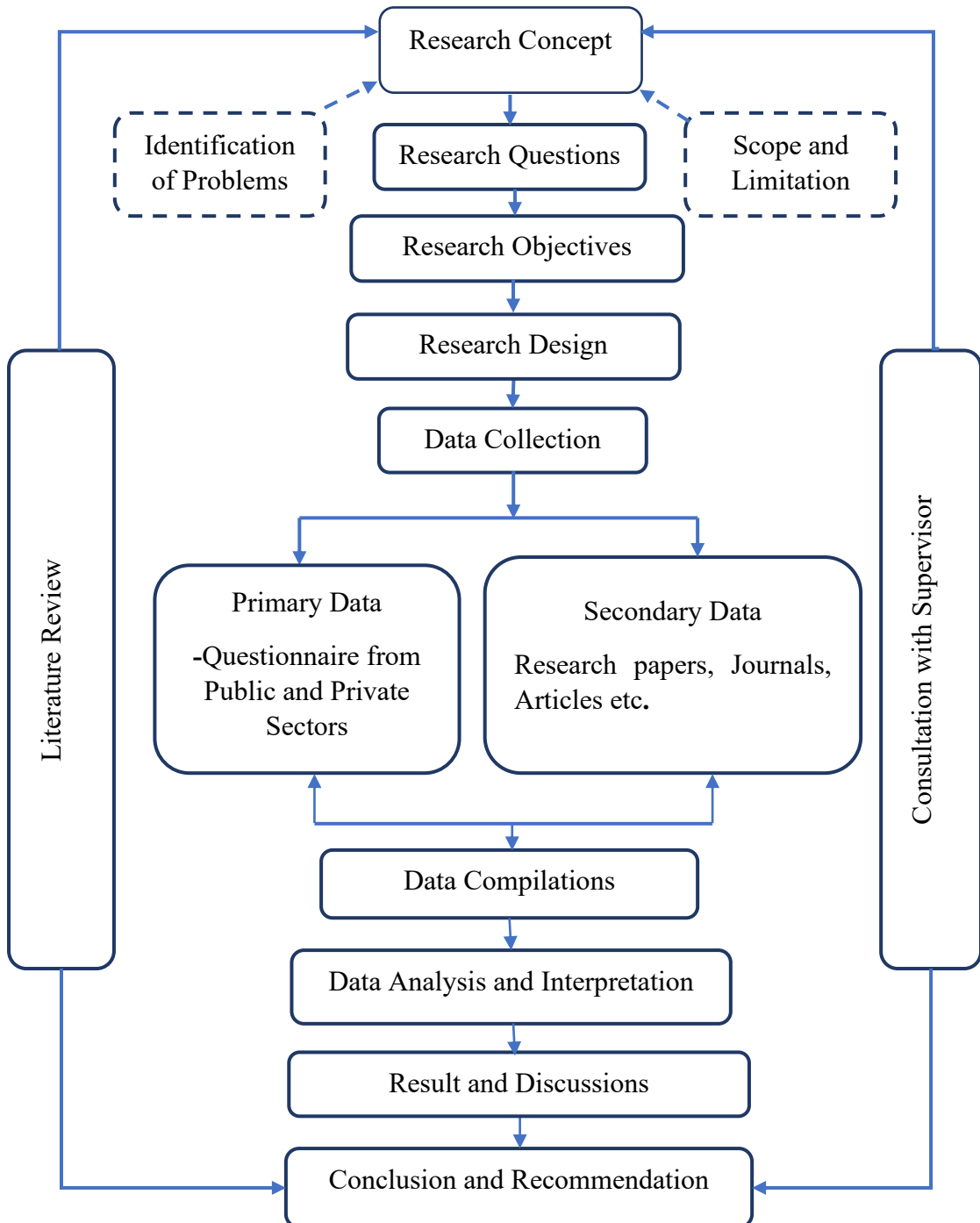
First and foremost, relevant literature regarding waste in construction were studied to understand the detailed overview of the study topic and also to get the ideas about the previous research conducted in the related field. The selected research questions made it necessary to do research on factors causing construction waste in the construction industry. To cover an extensive amount of the information regarding the topic of this study, technical reports, national and international journals, and theses were studied as a part of the literature.

3.1 Research Methodology

The research methodology follows a structured approach. The first step before starting the actual research process was to identify the research concept, based on the identification of problems which then highlighted the need for this research. The objectives for this research were set, which defined the study's scope and purpose. The research objective was based on the research question. In the next step, conceptual framework was developed that served as road map that specifies the methods and procedures for collecting and analyzing data to produce the best outcome that can address the research problem. For this, study on various literature and articles related to waste causing factors in building projects were reviewed, including published and unpublished sources. The research study utilized a questionnaire survey to collect primary data. The data obtained from stakeholders through the questionnaire survey and from secondary sources were then compiled, further analyzed and interpreted to meet the research objectives and get meaningful result. The findings are presented and validated through key informants so that result obtained are accurate, practical, and aligned with real industry conditions. The study ends with conclusions and recommendations that highlight the main lessons learnt and offer ideas for further

research or real-world applications. The literature study was done in all the phases and it served as a theoretical foundation for the process, and the consultation with the stakeholder or expert input guaranteed the quality and usefulness of the research.

Figure 5: Research Methodology



3.2 Research Design

Research design is the blueprint for conducting the study. It is a strategy developed to address the research question. It involves developing a research path by identifying the major variables (factors) defining the population, and selecting the sampling methods. The study utilized a mixed-method research design, wherein quantitative data were gathered through a structured questionnaire survey, and qualitative data were obtained via semi-structured interviews with experts to triangulate and corroborate the quantitative evidence.

3.2.1 Conceptual Framework

A conceptual framework visually illustrates the relationships among the variables in a study. After the variables are identified, the framework helps examine the cause & effect connections between them. It highlights the main research objectives and shows how they integrate to produce meaningful results. Developing a conceptual framework prior to data collection is essential because it serves as a roadmap, guiding the researcher on what information must be gathered to achieve the intended outcomes. Below given figure visually demonstrates the conceptual framework used in this study.

This conceptual framework illustrates the overall process undertaken in this study to identify, categorize, rank, and validate the factors causing construction waste in building construction projects. The framework begins by focusing on building construction projects, from which the issue of construction waste generation is recognized as a major challenge. To address this, two key inputs were used: factors were identified through an extensive literature review which was then contextualized from expert views. These combined inputs helped establish a comprehensive list of factors contributing to construction waste.

The next stage involved for the objective number 1 of this research involved categorizing the identified factors into thematic components using Principal Component Analysis (PCA). PCA helped in grouping related factors into meaningful clusters, ensuring a more structured understanding of waste causes. For this, data were collected from stakeholders (clients, contractors, and consultants).

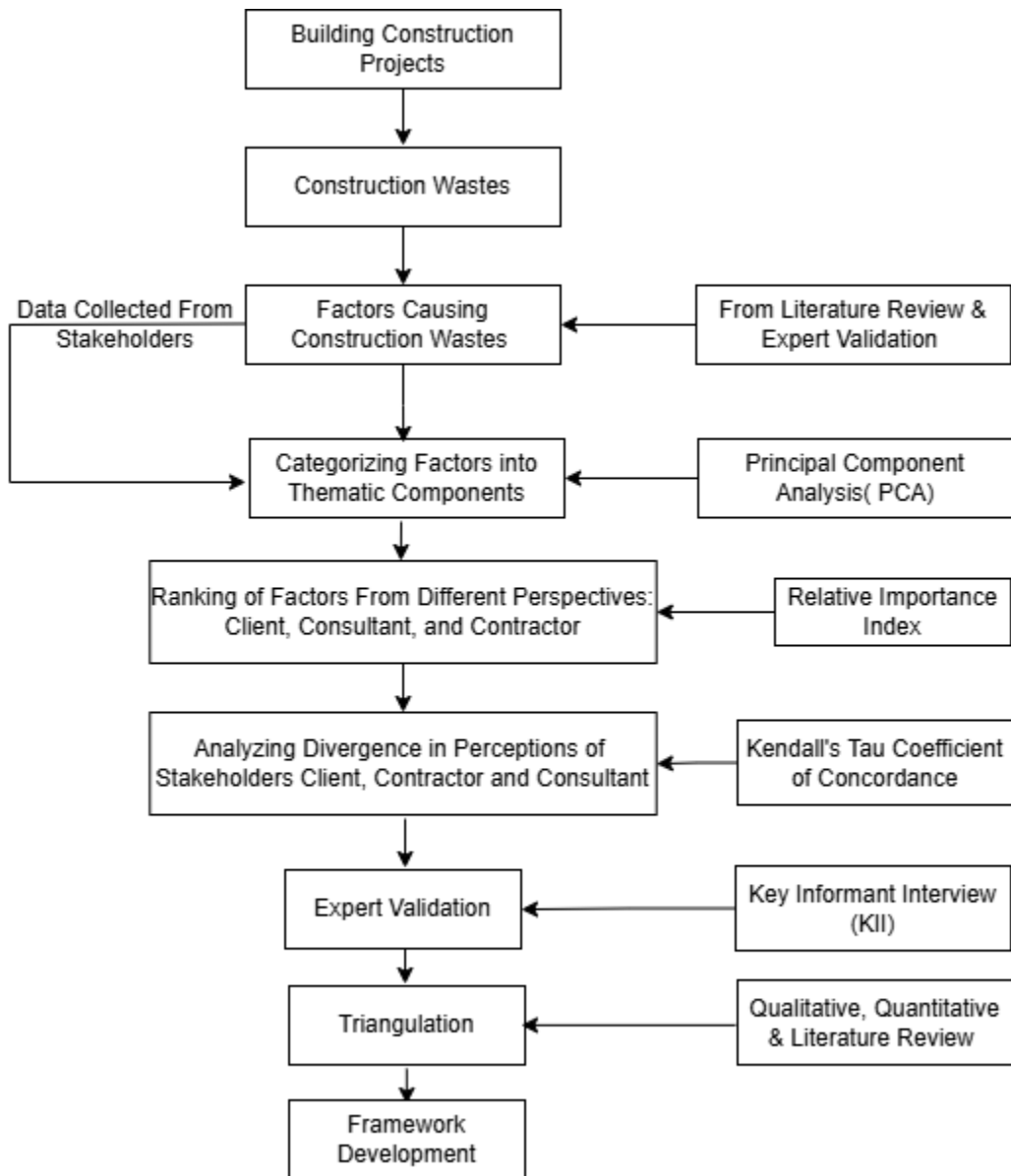


Figure 6: Conceptual Framework

For objective number 2, the study proceeded to rank the factors of thematic components from the perspective of the three stakeholder groups. This ranking was carried out using the Relative Importance Index (RII) to determine which factors were perceived as most critical by clients, consultants, contractors and their combined ranking in those themes. After ranking, the factors there is a need to understand whether perceptions varied significantly among stakeholder groups. To achieve this, the hypothesis testing in stakeholder views was analyzed using Kendall’s Tau Coefficient of Concordance. This statistical test measured the degree of agreement among clients, contractors, and consultants regarding the severity of waste-causing factors.

For objective number 3, to ensure the reliability and practical relevance of the findings, the next step involved expert validation. This was conducted through Key Informant Interviews (KII), which allowed experts to review and confirm the accuracy and applicability of the grouped factors, rankings, and interpretations. Following expert validation, the study employs Triangulation integrating quantitative findings, qualitative insights (via Key Informant Interviews), backed by literature review evidence. This triangulation strengthens the credibility and validity of the results by cross-verifying findings from multiple methods and data sources.

Finally, based on the validated results, the study proceeded to develop a comprehensive framework for effective construction waste minimization in building projects. This final framework integrates stakeholder perceptions, categorized components, ranked factors, and expert feedback to propose a structured and evidence-based approach to minimizing construction waste in the context of Nepal.

3.2.2 Questionnaire for Data Collection

The research mainly involved mixed-method approach for data collection. For that, the questionnaire was prepared based on the objective to be achieved. The questionnaire addressed the first two objectives of the research: To identify and categorize the key factors contributing to construction waste in building projects in Kathmandu Valley and to analyze the perceptions among stakeholders regarding the significance of the identified thematic components. For analyzing the causes of construction waste generation, the contributing factors were derived from literature: **“Factors influencing construction waste generation: perspectives from India (Chellappa et al., 2023)”**, **Material Waste In Construction Projects: Causes and Effects (“MATERIAL WASTE IN CONSTRUCTION PROJECTS: CAUSES AND EFFECTS,” 2023b)”**, **Deconstructing construction wastes: Exploring waste generation causes and their impact on project performances(Aftab et al., 2025)** . For the objective 2; same questionnaire is used for further ranking of factors. For the validation of these questionnaires, three experts: one from the contractor side, one from the consultant side, and one from the client side with more than 10 years of experience in the building construction sector were chosen and expert views were kept in which few of the variables were excluded and one factor was added according to view of expert. For objective 3, expert validation was carried out through key informant interviews with

key industry professionals. Accordingly, a semi-structured questionnaire was formulated to obtain the necessary insights.

3.2.3 Study Population and Sample Size

For the data collection using a questionnaire survey, the population referred to the stakeholders in the building construction sector. It included professionals from all three parties: client, contractor, and consultant in selected private and public building construction sector in the Kathmandu Valley. The study area were two metropolitan cities, Kathmandu and Lalitpur and one sub-metropolitan city, Bhaktapur. To prevent biases in the data-collecting process, random sampling was used.

Using Cochran’s formula, the sample size was determined as follows:

$$n_0 = z^2 pq / e^2 \text{----- (i)}$$

Where,

n_0 is the sample size,

z is the z-score corresponding to the desired confidence level,

p is the estimated proportion of the population,

$q = 1 - p$,

e is the margin of error.

Assuming the population size is infinite,

From equation (i),

$$n_0 = z^2 pq / e^2$$

Calculation:

Here for 90% confidence level;

$z = 1.64$; $e = 0.1$ and $p = 0.5$, $q = 0.5$

$$n_0 = \frac{1.64 * 1.64 * 0.5 * 0.5}{0.1 * 0.1}$$

$$= 67.24; \text{ i.e. } 68 \text{ numbers}$$

Therefore, the sample size was taken as 68 as per calculation.

3.3 Data Collection

3.3.1 Primary Data Collection

Primary data refers to the first-hand information that is collected by the researcher himself/herself. Primary data were collected through two main methods: a structured questionnaire survey and key informant interviews, targeting stakeholders such as clients, consultants, and contractors from building sector in construction projects in Kathmandu Valley.

Questionnaire Survey:

In this research, the primary data for analysis was collected through a questionnaire survey. The questionnaire was prepared on a Web-based platform using “Kobo-Toolbox”. The questionnaire had two sections: Sections 1 and 2. The respondents’ backgrounds, including their job titles, construction sector experience, and the kind of project they worked on, are shown in Section 1. These were all nominal scale data. Questions about the knowledge of the factors causing waste were addressed in Section 2. For Section 2 the questions used a five-point Likert scale, with 1 denoting "very minor", 2 "minor", 3 "moderate", 4 "major" and 5 "very major". The participants were requested to provide their opinions in the form of ratings. Before proceeding to the actual data collection, a pilot survey was done by taking responses from 15 respondents. The questionnaire was distributed to over 100 purposively selected respondents. Online platforms significantly reduce costs and time, while enabling rapid access to a wide audience with shared interests, including groups that are otherwise difficult to reach (Wright, 2017). KoboToolbox was used to re-create the questionnaire, and the link was sent to the selected stakeholders through social media groups such as WhatsApp, messenger, and e-mail addresses of some of the earlier identified participants across the zone. 70 valid responses received in a given timeframe in 2025. The survey was conducted in-person and via email to ensure accessibility. After analyzing their responses and making the necessary changes, the questionnaire was deployed again for the final data collection.

Key Informant Interviews (KIIs):

To gain deeper insights about construction waste, its factors and solutions to the major factors, semi-structured interviews were conducted with three key informants: public sector, private sector and an academician. The interviews explored four thematic areas:

professional background, ranking of the identified factors according to expert, reasons behind its causes, and recommendations for improvement. Each interview lasted approximately 45–60 minutes and was conducted in-person, with responses recorded and transcribed for thematic analysis. The selection of informants was purposive, ensuring diverse perspectives from stakeholders with significant experience in Kathmandu Valley's construction projects.

3.3.2 Secondary Data Collection

Secondary data refers to the information that is collected using the secondary sources i.e., the information based on other researcher's study. These data are collected by someone else rather than the researcher himself/herself to complement primary data and provide contextual insights into major factors causing construction wastes in building projects. These data were sourced from a comprehensive review of relevant literature including, NBC, Solid Waste Management Act, Solid Waste Management Rules, academic theses from national and international universities, peer-reviewed journal articles, websites, magazines, records, newspaper reports on construction waste in Nepal.

3.4 Data Analysis

Once the required number of responses were received, firstly, the data was pre-processed for the further analysis. The cleaned data was imported in the SPSS software to perform statistical analysis. Microsoft Excel and Statistical Package for Social Science (SPSS) was used to analyze, summarize, and tabulate the collected data. Various descriptive and inferential statistics have been used to visualize and understand the data. The analytical tools employed included the Principal Component Analysis, Relative Importance Index (RII), and Kendall's Tau Correlation, performed using SPSS and data were calculated using MS-Excel.

3.4.1 Descriptive Statistics

It provides the description of the sample and the observed data. It provides a description of the data without drawing conclusions about the larger population. The description provided may be quantitative or visual. Quantitative description involves the mainly two measures: Measures of Central Tendency and Measures of Dispersion. For the easier interpretation of data, they are expressed in percentages. Those percentages are implemented for expressing the findings as a proportion of the whole. For easy

understanding, these findings are expressed in the form of charts and tables for visual description. Measures of central tendency include data like mean, median, and mode, while measures of dispersion include data like standard deviation, variance, range, interquartile range, etc. Descriptive statistics also involve tabular data, which include frequency tables and contingency tables. In this study, descriptive statistics were used to analyze the questionnaires from all two sections.

Relative Importance Index (RII):

It was employed to rank the importance of waste factors based on Likert-scale responses from client, contractor and consultant. RII converts responses into a normalized index (0 to 1), facilitating the prioritization of factors (Holt, 2014).

Rationale for Selection: RII was selected for its simplicity, ability to normalize data for comparability, and effectiveness in ranking factors based on stakeholder perceptions. It provided a clear, quantitative measure of importance, which is valuable for practical recommendations in the construction industry. Comparison with Alternatives: Other ranking methods, such as the Analytic Hierarchy Process (AHP) or Weighted Mean, were evaluated but not adopted. AHP's pairwise comparisons were too complex for a large-scale survey, and the Weighted Mean lacks normalization, limiting comparability. It is suitable as RII's straightforward approach and established use in construction (Doloi et al., 2012).

3.4.2 Inferential Statistics

Inferential statistics describes the data from the sample and draws conclusions about the larger population. After that, based on the sample derived from the population, a hypothesis is created, and different statistical tools are used to test the formulated hypothesis. Some of the statistical tools used in this research are described below:

Kaiser-Meyer-Olkin (KMO) & Bartlett's Test of Sphericity:

The suitability of the assessed variable to factor analysis was determined by consideration of the sample size, the number of variables, Kaiser–Meyer–Olkin (KMO), Bartlett test of sphericity and commonalities. The Kaiser-Meyer-Olkin (KMO) statistic is used to measure sampling adequacy (Ramachandra & Rotimi, 2015). Thus, small values of the KMO statistic indicate that the correlations between pairs of variables cannot be explained by other variables and that factor analysis may not be

appropriate. Generally, a KMO of more than 0.50 is considered large enough to proceed with factor analysis (Gaur & Gaur, n.d.). Table 5 explains how different ranges of KMO (Kaiser–Meyer–Olkin) values are interpreted, showing that values above 0.90 indicate superb sampling adequacy, while values below 0.50 are considered unacceptable for factor analysis.

Table 3: Level of Acceptance of the Kaiser-Meyer-Olkin (KMO) Value.

KMO Value	Level of Acceptance
Above 0.90	superb
0.80 to 0.90	Great
0.70 to 0.80	Good
0.50 to 0.70	Mediocre
Below 0.50	Unacceptable

Source: Data Adapted from (Habidin et al., 2015)

Bartlett’s Test of Sphericity for Hypothesis Testing:

Null hypothesis (H0): The variables are orthogonal i.e. The original correlation matrix is an identity matrix indicating that the variables are unrelated and therefore unsuitable for structure detection.

Alternative hypothesis (H1): The variables are not orthogonal i.e. they are correlated enough to where the correlation matrix diverges significantly from the identity matrix. the significant value < 0.05 indicates that a factor analysis may be worthwhile for the data set (Shrestha, 2021).

Principal Component Analysis (PCA):

PCA, a multivariate statistical technique which is exploratory, it does not distinguish between independent and dependent variables; instead, it groups highly correlated items into common factors based on the correlation matrix (Shrestha, 2021). In this study, principal component extraction was applied to determine whether the items formed meaningful factors related to causes of wastes in building projects. PCA was used to summarize the underlying variance in the data and reveal dominant patterns through principal components.

Rationale for Selection: PCA was chosen because it is well-suited for exploratory studies aiming to uncover latent structures in complex datasets without preconceived assumptions. In this study, PCA enabled the identification of key waste causing factors by grouping related variables, addressing multicollinearity, and simplifying interpretation. Comparison with Alternatives: Alternative methods, such as Cluster Analysis or Structural Equation Modeling (SEM), were considered but deemed less appropriate. Cluster Analysis focuses on grouping cases rather than variables, which did not align with the study’s objectives. SEM requires a predefined theoretical model, which was not feasible for an exploratory study. PCA’s flexibility and robustness made it the optimal choice. Application in Construction Research: PCA has been widely used in construction management studies to identify critical factor supporting its applicability to this research(Chan & Chan, 2001).

Kendall’s coefficient of concordance (W):

Maurice G. Kendall and Bernard Babington Smith, proposed Kendall’s coefficient of concordance (W) as a measure of the agreement among several (m) quantitative or semiquantitative variables that are assessing a set of n objects of interest It is a non-parametric statistical measure used to assess the degree of agreement or consistency among multiple raters or judges when ranking a set of items. Kendall’s W ranges from 0 (no agreement in rankings) to 1 (perfect agreement), indicating the level of consensus among raters.

Table 4: Kendall's W Concordance Degree Scale.

W	Interpretation
0	No agreement
0.10	Weak agreement
0.30	Moderate agreement
0.60	Strong agreement
1	Perfect agreement

Source: Data Adapted from (Moslem et al., 2019)

Kendall’s Coefficient of Concordance (W) is calculated using formula:

$$W = \frac{12S}{m^2(n^3 - n)}$$

Where:

S = sum of squared deviations of the sum of ranks for each item

m = number of raters

n = number of items being ranked

Kendall's Tau (τ) was used in a hypothesis test to determine the significance of the correlation between Variable X and Variable Y. The alternative hypothesis (H1) proposed the existence of a substantial link, while the null hypothesis claimed that there is no association between the variables. A normal approximation was used to calculate the test statistic. The null hypothesis is rejected, suggesting a statistically insignificant correlation, if the computed p-value is less than the crucial p-value at the 5% significance level. In this study, Kendall's Tau was employed to evaluate the level of agreement between different stakeholder groups: client-contractor, contractor-consultant, and client-consultant across various components (Gibbons & Chakraborti, 2003).

Alignment with Objectives:

RII complemented PCA by quantifying the relative importance of identified factors, enabling a comparative analysis of stakeholders. The combination of PCA and RII directly supported the study's objectives. PCA facilitated the exploration and identification of key waste factors, while RII enabled their prioritization based on stakeholder input. Together, these methods provided a robust framework for analyzing and interpreting the data, ensuring both statistical rigor and practical relevance.

3.5 Research Matrix

The research matrix of the study is presented in Table 5.

Table 5: Research Matrix

S.N.	Objectives	Data Required	Data Collection Methods	Analysis Tools	Outcomes
1.	To identify and categorize the key factors contributing to construction waste in building projects in Kathmandu Valley.	Perspectives of Stakeholders (Client, Consultant, Contractor)	Questionnaire Survey (Structured)	Principal Component Analysis (PCA)	Thematic Components of waste factors in building projects.
2.	To analyze the divergence in perceptions among stakeholders regarding the significance of the identified thematic components.	Scores for each component from Obj. 1 survey	Data from Objective 1	Statistical Tests: RII and Kendall's coefficient of concordance	Identification of areas of significant agreement and disagreement between client, consultant, and contractor groups.
3.	To develop a stakeholder-informed framework for effective construction waste minimization in building projects.	Recommendations to bridge identified gaps; Best practices from literature	Key Informant Interviews (KII) with experts from each stakeholder group; Secondary Literature Review	Thematic Analysis of KII data; Framework development	An integrated, consensus-driven framework for CWM.

3.6 Reliability of Research

3.6.1 Reliability Checking of the Data

The internal consistency of the items in the questionnaire was assessed using Cronbach's Alpha value. Represented by alpha with the value between 0 and 1. Reliability or internal consistency of the data collected is analyzed by calculating the Cronbach's alpha (α) value. It uses statistics to determine consistency among the collected data of the same characteristics. Higher value indicates higher consistency among data. The range is well depicted in Table 6 below:

$$\text{Cronbach's } \alpha = \frac{k}{k-1} \left[1 - \frac{\sum s^2y}{s^2x} \right]$$

Where; k= number of scale item; $\sum s^2y$ =Sum of variance associated with the item;

s^2x = Variance associated with the observed total score

Table 6: Cronbach's Alpha Value

Cronbach's alpha (α)	Internal Consistency
0.9 -1	Excellent
0.8 – 0.89	Very Good
0.7 – 0.79	Good
0.6 – 0.69	Questionable
0.5 – 0.59	Poor
$\alpha < 0.49$	Unacceptable

Source: Adapted from (Habidin et al., 2015)

In this study, Cronbach's alpha was calculated by using SPSS The test was conducted when the number of responses reached 45 and the Cronbach's alpha value obtained was 0.947. Since 0.947 is very close to 1, it suggested that the items in the questionnaire were highly consistent with each other and contributed to a reliable overall score.

Table 7: Reliability Statistics Value

Reliability Statistics

Cronbach's Alpha	N of Items
.947	46

CHAPTER 4: RESULTS AND DISCUSSION

4.1 Demographics of the Respondents

The demographics of the study respondents are presented in the respective sections' hereafter.

a) Gender

Among the total number of respondents, more than two-third of the respondents were male and the remaining were female.

Table 8: Gender Distribution of Respondents

Gender		
	Frequency	Percent
Male	49	70
Female	21	30
Total	70	100.0

b) Working Sector

The respondents were from both government and private sector.

Table 9: Respondents' Working Sector

Which sector do you work in?		
	Frequency	Percent
Government	18	25.7
Private	52	74.3
Total	70	100.0

c) Parties

Among the 70 respondents, showing that consultants formed the largest proportion of participants, while contractors represented the smallest share.

Table 10: Respondents' Working Parties

Who do you work for?		
	Frequency	Percent
Client	26	37.1
Contractor	14	20.0
Consultant	30	42.9
Total	70	100.0

d) Years of experience

The majority of the respondents were having experience up to five years.

Table 11: Years of Experience

Years of experience		
	Frequency	Percent
1-5 years	38	54.3
6-10 years	26	37.1
11-15 years	4	5.7
16 years or more	2	2.9
Total	70	100.0

e) Number of projects involved by stakeholders

In terms of the maximum number of participants were involved in 0-10 projects.

Table 12: Number of Projects Stakeholders Involved In

What types of building projects are you involved in?		
	Frequency	Percent
0-10 Projects	27	38.6
10-20 Projects	18	25.7
20-30 Projects	8	11.4
More than 30 Projects	17	24.3

Total	70	100.0
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4.2 Section 2: Factors Causing Construction Waste in Building Projects In Kathmandu Valley

4.2.1 Identification of Thematic Components Using PCA

First objective of the study was to identify and categorize the key factors contributing to construction waste in building construction projects. To assess these, 46 different factors related to building construction waste were collected from the literature review. All questionnaire was assessed using the 5-point Likert's Scale stating 1 as "Very Minor" to 5 as "Very Major".

The Principal Component Analysis (PCA) within Exploratory Factor Analysis (EFA) has been carried out for the analysis of the data. Factor analysis is a data reduction technique that summarizes many variables into smaller factors based on inter-correlations, where initial variables are observed, extracted factors are latent, and it is commonly used to develop scales or questionnaires for measuring constructs that are not directly observable in real life (Fabrigar et al., 1999). The steps used for the factor analysis for this study is presented here below.

Step 1: Problem Formulation

Step 2: EFA Requirements

Step 3: Appropriate Factoring Technique

Step 4: Decision regarding No. of Factors

Step 5: Factor Rotation

Step 6: Model Fit

Step 7: Running Exploratory Factor Analysis

Step 8: Interpretation and Reporting

To achieve these results, Principal Component Analysis (PCA) was conducted. The study followed three major steps for factor analysis: (a) assessing the suitability of the data, (b) extracting factors, and (c) rotating and interpreting the factors.

The category of the factors including their coding considered for the study under objective 1 are presented in table as follows:

Table 13: The Category of the Factors and Their Coding for Objective 1

Factors	Factor Code
Frequent design changes/ rework caused by design changes	F1
Design Errors	F2
Lack of design information	F3
Complicated design	F4
Poor design quality	F4
Poor product knowledge	F5
Construction drawing errors	F6
Inadequate or improper storage / inventory away from site	F7
Poor material and equipment handling	F8
Accidents	F9
Damage during transportation	F10
Poor quality of materials	F11
Ordering errors/over-ordering/ mistakes in quantity survey	F12
Errors in packing and shipping	F13
Defective items	F14
Damaged materials	F15
Poor planning and scheduling	F16
Poor controlling and supervision/ lack of management	F17
Inappropriate construction method	F18
Poor co-ordination among parties	F19

Misuse or non-availability of tools or equipment	F20
Rework due to poor workmanship	F21
Material misuse	F22
Poor team selection	F23
Lack of waste minimization /waste management plan	F24
Designer inexperience	F25
Incompetent worker/improper worker's skill	F26
Poor attitude & behavior of worker's	F27
Lack of incentives	F28
Lack of training and awareness	F29
Lack of supplier involvement	F30
Leftover materials on site	F31
Poor site condition	F32
Site congestion	F33
Lightning problem	F34
Theft and vandalism	F35
Unpredictable local conditions	F36
Error in contract document/poor documentation/lack of documentation	F37
Delay in cash flow/irregular payments	F38
Long project duration leading to change in material price	F39
Poor co-ordination and communication between parties	F40
Waiting resulting from crew interference	F41
Inefficient consumption of resources	F42

Waiting due to equipment setup and sharing	F43
Composite and building design	F44
Waiting due to storage problem and material supplier delay	F45
Lack of proper construction waste management guidelines (expert view)	F46

Process of PCA for objective 1

Step a: KMO test to measure suitability of data for factor analysis

For assessment of the suitability of data for factors analysis, Kaiser-Meyer-Olkin (KMO) is used to measure the suitability of data for factor analysis. Similarly, Bartlett's test of Sphericity, correlation matrix, and determinant score are computed to detect the appropriateness of the data set for functioning factor analysis (Shrestha, 2021). The details are tabulated in table below.

Table 14: KMO and Bartlett's Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.717
Bartlett's Test of Sphericity	Approx. Chi-Square	2410.327
	df	1035
	Sig.	<.001

To assess the suitability of the dataset for Principal Component Analysis (PCA), the Kaiser-Meyer-Olkin (KMO) Measure of Sampling Adequacy and Bartlett's Test of Sphericity were conducted, as is standard practice in factor analysis (Tabachnick & Fidell, 2013). The KMO test measures the proportion of variance among the forty six waste-related factors that may be attributed to common underlying factors, with values ≥ 0.6 indicating adequate suitability, ≥ 0.7 good, and ≥ 0.8 excellent (Kaiser, 1974). Bartlett's Test of Sphericity evaluates whether the correlation matrix of these factors is significantly different from an identity matrix, with a significant p-value ($p < 0.05$) confirming enough correlations for PCA (Bartlett, 1954). Additionally, the correlation

matrix and determinant score were computed to verify the absence of multicollinearity or singularity, ensuring the dataset's appropriateness for factor analysis.

Applicability to the Current Study: The dataset, comprising 70 responses across 46 waste related factors, was subjected to KMO and Bartlett's tests to confirm its suitability for PCA. These tests are not restricted to large datasets but are essential for any dataset undergoing factor analysis to validate the correlation (Hair et al., 2016). The KMO value of 0.717, reported in Table 4.2, exceeds the threshold of 0.8, indicating excellent sampling adequacy. Bartlett's Test of Sphericity was highly significant ($\chi^2 = 2410.327$, $df = 1035$, $p < 0.001$), confirming significant correlations among variables, making PCA appropriate for this dataset (Shrestha, 2021) (Kaiser, 1974).

Step b: Factor Extraction

In this study two techniques are used to assist in the decision concerning the number of factors to retain: Kaiser's Criterion (Eigen Value) and Scree Test. In this section, a result on the answer to the question, which is "identification and categorization of key waste factors in building construction projects in Kathmandu valley" is discussed. For this purpose, the 46 factors were included in the PCA analysis. The eigenvalue technique was used to determine the number of factors to extract. In this case, only factors with eigenvalues of 1.0 or more were retained. Varimax was used for normalization to reduce the complexity of the factors to maximize the variance in the model.

In multivariate statistics, a scree plot is a line plot of the eigenvalues of factors or principal components in an analysis. The scree plot is used to determine the number of factors to retain in an exploratory factor analysis (EFA) or principal components to keep in a principal component analysis (PCA). As shown in Figure 7, scree plot describes that three latent variables have Eigen value > 1 .

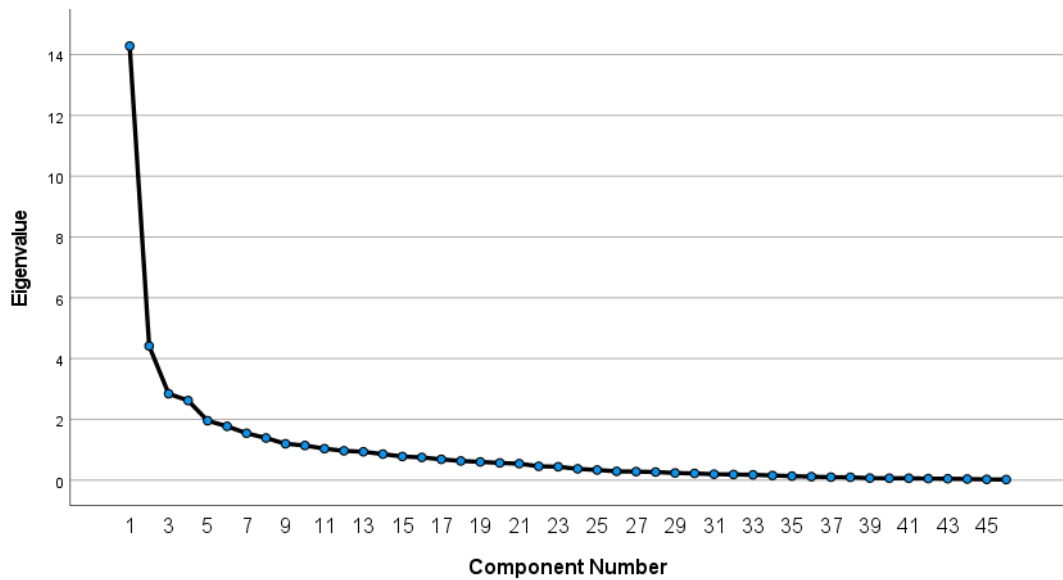


Figure 7: Scree Plot

In Figure 2, for a scree test, a graph is plotted with eigenvalues on the y-axis against the 46 component numbers in their order of extraction on the x-axis. The initial factors extracted are large factors with higher eigenvalues followed by smaller factors. The scree plot is used to determine the number of factors to retain. Here, the scree plot shows that there are 11 components for which the eigenvalue is greater than one and accounts for most of the total variability in data. The other component account for a very small proportion of the variability and are considered not so much important (Tabachnick & Fidell, 2013). The details are tabulated in table 3 below.

Table 15: Eigenvalues (EV) and Total Variance Explained Extraction Method: Principal Component Analysis

Total Variance Explained									
Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
	1	14.283	31.050	31.050	14.283	31.050	31.050	6.511	14.155
2	4.414	9.597	40.646	4.414	9.597	40.646	4.752	10.330	24.485
3	2.845	6.184	46.831	2.845	6.184	46.831	4.737	10.297	34.782

4	2.621	5.697	52.528	2.621	5.697	52.528	3.601	7.828	42.610
5	1.958	4.256	56.783	1.958	4.256	56.783	3.361	7.306	49.916
6	1.773	3.855	60.638	1.773	3.855	60.638	2.814	6.118	56.034
7	1.544	3.355	63.994	1.544	3.355	63.994	2.063	4.486	60.520
8	1.389	3.019	67.012	1.389	3.019	67.012	1.738	3.779	64.299
9	1.199	2.606	69.618	1.199	2.606	69.618	1.676	3.643	67.942
10	1.141	2.481	72.100	1.141	2.481	72.100	1.592	3.462	71.404
11	1.038	2.257	74.356	1.038	2.257	74.356	1.358	2.953	74.356
12	.967	2.102	76.458						
13	.935	2.032	78.491						
14	.858	1.865	80.356						
15	.780	1.696	82.053						
16	.749	1.628	83.681						
17	.687	1.494	85.175						
18	.633	1.375	86.550						
19	.603	1.310	87.860						
20	.568	1.234	89.095						
21	.545	1.184	90.278						
22	.458	.996	91.274						
23	.442	.962	92.236						
24	.374	.813	93.048						
25	.336	.731	93.779						
26	.291	.632	94.411						
27	.282	.614	95.025						
28	.269	.585	95.609						
29	.238	.517	96.127						

30	.223	.486	96.612						
31	.198	.431	97.043						
32	.188	.410	97.453						
33	.178	.387	97.839						
34	.155	.338	98.177						
35	.134	.291	98.469						
36	.117	.255	98.723						
37	.101	.219	98.942						
38	.097	.211	99.153						
39	.070	.151	99.304						
40	.065	.142	99.446						
41	.064	.140	99.586						
42	.053	.116	99.702						
43	.049	.106	99.808						
44	.039	.085	99.892						
45	.028	.060	99.952						
46	.022	.048	100.000						

Table 15 demonstrates the eigenvalues and total variance explained. The extraction method of factor analysis used in this study is principal component analysis. Before extraction, 46 linear components are identified within the data set. After extraction and rotation, there are eleven distinct components within the data set for the eigenvalue > 1. The eleven factors are extracted accounting for a combined 74.356% of the total variance. It is suggested that the proportion of the total variance explained by the retained factors should be greater than 50%. The result shows that 74.356% of common variance shared by 11 components. This is the reflection of the KMO value, 0.717, which can be considered good and indicates that factor analysis is useful for the variables. This initial solution suggests that the final solution has extract not more than 11 components. In the scope of the study, it was determined that there are 11

components with an eigenvalue greater than 1. The factor analysis extracted 11 components with eigenvalues and corresponding variance explained as follows: Component 1 (Eigenvalue = 14.283, 31.05%), Component 2 (4.414, 9.60%), Component 3 (2.845, 6.18%), Component 4 (2.621, 5.70%), Component 5 (1.958, 4.26%), Component 6 (1.773, 3.86%), Component 7 (1.544, 3.36%), Component 8 (1.389, 3.02%), Component 9 (1.199, 2.61%), Component 10 (1.141, 2.48%), and Component 11 (1.038, 2.26%).

C. Factor Rotation and Interpretation

After avoiding the negative, cross loadings and value lesser than 0.4 is tabulated in rotated component matrix in table 4 below:

A Principal Component Analysis (PCA) with Varimax rotation was conducted on 46 variables related to construction waste factors. The analysis resulted in the extraction of 11 distinct components, each clustering items that are conceptually related. The rotated component matrix helped identify underlying themes based on factor loadings. The extracted components are depicted in the Table 16 along with the component themes and in table below.

Table 16: Rotated Component Matrix

Rotated Component Matrix^a											
	Component										
	1	2	3	4	5	6	7	8	9	10	11
Frequent design changes/ rework caused by design changes					.617						
Design errors					.837						
Lack of design information					.613			.424			
Complicated design							.765				

Poor product knowledge	.418						.453				
Construction drawing errors	.412				.557						
Inadequate or improper storage / inventory away from site	.430	.405									
Poor material and equipment handling /double handling	.469	.587									
Accidents	.702										
Damage during transportation	.727										
Poor quality of materials	.761										
Ordering errors/over-ordering/ mistakes in quantity survey	.686										
Errors in packing and shipping	.847										
Defective items	.815										
Damaged materials	.742										
Poor planning and scheduling		.532									
Poor controlling and supervision/ lack of management		.734									
Inappropriate construction method	.553	.468									

Poor co-ordination among parties	.554					.404				
Misuse or non-availability of tools or equipment					.428	.454				
Rework due to poor workmanship	.451				.426					
Material misuse					.737					
Poor team selection					.774					
Lack of waste minimization /waste management plan	.657									
Designer inexperience				.668						
Incompetent worker/improper worker's skill					.431					
Poor attitude & behavior of worker's										
Lack of incentives	.542	.565								
Lack of training and awareness	.800									
Lack of supplier involvement										.548
Leftover materials on site			.803							
Poor site condition			.809							
Site congestion			.676							
Lightning problem	.409		.452							

Theft and vandalism									.784		
Unpredictable local conditions			.617								
Error in contract document/Poor documentation/lack of documentation			.506								
Delay in cash flow/irregular payments			.850								
Long project duration leading to change in material price			.736					.431			
Poor co-ordination and communication between senior management and workers								.638			
Waiting resulting from crew interference			.688								
Inefficient consumption of resources			.641								
Waiting due to equipment setup and sharing			.598				.457				
Composite and building design			.696								

Waiting due to storage problem and material supplier delay			.406							.673	
Lack of proper construction waste management guidelines		.466								.451	
Extraction Method: Principal Component Analysis.											
Rotation Method: Varimax with Kaiser Normalization.											
a. Rotation converged in 13 iterations.											

Discussions on Extracted Component:

Component 1: Material Quality and Handling deficiencies

F7: Inadequate or improper storage / Inventory away from site (0.430)

F9: Accidents (0.702)

F10: Damage during transportation (0.727)

F11: Poor quality of Materials (0.761)

F12 Ordering errors/Over-ordering/ Mistakes in quantity survey (0.686)

F13: Errors in packing and shipping (0.847)

F14: Defective items (0.815)

F15: Damaged Materials (0.742)

F18: Inappropriate construction method (0.553)

This component emphasizes that material quality and handling deficiencies are major contributors to construction waste in building projects. Issues such as improper storage, transportation damage, defective or damaged materials, and errors in ordering or shipping result in significant material loss and inefficiencies on site. Moreover,

accidents and the use of inappropriate construction methods further exacerbate wastage by causing avoidable damage, rework, and reduced productivity.

Component 2: Inefficient Site Management & Supervision

F8: Poor material and equipment handling /Double handling (0.587)

F16: Poor Planning and Scheduling (0.532)

F17: Poor controlling and supervision/ lack of management (0.734)

F19: Poor co-ordination among parties (0.554)

F21: Rework due to poor workmanship (0.451)

F24: Lack of waste minimization /waste management plan (0.657)

F29: Lack of training and awareness (0.800)

F46: Lack of proper construction waste management guidelines (0.466)

This component underscores that weaknesses in planning, supervision, and site management are key drivers of construction waste. Poor material and equipment handling, inadequate coordination, insufficient training, and lack of proper waste management guidelines lead to inefficiencies, rework, and unnecessary material loss. The absence of formal waste minimization plans and limited managerial oversight further intensify waste generation by hindering systematic control and prevention measures on construction sites.

Component 3: Project & Contract Administration Issues

F28: Lack of incentives (0.565)

F37: Poor Error in contract document/Poor documentation/lack of documentation (0.506)

F38 Delay in cash flow/irregular payments (0.850)

F39: Long project duration leading to change in material price (0.736)

F41: Waiting resulting from crew interference (0.688)

F42: Inefficient consumption of resources (0.641)

F43: Waiting due to equipment setup and sharing (0.598)

F44: Composite and building design (0.696)

Above component 3 reflects that shortcomings in project and contract administration contribute significantly to construction waste. Irregular payments, inadequate documentation, long project durations, and poorly defined incentives disrupt workflow continuity and lead to delays, resource misuse, and higher susceptibility to material price fluctuations. Additionally, issues such as crew interference, equipment setup delays, and complex building designs further intensify waste generation by causing waiting time, inefficiencies, and avoidable consumption of resources.

Component 4: Adverse On-Site Working Conditions

F31: Leftover materials on site (0.803)

F32: Poor site condition (0.809)

F33: Site congestion (0.676)

F34: Lightning problem (0.452)

F36: Unpredictable local conditions (0.617)

This component represents waste generated due to challenging physical and operational conditions on the construction site. Leftover materials, poor site conditions, congestion, inadequate lighting, and unpredictable local factors disrupt workflow, slow productivity, and increase errors. As a result, materials are more prone to damage, misplacement, and inefficient handling, ultimately contributing to higher waste levels.

Component 5: Design & Documentation Flaws

F1: Frequent design changes/ Rework caused by design changes (0.617)

F2: Design Errors (0.837)

F3: Lack of design information (0.613)

F6: Construction drawing errors (0.557)

F25: Designer inexperience (0.668)

This component reflects waste arising from shortcomings in the design phase and inadequate project documentation. Frequent design changes, errors in drawings,

missing information, and designer inexperience lead to rework, material mismatches, and disruptions during construction. These issues reduce efficiency and cause unnecessary material use, ultimately increasing construction waste.

Component 6: Workforce Competence & Selection

F22: Material misuse (0.737)

F23: Poor team selection (0.774)

F26: Incompetent Worker/Improper worker's skill (0.431)

This component highlights waste generated due to shortcomings in worker skills and team selection. Material misuse, poor team formation, and incompetent or improperly trained workers lead to errors, rework, and inefficient use of resources. These factors collectively increase material wastage and reduce overall productivity on construction sites.

Component 7: Technical Knowledge & Resource Availability

F4: Complicated design (0.765)

F5: Poor product knowledge (0.453)

F20: Misuse or non- availability of tools or equipment (0.454)

This component reflects waste arising from limited technical understanding and inadequate access to proper tools and equipment. Complicated designs, poor product knowledge, and the misuse or unavailability of necessary tools lead to operational inefficiencies and errors during execution. Consequently, these issues contribute to material wastage and disrupt smooth project progress.

Component 8: Poor coordination and communication between senior management and workers (F40)

Component 9: Theft and vandalism(F35)

Component 10: Waiting due to storage problems and material supplier delays(F45)

Component 11: Lack of supplier involvement(F30)

4.3 Section 3: Comparative Study on Perceptions of Client, Contractor and Consultant in Building Construction Projects.

Comparative study among client, contractor and consultant regarding waste causing factors in building construction projects has been depicted in the tables for major 7 components.

The second objective of the study was to compare the perceptions of client, consultant and contractor regarding the waste causing factors building construction projects. The details of responses and RII of each component are discussed hereafter.

4.3.1 RII for Component 1: Client, Contractor, Consultant, and Combined

Table 17: RII and Ranking for Component 1

S.N.	Material Quality & Handling deficiencies	Coding	Client		Contractor		Consultant		Combined	
			RII	Rank	RII	Rank	RII	Rank	RII	Rank
1.	Inadequate or improper storage / Inventory away from site	F7	0.685	1	0.686	1	0.693	2	0.689	1
2.	Accidents	F9	0.477	9	0.429	7	0.593	6	0.517	9
3.	Damage during transportation	F10	0.531	6	0.471	6	0.593	6	0.546	5
4.	Poor quality of Materials	F11	0.600	3	0.500	3	0.653	3	0.603	3
5.	Ordering errors/Over-ordering/ Mistakes in quantity survey	F12	0.546	4	0.500	3	0.613	4	0.566	4
6.	Errors in packing and shipping	F13	0.531	6	0.371	9	0.600	5	0.529	7
7.	Defective items	F14	0.515	8	0.429	7	0.580	8	0.526	8
8.	Damaged Materials	F15	0.538	5	0.486	5	0.573	9	0.543	6

9.	Inappropriate construction method	F18	0.662	2	0.557	2	0.753	1	0.680	2
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The ranking of factors under Component 1 (Material Quality and Handling deficiencies) based on the Relative Importance Index (RII) reveals notable variations in stakeholder perceptions across clients, contractors, and consultants.

Top priorities:

For the clients, the top-ranked factors include inadequate or improper storage/inventory away from site (RII = 0.685), inappropriate construction method (RII = 0.662), and poor quality of materials (RII = 0.600), reflecting their strong concern for effective material handling and site management practices that directly affect project cost and performance. The contractors, on the other hand, prioritized inadequate or improper storage/inventory away from site (RII = 0.686), inappropriate construction method (RII = 0.557), and poor quality of materials (RII = 0.500), emphasizing the importance of material accessibility, construction practices, and quality control during project execution. Similarly, the consultants identified inappropriate construction method (RII = 0.753), inadequate or improper storage/inventory away from site (RII = 0.693), and poor quality of materials (RII = 0.653) as the most significant contributors to material waste, indicating their focus on ensuring that design intentions and construction practices align to maintain quality standards. Overall, all three groups share a consensus that improper storage, poor construction methods, and material quality are the dominant causes of waste, though consultants rated the intensity of these issues slightly higher than the other groups.

Middle priorities

In the middle tier, the clients emphasized ordering errors or over-ordering (RII = 0.546), damaged materials (RII = 0.538), and damage during transportation (RII = 0.531) as moderately significant. The contractors displayed a similar perception, ranking damage during transportation (RII = 0.471), ordering errors (RII = 0.500), and damaged materials (RII = 0.486) as mid-level factors, indicating operational inefficiencies in handling and logistics. The consultants also placed damage during transportation (RII = 0.593) and ordering errors (RII = 0.613) in their mid-range rankings, reflecting

attention to material flow and procurement precision. These findings suggest that while all stakeholders acknowledge transportation and ordering-related issues, they perceive them as secondary to the more fundamental problems of method and storage.

Bottom priorities:

At the lower end, the clients identified defective items (RII = 0.515), errors in packing and shipping (RII = 0.531), and accidents (RII = 0.477) as the least critical causes of waste. The contractors shared a similar view, ranking errors in packing and shipping (RII = 0.371), defective items (RII = 0.429), and accidents (RII = 0.429) as the least influential. The consultants, however, rated these factors slightly higher — errors in packing and shipping (RII = 0.600) and defective items (RII = 0.580) — possibly due to their responsibility in ensuring material quality verification and documentation. Thus, while clients and contractors focus more on site-related inefficiencies, consultants tend to consider product and supply-related defects as relatively more important.

Overall, this comparative analysis demonstrates that all three stakeholder groups exhibit general agreement regarding the top-tier factors causing material waste but differ slightly in their perception of mid- and bottom-tier factors. The findings indicate that clients emphasize management and storage, contractors focus on handling and execution, and consultants prioritize technical and quality control aspects, highlighting the need for integrated stakeholder coordination in addressing material waste.

4.3.2 RII for Component 2: Client, Contractor, Consultant, and Combined

Table 18: RII and Ranking for Component 2

S. N.	Inefficient Site Management & Supervision	Coding	Client		Contractor		Consultant		Combined	
			RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Poor material and equipment handling /Double handling	F8	0.662	7	0.643	5	0.693	7	0.671	7
2	Poor Planning and Scheduling	F16	0.623	8	0.571	8	0.713	5	0.651	8
3	Poor controlling and supervision/ lack of management	F17	0.731	1	0.643	5	0.727	3	0.711	4

4	Poor co-ordination among parties	F19	0.677	6	0.757	1	0.727	3	0.714	2
5	Rework due to poor workmanship	F21	0.700	3	0.671	4	0.733	2	0.709	5
6	Lack of waste minimization /waste management plan	F24	0.731	1	0.686	2	0.713	5	0.714	2
7	Lack of training and awareness	F29	0.685	4	0.629	7	0.693	7	0.677	6
8	Lack of proper construction waste management guidelines	F46	0.685	4	0.686	2	0.773	1	0.723	1

For Component 2 (Management and Waste Minimization Factors), the Relative Importance Index (RII) analysis reveals both convergence and divergence in how clients, contractors, and consultants perceive the causes of construction waste.

Top Priorities:

For the clients, the most influential factors were poor controlling and supervision/lack of management (RII = 0.731), lack of waste minimization/waste management plan (RII = 0.731), and rework due to poor workmanship (RII = 0.700). This suggests that clients associate material waste primarily with managerial inefficiency and the absence of systematic waste management approaches. The contractors, however, ranked poor coordination among parties (RII = 0.757), lack of waste minimization/waste management plan (RII = 0.686), and lack of proper construction waste management guidelines (RII = 0.686) as their top priorities, indicating concern about communication gaps and the absence of clear policy-level guidance in waste control. In contrast, the consultants viewed lack of proper construction waste management guidelines (RII = 0.773), rework due to poor workmanship (RII = 0.733), and poor controlling and supervision/lack of management (RII = 0.727) as the most critical issues, emphasizing their focus on formal waste management standards and the importance of supervision in ensuring quality. Collectively, all three stakeholder groups agree that the lack of structured waste management systems and managerial inefficiency are the dominant

causes of waste generation, though the consultants prioritize policy and procedural aspects more heavily.

Middle Priorities:

In the middle tier, the clients identified lack of training and awareness (RII = 0.685), lack of proper construction waste management guidelines (RII = 0.685), and poor coordination among parties (RII = 0.677) as moderately significant factors, highlighting their view that awareness and coordination issues, while important, are secondary to direct management concerns. The contractors placed rework due to poor workmanship (RII = 0.671), poor controlling and supervision/lack of management (RII = 0.643), and poor material and equipment handling (RII = 0.643) in this category, indicating that they perceive inefficiencies in supervision and site operations as ongoing but manageable challenges. The consultants also considered poor planning and scheduling (RII = 0.713) and lack of waste minimization/waste management plan (RII = 0.713) to be of medium importance, showing that while planning lapses contribute to waste, they are less pressing compared to systemic policy issues.

Bottom Priorities:

At the lower end, the clients ranked poor planning and scheduling (RII = 0.623) and poor material and equipment handling/double handling (RII = 0.662) as less significant, suggesting that they see these as operational rather than strategic issues. The contractors also rated poor planning and scheduling (RII = 0.571) and lack of training and awareness (RII = 0.629) among the lowest priorities, possibly reflecting limited emphasis on formal training within existing site practices. Similarly, the consultants assigned lower importance to poor material and equipment handling (RII = 0.693) and lack of training and awareness (RII = 0.693), implying that while such issues exist, they are overshadowed by broader systemic deficiencies in management and policy.

Overall, these findings suggest that while all stakeholder groups recognize the importance of effective management and waste minimization, their focus differs. Clients emphasize managerial control and site-level waste planning, contractors focus on coordination and procedural clarity, and consultants prioritize formal waste management frameworks and regulatory guidance. This divergence highlights the need for an integrated stakeholder approach combining managerial effectiveness,

coordination, and policy implementation to achieve sustainable waste reduction in building projects.

4.3.3 RII for Component 3: Client, Contractor, Consultant, and Combined

Table 19: RII and Ranking for Component 3

S. N.	Project & Contract Administration Issues	Coding	Client		Contractor		Consultant		Combined	
			RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Lack of incentives	F28	0.515	7	0.500	4	0.553	8	0.529	8
2	Error in contract document/Poor documentation /lack of documentation	F37	0.577	1	0.571	2	0.627	3	0.597	2
3	Delay in cash flow/irregular payments	F38	0.531	4	0.514	3	0.633	2	0.571	3
4	Long project duration leading to change in material price	F39	0.562	2	0.614	1	0.653	1	0.611	1
5	Waiting resulting from crew interference	F41	0.500	8	0.500	4	0.627	3	0.554	4
6	Inefficient consumption of resources	F42	0.523	6	0.471	8	0.580	5	0.537	7
7	Waiting due to equipment setup and sharing	F43	0.546	3	0.486	6	0.567	7	0.543	5
8	Composite and building design	F44	0.531	4	0.486	6	0.573	6	0.540	6

The Relative Importance Index (RII) analysis highlights varying degrees of concern among clients, contractors, and consultants regarding payment irregularities, documentation issues, and project duration impacts.

Top Priorities:

For the clients, the top-ranked factors were error in contract document/poor documentation/lack of documentation (RII = 0.577), long project duration leading to change in material price (RII = 0.562), and waiting due to equipment setup and sharing (RII = 0.546). This shows that clients primarily associate material waste and inefficiency with poor contractual documentation, escalation of material costs in long-duration projects, and delays caused by resource sharing. The contractors, however, considered long project duration leading to change in material price (RII = 0.614), error in contract document/poor documentation (RII = 0.571), and delay in cash flow or irregular payments (RII = 0.514) as the most significant issues, indicating their strong concern over financial instability and poorly defined contractual terms that directly affect project cash flow and execution. For the consultants, long project duration leading to change in material price (RII = 0.653), delay in cash flow or irregular payments (RII = 0.633), and error in contract documentation (RII = 0.627) emerged as the top priorities, suggesting that consultants perceive financial uncertainty and inadequate documentation as critical risks that disrupt project planning and material management. Overall, all three stakeholder groups converge on the view that poor documentation, payment irregularities, and price fluctuations due to extended project timelines are major contributors to inefficiencies and waste in construction projects.

Middle Priorities:

In the middle tier, the clients ranked delay in cash flow or irregular payments (RII = 0.531), composite and building design (RII = 0.531), and inefficient consumption of resources (RII = 0.523) as moderately significant factors, reflecting their balanced view between financial and operational causes. The contractors placed waiting due to equipment setup and sharing (RII = 0.486), composite and building design (RII = 0.486), and waiting resulting from crew interference (RII = 0.500) in the middle range, indicating that coordination and technical design factors moderately affect their efficiency but are less critical than financial concerns. The consultants considered consumption of resources (RII = 0.580), composite and building design (RII = 0.573), and waiting due to equipment setup and sharing (RII = 0.567) to be of medium importance, showing their focus on technical optimization and design efficiency. This pattern suggests that middle-priority factors relate mainly to resource use and coordination, which are perceived as operational rather than systemic issues.

Bottom Priorities:

At the lower end, the clients rated lack of incentives (RII = 0.515) and waiting resulting from crew interference (RII = 0.500) as least important, implying limited attention to motivation-related factors. The contractors similarly ranked consumption of resources (RII = 0.471) and lack of incentives (RII = 0.500) at the bottom, possibly because these aspects are less directly tied to immediate financial constraints. The consultants also placed lack of incentives (RII = 0.553) at the bottom of their list, indicating that worker motivation is perceived as a secondary issue compared to financial and contractual inefficiencies.

In summary, the findings show that clients focus on documentation and management clarity, contractors emphasize financial regularity and time-related cost implications, while consultants prioritize documentation accuracy and financial stability. Despite these differing perspectives, all three groups agree that weak contractual control and unstable cash flow are major obstacles to effective project performance and material efficiency in Kathmandu Valley's building projects.

4.3.4 RII for Component 4: Client, Contractor, Consultant, and Combined

Table 20: RII and Ranking for Component 4

S.N.	Adverse On-Site Working Conditions	Coding	Client		Contractor		Consultant		Combined	
			RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Leftover materials on site	F31	0.615	4	0.671	1	0.620	2	0.629	2
2	Poor site condition	F32	0.662	1	0.557	4	0.600	3	0.614	3
3	Site congestion	F33	0.654	2	0.614	2	0.633	1	0.637	1
4	Lightning problem	F34	0.538	5	0.386	5	0.540	5	0.509	5
5	Unpredictable local conditions	F36	0.638	3	0.586	3	0.587	4	0.606	4

For Component 4 (Site Management and Environmental Conditions), the Relative Importance Index (RII) values reveal a strong divergence in how clients, contractors, and consultants perceive the challenges associated with site management, physical conditions, and environmental unpredictability.

Top Priorities:

For the clients, the most significant factors were poor site condition (RII = 0.662), site congestion (RII = 0.654), and unpredictable local conditions (RII = 0.638). This indicates that clients view site-related inefficiencies as primarily arising from unfavorable ground conditions, limited workspace, and uncontrollable external influences such as local disturbances or weather. The contractors, on the other hand, ranked leftover materials on site (RII = 0.671), site congestion (RII = 0.614), and unpredictable local conditions (RII = 0.586) as their top concerns. This highlights that contractors are most affected by material handling and site logistics challenges that directly impact productivity and waste management. The consultants prioritized site congestion (RII = 0.633), leftover materials on site (RII = 0.620), and poor site condition (RII = 0.600), suggesting their focus on spatial efficiency, material control, and maintaining workable site conditions. Overall, all three stakeholder groups agree that site congestion and poor physical conditions are critical challenges that reduce operational efficiency, though their emphasis varies according to their role in the project.

Middle Priorities:

In the middle tier, the clients placed leftover materials on site (RII = 0.615) as a moderately significant issue, reflecting some concern over material management, while unpredictable local conditions (RII = 0.638) also featured prominently. For the contractors, poor site condition (RII = 0.557) and unpredictable local conditions (RII = 0.586) occupied the middle range, emphasizing their moderate concern over environmental unpredictability and uneven site quality. The consultants ranked unpredictable local conditions (RII = 0.587) and poor site condition (RII = 0.600) as middle-priority factors, showing that these are important but manageable issues if addressed through proper planning and supervision. This pattern suggests that middle-tier concerns revolve around natural and environmental uncertainties that can be mitigated with effective site planning.

Bottom Priorities:

At the lower end, the clients and consultants both identified lighting problems (RII = 0.538 and 0.540 respectively) as the least significant issue, indicating that inadequate lighting is perceived as a minor and easily solvable problem. Similarly, contractors ranked lighting problem (RII = 0.386) at the bottom, suggesting that while lighting affects safety and night-time productivity, it does not pose a major hindrance to overall project progress compared to congestion and environmental constraints.

In summary, clients emphasize the impact of site conditions and local unpredictability, contractors focus on material and spatial management challenges, and consultants stress congestion and overall site coordination. Despite these differing priorities, all three stakeholder groups align in identifying site congestion and poor site management as leading contributors to inefficiency and material waste within construction projects across Kathmandu Valley.

4.3.5 RII for Component 5: Client, Contractor, Consultant, and Combined

Table 21: RII and Ranking for Component 5

S. N.	Component Design & Documentation Flaws	Coding	Client		Contractor		Consultant		Combined	
			RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Frequent design changes/ Rework caused by design changes	F1	0.600	3	0.614	4	0.700	2	0.646	3
2	Design Errors	F2	0.569	4	0.543	5	0.660	5	0.603	5
3	Lack of design information	F3	0.569	4	0.629	2	0.667	3	0.625	4
4	Construction drawing errors	F6	0.638	2	0.671	1	0.667	3	0.657	2
5	Designer inexperience	F25	0.677	1	0.629	2	0.713	1	0.683	1

For Component 5 (Design-Related Issues), the Relative Importance Index (RII) results indicate that all three stakeholder groups—clients, contractors, and consultants—acknowledge the significant influence of design-related deficiencies on project performance, but their perspectives on which specific factors are most critical differ based on their roles and responsibilities.

Top Priorities:

For the clients, designer inexperience (RII = 0.677) and construction drawing errors (RII = 0.638) were identified as the top-ranking factors. This shows that clients place the greatest concern on the competence and technical expertise of design professionals, as these directly impact design accuracy, coordination, and project execution. The contractors also regarded construction drawing errors (RII = 0.671) and designer inexperience (RII = 0.629) as their top priorities, emphasizing their dependence on clear and error-free drawings to avoid rework, delays, and resource wastage during construction. Meanwhile, the consultants ranked designer inexperience (RII = 0.713), frequent design changes/rework caused by design changes (RII = 0.700), and lack of design information (RII = 0.667) as the most significant issues. This suggests that consultants are highly aware of the technical and coordination challenges arising from inadequate expertise and the frequent need for revisions due to evolving project requirements. Overall, designer inexperience and drawing errors emerged as the most critical factors across all stakeholders, indicating the central importance of design quality and professional competency in minimizing waste and inefficiency.

Middle Priorities:

In the middle tier, the clients identified frequent design changes (RII = 0.600) as moderately significant, showing that while they recognize design modifications as problematic, they view them as manageable through communication and documentation. The contractors, on the other hand, placed frequent design changes (RII = 0.614) and lack of design information (RII = 0.629) in the middle range, which reflects their concern over incomplete or frequently revised drawings that can interrupt workflow and scheduling. For the consultants, construction drawing errors (RII = 0.667) and lack of design information (RII = 0.667) also occupied middle positions, implying that while these are significant, they can often be addressed through improved design coordination and quality assurance processes. This consistency across groups suggests that communication gaps and information flow issues during the design stage are persistent challenges that moderately influence project performance.

Bottom Priorities:

At the lower end, both the clients and contractors ranked design errors (RII = 0.569 and 0.543 respectively) as the least significant issues, indicating that while design mistakes occur, they are often caught and corrected before they lead to major consequences. The

consultants also placed design errors (RII = 0.660) at a relatively lower rank compared to other design issues, suggesting that with proper review mechanisms, such errors are perceived as less critical than systemic factors like inexperience or information deficiency.

In summary, all stakeholders collectively recognize design-related inefficiencies as a major source of rework and waste in construction projects. While clients emphasize the capability and accuracy of design professionals, contractors focus on drawing clarity and information consistency, and consultants highlight the impact of experience and frequent design revisions. Despite these differing viewpoints, all agree that enhancing design expertise, documentation, and communication among design teams is essential to improving project efficiency and minimizing rework within the Nepalese construction sector.

4.3.6 RII for Component 6: Client, Contractor, Consultant, and Combined

Table 22: RII and Ranking for Component 6

S.N.	Workforce Competence & Selection	Coding	Client		Contractor		Consultant		Combined	
			RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Material misuse	F22	0.662	2	0.586	3	0.667	3	0.649	3
2	Poor team selection	F23	0.654	3	0.600	2	0.680	2	0.654	2
3	Incompetent Worker/Improper worker's skill	F26	0.669	1	0.643	1	0.740	1	0.694	1

The Relative Importance Index (RII) analysis reveals that all three stakeholder groups clients, contractors, and consultants view workforce competency and team efficiency as crucial determinants of construction waste generation. However, the degree of emphasis on each factor varies according to the stakeholders' roles in project implementation and management.

Top Priorities:

For the clients, incompetent workers/improper worker's skill (RII = 0.669) was identified as the most significant factor contributing to waste. This indicates that clients recognize the direct relationship between worker skill levels and the overall quality and

efficiency of construction activities. The contractors also ranked incompetent workers/improper worker's skill (RII = 0.643) as their top concern, reflecting their practical experience with on-site labor productivity and material wastage resulting from poor workmanship or lack of technical know-how. Similarly, the consultants considered incompetent workers/improper worker's skill (RII = 0.740) as their foremost issue, signifying strong agreement across all groups that inadequate worker competency is a dominant factor in project inefficiency. The combined ranking (RII = 0.694) further supports this consensus, positioning labor skills as the most critical area for improvement in construction waste management.

Middle Priorities:

In the middle tier, the clients ranked material misuse (RII = 0.662) slightly lower than workforce skill but still as a key issue, reflecting their awareness of the cost and quality implications of improper material handling on-site. The contractors, however, prioritized poor team selection (RII = 0.600) as their second most significant factor, emphasizing the importance of choosing competent and coordinated teams capable of executing work efficiently. Likewise, the consultants placed poor team selection (RII = 0.680) as their second-highest concern, aligning with the view that misaligned or poorly coordinated teams often result in process inefficiencies, miscommunication, and increased material waste. This convergence highlights that team formation and management are central to improving performance across all project stages.

Bottom Priorities:

At the lower end, poor team selection was ranked lowest by clients (RII = 0.654), whereas contractors (RII = 0.586) and consultants (RII = 0.667) viewed material misuse as the least critical among the three factors. This indicates that while these issues are not disregarded, they are perceived as secondary to the more pressing challenge of ensuring skilled and capable human resources.

In summary, all stakeholders consistently acknowledge that incompetent or unskilled workers are the most significant contributors to construction waste, followed by issues of team coordination and material misuse. The results suggest that improving labor training, team selection processes, and supervision practices could substantially enhance construction efficiency and minimize material wastage in building projects across the Kathmandu Valley.

4.3.7 RII for Component 7: Client, Contractor, Consultant, and Combined

Table 23: RII and Ranking for Component 7

S.N.	Technical Knowledge & Resource Availability	Coding	Client		Contractor		Consultant		Combined	
			RII	Rank	RII	Rank	RII	Rank	RII	Rank
1	Complicated design	F4	0.569	3	0.657	1	0.613	2	0.606	2
2	Poor product knowledge	F5	0.646	1	0.600	2	0.707	1	0.663	1
3	Misuse or non-availability of tools or equipment	F20	0.577	2	0.514	3	0.593	3	0.571	3

The analysis based on the Relative Importance Index (RII) highlights varying perceptions among clients, contractors, and consultants regarding the factors that contribute to construction waste. These variations stem mainly from their different roles in design implementation, material handling, and technical oversight within building projects.

Top Priorities:

For the clients, poor product knowledge (RII = 0.646) emerged as the most critical factor influencing waste generation. This finding indicates that clients recognize the lack of adequate understanding of construction materials and products as a leading cause of inefficiencies and wastage during project execution. Similarly, the contractors ranked complicated design (RII = 0.657) as their top priority, which reflects their direct challenges in translating complex architectural or structural designs into practical on-site operations. In contrast, the consultants placed poor product knowledge (RII = 0.707) as the highest-ranked issue, signifying their concern that insufficient knowledge of materials and construction technology can lead to design misinterpretations, material misapplications, and subsequent rework. The combined ranking (RII = 0.663) also positioned poor product knowledge as the top overall factor, reinforcing the consensus that better technical awareness is crucial for minimizing design- and equipment-related waste.

Middle Priorities:

In the middle tier, the clients considered misuse or non-availability of tools or

equipment (RII = 0.577) as their second priority, indicating their awareness of how inadequate tools or improper equipment use can slow productivity and cause material damage. The contractors, however, assigned this factor the third rank (RII = 0.514), reflecting their belief that while tool-related inefficiencies contribute to waste, they are less significant compared to issues in design complexity and planning. The consultants also viewed complicated design (RII = 0.613) as a secondary concern, acknowledging that intricate designs often lead to miscommunication, errors in interpretation, and execution delays. Collectively, the combined ranking (RII = 0.606) identifies complicated design as the second most important factor across all stakeholders.

Bottom Priorities:

At the lower end, complicated design (RII = 0.569) was ranked third by clients, while contractors (RII = 0.514) and consultants (RII = 0.593) both placed misuse or non-availability of tools or equipment at the bottom. Although these factors are comparatively lower in rank, they remain significant as they highlight recurring technical inefficiencies and logistical challenges within the construction process.

Overall, the findings suggest that poor product knowledge is the most prominent driver of waste among design and equipment-related factors, followed by challenges linked to complex designs and equipment handling issues. These results underscore the need for enhanced training programs, improved design communication, and effective equipment management practices to reduce waste generation and improve project performance in the Kathmandu Valley.

4.3.8 Hypothesis Testing for Ranking of Viewpoints of Stakeholders (Client/ Consultant/ Contractor) Regarding Thematic Components of Factors Causing Waste in Building Construction Projects.

The perceptions of the stakeholders were further analyzed using the Kendall's tau on viewpoint regarding agreement and disagreements of thematic components of factors causing waste in building construction projects. Separate hypothesis tests were carried out in the sub-sections below.

4.3.8.1 Hypothesis Testing Between Client and Contractor

Null Hypothesis (H0): There is no significant difference between the viewpoint of Client and Contractor on ranking regarding thematic components of factors causing waste in building construction.

Alternative Hypothesis (H1): There is a significant difference between the viewpoint of Client and Contractor on ranking regarding thematic components of factors causing waste in building construction.

Table 24 Hypothesis test: Viewpoint of Client & Contractor on Ranking Regarding Thematic Components of Factors Causing Waste in Building Construction

Components	W	Chi-Square	P-value	Decision
Viewpoint Component 1 on	0.770010288	12.32016461	0.13748039	Fail to Reject H0
Viewpoint Component 2 on	0.68452381	9.583333333	0.213440376	Fail to Reject H0
Viewpoint Component 3 on	0.684151786	9.578125	0.213767404	Fail to Reject H0
Viewpoint Component 4 on	0.55	4.4	0.354570107	Fail to Reject H0
Viewpoint Component 5 on	0.68	5.44	0.245054086	Fail to Reject H0
Viewpoint Component 6 on	0.75	3	0.22313016	Fail to Reject H0
Viewpoint Component 7 on	0.25	1	0.60653066	Fail to Reject H0

Since, the p-values (Sig.) is more than $\alpha = 0.05$, (α is the level of significance) the null hypothesis, H0, is fail to reject and the alternative hypothesis, H1, is rejected. Thus, it can be said from above mentioned Table 24 there is no significant difference between the viewpoint Client and Contractor on ranking regarding thematic components of factors causing waste in building construction.

4.3.8.2 Hypothesis Testing Between Contractor and Consultant

Null Hypothesis (H0): There is no significant difference between the viewpoint of Contractor and Consultant on ranking regarding thematic components of factors causing waste in building construction.

Alternative Hypothesis (H1): There is a significant difference between the viewpoint of Contractor and Consultant on ranking regarding thematic components of factors causing waste in building construction.

Table 25 Hypothesis test: Viewpoint of Contractor & Consultant on Ranking Regarding Thematic Components of Factors Causing Waste in Building Construction

Components	W	Chi-Square	P-value	Decision
Viewpoint on Component 1	0.652314815	10.43703704	0.235680815	Fail to Reject H0
Viewpoint on Component 2	0.67624628	9.467447917	0.220813462	Fail to Reject H0
Viewpoint on Component 3	1.069940476	14.97916667	0.036267387	Reject H0
Viewpoint on Component 4	0.9	7.2	0.125689123	Fail to Reject H0
Viewpoint on Component 5	0.73	5.84	0.211420054	Fail to Reject H0
Viewpoint on Component 6	1	4	0.135335283	Fail to Reject H0
Viewpoint on Component 7	0.75	3	0.22313016	Fail to Reject H0

Since, the p-values (Sig.) is more than $\alpha = 0.05$, (α is the level of significance) the null hypothesis, H0, is fail to reject and the alternative hypothesis, H1, is accepted. Thus, it can be said from above Table 25 there is no significant difference between the viewpoint Contractor and Consultant on ranking regarding thematic components of factors causing waste in building construction except for component 3 i.e., project and contract administration issues, where significant difference can be seen between viewpoint Contractor and Consultant.

4.3.8.3 Hypothesis Testing Between Contractor and Consultant

Null Hypothesis (H0): There is no significant difference between the viewpoint of Client and Consultant on ranking regarding thematic components of factors causing waste in building construction.

Alternative Hypothesis (H1): There is a significant difference between the viewpoint of Client and Consultant on ranking regarding thematic components of factors causing waste in building construction.

Table 26 Hypothesis test: Viewpoint of Client & Consultant on Ranking Regarding Thematic Components of Factors Causing Waste in Building Construction

Components	W	Chi-Square	P-value	Decision
Viewpoint on Component 1	0.662602881	10.60164609	0.13748039	Fail to Reject H0
Viewpoint on Component 2	0.464192708	6.498697917	0.482867843	Fail to Reject H0
Viewpoint on Component 3	0.76999628	10.77994792	0.14850977	Fail to Reject H0
Viewpoint on Component 4	0.75	6	0.199148273	Fail to Reject H0
Viewpoint on Component 5	0.68	5.44	0.245054086	Fail to Reject H0
Viewpoint on Component 6	0.75	3	0.22313016	Fail to Reject H0
Viewpoint on Component 7	0.75	3	0.22313016	Fail to Reject H0

Since, the p-values (Sig.) is more than $\alpha = 0.05$, (α is the level of significance) the null hypothesis, H0, is fail to reject and the alternative hypothesis, H1, is accepted. Thus, it can be said from above Table 26 that there is no significant difference between the viewpoint Client and Consultant on ranking regarding thematic components of factors causing waste in building construction.

4.3.9 Triangulation for Cross Validating Qualitative and Quantitative Results

The ranking of RII and testing of hypothesis provides a valuable information regarding the factors causing construction waste minimization. After the ranking from the QS survey, study also comprised of KII with the relevant stakeholders followed by review of the literatures was done to analyze the triangulations of the findings.

Triangulation was integrated into the research design to strengthen the study's validity, reliability, and overall analytical rigor (Bans-Akutey & Tiimub, 2021). Methodological triangulation was applied by using three different data-collection methods: (i) a structured questionnaire survey with three stakeholder's client, contractor and consultant, (ii) semi-structured interviews with key informants, and (iii) review of relevant documents such as project reports, guidelines, and previous research.

The findings obtained from each method were compared and cross-validated to identify areas of convergence and divergence. Converging results across methods increased confidence in the accuracy of the conclusions, while any inconsistencies provided deeper insights into contextual factors affecting the study variables. By integrating multiple data sources, triangulation minimized method-specific biases and enhanced the credibility, robustness, and overall trustworthiness of the research outcomes (Bans-Akutey & Tiimub, 2021).

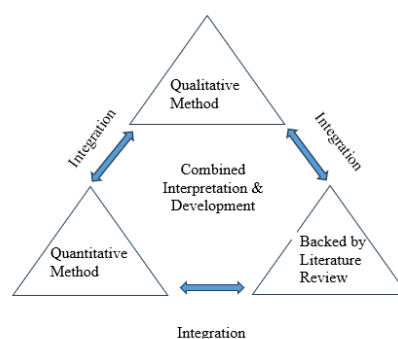


Figure 8 Triangulation Analysis

Three experts were first provided with the factors in thematic components for ranking which was then compared with the quantitative data and interpreted provided in tables given below:

Triangulation of Component 1: Material Quality & Handling Deficiencies

Table 27: Triangulation Table for Component 1

Material quality & handling deficiencies	Combined quantitative (RII & Rank)	Expert 1 Rank	Expert 2 Rank	Expert 3 Rank	KII Results	Triangulation Conclusion
Inadequate or improper storage / inventory away from site	0.689 (1)	1	1	1	All experts confirmed it as major cause	Strong Agreement
Accidents	0.517 (9)	9	9	9	Identified as least critical factor	Strong Agreement
Damage during transportation	0.546 (5)	5	5	5	Mentioned as contributing factor	Strong Agreement
Poor quality of materials	0.603 (3)	3	4	3	Frequently highlighted by KII respondents	Strong Agreement
Ordering errors / over-ordering / mistakes in quantity survey	0.566 (4)	4	3	4	Reported as significant issue in material planning	Strong Agreement
Errors in packing and shipping	0.529 (7)	7	7	7	Discussed but considered less influential	Strong Agreement
Defective items	0.526 (8)	8	8	8	Identified as minor issue	Strong Agreement
Damaged materials	0.543 (6)	6	6	6	Mentioned occasionally in discussions	Strong Agreement
Inappropriate construction method	0.680 (2)	2	2	2	Highlighted prominently by experts	Strong Agreement

Overall, the triangulation results suggest that material handling (storage, quality control, and quantity management) and execution practices at site are the dominant causal factors of construction waste, indicating a need for improved material inventory management, construction planning, and quality assurance procedures.

Triangulation of Component 2: Inefficient Site Management & Supervision

Table 28: Triangulation Table for Component 2

Inefficient Site Management & Supervision	Quantitative (RII & Rank)	Expert 1 Rank	Expert 2 Rank	Expert 3 Rank	KII Results	Triangulation Conclusion
Poor material and equipment handling /double handling	0.662(7)	7	7	8	Mentioned as a less contributing issue	Strong Agreement
Poor Planning and scheduling	0.623(8)	8	4	3	Contributing factor of delay and waste	Weak Agreement
Poor controlling and supervision/ lack of management	0.731(4)	4	4	5	Highlighted by experts as one of the major issues	Strong Agreement
Poor co-ordination among parties	0.677(2)	3	3	4	Discussed as one of the major causes	Moderate Agreement
Rework due to poor workmanship	0.700(5)	5	8	7	Recognized as moderate but less frequent	weak Agreement
Lack of waste minimization /waste management plan	0.731(2)	2	2	2	All experts emphasized equal importance	Strong Agreement
Lack of training and awareness	0.685(6)	6	6	6	Identified as common issue	Strong Agreement
Lack of proper construction waste management guidelines	0.685((1)	1	1	1	Consistently cited as major gap	Strong Agreement

Factors related to management and supervision, particularly lack of construction waste management guidelines, absence of waste minimization plans, poor co-ordination among parties, poor planning, and scheduling are the most influential contributors to construction waste as well as rework due to poor workmanship issues also contribute to some extent but with slightly lower consensus among experts. Overall, weak management practices and insufficient waste control strategies significantly increase construction waste, indicating an urgent need for improved planning, policy implementation, and personnel training.

Triangulation of Component 3: Project & Contract Administration Issues

Table 29: Triangulation Table for Component 3

Project & Contract Administration Issues	Quantitative (RII & Rank)	Expert 1 Rank	Expert 2 Rank	Expert 3 Rank	KII Results	Triangulation Conclusion
Lack of incentives	0.515(8)	4	4	4	Considered as a major administrative problem by experts	Weak Agreement
Error in contract document/Po or documentation/lack of documentation	0.577 (2)	2	2	1	Major root cause of delays & disputes	Strong Agreement
Delay in cash flow/irregular payments	0.531(3)	3	3	3	Highlight as a frequent cause of slowdowns	Strong Agreement
Long project duration leading to change in material price	0.562(1)	1	1	2	Highlighted as major cause for waste	Strong Agreement
Waiting resulting from crew interference	0.500(4)	6	4	5	Mentioned but not rated as the topmost issue	Moderate Agreement
Inefficient Consumption of resources	0.523(7)	8	7	7	Acknowledged as an issue but considered secondary	Strong Agreement
Waiting due to equipment setup and sharing	0.546(5)	5	5	5	Specially in large projects with shared equipment	Strong Agreement
Composite and building design	0.531(6)	7	8	8	Recognized as less frequent	Moderate Agreement

Triangulation shows that Component 3 revolves around financial instability and administrative weaknesses in construction projects. Long project duration, poor documentation, irregular payments, and insufficient incentives collectively undermine project performance. These issues highlight the need for improved financial planning, transparent documentation practices, timely payment mechanisms, and performance-based incentive systems to enhance efficiency and minimize project delays and cost overruns.

Triangulation of Component4: Adverse On-Site Working Conditions

Table 30: Triangulation Table for Component 4

Adverse On-Site Working Conditions	Quantitative (RII Rank) &	Expert 1 Rank	Expert 2 Rank	Expert 3 Rank	KII Results	Triangulation Conclusion
Leftover materials on site	0.615(2)	4	3	4	Considerable issue but not as major one	Moderate Agreement
Poor site condition	0.662(3)	1	2	2	Highlighted as a frequent cause	Moderate Agreement
Site congestion	0.654(1)	2	1	1	Major operational problem	Strong Agreement
Lightning problem	0.538(5)	5	4	5	Mentioned as secondary cause	Strong Agreement
Unpredictable local conditions	0.638(4)	4	4	3	Affects workflow but varies by project	Strong Agreement

Overall, the triangulation suggests that Component 4 reflects a combination of **site** management deficiencies, environmental uncertainties, and operational constraints that collectively impact project performance. The results point toward the need for improved site planning, material handling systems, traffic and access management, and site safety measures, along with better anticipation of local conditions through proactive risk assessment. These improvements can significantly enhance workflow, minimize delays, and create safer, more efficient construction environments.

4.4 A Stakeholder-Informed Framework for Effective Construction Waste Minimization in Building Projects in Kathmandu Valley

The third objective of the study was to prepare a stakeholder informed framework for effective construction waste minimization in building projects in Kathmandu valley. For this a systematic framework preparation philosophy and process were carried out citing the relevant literature and findings from the QS and KII.

Philosophy: The framework is proactive and preventive, focusing on eliminating waste at its source rather than just managing it after it is generated. It is built on the principle of Continuous Improvement and is divided into three core phases, supported by an enabling foundation.

Foundation: Governance & Stakeholder Alignment

This is the bedrock of the entire framework, ensuring all parties are committed and coordinated.

1 Develop a Project-Specific Waste Management Plan (WMP):

- Action: Make the WMP a mandatory document in the project charter.
- Stakeholder Responsibility: Led by the client and project manager, with input from the architect, engineer, and main contractor.
- Content: Define waste reduction targets, assign roles and responsibilities, outline procedures for material handling, and set protocols for waste segregation and disposal.

2 Contractual Integration of Waste Management:

- Action: Include clear clauses in all contracts that incentivize waste minimization and penalize poor practices.
- Stakeholder Responsibility: Clients, Lawyers, and Project Managers.

3 Pre-Construction Workshops:

- Action: Conduct workshops with all key stakeholders (Client, Designer, Contractor, Subcontractors) to review the WMP and align on waste reduction goals.
- Stakeholder Responsibility: Project Manager.

4.4.1 The Three Core Phases of Waste Minimization

The core phases of waste management are depicted and discussed hereafter.

4.4.1.1 Phase 1: Pre-Construction & Design Phase (Prevention at Source)

This phase targets the root causes identified as most critical: Inappropriate Construction Methods and Substandard Material Quality.

Table 31: Pre-Construction Phase Objective, Strategic Actions & Stakeholders Role

Objective	Strategic Action	Key Stakeholders & Their Roles
Eliminate Design & Method Errors	<ul style="list-style-type: none"> • Adopt Value Engineering & constructability reviews to simplify designs and avoid errors. • Digitally model and simulate construction sequences to identify and rectify potential method-related waste (e.g., formwork, cutting). 	Architects & Engineers: Design for standard material sizes, avoid complex geometries, specify durable materials. Project Manager: Facilitate reviews.
Ensure Material Quality & Accuracy	<ul style="list-style-type: none"> • Implement a rigorous Material Quality Assurance protocol for all suppliers. • Use Building Information Modeling (BIM) for accurate quantity take-offs to prevent ordering errors and over-ordering. 	Client: Approve budget for quality materials. Quantity Surveyor: Perform precise BIM-based calculations. Project Manager: Oversee supplier qualification.

4.4.1.2 Phase 2: Construction & Execution Phase (Minimization & Control)

This phase directly addresses the top-ranked factor: Inadequate Storage and other on-site issues.

Table 32: Construction & Execution Phase Objective, Strategic Actions & Stakeholders Role

Objective	Strategic Action	Key Stakeholders & Their Roles
Prevent On-Site Damage & Loss	<ul style="list-style-type: none"> Establish a dedicated, secure, and organized Storage Area with proper shelving, weather protection, and clear labelling. Implement a First-In, First-Out (FIFO) inventory system. Train workers on proper material handling to prevent damage during transportation on-site. 	<p>Main Contractor: Allocate space, provide infrastructure, enforce protocols.</p> <p>Site Supervisor: Daily management of storage and handling.</p> <p>Workers: Adhere to trained procedures.</p>
Monitor & Control Material Flow	<ul style="list-style-type: none"> Designate specific unloading zones close to the point of use. Conduct immediate inspection of delivered materials for defective items or damage from shipping. 	<p>Storekeeper: Manage inventory and inspect deliveries.</p> <p>Site Engineer: Verify materials meet specifications.</p>

4.4.1.3 Phase 3: Post-Construction & Closeout Phase (Management & Improvement)

This phase deals with waste that could not be prevented.

Table 33: Post-Construction Phase Objective, Strategic Actions & Stakeholders Role

Objective	Strategic Action	Key Stakeholders & Their Roles
Segregate and Handle Waste Properly	<ul style="list-style-type: none"> Provide clearly labeled segregation bins (e.g., for wood, metal, concrete, plastic). Partner with authorized recycling facilities and waste collectors. 	<p>Main Contractor: Provide bins and logistics.</p> <p>Waste Management Crew: Perform segregation.</p>

<p>Measure, Learn, and Improve</p>	<ul style="list-style-type: none"> • Audit and quantify the waste generated by type. • Analyze the data to identify recurring issues (e.g., is one material frequently damaged?). • Document lessons learned and update the company's standard WMP for the next project. 	<p>Project Manager: Oversee the audit.</p> <p>Company Management: Institutionalize the learnings.</p>
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Stakeholder Informed Framework for Construction Waste Minimization

The conceptual framework developed from stakeholder's perception, KII discussion backed by literature review is provided below in Figure 9.

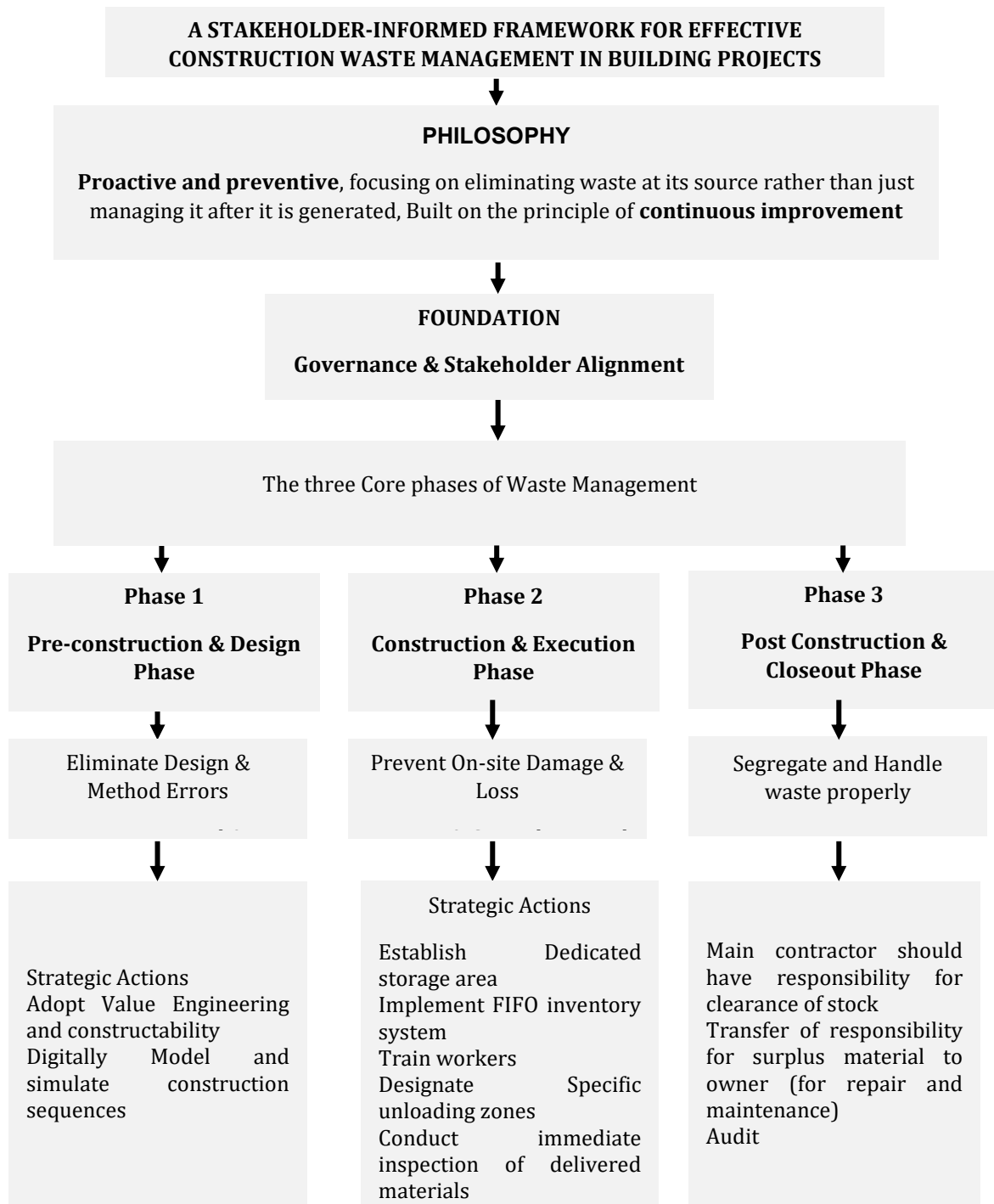


Figure 9: Stakeholder Informed Framework for Construction Waste Minimization in Building Projects of Kathmandu Valley

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

This section summarizes the key findings derived from the analyses conducted in this study. The research examined construction waste issues in building projects within the Kathmandu Valley, focusing on identifying major waste-generating factors from literature review and contextualization, and then understanding stakeholder perceptions, and developing a stakeholder-informed waste management framework. Using data collected from clients, contractors, and consultants supported by expert validation, PCA, RII, and Kendall's Tau the study provides clearer insights into waste-generating practices and proposes a structured approach for improving construction waste minimization framework. A perception-based questionnaire survey was used for the data collection process. Based on the results obtained and discussions of this research study, important conclusions can be drawn which are discussed below:

Objective 1: To identify and categorize the key factors contributing to construction waste in building projects of Kathmandu Valley

From an extensive literature review and stakeholder survey, this study identified numerous factors contributing to construction waste across building projects. These factors were validated by industry experts to ensure contextual accuracy. Using Principal Component Analysis (PCA), the factors were grouped into thematic components, providing a clear and organized representation of the major sources of waste.

The categorization revealed that waste generation is influenced by several interrelated domains, including material quality and handling deficiencies, inefficient site management & supervision, project & contract administration, adverse on-site conditions issues shortcomings, design & documentation flaws, workforce competence & Selection, technical knowledge & resource availability.

This structured classification offers a foundational understanding of where waste originates, by loading different factors causing waste in those thematic components enabling stakeholders to address root causes rather than isolated symptoms.

Objective 2: To analyze the perceptions among stakeholders regarding the significance of the identified factors causing wastes.

To assess stakeholders' differing viewpoints, Relative Importance Index (RII) and Kendall's Tau Coefficient of Concordance were used.

Since the RII rankings provided by the client, contractor, and consultant for most factors were closely aligned, Kendall's Tau correlation was employed to assess the level of agreement and disagreement among the three groups. Hypothesis testing was carried out to determine whether the observed rankings differed significantly across stakeholders. The results indicated no statistically significant difference in the viewpoints of the client, contractor, and consultant for the majority of the components. However, for Component 3, a significant difference was identified between the consultant and contractor, suggesting that their perceptions for this specific component were not in agreement. These similarities and differences highlight the importance of a collaborative and harmonized approach to waste reduction, ensuring that all stakeholders share aligned priorities and responsibilities.

Objective 3: To develop a stakeholder-informed framework for effective construction waste minimization in building projects.

After triangulating findings from quantitative analysis, qualitative expert input, and backed by literature evidence, a comprehensive framework for construction waste minimization was developed. The framework integrates the categorized thematic components, stakeholder perspectives, and areas of convergence and divergence to guide effective decision-making. Expert validation further strengthened the framework's relevance, ensuring that its recommendations reflect real-world feasibility and industry practices.

This stakeholder-informed model emphasizes preventive planning, improved coordination among parties, early-stage design reviews, enhanced site supervision, and structured material management practices as well as proper audit is most important for waste minimization. The developed framework serves as a practical tool for reducing waste adopting lean philosophy as a foundation for minimizing wastes, improving

project performance, and promoting sustainable construction practices in the Kathmandu Valley.

5.2 Recommendations

- Improve planning and coordination among project teams to reduce errors and prevent unnecessary waste
- Ensure accurate and complete design documents to minimize rework and material wastage.
- Adopt proper material storage, handling, and procurement methods to avoid damage and excess use.
- Provide regular supervision and training to workers to promote efficient and waste-reducing practices.
- Implement waste segregation, reuse, and disposal procedures on every construction site.
- Encourage clients, contractors, and consultants to work together to improve waste management outcomes
- Develop and enforce government policies that promote systematic construction waste management.
- Use the proposed waste management framework in actual projects to improve waste-reduction practices.
- Conduct awareness programs and training sessions to enhance stakeholders' understanding of waste issues.

5.2.1 Recommendations for Further Studies

- Future research should explore additional waste factors for different regions.,
- Research on the testing of the framework in different project types
- A comparative study can be done between the various project types.
- Research on the circular economy of construction waste in building projects.

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APPENDIX 1: QUESTIONNAIRE SURVEY (QUANTITATIVE)
**A Principal Component and Stakeholder Analysis for
Consensus-Driven Waste Management in Nepalese Building
Projects**

Dear Respondent, I am a student pursuing a Master of Science in Construction Management (MSCOM), currently working on my master's thesis titled: **"A Principal Component and Stakeholder Analysis for Consensus-Driven Waste Management in Nepalese Building Projects"**. This thesis aims to **1. To identify and categorize the key factors contributing to construction waste in building projects in Kathmandu Valley. 2.To analyze the divergence in perceptions among stakeholders regarding the significance of the identified thematic components 3.To develop a stakeholder-informed framework for effective construction waste management in building projects.** Your expert opinion and valuable input will play a crucial role in achieving the objectives of this research. The collected data will remain strictly confidential and will be used solely for academic purposes. Instructions for Completing the Questionnaire: Carefully read each question or statement. Respond based on your knowledge, experience, and observations related to the building construction industry. Your participation in this study is highly appreciated. Thank you for your time and cooperation.

Demographics

1.Name of the respondent

2.Gender

- Male
- Female
- Prefer not to say

3. Which type of organization are you working for ?

- Private
- Government

4.What is your job role to whom do you represent?

- Client
- Contractor
- Consultant

5. How many years of experience do you have in construction?

- 1-5 years
- 6-10 years
- 11-15 years
- 16 years or more

6. Which types of building projects are you involved in?

select many if applicable

- Residential
- Commercial
- Institutional
- Mixed use
- Others

7. How many projects have you been involved in till now?

- 0-10 projects
- 10-20 projects
- 20-30 projects
- More than 30 projects

Factors causing construction wastes

Q.8 The following factors contribute to waste generation for building projects in kathmandu valley. Please rate your perception for the factors responsible for construction wastes in building projects from 1- 5 where 1= Very Minor 2=Minor 3= Moderate 4= Major 5= Very Major.

	Very Minor	Minor	Moderate	Major	Very Major
Frequent design changes/ Rework caused by design changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Design Errors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of design information	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Complicated design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor product knowledge	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Construction drawing errors	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inadequate or improper storage / Inventory away from site	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor material and equipment handling /Double handling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Accidents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Damage during transportation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor quality of Materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ordering errors/Over-ordering/ Mistakes in quantity survey	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Errors in packing and shipping	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Defective items	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Damaged Materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor Planning and Scheduling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor controlling and supervision/ lack of management	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inappropriate construction method	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor co-ordination among parties	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Misuse or non-availability of tools or equipment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Rework due to poor workmanship	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Material misuse	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor team selection	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of waste minimization /waste management plan	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Designer inexperience	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Incompetent Worker/Improper worker's skill	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor attitude & behaviour of worker's	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of incentives	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of training and awareness	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of supplier involvement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Leftover materials on site	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor site condition	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Site congestion	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lightning problem	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Theft and Vandalism	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Unpredictable local conditions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Error in contract document/Poor documentation/lack of documentation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Delay in cash flow/irregular payments	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Long project duration leading to change in material price	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor co-ordination and communication among senior management and workers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Waiting resulting from crew interference	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Consumption of resources	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Waiting due to equipment setup and sharing	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Composite and building design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Waiting due to storage problem and material supplier delay	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of proper construction waste management guidelines	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

APPENDIX 2: SEMI- STRUCTURED QUESTIONNAIRE (QUALITATIVE)

Key Informant Interview (KII) Protocol: Validation of PCA Components and RII Rankings

Research Title: Analysis of Critical Factors Influencing Construction Waste Using Principal Component Analysis (PCA) and Relative Importance Index (RII)

Interviewer: Neha Mishra

Interviewee (Expert):

Organization:

Stakeholder Group: Client Contractor Consultant Academician

Date & Time:

Duration: 45-60 Minutes

Part A: Introduction & Consent (5 Minutes)

"Good [Morning/Afternoon]. Thank you for taking the time to meet with me today. My name is Neha Mishra and I am conducting research on the critical factors influencing construction waste management.

As part of this study, we have already surveyed professionals and identified 46 sub-factors, which we statistically grouped into 7 major components. We also calculated their relative importance from the perspectives of Clients, Contractors, and Consultants.

The purpose of this interview is to get your expert opinion to help us validate and understand the 'why' behind these statistical findings. Your insights will be invaluable in interpreting the results correctly.

This interview will take about 45 minutes. With your permission, I would like to audio record the conversation to ensure I accurately capture your views. All your responses will be kept confidential and will be used solely for academic purposes. The recording will be deleted after transcription. Are you comfortable with me proceeding with the recording?"

Interviewee consents to recording.

Interviewee does not consent to recording (researcher will take detailed notes).

Part B: Broad Opening Question (5 Minutes)

Objective: To get the expert's top-of-mind concerns before introducing the study's specific findings.

Question 1:

"Based on your extensive experience, what would you say are the top three causes of material waste and inefficiency on construction projects you have been involved in?"

Prompts:

Why do you think these are the most critical?

Can you give a brief example from a recent project?

Part C: Validation of PCA Components & RII Rankings (30 Minutes)

Objective: To present the study's core findings and get expert validation and interpretation.

Script:

"Now, I'd like to walk you through the seven major groupings, or 'components,' that our analysis revealed. For each, I'll show you the factors it contains and how different stakeholders ranked them. I'm very interested in whether these groupings make sense to you and your thoughts on the rankings."

A) Does all these grouping feel logical and complete to you?"

Component	Proposed Name
1	Material Quality & Handling Deficiencies
2	Inefficient Site Management & Supervision
3	Project & Contract Administration Issues
4	Adverse On-Site Working Conditions
5	Design & Documentation Flaws
6	Workforce Competence & Selection
7	Technical Knowledge & Resource Availability
8	Poor co-ordination and communication between senior management and workers
9	Theft and Vandalism
10	Waiting due to storage problem and material supplier delay

11	Lack of supplier involvement
----	------------------------------

Component -1(Questions)

1. “Based on your experience, which of these factors cause the most material waste on site?”
2. “Do you agree with the order of importance shown by the RII results?”
3. “Are there any factors that are missing or overestimated in this ranking?”
4. “How can these issues be practically reduced?”
5. Please rank given table from 1-9
6. "In your view, what is the single most important underlying issue that connects all these factors?"
7. A factors like Inadequate or improper storage / Inventory away from site have very high RII, why is this such a universal pain point?"

S.N.	Factors for component 1 (Material Quality and Handling deficiencies)	Rank provided by experts
1.	Inadequate or improper storage / Inventory away from site	
2.	Accidents	
3.	Damage during transportation	
4.	Poor quality of Materials	
5.	Ordering errors/Over-ordering/ Mistakes in quantity survey	
6.	Errors in packing and shipping	
7.	Defective items	
8.	Damaged Materials	
9.	Inappropriate construction method	

Component -2

1. “Based on your experience, which of these factors cause the most material waste on site?”
2. “Do you agree with the order of importance shown by the RII results?”
3. “Are there any factors that are missing or overestimated in this ranking?”

4. "How can these issues be practically reduced?"
5. Please rank this table from 1-8

S.N.	Factors for Component 2(Inefficient Site Management & Supervision)	Rank provided by experts
1.	Poor material and equipment handling /Double handling	
2.	Poor Planning and Scheduling	
3.	Poor controlling and supervision/ lack of management	
4.	Poor co-ordination among parties	
5.	Rework due to poor workmanship	
6.	Lack of waste minimization /waste management plan	
7.	Lack of training and awareness	
8.	Lack of proper construction waste management guidelines	

Component -3

1. "Based on your experience, which of these factors cause the most material waste on site?"
2. "Do you agree with the order of importance shown by the RII results?"
3. "Are there any factors that are missing or overestimated in this ranking?"
4. "How can these issues be practically reduced?"
5. Please rank this table from 1-8
6. **Probing Stakeholder Perception Gaps**

Gap 1: Client vs. Contractor on Equipment Issues

"Let's look at a factor like 'Waiting due to equipment setup and sharing (F43)'. Our data shows that Clients tend to rate this as more critical than Contractors. Why do you think this perception gap exists?"

S.N.	Factors for Component 3(Project & Contract Administration Issues)	Rank provided by experts
1.	Lack of incentives	
2.	Error in contract document/Poor documentation/lack of documentation	

3.	Delay in cash flow/irregular payments	
4.	Long project duration leading to change in material price	
5.	Waiting resulting from crew interference	
6.	Inefficient consumption of resources	
7.	Waiting due to equipment setup and sharing	
8.	Composite building design	

Component -4

1. “Based on your experience, which of these factors cause the most material waste on site?”
2. “Do you agree with the order of importance shown by the RII results?”
3. “Are there any factors that are missing or overestimated in this ranking?”
4. “How can these issues be practically reduced?”
5. Please rank this table from 1-5
6. **Gap 2: Consultant vs. Others on Site Conditions**

"For factors in **Component 4 (Adverse On-Site Conditions)**, such as site congestion (F33), Contractors consistently provided lower RII scores than Clients and Consultants. From your perspective, what explains this difference in perceived importance?"

S.N.	Factors for Component4 (Adverse On-Site Working Conditions)	Rank provided by experts
1.	Leftover materials on site	
2.	Poor site condition	
3.	Site congestion	
4.	Lightning problem	
5.	Unpredictable local conditions	

Component -5

1. “Based on your experience, which of these factors cause the most material waste on site?”
2. “Do you agree with the order of importance shown by the RII results?”
3. “Are there any factors that are missing or overestimated in this ranking?”
4. “How can these issues be practically reduced?”
5. Please rank this table provided below from 1-5
6. "This component is entirely focused on design-phase issues. How early in a project do this design flaws typically get introduced, and why are they so hard to correct later?"
7. "From your stakeholder's perspective, what is the most effective way to mitigate these design-related issues *before* construction begins?"

S.N.	Factors for Component5 (Design & Documentation Flaws)	Rank provided by experts
1.	Frequent design changes/ Rework caused by design changes	
2.	Design Errors	
3.	Lack of design information	
4.	Construction drawing errors	
5.	Designer inexperience	

Component -6

1. “Based on your experience, which of these factors cause the most material waste on site?”
2. “Do you agree with the order of importance shown by the RII results?”
3. “Are there any factors that are missing or overestimated in this ranking?”
4. “How can these issues be practically reduced?”
5. Please rank this table provided below from 1-3.
6. Client rate it differently than contractor and consultant? What may be the reason?

S.N.	Factors for Component6 (Workforce Competence & Selection)	Rank provided by experts
1.	Material misuse	
2.	Poor team selection	
3.	Incompetent Worker/Improper worker's skill	

Component -7

1. “Based on your experience, which of these factors cause the most material waste on site?”
2. “Do you agree with the order of importance shown by the RII results?”
3. “Are there any factors that are missing or overestimated in this ranking?”
4. “How can these issues be practically reduced?”
5. Please rank this table provided below from 1-3.

S.N.	Factors for Component7 (Technical Knowledge & Resource Availability)	Rank provided by experts
1.	Complicated design	
2.	Poor product knowledge	
3.	Misuse or non-availability of tools or equipment	

Part B: High-Consensus Critical Factor

"Across the board, a factor like '**Lack of proper construction waste management guidelines (F46)**' was seen as very important. Why has this been a persistent challenge in the industry, and what would it take to implement it effectively?"

Part C: Solutions and Recommendations (10 Minutes)

Objective: To move from problem identification to solution-oriented discussion.

Questions:

1. "If you had the authority to implement one change to address the issues in **Component 2 (Inefficient Site Management)**, what would it be?"

2. "Looking at all the factors we've discussed, which one do you believe offers the 'biggest bang for the buck' meaning, if improved, it would have the largest positive ripple effect on reducing waste and improving efficiency?"
3. "Are there any emerging technologies (e.g., BIM, AI) or management practices (e.g., Lean, Prefabrication) that you see as particularly effective in tackling these root causes?"

Part D: Conclusion (5 Minutes)

Script:

"That covers all the specific questions I have for you today."

1. "Is there any critical factor or issue related to construction waste that you feel our study has missed?"
2. "Do you have any final thoughts or comments on anything we discussed?"
3. "Thank you once again for your invaluable time and expert insights. Your contribution is crucial to the success of this research. Would you be open to a brief follow-up via email if I need to clarify any points?"

APPENDIX 3: VALIDATING QUNATITATIVE DATA

Key Informant Interview (KII) Protocol: Validation of PCA Components and RII Rankings

Research Title: Analysis of Critical Factors Influencing Construction Waste Using Principal Component Analysis (PCA) and Relative Importance Index (RII)

Interviewer: Neha Mishra

Interviewee (Expert): ① Naboraj Pyakurel sir (Govt.) ② Dr. Santosh Kaini (Deputy Director General/Academician)

Organization :

Stakeholder Group: Client Contractor Consultant Academician (Contractor)

Date & Time: 13 Nov, 2025.

Duration: 45-60 Minutes

Part A: Introduction & Consent (5 Minutes)


"Good [Morning/Afternoon]. Thank you for taking the time to meet with me today. My name is Neha Mishra and I am conducting research on the critical factors influencing construction waste management.


As part of this study, we have already surveyed professionals and identified 46 sub-factors, which we statistically grouped into 7 major components. We also calculated their relative importance from the perspectives of Clients, Contractors, and Consultants.

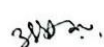
The purpose of this interview is to get your expert opinion to help us validate and understand the 'why' behind these statistical findings. Your insights will be invaluable in interpreting the results correctly.

This interview will take about 45 minutes. With your permission, I would like to audio record the conversation to ensure I accurately capture your views. All your responses will be kept confidential and will be used solely for academic purposes. The recording will be deleted after transcription. Are you comfortable with me proceeding with the recording?"

- Interviewee consents to recording.
- Interviewee does not consent to recording (researcher will take detailed notes).

Signature: 

Signature: 

Signature: 

ANNEX -I SUBMISSION ACKNOWLEDGEMENT FROM IOEGC-17 TEAM

From: "IOEGC-17 Working Committee" <ioegc17@gmail.com>
To: "Neha Mishra" <079rmscom016.neha@pcampus.edu.np>
Date: 11/29/2025 6:30:22 AM
Subject: [IOEGC17] Submission Acknowledgement

Neha Mishra:

Thank you for submitting the manuscript, "Identification and Categorization of Key Factors Contributing to Construction Waste in Building Projects of Kathmandu Valley" to 17th IOE Graduate Conference. With the online conference paper management system that we are using, you will be able to track its progress through the editorial process by logging in to the conference portal:

Submission URL: <https://conference.ioe.edu.np/gc/index.php/17/authorDashboard/submission/697>
Username: neha_123

If you have any questions, please contact me. Thank you for considering this conference as a venue for your work.

IOEGC-17 Working Committee

With Warm Regards,
IOEGC-17 Editorial Team

ANNEX-II ORIGINALITY REPORT



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