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**Assessment of Waste Factors due to Non-Value Adding Activities
and Evaluation of Mitigation Strategies in Hydropower
Construction Projects in Nepal**

By

Sudin Raj Shrestha

A THESIS

**SUBMITTED TO THE DEPARTMENT OF CIVIL ENGINEERING IN
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OF MASTER OF SCIENCE IN CONSTRUCTION MANAGEMENT**

**DEPARTMENT OF CIVIL ENGINEERING
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April, 2026

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The undersigned certify that we have read, and recommended to the Institute of Engineering for acceptance, a thesis entitled **“Assessment of Waste Factors due to Non-Value Adding Activities and Evaluation of Mitigation Strategies in Hydropower Construction Projects in Nepal”** submitted by Sudin Raj Shrestha in partial fulfilment of the requirements for the degree of Master of Science in Construction Management.


.....
Supervisor,
Asst. Professor Mahendra Raj Dhital
Department of Civil Engineering
IOE, Pulchowk Campus


.....
External Examiner,
Er. Subash Kumar Bhattarai
Visiting Faculty
Construction Management
Centre for Post Graduate Studies
Nepal Engineering College (nec-CPS)


.....
Program Coordinator,
Asst. Professor Mahendra Raj Dhital
M.Sc. in Construction Engineering and
Management Program
Department of Civil Engineering
IOE, Pulchowk Campus

April, 2026

DECLARATION

I hereby declare that the thesis entitled “**Assessment of Waste Factors due to Non-Value Adding Activities and Evaluation of Mitigation Strategies in Hydropower Construction Projects in Nepal**” submitted to the Department of Civil Engineering in partial fulfilment of the requirement for the degree of Master of Science in Construction Management, is a record of an original work done under the guidance of Asst. Prof. Santosh Kumar Shrestha, Institute of Engineering, Pulchowk Campus. This thesis contains only work completed by me except for the consulted material which has been duly referenced and acknowledged.



Sudin Raj Shrestha

PUL080MSCoM021

Msc in Construction Management

Date: April, 2026

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Sudin Raj Shrestha

PUL080MSCoM021

April, 2026

ABSTRACT

Nepal is a country that has sufficient resources from water and largely depends much on hydropower as a major energy source and more than 90% of its energy is generated from hydropower which is very important for the economic boost through energy generation. However, in the present scenario the construction of hydropower projects face delays as well as high waste generation.

This study addresses the predominant challenge of Non-Value Adding Activities (NVAAs) in Hydropower construction projects in Nepal, where construction waste majorly hampers the efficiency of project. The primary objective is to systematically assess and prioritize factors contributing to NVAAs in Hydropower construction projects in Nepal. Employing a comprehensive framework with 8 groups and 51 factors along with 24 mitigating measures, the methodology includes structured questionnaire surveys to collect stakeholder perspectives, using the Likert scale. The Relative Importance Index (RII) is computed to rank these NVAA groups and factors based on stakeholders perspectives, illuminating their relative significance. Design and Documentation related factors emerged as the most critical group (RII = 0.782), followed by Construction Site related factors (0.747) and Worker/Labour related factors (0.727). At the sub-factor level, inadequate site control and supervision (RII = 0.886), frequent design changes (0.857), and lack of coordination among project parties (0.854) were consistently the highest ranked contributors to NVAAs. Proper project planning ranked as the most effective mitigation strategy (Mean = 3.34), followed by preparation of accurate material specifications and adoption of effective site management practices. Moreover, Sankey diagram was generated to show the linkage between these top ranked NVAA factors and their mitigation.

Thus, this study develops a recommendations section that is useful for policymakers, industry leaders, researchers and the person involved in this sector, and can help in achieving a sustainable and secure energy future.

Keywords: *Non-Value Adding Activities (NVAA), Hydropower construction, Stakeholder Perspectives, Relative Important Index, Waste factors, Mitigating strategies*

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LIST OF ACRONYMS

NVAAs	Non-Value Adding Activities
RII	Relative Important Index
CPW	Construction Process Waste
DOED	Department of Electricity Development
F/Y	Fiscal Year
GON	Government of Nepal
PPP	Public Private Partnership
IPPAN	Independent Power Producers' Association – Nepal
VAAAs	Value Adding Activities
VSAAs	Value Supporting Activities

CHAPTER 1 INTRODUCTION

1.1 Background

Hydropower is a major source of sustainable energy in developing countries like Nepal, owing to the country's exceptionally rich water resources and high topographic relief. The sector is vital for economic growth and energy security, and the theoretical hydropower potential of Nepal is approximately 83,000 MW which makes it one of the richest nations in the world in terms of untapped renewable energy capacity (WECS, 2022). In the past two decades, the government and private sector have together have invested heavily in hydropower sector, with a growing portfolio of projects ranging from small run-of-river schemes to large peaking run-of-river and storage projects.

Major source of waste globally is the construction source; the waste may be the waste of physical materials or process-related inefficiencies that consume resources, time and space without any contribution to the end product or service. Waste occurring in construction can be categorized into three classes which are construction material waste (physical waste), non-value-adding activities (process waste), and accidental and rework-specific waste) (Viana, Formoso, Kalsaas, 2012). The particular category of waste that is of interest to this research is the second one, Non-Value-Adding Activities (NVAAs), a type of waste which is an especially insidious one since it is integrated into construction processes which is frequently not measured or addressed.

Non-Value-Adding Activities (NVAAs) can be described as those activities that consume resources, time, or space without adding value to the final product or service (Becher, 2020). Activities in any ongoing construction project can be classified broadly into three groups i.e. Value-Adding Activities (VAAs), activities that directly recondition the product in a technique that the client is willing to pay; Value-Supporting Activities (VSAs), which are required but do not add value directly; and Non-Value-Adding Activities (NVAAs), which are wasteful and should generally be avoided (Hines & Rich, 1997). Studies have continually shown that NVAAs affect project budget, project schedule, project quality, and project productivity adversely (Yusof et al., 2016).

The perception of waste avoidance as the key component of efficiency improvement dates back to the Toyota Production System, which was created by, who identified seven primary types of waste, usually remembered with the help of an acronym

WORMPIT: Waiting, Overproduction, Rework/Defects, Movement, Processing, Inventory, and Transportation (Ohno, 1998). This framework later was extended to identify an additional waste, which was the underutilization of human talent, leading to a now common DOWNTIME categorization (Motavallian, 2013). These principles, applied to construction, is now formally applied to the construction field also known as Lean Construction, which is based on the ideas of the Toyota Production System (Koskela, 1992) Lean building is designed to reduce the non-value-adding resources and time expenditures in an attempt to enhance every aspect of the construction (Abdelhamid, 2007).

In the particular case of Nepal, in a study of non-value-adding activities in construction of roads, it was discovered that NVAAs cause poor project performance which are in the form of cost overruns, time overruns, client dissatisfaction, and disruption of activity sequences (Bhatta et al., 2023). The construction business in Nepal has traditionally taken a large share of the total development outlay, about 70 percent, but the time/ cost performance of projects has been systematically poor (Panta, 2021). Although the body of research on NVAAs that currently exists has concerned road construction and building projects, hydropower construction, which is debatably a more complex, capital-intensive, and impactful phenomenon on the development trajectory of Nepal has been comparatively under-scholarised in this respect.

Hydropower projects involve a wide range of construction on steep landscapes, which entails civil construction of dams, tunnels, powerhouses, and transmission systems. These projects are both complex and geographically and geotechnically challenging due to the nature of the river gorges and mountain sites, which means that they are especially vulnerable to activities that produce waste. Such factors as a lack of site supervision, constant design alteration, the project stakeholders' lack of coordination, ineffective procurement, and lack of training of the workers are the well-documented contributors to NVAAs in construction (Nagapan, Rahman, Asmi, et al., 2012; Luangcharoenrat, Intrachooto, Peansupap, and Sutthinarakorn) The distance to the site, weather extremes during the seasons, supply chain issues, and the presence of numerous specialized contractors and consultants are compounded in hydropower projects.

Despite the scale and significance of Nepal's hydropower sector, there exists a notable gap in the literature: no systematic study has been undertaken to identify, categorize, and prioritize waste factors due to NVAAs specifically within hydropower construction

projects in Nepal, nor has there been any structured evaluation of mitigation strategies applicable to this sector. This research seeks to identify, analyze and propose mitigating strategies to minimize such activities and contribute to efficient development.

1.2 Statement of Problem

The hydropower industry of Nepal has long-standing and documented project delivery challenges. Projects are often affected by delays and cost increases and most of the infrastructure projects that are given priority at the national level have been unable to deliver according to the scheduled expectations. A large percentage of these inefficiencies are attributed to Non-Value-Adding Activities inherent in the construction process - between procurement and design and site execution and material handling.

The issue is two-fold. To begin with, there is no systematic documentation and classification of the particular waste-inducing factors that work in Nepal's hydropower construction. In the absence of this identification, project managers and policymakers are unable to prioritize interventions, as they cannot have empirical grounding. Second, despite the occurrence of awareness of NVAAs, there has not been a systematic appraisal of the relative effectiveness of the mitigation strategies available as perceived by the principal project stakeholders, that is, the clients, consultants, and contractors.

NVAAs include a broad range of inefficiencies, such as ordering and procurement mistakes; rework caused by design changes or poor workmanship; waiting time caused by material delivery delays or equipment failures; unnecessary movement of materials and people; over-ordering; and accident caused by poor safety practices, among others (Ismail and Mohd Yusof, 2016; Alwi, Hampson and Mohamed), These challenges are also compounded in the hydropower sector by the technical complexity of the construction activities, multi-party project structure, and the harsh environmental conditions.

Lack of specific research implies that the managers of hydropower projects in Nepal at present lack an empirically based, sector-specific model as to the factors of waste that are most important in their setting, or the measures to mitigate them that are most likely to be effective. The pressing practical necessity to offer such a framework is thus the motivation of this research.

1.3 Research Questions

This study is directed by three primary questions:

- a) **RQ-1:** What are the major group factors contributing to waste due to Non-Value-Adding Activities in the perception of stakeholders involved in hydropower construction projects in Nepal?
- b) **RQ-2:** How can the sub-factors contributing to waste due to NVAAs be prioritized and ranked based on stakeholder perceptions?
- c) **RQ-3:** How could the repercussions of NVAAs on hydropower projects be mitigated, and which mitigation strategies are considered most effective?

1.4 Research Objectives

The overall objective of this study is to identify and categorize waste factors due to non-value adding activities and evaluation of mitigation strategies in hydropower construction projects in Nepal. Whereas, specific objectives are as follows:

- a) To identify, categorize, and prioritize the major group factors contributing to waste due to Non-Value-Adding Activities (NVAAs) in the perception of stakeholders who are involved in Nepal's hydropower construction.
- b) To prioritize and rank the factors within each major group contributing to waste due to NVAAs, based on the perceptions of stakeholders.
- c) To propose and evaluate possible mitigation measures for minimizing the occurrence and impact of Non-Value-Adding Activities (NVAAs) in future hydropower construction projects in Nepal.

1.5 Significance of Study

This study is significant because it systematically identifies and prioritizes the major waste factors caused by NVAAs in Nepal's hydropower construction projects. By ranking these factors based on stakeholder perspectives, the study delivers a clear understanding of the most critical sources of inefficiency affecting project delivery. This helps project stakeholders focus their attention and resources on the areas that have the greatest negative impact.

The findings of this research are valuable to project owners, consultants, contractors, and policymakers. For project owners and developers, the study supports better decision-making, improved planning, and more efficient investment utilization. For

consultants, it highlights the importance of effective design coordination, communication, and supervision practices. For contractors, it provides insights into improving site operations, labor productivity, material handling, equipment usage, and workflow management. This can lead to reduced waste, shorter project durations, lower costs, and improved quality performance.

Furthermore, the mitigation strategies proposed through this study can serve as practical guidelines for improving future hydropower projects in Nepal. These strategies may assist organizations in developing better organization systems, firming stakeholder coordination, upgrading workforce skills, and applying continuous improvement practices.

Academically, this study subsidizes to the limited knowledge regarding construction waste and non-value-adding activities in hydropower projects, particularly in Nepalese context. While many studies focus on building and road projects, fewer studies have specifically examined waste factors in hydropower construction. Thus, this thesis fills an important research gap and can act as a reference for future researchers, students, and experts interested in lean construction, project management, and infrastructure development.

1.6 Scope and Limitations

Scope

This study primarily focuses on construction projects within the hydropower sector in Nepal, encompassing three primary stakeholder groups: clients, consultants, and contractors. It majorly centers on identifying and prioritizing waste aspects in hydropower construction, along with analyzing potential mitigation options for the identified waste.

Limitations

The outcomes of this study are intended to be comprehensive within the Nepalese hydropower sector only. The results may not be directly transferable to other types of infrastructure projects within Nepal, nor to hydropower projects situated in other countries, given the contextual differences in regulatory, environmental, and operational conditions that may vary across sectors and regions.

CHAPTER 2 LITERATURE REVIEW

2.1 Value in Construction

Value in construction works is described as fulfillment of the needs of the customer in comparison to the resources that have been utilized in attaining it. Satisfaction of the need of the customer is referred to as Value.

(Ohno, T., 1998) categorized activities into two groups: value-adding and non-value-adding. Activities that don't provide value need to be eliminated. Furthermore, (Hines, 1997) splitted the production activities into 3 categories:

- Non-value adding activities (NVAAs)
- Activities which are necessary but do not contribute to value; and
- Value-adding activities (VAAs)

Value-adding activities consists those activities, processes, or tasks that positively contribute to the quality, functionality, or desirability of a product as required by the client. These activities improve the end product, meet customer needs, and increase the overall value intention. Value-adding endeavours need to meet these three necessities:

- Work that physically alters the product;
- Work that the client is interested to pay;
- Work that is completed in the opening time in correct manner

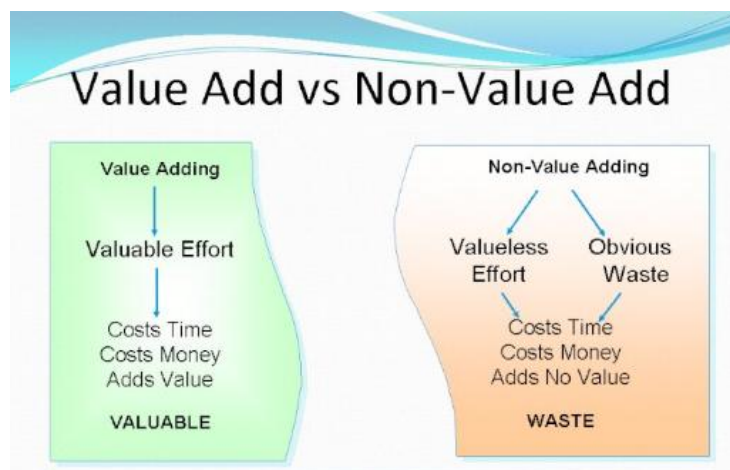


Figure 2-1: Value and Non-Value Adding activities

Source: <https://www.advanceinnovationgroup.com/blog/value-added-and-non-value-added-activities-in-lean>

2.2 Non value adding activities/ Waste

Any unnecessary products or materials which can be considered as inefficiencies that promote excessive use of resources, materials, labour, or cost which is more than what is necessary for the building process is referred to as waste (Koskela L. , 1992). According to (Becher, 2020), non-value adding activities include those tasks which consume resources, time or space without contributing value to the final product or service.

Wastes in construction have been classified by different authors in various ways:

Formoso et al. (2003) distinguished between direct and indirect waste. Direct waste was defined as the materials loss due to damage, which lead to complete wastage. In general, indirect waste refers to unnecessary work that diverges from planned design. For example, constructing a concrete culvert which does not follow the specified requirements can be measured an example of indirect waste.

(Yahya, 2006) classified construction waste into three major categories: a) Labour related waste; b) Materials related waste; and c) Machinery related waste. Waste generated by construction activities is referred as a blend of inert materials (such as earth, soil, and slurry) and non-inert materials such as timber, metal, and packaging waste (Jaillon, 2009).

(Nagapan, 2011) similarly considered construction waste into two major categories: physical waste and non-physical waste. Non-physical waste arises during the construction process and includes issues like time and cost aspects. On the other hand, physical waste is an end product of the real construction activities themselves.

Formoso et al. classified construction waste into unavoidable waste (i.e. natural waste) and waste which can be avoided. Unavoidable waste/ natural waste is the waste which are produced during construction for which the cost required to reduce or avoid it is more than the gains which are obtained from doing so. Moreover, avoiding this kind of waste is tough or costly. Particular materials, design which are complex, unexpected site conditions, etc. are some of of unavoidable waste. Avoidable wastes are those wastes that are formed in construction projects but could have been omitted for a lower cost. Ordering of materials which is more than required, lack of communication between project parties, inefficient workmanship, inadequate project planning, etc. are some of the cases of avoidable waste.

2.3 Categories of Non-Value Adding Activities

For a successful project completion, one of the most important prerequisites is eliminating ineffective acts. Toyota's head engineer Taichi Ohno, in 1998, introduced the idea of eliminating waste as the cornerstone of lean manufacturing. From the observations and thorough research, seven groups of waste were introduced i.e. seven "mudas" in Japanese, which is another way of saying "WORMPIT".

Waiting

It refers to the idle moment when a worker could be working on anything. Minimizing or eliminating this idle time enhances the value-added operations and gets rid of waste. Waiting times that are unnecessary might be produced by a lack of coordination, an uneven workflow, and a lengthy approval process. For instance, waiting for supplies, machinery, maintenance, scheduling, etc. throughout the building process is an example of idle time (Ohno, T., 1998).

Overproduction

This occurs when extra products are produced than is required or when it is produced sooner than is necessary. (Formoso, 2002) states that unnecessary material production above and beyond what is required results in overproduction of waste. Issues like quantity issues, pointless paperwork, and rivalry for scarce resources are the causes for these. In construction projects, due to overproduction, material waste, longer workdays, and increased equipment use are resulted. Overproduction refers to producing materials, outputs, or work in quantities greater than required or earlier than needed. According to Formoso (2002), waste from overproduction arises when materials are generated in excess of actual project requirements. This commonly occurs due to inaccurate quantity estimation, unnecessary documentation processes, and competition for limited resources.

Rework

Rework or defects can arise from several causes, such as work that fails to meet required specifications, poor planning and control, lack of adequate work experience, and incomplete or inaccurate information. Defects can have a straight impact on both the cost and quality of construction projects. They also create additional problems, including repeated inspections and the need to reschedule work activities.

Movement

Waste of movement refers to unnecessary or excessive motion by workers or equipment during the execution of tasks. Human movement waste includes avoidable or inefficient actions performed by employees during working hours, often caused by ineffective work methods or poorly arranged workspaces (Pinch, 2005). Activities that involve excessive movement should be improved or redesigned to enhance productivity while also promoting worker safety and well-being.

Processing

Processing waste arises when activities exceed what is actually required, including overly complex process designs, unnecessary design stages, and the use of over-engineered materials. This type of waste leads to unnecessary consumption of resources, labor, time, and effort. According to Tersine (2004), it may also occur due to quality standard issues or specifications of the final product.

Inventory

Examples of inventory waste include the accumulation of unprocessed documents, drawings, specifications, and unused data, as well as losses caused by material deterioration and poor storage conditions. It may also arise due to inaccurate quantity estimation or insufficient planning. According to Choong (2001), such issues can result in excess material stock and increased project costs.

Transportation

Transportation waste arises from several factors, including the use of unsuitable equipment, inefficient site layout, and unnecessary handling, delivery, or internal materials movement within the construction site. This type of waste significantly increases transportation costs and disrupts the smooth flow of work. According to Han (2007), it also leads to the loss of labor hours, energy, and valuable site space.

According to Motavallian (2013), many scholars recognize “unused human talent” as the 8th type of waste. This refers to situations where workers’ skills, knowledge, creativity, and experience are not fully utilized. The 8 categories of non-value-adding activities are commonly summarized using the acronym DOWNTIME, as presented in table below.

Table 2-1: DOWNTIME categories of Waste

S.N.	Waste/ NVAA	Interpretation	Examples
1	Defect	Wasted efforts by reworks, incorrect information, etc.	<ul style="list-style-type: none"> • Poor documentation • Poor work quality • Lack of repair
2	Overproduction	Excess production than demands	<ul style="list-style-type: none"> • Frequent changes in demands • Unclear customers' needs
3	Waiting	Waiting for instructions for further step	<ul style="list-style-type: none"> • Lack of communication • Insufficient staffing • Imbalanced workloads
4	Non-utilized talent	Unsuccessful for using workers' qualification	<ul style="list-style-type: none"> • Workers being given incorrect assignments • Inefficient teamwork • Insufficient training
5	Transportation	Improper materials movement	<ul style="list-style-type: none"> • Inadequate layout • Unbalanced process flow
6	Inventory	Improper storage or over storage	<ul style="list-style-type: none"> • Inadequate monitoring systems • Untrustworthy suppliers
7	Motion	Unnecessary movement of workers	<ul style="list-style-type: none"> • Workplace congestion • Inefficient control
8	Extra-processing	Requirement of more work or more quality	<ul style="list-style-type: none"> • Inadequate comprehension of client needs

According to various researchers, Non-Value-Adding Activities (NVAAs) encompass a extensive range of tasks like substandard workmanship, delayed repairs, late start times, excessive communication with minimal productivity, surplus materials on site,

long travel distances, inefficient movement of workers or resources, unnecessary on-site interventions, and information overload. By systematically categorizing the majority of these tasks, they can be more readily identified and eliminated from the workflow. For instance, poor workmanship can be classified under defects, excess materials on site under inventory, and waiting for equipment to be repaired under waiting time. Most of these unproductive activities can be mapped to one of the eight waste categories represented by the acronym DOWNTIME.

2.4 Non-value adding activities in Construction: Global Evidence

Horman and Kenley (2005) estimated that approximately half of the time spent during construction involves wasteful, non-productive activities. Research conducted in the United Kingdom further reveals that nearly thirty percent of construction work consists of rework, while between forty and sixty percent of work activities and a minimum of ten percent of materials are wasted (Singh & Kumar, 2020). In the Australian construction industry, rework is considered as the primary contributors to poor productivity (Singh & Kumar, 2020). Koskela (1994) defined value-adding activities as those that effectively convert materials and/or information into outputs that meet the needs of the client. While many construction professionals and managers tend to associate waste solely with physical scrap and debris (Achell & Bonet, 2013), Koskela (1992) argued that any inefficient use of labor, materials, equipment, or capital throughout the production process should equally be regarded as waste. Despite this, a significant proportion of construction practitioners remain unaware that many of the ongoing activities on their sites contribute little to no value to the overall project. This stagnation is further highlighted by the contrast with the manufacturing industry, whose productivity has grown exponentially over the past two decades, while construction productivity has largely remained unchanged (Kimball & Howell, 1999). Studies examining NVAAs in construction have been carried out across a wide range of countries and national contexts, with findings consistently indicating that waste-generating factors tend to converge around four broad areas: management practices, design quality, workforce competency, and procurement processes. The following represents a synthesis of key insights drawn from the global body of literature:

A review of international research highlights recurring patterns in the sources of NVAAs across different construction environments. In Australia, Teo (2001) found that

waste was largely rendered unavoidable due to management's tendency to treat waste reduction as a low priority, compounded by a shortage of dedicated resources and the absence of meaningful incentive structures that would otherwise motivate teams to minimize wasteful practices on site.

In Indonesia, Alwi (2002) identified several dominant contributors to NVAAs, including frequent repair and rework activities, prolonged waiting periods caused by delayed material deliveries, the engagement of unskilled workers, inadequate supervision, and persistent issues related to the quality and availability of raw materials. These factors collectively disrupted workflow continuity and diminished overall site productivity.

Ekanayake (2004) examined the construction landscape in Singapore and pointed to design deficiencies, inefficient operational processes, and poor material handling practices as the principal sources of waste, suggesting that waste in this context was often embedded in the planning and coordination stages rather than solely in physical execution.

Considering United Kingdom, research by Osmani et al. (2006) revealed that design changes at the last-minute were consistently regarded as the leading cause of construction waste by both contractors and architects alike, underscoring how late-stage alterations can trigger significant rework, material wastage, and schedule disruptions.

Malaysian studies conducted by Ika, Joseph, and Tawie (2016) highlighted that waste generation in construction projects was heavily influenced by weaknesses in site management, flaws in the design process, and inefficiencies within procurement systems, all of which created conditions favorable to the accumulation of non-value-adding tasks.

In Thailand, Luangcharoenrat et al. (2019) established that critical drivers of NVAAs included inadequate design documentation, poor communication of project information, and ineffective management of the overall construction process, reinforcing the view that administrative and documentation-related shortcomings can be just as damaging to productivity as physical site inefficiencies.

Construction waste is not confined to a single stage of a project but rather has the potential to emerge across every phase of the construction lifecycle. During the design phase, waste commonly arises from inaccuracies in drawings, insufficient detailing, and

frequent design alterations that necessitate rework. In the material handling phase, improper storage conditions and careless handling of materials contribute significantly to unnecessary losses. The procurement phase introduces waste through ordering errors, such as over-ordering or sourcing incorrect specifications. During the operational phase, waste stems from human error, on-site accidents, and equipment-related inefficiencies that interrupt workflow and reduce overall productivity. Beyond these primary phases, external factors such as theft and vandalism also contribute for a notable share of material losses on construction sites (Graham & Smithers, 1996). Taken together, these sources illustrate that effective waste management in construction demands a holistic approach that addresses vulnerabilities at each stage of project cycle.

2.5 Effects of NVAAs in Construction

Non-value-adding activities (NVAAs) broadly have a damaging impact on construction projects; however, the precise quantification of their effects and the detailed examination of their consequences remain zones that permit further scholarly study. One of the most tangible manifestations of NVAAs is rework, which simultaneously inflates project costs and extends delivery timelines. Research by Hwang et al. (2009) indicates that the costs associated with rework typically account for approximately five percent of total construction expenditure. Furthermore, Horman and Kenley established that NVAAs can consume up to 496 percent of the planned construction work duration, a finding that underscores the profound scale of disruption these activities can cause. Even overtime work, which is often perceived as a sign of dedication and effort, carries its own set of negative consequences, including increased worker fatigue, a higher likelihood of accidents, and ultimately, elevated project costs and extended timelines.

A case study which was conducted in Cape Town, South Africa by Ndiokubwayo and Haupt (2008) examined two residential projects and found that design modifications, omissions, errors, and engineering adjustments were recurring occurrences throughout the construction process. These issues were identified as the primary cause of incorrect instructions on site. The ripple effects of these changes were significant — in one project, change orders pushed the completion date back by nearly 33 percent, while the other experienced a delay of approximately 9 percent. In terms of financial impact, change orders increased the total project costs of both projects by an average of 6 percent compared to the original budget.

It is therefore evident that NVAAs exert considerable influence over both the productivity and the overall cost performance of construction projects. Emuze (2014) identified the following key effects of NVAAs in the construction industry:

1. Time overruns
2. Cost overruns
3. Reduced productivity
4. Variations and claims
5. Client dissatisfaction

Building upon this framework, a study conducted in Nepal by Tamrakar and Panta (2021) sought to rank these effects in the context of building sector construction projects based on their relative significance and frequency of occurrence. The results of the Nepal-based study revealed the following order of impact:

1. Time overruns
2. Cost overruns
3. Dissatisfaction of Client
4. Clash and overlapping of activities
5. Interruptions to activity sequence

2.6 Minimization of NVAAs

Lean thinking is a management philosophy centered on delivering value to the customer while consuming fewer resources and systematically eliminating waste from processes. Within this framework, NVAAs are essentially the wastes that lean thinking seeks to identify and eradicate (Tamrakar & Panta, 2021). The notion of waste elimination as a core operational principle was first introduced by Toyota in Japan in 1988, forming one of the foundational pillars of what became known as Lean Manufacturing (Ohno, 1998). Since its inception, Lean Thinking has grown into a widely embraced solution to management challenges across various industries, largely owing to its confirmed capacity to enhance operational efficiency, significantly minimize waste, and drive meaningful improvements in productivity. In this regard, minimizing NVAAs is closely linked to achieving higher productivity and greater efficiency, and these concepts are often used interchangeably within lean discourse.

The practical application of lean principles extends across both manufacturing and construction sectors, drawing from a rich body of real-world examples. These include

insights from the Toyota Production System, Lean Production methodologies, Japanese Lean Construction practices, and several other established frameworks, all of which collectively demonstrate how lean concepts can be effectively translated from theory into practice across diverse industrial settings (Singh & Kumar, 2020).

2.6.1 Lean Techniques

Lean thinking and lean construction have been positively implemented across numerous countries worldwide, including Turkey, the United Kingdom, South Africa, Brazil, Chile, Singapore, the Netherlands, and the United States, among others, yielding significant benefits in each context (Singh & Kumar, 2020). In the construction industry, the product may take the form of a building, a bridge, or any other structural infrastructure delivered to meet the specific requirements of a client. Although lean techniques were originally developed and applied within the manufacturing sector, their adoption in construction has proven equally effective, given that both industries fundamentally rely on the coordinated management of people and tools to produce a defined outcome or end product.

Several lean techniques have been identified as being directly applicable to construction projects, some of them are defined below:

i. Last Planner System

A Last Planner is defined as any individual or group responsible for determining and committing to output assignments, with these assignments typically referring to specific units of work planned for execution the following day (Ballard, 2000).

It is a production planning and system control in which the term "last planner" denotes any person or team responsible for delivering the final output by carrying out assigned tasks at the field level (Tamrakar & Panta, 2021). Unlike traditional top-down scheduling approaches, the Last Planner System operates most effectively within the Should-Can-Will-Did framework, which guides planners through a structured thought process: identifying what should be done according to the overall schedule, determining what can be done given the available resources and conditions, committing to what will be done in the upcoming period, and finally reviewing what did get accomplished in order to learn from any variances and continuously improve future planning reliability.

ii. Just in Time

This concept refers to ‘production of right quantity at the requiring time’ is the real direction towards smooth and productive operations. JIT notion is to take orders based on currently occurring demand and always to keep the minimum quantities of inventories (Ballard, Glenn & Howell, 2014).

iii. Daily Huddle Meetings

These are brief, informal gatherings which are held at the start of each working day that provide all team members with an opportunity to communicate the nature and scope of the tasks they intend to complete during that shift (Le Gratiet, 2017). These sessions foster transparency within the team by allowing members to share updates on what has been accomplished and to flag any tasks that are falling behind schedule. Beyond their organizational function, such meetings have also been associated with improved job satisfaction among workers, positively influencing their sense of purpose, self-esteem, and personal growth within the workplace (Tamrakar & Panta, 2021).

iv. 3D Models

Three-dimensional modeling serves as a valuable tool for improving constructability by facilitating design coordination and enabling the integration of multiple models to detect clashes and inconsistencies before they manifest on site (Thilakarathna & Senaratne, 2012). Emerging technologies adoption such as 3D and 4D modeling has demonstrated a considerable positive influence on project outcomes, contributing to the elimination of interferences, reduction of rework, improved productivity, fewer information requests, reduced change orders, notable cost savings, and shorter overall project durations (Staub-French & Khanzode, 2007).

v. Increased Visualization

Visualization in a construction management context can be understood as the practice of aligning an organization's vision, goals, values, and culture with its broader management systems through stimuli that engage any of the five human senses — sight, hearing, touch, odour, and taste (Tezel, Koskela & Tzortzopoulos, 2009). The underlying principle is that when employees are regularly exposed to visual representations of organizational goals and values, they are more likely to internalize and act in accordance with them throughout their daily work (Moser & Santos, 2003).

vi. Value Stream Mapping

It is a lean tool designed to add value to a process by identifying and eliminating unnecessary waste while establishing a smooth and continuous workflow (Le Gratiel, 2017). It typically involves the use of process flow charts to visually represent the entire production or construction process (Ballard & Howell, 1998). Under this approach, the manager overseeing the process develops a map that accurately reflects the current state of operations, enabling a clear and unbiased understanding of each process step without the risk of data being skewed by individuals who may underestimate or overestimate progress (Le Gratiel, 2017). This mapping process generally encompasses the following key elements: the client's value, the process flow, material flow, information flow, and lead time.

vii. Make It Flow

This lean principle focuses on creating a working environment that optimizes the entire construction process by systematically reducing unnecessary activities and waste, removing bottlenecks, and addressing other obstacles that disrupt the continuity of work (Ballard & Howell, 1998).

viii. Five S (5S)

It is a widely recognized lean tool that purposes to reduce waste through the structured application of five housekeeping principles (Thilakarathna & Senaratne, 2012). Rooted in Japanese workplace culture and practice, each of the five S's corresponds to a Japanese term: Seiri (Sort), which involves removing incorrect items; Seiton (Set in Order), which focuses on organizing materials and tools for efficient access; Seiso (Shine), which underlines cleanliness and periodic maintenance of the workspace; Seiketsu (Standardize), which creates consistent processes and standards; and Shitsuke (Sustain), which promotes the ongoing discipline required to maintain the previous four practices over time (Le Gratiel, 2017).

CHAPTER 3 RESEARCH METHODOLOGY

A systematic way of collecting, analyzing, and understanding information to understand, clarify, forecast, or solve any problem, especially in education or psychology is known as research. It helps people gain knowledge and make better decisions (Snyder, 2019).

The aim of the research is to analyze the key factors that contribute to waste due to Non-Value Adding activities and the mitigating measures to reduce them in Nepal's hydropower sector. A systematic methodology was followed beginning with a brief literature review, classifying the factors into different categories. Expert opinions were collected and gathered from the industry professionals, such as clients, consultants and contractors in hydropower sector to ensure that these factors are valid and relevant. These insight helped to refine and validate the factors that are identified.

Following this, the KOBO Toolbox platform was used to develop a structured online questionnaire. Likert scale with 5-points was used to assess the severity and significance of each factor, enabling a prioritized ranking based on expert responses. In addition, a separate joint survey was conducted to explore various strategies for addressing these challenges. This survey also utilized a 5-point Likert scale to capture the level of agreement and feasibility of different proposed solutions.

So, for this research, a literature based approach is merged with expert validation and quantitative survey methods in order to contribute a comprehensive analysis of the NVAA factors in the hydropower sector.

3.1 Study Approach

A study approach refers to the overarching plan or strategy that defines how a study is designed and carried out. It essentially outlines the means through which research objectives are to be accomplished, including how data will be collected, measured, and analyzed. Research approaches are broadly classified into three types: quantitative, qualitative and mixed methods.

The method applied in this research was a mixed approach which focussed on collect and analyze data. From the survey key challenges in hydropower sector have been identified. Furthermore, different strategies of how to reduce the waste causing

activities could be implemented were given. The qualitative solutions of which the qualitative insights provided became clear vision, while the quantitative data confirmed problems. Together these both were able to give a perfect picture of how NVAAs can be reduced in hydropower industry.

3.2 Study Methodology

This study is classified into eleven distinct phases, as illustrated below, with nine phases occurring in a sequential manner, one after the other. However, the phases of "Literature Review" and "Supervisor Input" were ongoing processes throughout the study.

- **Topics Selection:** A relevant topic of interest is identified, ensuring its significance within the chosen field.
- **Problem Statement:** A specific research problem or gap was defined which the study aims to address.
- **Objective Formulation:** A specific research objectives is set clear, which outlines what is intended to achieve through the study.
- **Thesis Proposal:** A formal document is prepared, outlining the research plan, methodology, scope, and expected outcomes.
- **Literature Review:** A critical review of existing research helps in understanding previous findings, identifying research gaps, and justifying the need for the study.
- **Questionnaire Design:** A structured survey is designed to obtain necessary information from respondents.
- **Data Collection:** Data is gathered through surveys, interviews ,case studies, experiments or other methods.
- **Data Analysis:** Using statistical tools such as SPSS, the collected data is processed and analysed.
- **Result Comparison:** The results are compared with previous research, theoretical frameworks, or industry benchmarks to validate their significance and relevance.
- **Conclusion and Recommendation:** Based on the results, key insights are summarized and recommendations for future research,policy implications or practical applications are provided.

- **Supervisor Input:** Guidance and feedback is provided by the supervisor, which ensures that the study maintains academic rigor and meets required standards.

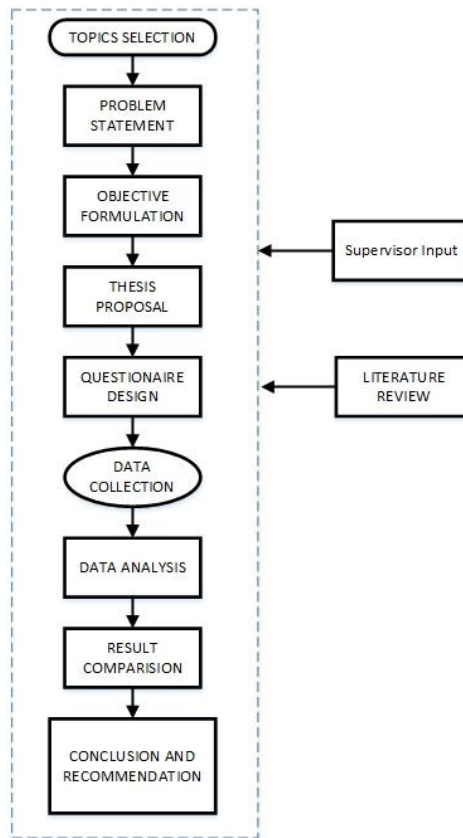


Figure 3-1 Research Methodology Flow Chart

3.3 Study Area

The study area of this research comprises hydropower construction projects across Nepal. Nepal possesses significant hydropower capacity due to its steep topography and numerous rivers originating from the Himalayas. The sector has been a key focus of national development, with projects ranging from small-scale schemes to large storage and run-of-river developments implemented by both public and private stakeholders.

3.4 Study Population, Sampling technique and Sample size

The study population only focused on hydropower projects in Nepal, which are executed by government agencies and private sector entities. To identify the research population, a brief examination was conducted of annual reports, website and publications released by the Department of Electricity Development. However, considering that new hydropower projects continue to be licensed and the sector is continuously expanding, the target population was treated as large (infinite) for the

purpose of sample size calculation. Therefore, Cochran's formula for an infinite population was adopted to estimate the required sample size for this study.

In such cases, when $p=0.5$ (50 percent) is used as the maximum uncertainty (or extreme variability), it is standard practice in such cases to assume maximum variability. For instance, suppose one wants a sample size with a precision measure of 10% with a 90% confidence level, in that case, Cochran's formula could be used to determine the required sample size, which results in 68. This method allows the sample to be big enough in size to give reliable information of the population. The sampling technique used was purposive sampling.

3.5 Methods of Data Collection

The data collected for the study consists of primary and secondary data which are described below:

Primary Data

To collect primary data, the survey was administered by using KoboToolbox, a digital data collection platform. The finalized questionnaire was distributed to participants electronically via a unique survey link. Upon receiving the link, participants were able to access the questionnaire directly through the internet. They were required to fill in the necessary information and respond to each question before submitting their responses digitally. Also to gain deeper insights, Key Informant Interviews (KII) were conducted with 3 key experts representing three hydropower projects.

Secondary Data

The secondary data for the study was gathered through a systematic evaluation of various published academic literatures which was relevant to Non-value adding activities and their mitigation. The factors and mitigation strategies so collected were validated with experts having minimum ten years of experience in hydropower sector.

3.6 Questionnaire Development

Questionnaire is a widely used tool of collecting data which involves an attempt to find out the correlation between two or more factors. The questionnaire was divided into three different parts which was dedicated to some particular aspect to obtain a complete and accurate data.

Section 1: General Data of the respondent.

The General data of the Respondent section includes the education, organization type, occupation, work experience and sector of expertise in hydropower used to classify the respondent.

Section 2: Defines the causes of waste due to NVAAs in Hydropower sector

The analysis of this section includes an analysis and ranking of eight different groups and 51 factors contributing to waste due to NVAAs. It is a 5-point Likert Scale ranging from 0 for “Strongly Disagree”, 1 for “Disagree”, 2 for “Agree”, 3 for “Neutral” and 4 for “Strongly Agree”. Respondents were also asked to indicate which are the most inhibiting groups in contributing to NVAA.

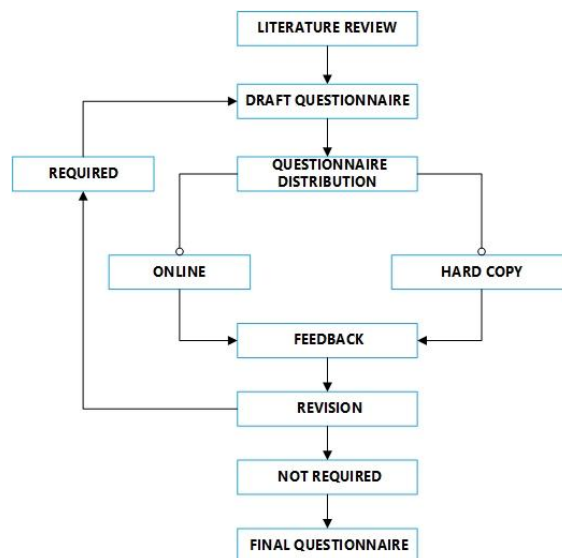


Figure 3-2 Questionnaire Design Process

Section 3: Different strategies for mitigating or reducing NVAA.

The main outcome of this section was to get the relevant information on the various strategies proposed which may help reduce NVAAs in construction. A 5-point Likert scale was used, where 1 represents "Not at all," 2 stands for "Slightly," 3 indicates "Moderately," 4 corresponds to "Very much," and 5 means "Extremely."

3.7 Data Analysis

After data collection it has to be processed and analyzed as per the research objective set at the beginning of research plan. Processing and analyzing of data means editing,

classification, coding, tabulating and transforming the collected data into general information. (Kothari, n.d.). Thus, the complicated data were exported to Excel then it was filter out and uploaded to SPSS for further analysis.

3.10.1 Ranking of factors and mitigation measures

The data that is collected will be analyzed through RII method to rank the waste causing factors due to NVAAs and their mitigation. The 5-point Likert scale range from 0 to 4 is adopted and converted to relative important indices (RII) of each groups.(Azman et al., 2019)

$$RII = \frac{\Sigma W}{A * N}$$

Where,

- **W** = Weightage given by the respondent to each factor (0 for Strongly Disagree, 1 for Disagree, 2 for Neutral, 3 for Agree and 4 for Strongly Agree)
- **A** = Highest Weightage (here,4)
- **N** = Total No of Sample

Here RII values ranges from 0 to1 where the maximum value indicates the higher rank.

3.10.2 Correlation check

Correlation of identified factors will be checked by Spearman's rank correlation test. The main advantage of this test is, it doesn't require the assumption of homogeneity and normality of variance. The coefficient varies from +1 to -1. +1 indicates the perfect positive relation and -1 indicates the perfect negative relationship. The Spearman's rank correlation coefficient can be considered by following formula.(Schober et al., 2018).

$$r = 1 - \frac{6\Sigma d}{n^3 - n}$$

Where,

- **r** = Spearman's rank correlation coefficient between two parties
- **d** = Rank difference between two parties
- **n** = number of rank pairs

3.10.3 Chi-Square Test

This test (also written as chi-square or χ^2 test) is a statistical tool commonly applied in the analysis of contingency tables, mostly when dealing with large sample sizes. This test is used to determine whether two categorical variables — represented by the two dimensions of a contingency table — are statistically independent of one another in their influence on the test statistic (Rana and Singhal, 2015). The formula for chi-square test is given below:

$$\chi^2 = \sum \frac{(O_i - E_i)^2}{E_i}$$

Where,

- χ^2 = Chi-Squared Value
- O_i = Observed Value
- E_i = Expected Value

3.10.4 Kruskal Wallis H- Test

This test is a non-parametric statistical tool employed to determine whether significant differences exist among three or more independent groups. It is particularly useful when the data does not follow a normal distribution and fails to meet the assumptions required by parametric tests such as ANOVA (Ostertagova, Ostertag, and Kováč, 2014). The test works by ranking all data points collectively and then examining whether the mean ranks differ meaningfully across the groups being compared. Statistical significance is subsequently determined using the p-value, whereby a value of $p < 0.05$ is considered statistically significant, indicating that a meaningful difference exists in at least one of the groups.

$$H = \left(\frac{12}{N(N+1)} \sum \frac{R_j^2}{n_j} \right) - 3(N+1)$$

Where:

- H=the degree of difference in distributions across groups
- N = total number of observations for all groups
- R_j = sum of ranks for group j
- n_j = number of observations in group j

- k = number of group

3.10.5 Interlinkage Analysis between Top ranked NVAA sub-factors and Top ranked mitigation measures

The ranking alone for sub-factors and mitigation measures alone do not reveal whether the mitigation strategies prioritized by stakeholders adequately address the most critical waste causing sub-factors. To bridge this gap, an interlinkage analysis was conducted. The objective of this study is to find the extent to which each mitigation strategy addresses each waste causing sub-factor, identify patterns of strong and weak reflection, and highlight gaps where high-priority waste causes are not matched by correspondingly high-priority mitigation measures. This analysis is essential for answering the overarching research question: Are the challenges (waste causing sub-factors) well reflected in the proposed mitigation measures? Without such an interlinkage assessment, stakeholders may implement mitigation strategies that are perceived as effective in isolation but do not directly address the root causes of waste.

Linkage Strength Calculation

Since no direct expert judgment data was collected for pairwise waste-mitigation effectiveness, linkage strengths were calculated using an objective, replicable formula based solely on available data:

$$\text{Linkage Strength} = (\text{Direct Match Score} \times 0.6) + (\text{Rank Proximity Score} \times 0.4)$$

a) Direct Match Score (DM)

The Direct Match Score (0–100) was assigned based on semantic (keyword) similarity between each waste sub-factor and each mitigation strategy. Three levels of matching were defined:

Table 3-1: Levels of matching for DM

Match Type	Score	Condition	Example
Perfect / Opposite Match	100	Identical or directly opposing keywords	"Frequent design changes" ↔ "Minimization of design changes"

Match Type	Score	Condition	Example
Strong Partial Match	75	Closely related concepts	"Inadequate site control" ↔ "Adoption of effective site management practices"
Weak Partial Match	50	Somewhat related concepts	"Ineffective scheduling" ↔ "Proper project planning"
No Match	0	No keyword relationship	"Poor quality of workmanship" ↔ "Use of efficient equipment"

The weight of 60% was assigned to Direct Match to reflect the importance of semantic relevance in establishing logical waste-mitigation relationships.

b) Rank Proximity Score (RP)

The Rank Proximity Score was calculated using the following formula:

$$\text{Rank Proximity Score} = 100 - (|\text{Waste Rank} - \text{Mitigation Rank}| \times 5)$$

This formula penalizes mismatches in priority order. The underlying assumption is that higher-ranked (more critical) waste causes should be addressed by higher-ranked (more effective) mitigation strategies. A waste-mitigation pair with identical ranks receives a score of 100. Each rank difference of 1 reduces the score by 5 points. A maximum difference of 20 ranks would yield a score of zero, but given the range of 1–10, the minimum possible score is $100 - (9 \times 5) = 55$.

The weight of 40% was assigned to Rank Proximity to reflect stakeholder priorities without allowing rank mismatches to dominate the linkage strength calculation.

3.11 Internal Consistency Reliability of Data

Internal consistency reliability of delay items test was conducted by using Cronbach's alpha. This test determined how all the factors related to the test were correlated with each other. When all factors measured the same construct, the values of Cronbach's alpha were maximized (Hajjar, 2018). Generally following Thumb rule is applied.(Tavakol & Dennick, 2011).

$C\alpha > 0.9$ - Excellent

$C\alpha > 0.8$ - Good

$C\alpha > 0.7$ - Acceptable

$C\alpha > 0.6$ - Questionable

$C\alpha > 0.5$ - Poor

$C\alpha > 0.4$ - Unacceptable

Table below shows that all Cronbach's alpha ($C\alpha$) values for the NVAA factor groups were higher than 0.7, which indicates that they are within an acceptable range for constructing performance measurement (Zhang, 2005).

Table 3-2 Internal Consistency Reliability Test

S.N	Groups	Sample	Items	Cronbach's Alpha
1	G1	77	7	0.728
2	G2	77	8	0.729
3	G3	77	10	0.864
4	G4	77	6	0.741
5	G5	77	4	0.793
6	G6	77	7	0.717
7	G7	77	6	0.753
8	G8	77	3	0.808

Table 3-3 Internal Consistency Reliability Test for Strategies

Cronbach's Alpha	Sample	No of Items
0.923	77	23

3.12 Research Matrix

Table 3-4 Research Matrix

Objective	Methods/Approach	Data Collection Tools	Data Sources	Expected Outcome
Prioritize and rank major group factors	Qualitative & Quantitative (using RII)	Literature review, Expert validation, Questionnaire survey with Likert scale	Hydropower professionals (clients, consultants, contractors), academic papers, reports	Identification and ranking of major group factors contributing to waste due to NVAAs occurring in hydropower projects
Prioritize and rank sub-factors for groups.	Qualitative & Quantitative (using RII)	Literature review, Expert validation, Questionnaire survey with Likert scale	Survey respondents (industry professionals), reports	Ranking of sub-factors of the major groups contributing to waste
Propose mitigating strategies	Qualitative and Quantitative (Mean Ranking followed by Kruskal Wallis H and Chi square Test)	Literature review, Expert validation, Questionnaire Surveys with Likert scale	Survey respondents (industry professionals)	Ranking strategies for minimizing wastes due to NVAAs in hydropower projects.

CHAPTER 4 RESULT AND ANALYSIS

4.1 Prioritization and Ranking of major group factors

The data was collected from 77 respondents, including 29 consultants, 23 clients, and 25 contractors. As mentioned in Chapter 3, the minimum required sample size was 68, so collecting 77 responses met this requirement. The responses were coded in SPSS and analyzed using various statistical methods, including Relative Importance index, Spearman's rank coefficient, Kruskal-Wallis H-Test and Chi-Square Test.

Final list of NVAA groups and factors were obtained as follows:

Table 4-1 Groups for Factors

S.N	Group Name	Group Code
1	Procurement related	G1
2	Construction site related	G2
3	Design and Documentation related	G3
4	Material handling, transportation and storage related	G4
5	Management related	G5
6	Workers/Labors related	G6
7	Environment and other external factors	G7
8	Equipment and machinery	G8

The major factors for NVAAs with their respective group and their code are presented in Table 4-2 table below.

Table 4-2 Summary of Groups, Factors and Code

Groups	Factors	Code
Procurement related factors	Errors in material ordering	G1F1
	Inaccurate quantity estimation	G1F2
	Delays due to waiting for material replacement	G1F3
	Errors by suppliers	G1F4
	Use of inconsistent estimation methods	G1F5
	Ineffective procurement scheduling	G1F6
	Fluctuations in material prices	G1F7
Construction site related factors	Rework due to errors or changes	G2F1
	Use of inappropriate construction methods	G2F2
	Inadequate site control and supervision	G2F3
	Lack of coordination among client, contractor, and consultant	G2F4
	Ineffective project scheduling	G2F5
	Inadequate waste management practices	G2F6
	Misuse of construction materials	G2F7
	Accidents due to negligence or unsafe practices	G2F8
Design and Documentation related factors	Frequent design changes	G3F1
	Lack of constructability knowledge during design	G3F2
	Errors in construction drawings	G3F3
	Poor communication among project stakeholders	G3F4
	Incomplete or unclear contract documents	G3F5
	Inefficient site layout planning	G3F6
	Lack of contractor involvement during design phase	G3F7
	Inexperience of the design team	G3F8
	Errors in technical specifications	G3F9
	Last-minute client requirements leading to rework	G3F10
Material handling, transportation	Overproduction of materials	G4F1
	Improper handling of construction materials	G4F2

Groups	Factors	Code
and storage related factors	Material defects	G4F3
	Inadequate quality control and inspection	G4F4
	Accidents during material handling and transportation	G4F5
	Damage to materials during transportation	G4F6
Management related factors	Lack of control over construction materials	G5F1
	Ineffective planning and project control	G5F2
	Absence of waste management plans	G5F3
	Lack of management commitment to waste reduction	G5F4
Workers/Labors related factors	Worker errors during construction	G6F1
	Poor worker attitudes toward quality and productivity	G6F2
	Insufficient training of workers	G6F3
	Poor quality of workmanship	G6F4
	Excessive overtime leading to reduced productivity	G6F5
	Lack of experience	G6F6
	Shortage of skilled workers	G6F7
Environment and external factors	Severe weather conditions	G7F1
	Labor strikes and public protests	G7F2
	Political instability affecting project activities	G7F3
	Additional costs due to safety requirements	G7F4
	Unpredictable site and local conditions	G7F5
	Theft and vandalism	G7F6
Equipment and machinery related factors	Use of inappropriate equipment	G8F1
	Equipment malfunction and breakdowns	G8F2
	Insufficient equipment availability on site	G8F3

4.2 Normality Test of Data

The normality of data can be assessed using both graphical and numerical methods, with graphical methods generally considered more sensitive than their numerical counterparts. Commonly used techniques for testing normality consist of Shapiro–Wilk test, Kolmogorov–Smirnov test, histogram, P–P plot, Q–Q plot, skewness, and kurtosis. Among these, the Kolmogorov–Smirnov test and the Shapiro–Wilk test are the most widely adopted methods in practice, both of which can be conveniently computed using the statistical software SPSS (Rani Das, 2016).

Both the Kolmogorov–Smirnov and Shapiro–Wilk tests are structured around the null hypothesis that the sample is normally distributed, with the alternative hypothesis stating that the sample does not follow a normal distribution. If the test yields a statistically significant result — that is, if the p-value falls below 0.05 — the null hypothesis is rejected, indicating that the data does not conform to a normal distribution (Mohd Razali and Yap, 2011).

The normality test of groups, factors and mitigation strategies was conducted and the data conform to non-normal distribution.

4.3 Correlation for the NVAA groups

As discussed in Section 3.10.1 correlation between different factors were checked by Spearman’s rank correlation test. It is used to check the correlation and relationship between two variables.(Mohd Razali & Yap, 2011) The coefficient varies from -1 to +1. +1 indicates the perfect positive relationship and -1 indicates the perfect negative relationship. The correlation matrix of different groups is given in APPENDIX C.

4.4 Ranking and RII of Factors

For each group and factor, RII was calculated for every individual stakeholders. Also, a total RII was calculated. The RII values and rankings along with overall RII values and rankings are shown in table below.

Table 4-3 RII and Ranking of NVAA factors

S.N	Factor	Client			Consultant			Contractor			Overall		
		RII	G-Rank	All rank	RII	G-Rank	All rank	RII	G-Rank	All rank	RII	G-Rank	All Rank
1	G1F1	0.587	6	49	0.672	4	45	0.680	4	32	0.649	5	44
2	G1F2	0.685	3	35	0.733	2	27	0.740	2	25	0.721	2	31
3	G1F3	0.696	2	31	0.612	6	50	0.640	6	42	0.646	6	45
4	G1F4	0.630	5	46	0.603	7	51	0.640	6	42	0.623	7	49
5	G1F5	0.587	6	49	0.672	4	45	0.710	3	29	0.659	4	42
6	G1F6	0.772	1	18	0.776	1	16	0.790	1	19	0.779	1	17
7	G1F7	0.652	4	43	0.724	3	33	0.650	5	41	0.679	3	37
8	G2F1	0.804	5	8	0.784	5	11	0.900	2	3	0.828	4	5
9	G2F2	0.815	4	6	0.784	6	15	0.840	5	10	0.812	5	9
10	G2F3	0.859	1	2	0.853	1	1	0.950	1	1	0.886	1	1
11	G2F4	0.848	2	3	0.819	3	5	0.900	2	3	0.854	2	3
12	G2F5	0.848	2	3	0.810	4	6	0.850	4	8	0.834	3	4
13	G2F6	0.728	7	28	0.776	7	16	0.710	6	31	0.740	7	26
14	G2F7	0.750	6	24	0.819	2	4	0.680	8	34	0.753	6	23
15	G2F8	0.696	8	31	0.724	8	31	0.680	7	32	0.701	8	33
16	G3F1	0.880	1	1	0.793	2	9	0.910	1	2	0.857	1	2
17	G3F2	0.804	2	12	0.750	7	26	0.850	5	9	0.799	5	14
18	G3F3	0.750	6	24	0.784	3	11	0.880	3	6	0.805	4	12
19	G3F4	0.793	3	14	0.776	5	16	0.870	4	7	0.812	3	9
20	G3F5	0.674	10	37	0.724	8	31	0.810	8	16	0.737	8	27
21	G3F6	0.707	8	30	0.698	10	41	0.670	9	35	0.692	10	35
22	G3F7	0.696	9	34	0.759	6	23	0.670	9	35	0.711	9	32
23	G3F8	0.783	4	17	0.716	9	34	0.840	6	10	0.776	7	18
24	G3F9	0.750	6	24	0.784	3	11	0.830	7	12	0.789	6	15
25	G3F10	0.761	5	22	0.802	1	7	0.890	2	5	0.818	2	8
26	G4F1	0.598	6	47	0.655	5	47	0.660	2	37	0.640	5	46
27	G4F2	0.663	5	42	0.767	1	20	0.660	3	39	0.701	2	33
28	G4F3	0.663	4	41	0.698	4	39	0.650	4	40	0.672	4	39
29	G4F4	0.772	1	19	0.707	3	38	0.790	1	19	0.753	1	23
30	G4F5	0.685	2	36	0.612	6	49	0.630	5	44	0.640	5	46
31	G4F6	0.674	3	38	0.716	2	35	0.630	5	44	0.675	3	38
32	G5F1	0.804	3	8	0.690	4	42	0.730	3	26	0.737	4	27
33	G5F2	0.837	1	5	0.802	1	7	0.830	1	12	0.821	1	6
34	G5F3	0.772	4	19	0.776	2	16	0.720	4	27	0.756	3	22
35	G5F4	0.815	2	6	0.733	3	30	0.740	2	24	0.760	2	21
36	G6F1	0.783	4	16	0.716	7	36	0.720	5	27	0.737	5	27
37	G6F2	0.728	6	27	0.759	4	23	0.710	6	29	0.734	6	30
38	G6F3	0.804	1	8	0.828	2	3	0.800	2	17	0.812	2	9
39	G6F4	0.793	3	15	0.845	1	2	0.820	1	14	0.821	1	6
40	G6F5	0.663	7	39	0.733	6	29	0.580	7	48	0.662	7	41
41	G6F6	0.761	5	22	0.750	5	25	0.800	2	17	0.769	4	20
42	G6F7	0.804	1	8	0.767	3	21	0.780	4	21	0.782	3	16
43	G7F1	0.663	2	39	0.716	2	36	0.620	2	46	0.669	2	40
44	G7F2	0.652	3	43	0.698	3	39	0.560	5	50	0.640	4	46

S.N	Factor	Client			Consultant			Contractor			Overall		
		RII	G-Rank	All rank	RII	G-Rank	All rank	RII	G-Rank	All rank	RII	G-Rank	All Rank
45	G7F3	0.696	1	31	0.690	5	44	0.570	4	49	0.653	3	43
46	G7F4	0.598	5	47	0.690	4	43	0.560	5	50	0.620	5	50
47	G7F5	0.652	3	43	0.733	1	27	0.660	1	38	0.685	1	36
48	G7F6	0.587	6	51	0.647	6	48	0.610	3	47	0.617	6	51
49	G8F1	0.793	1	13	0.793	1	10	0.820	1	14	0.802	1	13
50	G8F2	0.728	3	28	0.767	3	21	0.750	3	23	0.750	3	25
51	G8F3	0.772	2	19	0.784	2	14	0.770	2	22	0.776	2	18

Factors relating to Procurement

There are 7 factors in this group. Among all the procurement-related factors, ineffective procurement scheduling emerged as the most critical factor, ranking first across all three respondent groups as well as in the overall ranking, with the highest overall RII value of 0.779. This strong consensus across all stakeholders highlights that poor planning and scheduling of procurement activities is widely regarded as a major concern in hydropower projects. Inaccurate quantity estimation was identified as the second most contributing factor overall (RII = 0.721), also ranking second among both consultants and contractors, reflecting a shared concern about the consequences of imprecise material quantity assessments during the planning phase. Fluctuations in material prices ranked third overall (RII = 0.679), indicating that price volatility in the supply market is another prominent challenge faced by project stakeholders. Use of inconsistent estimation methods and errors in material ordering ranked fourth and fifth overall, with RII values of 0.659 and 0.649 respectively, suggesting that standardization of estimation practices and accuracy in ordering processes remain areas requiring attention. Delays due to waiting for material replacement and errors by suppliers were ranked sixth and seventh overall, with RII values of 0.646 and 0.623 respectively. Although these factors are relatively lower in rank, they still carry notable implications for project timelines and material management.

Table 4-4: Procurement related Factors

Factor related to "Procurement"	Client		Consultant		Contractor		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Errors in material ordering	0.587	6	0.672	4	0.680	4	0.649	5

Factor related to “Procurement”	Client		Consultant		Contractor		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Inaccurate quantity estimation	0.685	3	0.733	2	0.740	2	0.721	2
Delays due to waiting for material replacement	0.696	2	0.612	6	0.640	6	0.646	6
Errors by suppliers	0.630	5	0.603	7	0.640	6	0.623	7
Use of inconsistent estimation methods	0.587	6	0.672	4	0.710	3	0.659	4
Ineffective procurement scheduling	0.772	1	0.776	1	0.790	1	0.779	1
Fluctuations in material prices	0.652	4	0.724	3	0.650	5	0.679	3

Factors related to Construction Site

There are 8 factors in this group. Inadequate site control and supervision was unanimously identified as the most critical factor across all three respondent groups, securing the first rank overall with the highest RII value of 0.886. Notably, contractors assigned this factor an exceptionally high RII of 0.950, reflecting their on-ground experience with the direct consequences of poor supervision on construction site performance. Lack of coordination among client, contractor, and consultant ranked second overall (RII = 0.854), highlighting that communication gaps and insufficient collaboration among key project stakeholders remain a significant challenge on construction sites. Ineffective project scheduling followed closely in third place overall (RII = 0.834), indicating that inadequate planning and time management continues to be a persistent concern across all stakeholder groups. Rework due to errors or changes ranked fourth overall (RII = 0.828), with contractors assigning it a notably high RII of 0.900, suggesting that on-site errors and design changes frequently result in substantial rework, adding to material waste and project delays. Use of inappropriate construction methods ranked fifth overall (RII = 0.812), pointing to the need for better technical guidance and method selection in the construction phase. Misuse of construction materials and inadequate waste management practices ranked sixth and seventh overall, with RII values of 0.753 and 0.740 respectively. An interesting observation here is that consultants ranked misuse of construction materials considerably higher (Rank 2, RII = 0.819) compared to contractors (Rank 8, RII = 0.680), reflecting a difference in

perception between the two groups regarding on-site material handling. Accidents due to negligence or unsafe practices ranked last overall (RII = 0.701), though this should not diminish its importance, as safety-related incidents carry serious implications for both human welfare and project continuity.

Table 4-5: Construction Site related factors

Factor related to “Construction Site”	Client		Consultant		Contractor		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Rework due to errors or changes	0.804	5	0.784	5	0.900	2	0.828	4
Use of inappropriate construction methods	0.815	4	0.784	6	0.840	5	0.812	5
Inadequate site control and supervision	0.859	1	0.853	1	0.950	1	0.886	1
Lack of coordination among client, contractor, and consultant	0.848	2	0.819	3	0.900	2	0.854	2
Ineffective project scheduling	0.848	2	0.810	4	0.850	4	0.834	3
Inadequate waste management practices	0.728	7	0.776	7	0.710	6	0.740	7
Misuse of construction materials	0.750	6	0.819	2	0.680	8	0.753	6
Accidents due to negligence or unsafe practices	0.696	8	0.724	8	0.680	7	0.701	8

Factors related to Design and Documentation

There are 10 factors in this group. Frequent design changes ranked first overall (RII = 0.857), with consensus across all three groups, highlighting it as the most disruptive factor in the design and documentation phase. Last-minute client requirements leading to rework ranked second overall (RII = 0.818), with consultants and contractors both assigning it notably high importance, reflecting the downstream consequences of late-stage client-driven changes. Poor communication among project stakeholders and errors in construction drawings ranked third and fourth overall, with RII of 0.812 and 0.805 respectively, underlining the critical role of clear communication and accurate documentation in project success. Lack of constructability knowledge during design ranked fifth overall (RII = 0.799), followed by errors in technical specifications and

inexperience of the design team in sixth and seventh place, pointing to skill and knowledge gaps within design teams as recurring concerns. Incomplete or unclear contract documents, lack of contractor involvement during the design phase, and inefficient site layout planning ranked eighth, ninth, and tenth overall, representing relatively lower but still noteworthy challenges in the documentation process.

Table 4-6: Design and Documentation related factors

Factor related to “Design and Documentation”	Client		Consultant		Contractor		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Frequent design changes	0.880	1	0.793	2	0.910	1	0.857	1
Lack of constructability knowledge during design	0.804	2	0.750	7	0.850	5	0.799	5
Errors in construction drawings	0.750	6	0.784	3	0.880	3	0.805	4
Poor communication among project stakeholders	0.793	3	0.776	5	0.870	4	0.812	3
Incomplete or unclear contract documents	0.674	10	0.724	8	0.810	8	0.737	8
Inefficient site layout planning	0.707	8	0.698	10	0.670	9	0.692	10
Lack of contractor involvement during design phase	0.696	9	0.759	6	0.670	9	0.711	9
Inexperience of the design team	0.783	4	0.716	9	0.840	6	0.776	7
Errors in technical specifications	0.750	6	0.784	3	0.830	7	0.789	6
Last-minute client requirements leading to rework	0.761	5	0.802	1	0.890	2	0.818	2

Factors related to “Material Handling, Transportation and Storage”

There are 6 factors in this group. Inadequate quality control and inspection identified as the most critical factor overall (RII = 0.753), ranking first among both clients and contractors, indicating that insufficient quality checks during material handling and storage is a widely shared concern across stakeholder groups. Improper handling of construction materials ranked second overall (RII = 0.701), with consultants assigning it the highest priority among all factors in this category (RII = 0.767), showing their strong emphasis on proper material handling practices on site. Damage to materials

during transportation and material defects ranked third and fourth overall, with RII values of 0.675 and 0.672 respectively, suggesting that material integrity during transit and supply remain consistent concerns. Overproduction of materials and accidents during material handling and transportation both shared the fifth rank overall (RII = 0.640), indicating that while these factors are relatively lower in priority, they still represent areas warranting attention in material management planning.

Table 4-7: Material Handling, transportation and Storage related factors

Factor related to “material handling, Transportation and Storage	Client		Consultant		Contractor		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Overproduction of materials	0.598	6	0.655	5	0.660	2	0.640	5
Improper handling of construction materials	0.663	5	0.767	1	0.660	3	0.701	2
Material defects	0.663	4	0.698	4	0.650	4	0.672	4
Inadequate quality control and inspection	0.772	1	0.707	3	0.790	1	0.753	1
Accidents during material handling and transportation	0.685	2	0.612	6	0.630	5	0.640	5
Damage to materials during transportation	0.674	3	0.716	2	0.630	5	0.675	3

Factors relating to “Management”

There are 4 factors of NVAAs related to management. Ineffective planning and project control was unanimously ranked first across all three stakeholder groups, achieving the highest overall RII of 0.821. This strong agreement underscores that poor planning and inadequate project control are considered the most significant management-related contributors to material waste in hydropower projects. Lack of management commitment to waste reduction ranked second overall (RII = 0.760), indicating that insufficient dedication at the management level toward minimizing waste is widely recognized as a critical concern across all respondent groups. Absence of waste management plans followed closely in third place overall (RII = 0.756), reflecting that the lack of formally structured waste management strategies remains a notable gap in project management practices. Lack of control over construction materials ranked

fourth overall (RII = 0.737), suggesting that inadequate oversight of material usage and inventory management also contributes meaningfully to waste generation on site.

Table 4-8: Management related factors

Factor related to “Management”	Client		Consultant		Contractor		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Lack of control over construction materials	0.804	3	0.690	4	0.730	3	0.737	4
Ineffective planning and project control	0.837	1	0.802	1	0.830	1	0.821	1
Absence of waste management plans	0.772	4	0.776	2	0.720	4	0.756	3
Lack of management commitment to waste reduction	0.815	2	0.733	3	0.740	2	0.760	2

Factors related to “Workers/ Labours”

There are 7 NVAA related factors in this group. Poor quality of workmanship was identified as the most influencing factor overall (RII = 0.821), ranking first among both consultants and contractors, and third among clients. This strong consensus reflects widespread concern that substandard workmanship is a leading contributor to material waste and construction inefficiencies. Insufficient training of workers ranked second overall (RII = 0.812), with all three stakeholder groups assigning it consistently high importance, highlighting that inadequate skill development and training programs remain a fundamental challenge in the hydropower construction workforce. Shortage of skilled workers ranked third overall (RII = 0.782), further reinforcing the theme of workforce capability as a central concern, particularly among clients who jointly ranked it first alongside insufficient training. Lack of experience and worker errors during construction ranked fourth and fifth overall, with RII values of 0.769 and 0.737 respectively, suggesting that workforce inexperience and on-site mistakes continue to pose meaningful challenges to project quality and material efficiency. Poor worker attitudes toward quality and productivity ranked sixth overall (RII = 0.734), indicating that motivational and behavioural factors within the workforce also contribute to suboptimal construction outcomes. Excessive overtime leading to reduced productivity ranked last overall (RII = 0.662), reflecting that while fatigue-related productivity loss

is a recognized concern, it is considered comparatively less critical than skill and quality-related factors by all stakeholder groups.

Table 4-9: Workers/ Labours related factors

Factor related to “Workers/ Labours”	Client		Consultant		Contractor		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Worker errors during construction	0.783	4	0.716	7	0.720	5	0.737	5
Poor worker attitudes toward quality and productivity	0.728	6	0.759	4	0.710	6	0.734	6
Insufficient training of workers	0.804	1	0.828	2	0.800	2	0.812	2
Poor quality of workmanship	0.793	3	0.845	1	0.820	1	0.821	1
Excessive overtime leading to reduced productivity	0.663	7	0.733	6	0.580	7	0.662	7
Lack of experience	0.761	5	0.750	5	0.800	2	0.769	4
Shortage of skilled workers	0.804	1	0.767	3	0.780	4	0.782	3

Factors related to Environment and external

There are 6 factors related to this group. Unpredictable site and local conditions emerged as the most significant factor overall (RII = 0.685), ranking first among both consultants and contractors, reflecting that unforeseen ground, geological, or local environmental conditions pose the greatest external challenge to hydropower construction projects. Severe weather conditions ranked second overall (RII = 0.669), with consistent agreement across all three stakeholder groups, underscoring that adverse climatic conditions significantly disrupt construction activities and material management. Political instability affecting project activities ranked third overall (RII = 0.653), with clients assigning it the highest priority among all external factors (Rank 1, RII = 0.696), indicating that project owners are particularly sensitive to the risks posed by an unstable political environment. Labor strikes and public protests ranked fourth overall (RII = 0.640), suggesting that social and industrial unrest remains a notable external risk that can interrupt project progress and supply chains. Additional costs due to safety requirements ranked fifth overall (RII = 0.620), reflecting that compliance with safety regulations, while necessary, introduces additional financial burdens that

stakeholders recognize as an external constraint. Theft and vandalism ranked last overall (RII = 0.617), indicating that although material security is a concern on construction sites, it is considered comparatively less impactful than other external factors by all respondent groups.

Table 4-10: Environment and external factors

Factor related to “Environment and External”	Client		Consultant		Contractor		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Severe weather conditions	0.663	2	0.716	2	0.620	2	0.669	2
Labor strikes and public protests	0.652	3	0.698	3	0.560	5	0.640	4
Political instability affecting project activities	0.696	1	0.690	5	0.570	4	0.653	3
Additional costs due to safety requirements	0.598	5	0.690	4	0.560	5	0.620	5
Unpredictable site and local conditions	0.652	3	0.733	1	0.660	1	0.685	1
Theft and vandalism	0.587	6	0.647	6	0.610	3	0.617	6

Factors related to Equipment and machinery

There are 3 factors that are related to non-value adding activities in this group. Use of inappropriate equipment was unanimously ranked first across all three stakeholder groups, achieving the highest overall RII of 0.802. This strong and consistent agreement highlights that deploying unsuitable or ill-matched equipment for construction tasks is regarded as the most significant equipment-related contributor to inefficiency and material waste in hydropower projects. Insufficient equipment availability on site ranked second overall (RII = 0.776), with all three groups assigning it the same rank, reflecting a shared concern that inadequate equipment resources on site directly hampers construction progress and productivity. Equipment malfunction and breakdowns ranked third overall (RII = 0.750), again with full consensus across all respondent groups, indicating that mechanical failures and poor equipment maintenance are consistently recognized as disruptive to construction operations.

Table 4-11: Equipment and machinery related factors

Factor related to “Equipment and machinery”	Client		Consultant		Contractor		Overall	
	RII	Rank	RII	Rank	RII	Rank	RII	Rank
Use of inappropriate equipment	0.793	1	0.793	1	0.820	1	0.802	1
Equipment malfunction and breakdowns	0.728	3	0.767	3	0.750	3	0.750	3
Insufficient equipment availability on site	0.772	2	0.784	2	0.770	2	0.776	2

4.5 RII and Ranking of Groups

The RII and ranking of the NVAA groups based on the concerned parties and overall are shown below.

Table 4-12 RII and Ranking of Groups

Group	Client		Consultant		Contractor		Overall	
	RII	G Rank	RII	G Rank	RII	G Rank	RII	Rank
Procurement related factors	0.707	4	0.750	2	0.650	5	0.705	5
Construction site related factors	0.707	4	0.784	1	0.740	2	0.747	2
Design and Documentation related factors	0.772	2	0.741	3	0.840	1	0.782	1
Material handling, transportation and storage related factors	0.641	6	0.698	7	0.630	7	0.659	7
Management related factors	0.783	1	0.733	5	0.660	4	0.724	4
Workers/Labors related factors	0.728	3	0.741	3	0.710	3	0.727	3

Environment and external factors	0.609	8	0.698	7	0.610	8	0.643	8
Equipment and machinery related factors	0.641	6	0.707	6	0.640	6	0.666	6

Design and documentation related factors emerged as the most critical group overall (RII = 0.782), ranking first among contractors and second among clients, reflecting that design instability, documentation errors, and communication gaps are collectively regarded as the greatest contributors to material waste across the project lifecycle.

Construction site related factors ranked second overall (RII = 0.747), with consultants assigning it the highest priority among all groups (G Rank 1, RII = 0.784), underscoring that on-site management deficiencies such as inadequate supervision and poor coordination remain a dominant concern.

Workers and labour related factors ranked third overall (RII = 0.727), with a consistent ranking of third across all three stakeholder groups, reflecting a shared recognition that workforce skill gaps, workmanship quality, and training deficiencies significantly influence material waste generation.

Management related factors ranked fourth overall (RII = 0.724), with clients assigning it the highest group ranking (G Rank 1, RII = 0.783), highlighting that project owners place particular emphasis on the role of planning and managerial commitment in waste reduction.

Procurement related factors ranked fifth overall (RII = 0.705), ranking second among consultants but fifth among contractors, indicating some variation in how different stakeholders perceive the significance of procurement-related challenges.

Equipment and machinery related factors ranked sixth overall (RII = 0.666), followed by material handling, transportation and storage related factors in seventh place (RII = 0.659), both receiving comparatively lower overall importance across all stakeholder groups.

Environment and external factors ranked last overall (RII = 0.643), which is consistent across both clients and contractors who assigned it the lowest group rank, suggesting

that external and environmental challenges, while recognized, are considered less controllable and thus relatively lower in priority compared to internal project factors.

Overall, the findings reveal that internal project-related factors — particularly those associated with design, site management, workforce, and planning — are perceived as far more influential in driving material waste than external or logistical factors in hydropower construction projects.

4.6 Prioritize and rank sub-factors of groups

The overall ranking of sub-factors for groups is given in table below:

Table 4-13 Overall Top 10 factors

	Factors contributing to waste due to NVAAs	RII	Code	Rank
1	Inadequate site control and supervision	0.886	G2F3	1
2	Frequent design changes	0.857	G3F1	2
3	Lack of coordination among client, contractor, and consultant in site	0.854	G2F4	3
4	Ineffective project scheduling	0.834	G2F5	4
5	Rework due to errors or changes	0.828	G2F1	5
6	Ineffective planning and project control	0.821	G5F2	6
7	Poor quality of workmanship	0.821	G6F4	6
8	Last-minute client requirements leading to rework	0.818	G3F10	8
9	Use of inappropriate construction methods	0.812	G2F2	9
10	Insufficient training of workers	0.812	G6F3	9

4.7 Evaluation of Factors from the Perspectives of Stakeholders

The major NVAA factors are ranked on the view of the parties involved in Hydropower Sector i.e. Consultant, Client and Contractor are shown below:

Table 4-14 Ranking of the NVAA factors by Client

S.N	Factors contributing to waste due to NVAAs	Code	RII	Rank
1	Frequent design changes	G3F1	0.880	1
2	Inadequate site control and supervision	G2F3	0.859	2
3	Lack of coordination among client, contractor, and consultant	G2F4	0.848	3
4	Ineffective project scheduling	G2F5	0.848	3
5	Ineffective planning and project control	G5F2	0.837	5
6	Use of inappropriate construction methods	G2F2	0.815	6
7	Lack of management commitment to waste reduction	G5F4	0.815	6
8	Rework due to errors or changes	G2F1	0.804	8
9	Lack of control over construction materials	G5F1	0.804	8
10	Insufficient training of workers	G6F3	0.804	8

Table 4-15 Ranking of the NVAA factors by Consultant

S.N	Factors contributing to waste due to NVAAs	Code	RII	Rank
1	Inadequate site control and supervision	G2F3	0.853	1
2	Poor quality of workmanship	G6F4	0.845	2
3	Insufficient training of workers	G6F3	0.828	3
4	Misuse of construction materials	G2F7	0.819	4
5	Lack of coordination among client, contractor, and consultant	G2F4	0.819	5
6	Ineffective project scheduling	G2F5	0.810	6
7	Last-minute client requirements leading to rework	G3F10	0.802	7
8	Ineffective planning and project control	G5F2	0.802	7

S.N	Factors contributing to waste due to NVAAs	Code	RII	Rank
9	Frequent design changes	G3F1	0.793	9
10	Use of inappropriate equipment	G8F1	0.793	10

Table 4-16 Ranking of the NVAA factors by Contractor

S.N	Factors contributing to waste due to NVAAs	Code	RII	Rank
1	Inadequate site control and supervision	G2F3	0.95	1
2	Frequent design changes	G3F1	0.91	2
3	Rework due to errors	G2F1	0.9	3
4	Lack of coordination among client, contractor, and consultant	G2F4	0.9	3
5	Last-minute client requirements leading to rework	G3F10	0.89	5
6	Errors in construction drawings	G3F3	0.88	6
7	Poor communication among project stakeholders	G3F4	0.87	7
8	Ineffective project scheduling	G2F5	0.85	8
9	Lack of constructability knowledge during design	G3F2	0.85	9
10	Use of inappropriate construction methods	G2F2	0.84	10

Frequent design changes, rework due to last-minute client requirements, and inadequate worker training emerged as the most consistently identified NVAA sub-factors for the three Hydropower projects that were considered in the Key Informant Interview. In Ridi Hydropower Project, frequent design modifications led to mid-construction changes such as the addition of extra weir gates and the redesign of the surge shaft, while the absence of locally trained personnel to handle imported specialized equipment resulted in significant time losses. The Isuwa Khola project similarly confirmed frequent design changes as a high-severity factor, with a complete tailrace culvert redesign necessitated by unforeseen site conditions, alongside inadequate site supervision evidenced by the need to chip out already-placed concrete at the headpond. Poor stakeholder communication was also notable in this project, compounded by the interdependent cascade project structure that restricted timely information exchange between project

teams. In the Hidi Khola project, repeated redesigns of penstock anchor blocks, errors during penstock bifurcation construction, and late client-initiated redesign of flood walls were the primary waste-generating activities. Additionally, project-specific contextual factors were identified, including social pressures from land acquisition disputes and non-contractual community demands in the Ridi project, and an uncontrollable flood event that damaged project structures, both of which fall outside the conventional NVAA framework but carried significant time and cost impacts.

4.8 Agreement between consultant, client and contractor

The Spearman’s rank-order correlation method was applied to assess the level of agreement among project parties. Table below presents the correlation values for ranking delay factors among different stakeholders. The results indicate a correlation of 0.708 between the client and consultant, 0.808 between the client and contractor, and 0.732 between the consultant and contractor. The agreement among project parties is statistically significant at the 0.01 level.

Table 4-17 Agreement between Stakeholders

	Consultant	Client	Contractor	Overall
Consultant	1.000			.900**
Client	.708**	1.000		.885**
Contractor	.808**	.732**	1.000	.937**

**Correlation is significant at the 0.01 level (2-tailed).

4.9 Mean Ranking of the Strategies

A total of 24 different strategies were identified from various literature review which is shown in table below:

Table 4-18 Summary of Strategies and Code

S.N	Mitigating strategies	Code
1	Adoption of effective site management practices	S1
2	Preparation of accurate material specifications	S2
3	Proper storage of materials on site	S3
4	Recycling of waste materials on site	S4

S.N	Mitigating strategies	Code
5	Minimization of design changes	S5
6	Effective coordination among project stakeholders	S6
7	Proper material handling	S7
8	Use of more efficient and appropriate construction equipment	S8
9	Encouraging reuse of waste materials	S9
10	Timely scheduling of material deliveries	S10
11	Deployment of experienced personnel	S11
12	Site quality management system	S12
13	Implementation of effective strategic planning	S13
14	Proper project planning	S14
15	Frequent project meetings	S15
16	Emphasis on learning from past project experience	S16
17	Establishment of clear communication channels	S17
18	Training programs for site management personnel	S18
19	Proper project scheduling	S19
20	Regular site inspections and audits by regulatory authorities	S20
21	Regular safety meetings with safety personnel	S21
22	Establishment of a quality control monitoring team	S22
23	Monitoring of compliance with state and local regulations	S23
24	Establishment of a quality control enforcement team	S24

The table below analyzes strategies using statistical measures as discussed in previous section. It includes the Mean, SD, S-K (distribution shape), K-S (normality test), t-value (comparison test), D_f , and Sig. R prioritizes strategies based on their effectiveness and significance in the analysis.

Table 4-19 Mean Ranking of the strategies

Strategies	Mean	SD	S-K	K-S	Test value-2.5			R
					t	D_f	Sig	
Proper project planning	3.338	0.736	-1.039	1.055	15.938	76	0	1
Preparation of accurate material specifications	3.312	0.693	-0.749	0.394	16.604	76	0	2

Strategies	Mean	SD	S-K	K-S	Test value-2.5			R
					t	D _f	Sig	
Adoption of effective site management practices	3.273	0.772	-0.694	-0.389	14.470	76	0	3
Use of more efficient and appropriate construction equipment	3.260	0.696	-0.642	0.242	15.885	76	0	4
Minimization of design changes	3.182	0.823	-0.934	0.597	12.603	76	0	5
Proper project scheduling	3.182	0.756	-1.255	3.433	13.715	76	0	6
Effective coordination among project stakeholders	3.169	0.909	-1.100	1.121	11.283	76	0	7
Establishment of clear communication channels	3.169	0.818	-0.917	0.616	12.544	76	0	8
Deployment of experienced personnel	3.156	0.779	-0.796	0.534	13.018	76	0	9
Training programs for site management personnel	3.156	0.812	-1.052	1.940	12.488	76	0	10
Implementation of effective strategic planning	3.143	0.790	-1.248	2.917	12.695	76	0	11
Establishment of a quality control monitoring team	3.143	0.738	-0.637	0.363	13.583	76	0	12
Proper storage of materials on site	3.117	0.668	-0.408	0.333	14.664	76	0	13
Proper material handling	3.104	0.788	-0.851	0.786	12.296	76	0	14
Emphasis on learning from past project experience	3.091	0.747	-0.344	-0.521	12.822	76	0	15
Timely scheduling of material deliveries	3.078	0.721	-0.334	-0.309	13.115	76	0	16
Site quality management system	3.013	0.769	-0.556	0.207	11.553	76	0	17
Establishment of a quality control enforcement team	2.961	0.733	-0.555	0.524	11.498	76	0	18
Regular safety meetings with safety personnel	2.922	0.774	-0.563	0.302	10.453	76	0	19
Frequent project meetings	2.896	0.754	-0.393	0.056	10.433	76	0	20
Recycling of waste materials on site	2.831	0.715	0.038	-0.556	10.207	76	0	21
Monitoring of compliance with state and local regulations	2.831	0.801	-0.943	1.654	9.101	76	0	22
Encouraging reuse of waste materials	2.805	0.874	-0.697	1.188	8.083	76	0	23
Regular site inspections and audits by regulatory authorities	2.805	0.889	-0.525	0.248	7.947	76	0	24

4.9.1 Non-Parametric test for Strategies

The table below presents statistical tests for strategy comparison. Chi-square measures differences between expected and observed values, with df (degrees of freedom) indicating independent variables. Asymp. Sig shows statistical significance. Kruskal-Wallis H tests differences among multiple groups, with its own df and Asymp. Sig to determine significance.

Table 4-20 Chi-Square and Kruskal Wallis-H

Strategies	Chi-square	df	Asymp. Sig	Kruskal Wallis-H	df	Asymp. Sig
Adoption of effective site management practices	37.857 ^a	3	0.000	9.910	2	0.065
Preparation of accurate material specifications	49.494 ^a	3	0.000	4.434	2	0.109
Proper storage of materials on site	56.351 ^a	3	0.000	1.450	2	0.484
Recycling of waste materials on site	40.766 ^a	3	0.000	3.399	2	0.183
Minimization of design changes	37.545 ^a	3	0.000	3.978	2	0.137
Effective coordination among project stakeholders	56.831 ^b	4	0.000	1.413	2	0.493
Proper material handling	44.403 ^a	3	0.000	1.386	2	0.500
Use of more efficient and appropriate construction equipment	48.143 ^a	3	0.000	0.982	2	0.612
Encouraging reuse of waste materials	53.844 ^b	4	0.000	6.195	2	0.055
Timely scheduling of material deliveries	41.494 ^a	3	0.000	3.676	2	0.159
Deployment of experienced personnel	40.558 ^a	3	0.000	4.805	2	0.090
Site quality management system	40.351 ^a	3	0.000	0.060	2	0.970
Implementation of effective strategic planning	81.636 ^b	4	0.000	4.297	2	0.117
Proper project planning	48.974 ^a	3	0.000	1.508	2	0.470
Frequent project meetings	41.805 ^a	3	0.000	0.754	2	0.686
Emphasis on learning from past project experience	35.779 ^a	3	0.000	3.539	2	0.170
Establishment of clear communication channels	38.169 ^a	3	0.000	2.808	2	0.246
Training programs for site management personnel	66.052 ^b	4	0.000	1.160	2	0.560
Proper project scheduling	84.753 ^b	3	0.000	5.246	2	0.073
Regular site inspections and audits by regulatory authorities	46.571 ^b	4	0.000	2.175	2	0.337
Regular safety meetings with safety personnel	43.364 ^a	4	0.000	1.323	2	0.516
Establishment of a quality control monitoring team	43.987 ^a	3	0.000	1.058	2	0.589
Monitoring of compliance with state and local regulations	83.584 ^b	4	0.000	7.965	2	0.099
Establishment of a quality control enforcement team	50.740 ^a			4.831	2	0.089

a. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 19.3.

b. 0 cells (0.0%) have expected frequencies less than 5. The minimum expected cell frequency is 15.4.

4.9.2 Ranking of Mitigating Strategies

Based on the observed mean values, different strategies were ranked accordingly. This ranking identifies the top 10 strategies that can be implemented to promote circular economy (CE) practices in the hydropower sector are listed in table below.

Table 4-21 Overall Top 10 Mitigating Strategies

S.N	Strategies	Code	Mean	Chi-square	Kruskal Wallis-H	Rank
1	Proper project planning	S14	3.34	48.974 ^a	1.508	1
2	Preparation of accurate material specifications	S2	3.31	49.494 ^a	4.434	2
3	Adoption of effective site management practices	S1	3.27	37.857 ^a	9.910	3
4	Use of more efficient and appropriate construction equipment	S8	3.26	48.143 ^a	0.982	4
5	Minimization of design changes	S5	3.18	37.545 ^a	3.978	5
6	Proper project scheduling	S19	3.18	84.753 ^b	5.246	6
7	Effective coordination among project stakeholders	S6	3.17	56.831 ^b	1.413	7
8	Establishment of clear communication channels	S17	3.17	38.169 ^a	2.808	8
9	Deployment of experienced personnel	S11	3.16	40.558 ^a	4.805	9
10	Training programs for site management personnel	S18	3.16	66.052 ^b	1.160	10

Proper Project Planning

The most important of all mitigation strategies is proper project planning with the mean score of 3.34. This is a basic approach towards reduction of non-value adding activities because when a project is planned properly in the initial stages, it becomes easy to predict the possible risks, allocate resources effectively, and set clear time lines and goals. The chi-square value of 48.974 is used to justify that the distribution of the

responses is statistically significant and the Kruskal-Wallis H value of 1.508 is used to justify that agreement with the three stakeholder groups is very high and that proper planning of the project is universally accepted as the most important mitigation measure among the clients, consultants, and contractors.

Accurate Material Specifications Preparation

Being the second one with an average mark of 3.31, preparation of correct material specifications is fundamental in minimizing procurement errors, reducing the amount of waste material and preventing the expensive rework. Specifications of the materials used will be clear and precise so that the correct materials are ordered at the correct quantities and they can hardly be misunderstood or substituted. The statistically significant response pattern is demonstrated by the chi-square value of 49.494 and the Kruskal-Wallis H value of 4.434 shows that there is a fairly consistent level of agreement between the stakeholder groups, indicating the widespread acknowledgment of the significance of this strategy in the industry.

Implementation of good site management practices.

The effective site management practices is ranked number three on average with a mean score of 3.27. Good site management is important in making sure that the construction activities are being conducted efficiently, resources are used in the right manner and that waste is minimized at all levels of the construction process. It involves controlling, coordinating and enforcement of quality standards on the ground. The value of chi-square of 37.857 validates the presence of statistical significance whereas the Kruskal Wallis H value of 9.910 which is the highest of the top ten strategies reveals that there is a slight variation in perception between the groups of stakeholders implying that the stakeholders might have slight differences in the extent to which they prioritize or interpret the effective site management practices.

More Efficient and appropriate construction equipment.

The fourth position with the mean score 3.26 of the use of efficient and appropriate construction equipment is one of the factors helping to the minimization of non-value adding activities. Implementing the appropriate equipment to carry out certain tasks enhances productivity, minimizes damage of materials, rework and delays in operations. The chi-square test value of 48.143 shows the response distribution is statistically significant, and the Kruskal-Wallis H value of 0.982 is low, which shows

that all three stakeholder groups have a strong consensus that the equipment suitability is always on the high-priority list of mitigation measures.

Minimization of Design Changes

Minimization of design changes is fifth among the mitigation strategies with the mean score of 3.18. One of the most disruptive elements of construction projects is the frequent change of design that usually results into rework, material waste, delays, and cost increase. Efficiency in the project can be enhanced greatly by minimizing design changes by designing them properly and engaging the stakeholders early in design process. The statistical significance of the chi-square value of 37.545 is confirmed, and the Kruskal-Wallis H value of 3.978 represents the degree of agreement between respondents that is reasonable, which means that this strategy is widely appreciated by all stakeholders groups.

Proper Project Scheduling

Proper project scheduling also recorded a mean score of 3.18, it also got the fifth position in terms of mean score but it was sixth in terms of overall position. Good scheduling is essential to synchronize all the construction operations, delivery of materials and distribution of the resources in a proper way to minimize wastage of time and congestion as well as unnecessary movement of materials. Interestingly, this strategy yielded the greatest chi-square, among the top ten strategies, at 84.753, which suggests a very significant and diverse distribution of the responses. The Kruskal-Wallis H of 5.246 indicates that there is moderate variance between the stakeholder groups, or differences in the views on the relative importance of scheduling as a mitigation action.

Good Co-ordination between Project Stakeholders.

With a position of seven and a mean score of 3.17, effective coordination among project stakeholders is critical in ensuring that all the parties that are involved in a project; the clients of a project, the consultants as well as the contractors are all working towards one direction in terms of objectives, decisions and actions. A poorly-coordinated approach is a documented reason of miscommunication, rework, and resource wastage. The chi-square reason of 56.831 indicates a statistically significant distribution of the responses and Kruskal-Wallis H value of 1.413 indicates that there is top level of agreement in the distribution of responses among the three stakeholders, showing that

the significance of stakeholder coordination is largely and consistently accepted across the industry.

Development of effective Communication Channels.

Clear communication channels were established, and the mean score was 3.17, which is the eighth among the overall ones. Successful execution of a project is based on effective communication through which instructions, updates and decisions are properly communicated to all stakeholders that are involved during the project. Communication failures often contribute to mistakes, time loss, wastage of materials. The statistical significance of the chi-square value of 38.169 can be confirmed, and the Kruskal-Wallis H value of 2.808 is a reminder that there is a general consistency of the agreement of the respondents, which means that the clear communication is generally accepted as a significant mitigation strategy within the stakeholder groups.

Experienced Personnel Deployment.

The ninth ranking and a mean score of 3.16 indicates that deployment of experienced personnel is a key strategy of minimizing non-value adding activities on construction sites. The more experienced professionals are, the more they can predict the issues, make quality decisions and perform tasks more accurately, thus, minimizing the number of errors, reworking, and waste of materials. The chi-square value of 40.558 suggests a statistically significant pattern of responses, and the Kruskal-Wallis H value of 4.805 indicates a moderate level of variation between the stakeholder groups, indicating that there are some differences in the way the clients, consultants and contractors might rate the relative importance of personnel experience in waste reduction.

Site Personnel Training Programs.

Training programs on site management personnel come in as the last in a list of the top ten with a mean score of 3.16, this is necessary to develop the capabilities needed to operate effectively and efficiently in construction sites to minimize wastage. Site managers who are well trained will be in a better position to implement quality standards, coordinate teams and ensure a steady implementation of waste reduction measures. The chi-square value of 66.052 shows a very significant response distribution and the very low Kruskal-Wallis H value of 1.160 demonstrates that there is almost unanimity among all three groups of stakeholders that investment in training and

capacity building is universally perceived as an important mitigation measure in hydropower construction projects.

Mitigation strategies were implemented across all three projects in response to the identified NVAA sub-factors, though their effectiveness was predominantly partial rather than complete. Common measures applied across all projects included proper project planning, deployment of skilled and experienced personnel, effective site management practices, improved stakeholder coordination, and the establishment of clear communication channels. Hidi Khola project demonstrated the broadest application of mitigation strategies, particularly for frequent design changes, incorporating additional measures such as use of efficient construction equipment, formal project scheduling, regular safety and project meetings, on-site waste recycling, material delivery scheduling, and regulatory compliance monitoring. In Ridi Hydropower project, government-regulated land acquisition and enhanced site security were fully implemented to address social factor-related waste, while no mitigation was feasible for the flood-related force majeure event. The recurring pattern of partial implementation across all three projects suggests that while awareness of appropriate mitigation strategies is present among project teams, their full and systematic integration into formal project management systems remains a major gap in the Nepalese hydropower construction sector.

The KII results also confirm the highest-ranking mitigation strategies of the questionnaire survey. The most common mitigation measures mentioned by all three projects were proper project planning, hiring of skilled staff, implementation of good site management procedures, good coordination among the stakeholders and having clear communication channels. Although their effectiveness was predominantly considered partial and not full, it is still an essential point: it implies that the gap between the strategy recognition and full implementation is the issue that is still crucial to the Nepali hydropower construction industry.

Besides, the KII results highlight contextually specific drivers, including social pressures of land acquisition in Ridi project, and cascade interdependency in Isuwa Khola project, which transcends standardized NVAA framework based on questionnaire survey. Such project-related specifics highlight the relevance of the quantitative survey results with the qualitative field observations when creating mitigation measures, and imply that future studies and industry standards must be more

forthright about the social, political, and systemic aspects of waste production in the Nepalese hydropower development.

4.9.3 Sub-Factor and Mitigation Measure Association Matrix

A complete 10×10 linkage matrix was calculated, resulting in 100 linkage strength values. Table below presents a condensed summary showing, for each waste cause, the best-matched mitigation strategy and the average linkage strength across all ten mitigations.

Table 4-22: Summary of Linkage Strengths between Top 10 sub-factors and Top 10 mitigation Strategies

Waste Rank	Waste Causing Sub-factor	Best Matched Mitigation	Best Match Strength	Average Linkage Strength (All 10 Mitigations)
1	Inadequate site control and supervision	Adoption of effective site management practices	80	61
2	Frequent design changes	Minimization of design changes	95	58
3	Lack of coordination among client, contractor, and consultant	Effective coordination among project stakeholders	90	64
4	Ineffective project scheduling	Proper project scheduling	95	62

Waste Rank	Waste Causing Sub-factor	Best Matched Mitigation	Best Match Strength	Average Linkage Strength (All 10 Mitigations)
5	Rework due to errors or changes	Preparation of accurate material specifications	65	57
6	Ineffective planning and project control	Proper project planning	90	63
7	Poor quality of workmanship	Deployment of experienced personnel	80	60
8	Last-minute client requirements leading to rework	Establishment of clear communication channels	85	59
9	Use of inappropriate construction methods	Use of more efficient and appropriate equipment	75	56
10	Insufficient training of workers	Training programs for site management personnel	100	65

The best match strengths range from 65 (rework due to errors) to 100 (insufficient training). The average linkage strengths across all ten mitigations range narrowly from 56 to 65, indicating that no waste cause is exceptionally well or poorly addressed on average. However, this narrow range masks important variations at the individual mitigation level, which are discussed in the following sections. The most concerning finding is that rework due to errors or changes (Rank 5) has the lowest best match strength (65), suggesting that stakeholders do not have a strongly perceived mitigation for this high-priority waste cause. The inter-linkage between the top 10 sub-factors and Top 10 mitigation strategies is shown in Shankey diagram below.

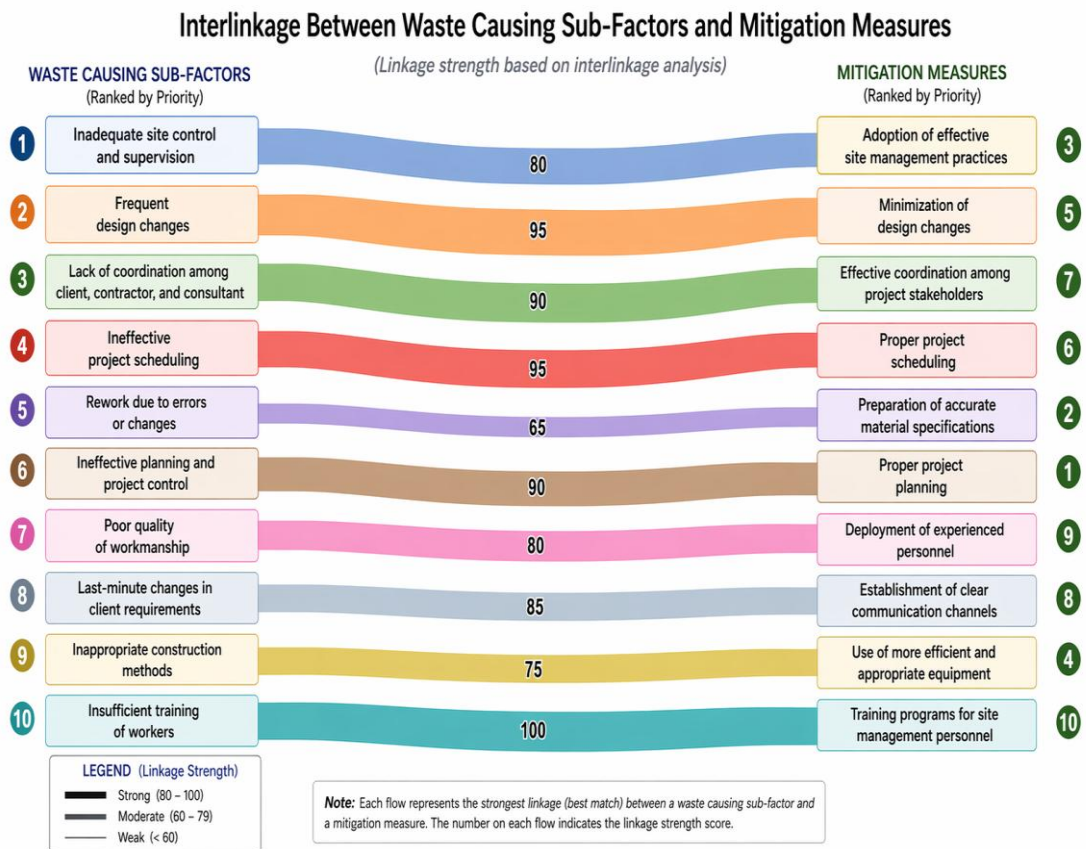


Figure 4-1: Sankey diagram for Top 10 Sub-factors and Top 10 Mitigation Strategies

CHAPTER 5 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This research identifies the major factors related to NVAAs with the hydropower industry in Nepal and also explores various mitigating strategies to reduce them. It also ranks these factors, examines correlations between factors and proposes strategies to reduce their impact. The key conclusions can be summarized as follows:

- “Design and documentation related factors” group is the major NVAA factor group with overall RII of 0.782 in the context of Hydropower Industry In Nepal.
- “Inadequate site control and supervision” is the most influencing NVAA factor with overall RII 0.886 in the context of Hydropower Industry In Nepal.
- Inadequate site control and supervision, frequent design changes, lack of coordination among stakeholders in site, ineffective project scheduling, rework due to errors, ineffective planning and project control, poor quality of workmanship, last-minute client requirements leading to rework, use of inappropriate construction methods and insufficient training of workers are the top ten major factors contributing to waste due to NVAAs in hydropower industry in Nepal.
- The NVAAs factors are ranked on the basis of their correlation with respect to project parties, revealing significant agreement at the 0.01 level. The correlation coefficients indicate a strong positive relationship between the consultant and client (0.708), strong positive correlation between the consultant and contractor (0.732), and strong correlation between the client and contractor (0.808).
- Proper project planning, preparation of accurate material specifications, adoption of effective site management practices, use of more efficient and appropriate construction equipment, minimization of design changes, proper project scheduling, effective coordination among project stakeholders, establishment of clear communication channels, deployment of experienced personnel and training programs for site management personnel are the top ten strategies to minimize such factors that contribute to waste in hydropower industry in Nepal.

5.2 Recommendation

For professionals in the construction sector, the conclusions from this study are very important. These findings lead to the following recommendations:

- Most of the personnels working in construction typically think of it in terms of tangible waste. Raising awareness on non-value adding activities is hence imperative.
- Coordination between stakeholders in construction must be done effectively.
- To increase efficiency, project managers are recommended to give planning of construction process top priority. Also, adequate supervision to construction sites is also advised.
- Periodic meetings between parties is recommended to deliberate on construction plans for the future, tackle existing issues and suggest mitigations
- Efforts should be made to reduce design changes whenever feasible.
- Given Nepal's challenging construction environment, project contracts should explicitly incorporate monsoon-contingency planning, including clearly defined seasonal work schedules accounting monsoon disruption), advance stockpiling of critical materials before the onset of the monsoon season, and dedicated logistics protocols for remote and high-altitude sites where access roads are frequently rendered impassable by landslides and flooding.

5.3 Recommendation for future research

In this study, questionnaire only covered respondents of the sample size but perhaps not should represent the industry as a whole in absolute sense since the respondents were few. The respondents can be generalized in the country in future researches to be more precise in the representation of results. Additionally, the study might be conducted in the industries beyond hydropower. Additional research may be conducted on the quantification of the contribution of the lean techniques to respective NVAA and identify the impact of the Lean Techniques. The study might be conducted to demonstrate the distinction between the lean approach and the conventional approach of the construction.

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APPENDICES

APPENDIX-A

NVAA factors along with References

Group	Sub-Factor	Citations
Procurement Related Factors (G1)	Errors in material ordering	(Khaleel & Al-Zubaidy, 2018; Nagapan et al., 2012; Luangcharoenrat et al., 2019; Ikau et al., 2016; Ismail & Mohd Yusof, 2016)
	Inaccurate quantity estimation	(Madan Sharma et al., 2022; Nagapan et al., 2012)
	Delays due to waiting for material replacement	(Nagapan et al., 2012; Shaqour, 2022; Hossain et al., 2019; Hosseini et al., 2012; Sarhan et al., 2017; Alwi et al., 2002; Imimole, 2018)
	Errors by suppliers	(Nagapan et al., 2012; Ikau et al., 2016; Arshad et al., 2017)
	Use of inconsistent estimation methods	(Madan Sharma et al., 2022; Hosseini et al., 2012; Ismail & Mohd Yusof, 2016)
	Ineffective procurement scheduling	(Madan Sharma et al., 2022; Ikau et al., 2016; Akhund et al., 2019; Imimole, 2018)
	Fluctuations in material prices	(Madan Sharma et al., 2022)
Construction Site Related Factors (G2)	Rework due to errors or changes	(Madan Sharma et al., 2022; Nagapan et al., 2012; Luangcharoenrat et al., 2019; Ikau et al., 2016; Arshad et al., 2017; Hosseini et al., 2012; Sarhan et al., 2017)
	Use of inappropriate construction methods	(Madan Sharma et al., 2022; Nagapan et al., 2012; Luangcharoenrat et al., 2019; Ikau et al., 2016; Alwi et al., 2002; Imimole, 2018)

	Inadequate site control and supervision	(Madan Sharma et al., 2022; Nagapan et al., 2012; Luangcharoenrat et al., 2019; Arshad et al., 2017; Ismail & Mohd Yusof, 2016; Imimole, 2018)
	Lack of coordination among client, contractor, and consultant	(Madan Sharma et al., 2022; Nagapan et al., 2012; Luangcharoenrat et al., 2019; Alwi et al., 2002; Imimole, 2018)
	Ineffective project scheduling	(Luangcharoenrat et al., 2019; Arshad et al., 2017; Alwi et al., 2002; Imimole, 2018)
	Inadequate waste management practices	(Khaleel & Al-Zubaidy, 2018; Nagapan et al., 2012; Luangcharoenrat et al., 2019)
	Misuse of construction materials	(Madan Sharma et al., 2022; Arshad et al., 2017; Imimole, 2018)
	Accidents due to negligence or unsafe practices	(Luangcharoenrat et al., 2019; Bhatla et al., 2016)
Design and Documentation Related Factors (G3)	Frequent design changes	(Madan Sharma et al., 2022; Nagapan et al., 2012; Luangcharoenrat et al., 2019; Ikau et al., 2016; Arshad et al., 2017; Akhund et al., 2019; Alwi et al., 2002; Imimole, 2018)
	Lack of constructability knowledge during design	(Madan Sharma et al., 2022; Ikau et al., 2016)
	Errors in construction drawings	(Madan Sharma et al., 2022; Luangcharoenrat et al., 2019; Hosseini et al., 2012; Alwi et al., 2002)

	Poor communication among project stakeholders	(Madan Sharma et al., 2022; Nagapan et al., 2012; Ikau et al., 2016)
	Incomplete or unclear contract documents	(Madan Sharma et al., 2022; Nagapan et al., 2012; Ikau et al., 2016; Arshad et al., 2017; Bhatla et al., 2016; Alwi et al., 2002)
	Inefficient site layout planning	(Madan Sharma et al., 2022; Awaad et al., 2022; Imimole, 2018)
	Lack of contractor involvement during design phase	(Madan Sharma et al., 2022; Luangcharoenrat et al., 2019)
	Inexperience of the design team	(Madan Sharma et al., 2022; Alwi et al., 2002; Imimole, 2018)
	Errors in technical specifications	(Madan Sharma et al., 2022; Nagapan et al., 2012; Luangcharoenrat et al., 2019; Ikau et al., 2016; Alwi et al., 2002; Imimole, 2018)
	Last-minute client requirements leading to rework	(Madan Sharma et al., 2022; Nagapan et al., 2012)
Material Handling, Transportation and Storage Related Factors (G4)	Overproduction of materials	(Madan Sharma et al., 2022; Shaqour, 2022; Hossain et al., 2019; Hosseini et al., 2012; Sarhan et al., 2017; Bhatla et al., 2016; Alwi et al., 2002; Imimole, 2018)
	Improper handling of construction materials	(Khaleel & Al-Zubaidy, 2018; Madan Sharma et al., 2022; Nagapan et al., 2012; Luangcharoenrat et al., 2019; Ikau et al., 2016; Akhund et al., 2019; Hosseini et al., 2012; Ismail & Mohd Yusof, 2016; Imimole, 2018)

	Material defects	(Khaleel & Al-Zubaidy, 2018; Madan Sharma et al., 2022; Shaqour, 2022; Luangcharoenrat et al., 2019; Hossain et al., 2019; Hosseini et al., 2012; Bhatla et al., 2016; Alwi et al., 2002; Imimole, 2018)
	Inadequate quality control and inspection	(Madan Sharma et al., 2022; Nagapan et al., 2012; Arshad et al., 2017; Bhatla et al., 2016; Ismail & Mohd Yusof, 2016; Imimole, 2018)
	Accidents during material handling and transportation	(Khaleel & Al-Zubaidy, 2018; Madan Sharma et al., 2022; Nagapan et al., 2012; Ikau et al., 2016; Arshad et al., 2017)
	Damage to materials during transportation	(Khaleel & Al-Zubaidy, 2018; Madan Sharma et al., 2022; Shaqour, 2022; Luangcharoenrat et al., 2019; Ikau et al., 2016; Hossain et al., 2019; Sarhan et al., 2017; Alwi et al., 2002)
Management Related Factors (G5)	Lack of control over construction materials	(Khaleel & Al-Zubaidy, 2018; Madan Sharma et al., 2022; Bhatla et al., 2016)
	Ineffective planning and project control	(Nagapan et al., 2012; Bhatla et al., 2016)
	Absence of waste management plans	(Khaleel & Al-Zubaidy, 2018; Madan Sharma et al., 2022; Nagapan et al., 2012; Arshad et al., 2017; Ismail & Mohd Yusof, 2016)
	Lack of management commitment to waste reduction	(Khaleel & Al-Zubaidy, 2018; Arshad et al., 2017)
Worker/Labour Related Factors (G6)	Worker errors during construction	(Nagapan et al., 2012)

	Poor worker attitudes toward quality and productivity	(Nagapan et al., 2012; Luangcharoenrat et al., 2019; Akhund et al., 2019; Ismail & Mohd Yusof, 2016)
	Insufficient training of workers	(Nagapan et al., 2012; Imimole, 2018)
	Poor quality of workmanship	(Madan Sharma et al., 2022; Nagapan et al., 2012; Alwi et al., 2002; Imimole, 2018)
	Excessive overtime leading to reduced productivity	(Madan Sharma et al., 2022; Nagapan et al., 2012; Hosseini et al., 2012; Imimole, 2018)
	Lack of experience	(Madan Sharma et al., 2022; Nagapan et al., 2012; Luangcharoenrat et al., 2019; Imimole, 2018)
	Shortage of skilled workers	(Khaleel & Al-Zubaidy, 2018; Madan Sharma et al., 2022; Nagapan et al., 2012; Arshad et al., 2017; Awaad et al., 2022; Imimole, 2018)
Environment and External Factors (G7)	Severe weather conditions	(Madan Sharma et al., 2022; Nagapan et al., 2012; Ikaou et al., 2016; Arshad et al., 2017; Awaad et al., 2022; Alwi et al., 2002; Imimole, 2018)
	Labour strikes and public protests	(Madan Sharma et al., 2022)
	Political instability affecting project activities	(Madan Sharma et al., 2022; Nagapan et al., 2012)
	Additional costs due to safety requirements	(Hosseini et al., 2012)

	Unpredictable site and local conditions	(Madan Sharma et al., 2022; Nagapan et al., 2012)
	Theft and vandalism	(Khaleel & Al-Zubaidy, 2018; Madan Sharma et al., 2022; Nagapan et al., 2012; Ikau et al., 2016; Arshad et al., 2017; Akhund et al., 2019; Bhatla et al., 2016)
Equipment and Machinery Related Factors (G8)	Use of inappropriate equipment	(Madan Sharma et al., 2022; Nagapan et al., 2012; Awaad et al., 2022; Imimole, 2018)
	Equipment malfunction and breakdowns	(Madan Sharma et al., 2022; Nagapan et al., 2012; Luangcharoenrat et al., 2019; Arshad et al., 2017; Hosseini et al., 2012; Imimole, 2018)
	Insufficient equipment availability on site	(Nagapan et al., 2012)

APPENDIX-B

Final Questionnaire Survey

Assessment of Waste due to Non-Value-Adding Activities and Evaluation of Mitigation Strategies in Hydropower Construction Projects

Dear respondent, I am a Master of Science student in construction management (MSCOM) currently working on my thesis titled "Assessment of Waste due to Non-Value-Adding Activities and Evaluation of Mitigation Strategies in Hydropower Construction Projects." Your expert insights and valuable inputs are essential for my study. Thank you for your time and consideration. All the details shall be kept confidential and is Solely used for academics' research purpose. Non-Value Adding Activities (NVAAs)* are waste causing activities involve work that consumes resources, time or space but does not add value to the product or service.

Section 1: General Information

What is your highest academic qualification?

- Bachelor
- Masters
- Doctorate

What type of organization do you work for?

- Private company
- Government Agency
- NGO
- Self Employed

Who do you work for?

- Client
- Consultant
- Contractor

How many years of experience do you have in Hydropower sector?

- 0-5 years
- 6-10 years
- 11-15 years
- 16-20 years
- 20 years above

What is your primary area of expertise in construction?

- Engineering and Design
- Environmental science
- Energy and Power system
- Geotechnical and Geological studies
- Quality Control
- Operation and Maintenance

Section 2: Factors contributing to waste due to non-value-adding activities (NVAA) in hydropower projects

A. The following are the "Procurement related factors" that cause waste in hydropower project. Please rate the extent to which the following factors contribute to waste in hydropower projects

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Errors in material ordering	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inaccurate quantity estimation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Delays due to waiting for material replacement	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Errors by suppliers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Use of inconsistent estimation methods	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ineffective procurement scheduling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Fluctuations in material prices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall contribution of 'Procurement related factors' to waste in hydropower projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

B. The following are the "Construction site related factors" that cause waste in hydropower project. Please rate the extent to which the following factors contribute to waste in hydropower projects

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Rework due to errors or changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Use of inappropriate construction methods	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inadequate site control and supervision	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of coordination among client, contractor, and consultant	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ineffective project planning and scheduling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inadequate waste management practices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Misuse of construction materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Accidents due to negligence or unsafe practices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall contribution of 'Construction site related factors' to waste in hydropower projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
C. The following are the "Design and Documentation related factors" that cause waste in hydropower project. Please rate the extent to which the following factors contribute to waste in hydropower projects	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Frequent design changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of constructability knowledge during design	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Errors in construction drawings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor communication among project stakeholders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Incomplete or unclear contract documents	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inefficient site layout planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of contractor involvement during design phase	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inexperience of the design team	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Errors in technical specifications	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Last-minute client requirements leading to rework	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall contribution of 'Design and Documentation related factors' to waste in hydropower projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
D. The following are the "Material handling, transportation and storage related factors" that cause waste in hydropower project. Please rate the extent to which the following factors contribute to waste in hydropower projects	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Overproduction of materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Improper handling of construction materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Material defects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Inadequate quality control and inspection	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Accidents during material handling and transportation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Damage to materials during transportation	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Unpredictable site and local conditions	<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"/>
Overall contribution of 'Environment/external factors' to waste in hydropower projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
H. The following are the "Equipment and machinery related factors" that cause waste in hydropower project. Please rate the extent to which the following factors contribute to waste in hydropower projects	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Use of inappropriate equipment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Equipment malfunction and breakdowns	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insufficient equipment availability on site	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall contribution of 'Equipment and machinery related factors' to waste in hydropower projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Section 3: Mitigation Strategies for Reducing Waste due to Non-Value-Adding Activities (NVAA) in Hydropower Projects

The following are the different measures that might help reducing waste in construction of Hydropower project. How effective are the following measures in reducing waste in hydropower construction projects? Please rate your perception against these measures from 1 to 5 where 1=Not at all, 2=Slightly, 3=Moderately, 4=Very much, 5=Extremely	Not at all	Slightly	Moderately	Very much	Extremely
Adoption of effective site management practices	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Preparation of accurate material specifications	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Proper storage of materials on site	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Recycling of waste materials on site	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Minimization of design changes	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Effective coordination among project stakeholders	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Proper material handling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Use of more efficient and appropriate construction equipment	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Encouraging reuse of waste materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Timely scheduling of material deliveries	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Deployment of experienced personnel	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Overall contribution of 'material handling, transportation and storage related factors' to waste in hydropower projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
E. The following are the "Management related factors" that cause waste in hydropower project. Please rate the extent to which the following factors contribute to waste in hydropower projects	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Lack of control over construction materials	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Ineffective planning and project control	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Absence of waste management plans	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of management commitment to waste reduction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall contribution of 'Management factors' to waste in hydropower projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
F. The following are the "Workers/Labors related factors" that cause waste in hydropower project. Please rate the extent to which the following factors contribute to waste in hydropower projects	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Worker errors during construction	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor worker attitudes toward quality and productivity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Insufficient training of workers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Poor quality of workmanship	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Excessive overtime leading to reduced productivity	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Lack of experience	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Shortage of skilled workers	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Overall contribution of 'Workers/labors related factors' to waste in hydropower projects	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
G. The following are the "Environment and external factors" that cause waste in hydropower project. Please rate the extent to which the following factors contribute to waste in hydropower projects	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree
Severe weather conditions	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Labor strikes and public protests	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Political instability affecting project activities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Additional costs due to safety requirements	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Site quality management system	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Implementation of effective strategic planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Proper project planning	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Frequent project meetings	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Emphasis on learning from past project experience	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Establishment of clear communication channels	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Training programs for site management personnel	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Proper project scheduling	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Regular site inspections and audits by regulatory authorities	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Regular safety meetings with safety personnel	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Establishment of a quality control monitoring team	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Monitoring of compliance with state and local regulations	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Establishment of a quality control enforcement team	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

APPENDIX C

Statistical calculations

Normality Tests of Groups

Group	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
G1	0.352	77	0.000	0.784	77	0.000
G2	0.325	77	0.000	0.783	77	0.000
G3	0.290	77	0.000	0.798	77	0.000
G4	0.362	77	0.000	0.698	77	0.000
G5	0.320	77	0.000	0.773	77	0.000
G6	0.325	77	0.000	0.769	77	0.000
G7	0.282	77	0.000	0.817	77	0.000
G8	0.287	77	0.000	0.818	77	0.000

a. Lilliefors Significance Correction

Normality Test of Factors

NVAA factors	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
G1F1	0.192	77	0.000	0.892	77	0.000
G1F2	0.258	77	0.000	0.856	77	0.000
G1F3	0.268	77	0.000	0.834	77	0.000
G1F4	0.264	77	0.000	0.864	77	0.000
G1F5	0.230	77	0.000	0.865	77	0.000
G1F6	0.254	77	0.000	0.803	77	0.000
G1F7	0.256	77	0.000	0.839	77	0.000
G2F1	0.282	77	0.000	0.783	77	0.000
G2F2	0.252	77	0.000	0.799	77	0.000
G2F3	0.378	77	0.000	0.681	77	0.000
G2F4	0.341	77	0.000	0.739	77	0.000
G2F5	0.283	77	0.000	0.773	77	0.000
G2F6	0.274	77	0.000	0.838	77	0.000
G2F7	0.234	77	0.000	0.843	77	0.000
G2F8	0.255	77	0.000	0.854	77	0.000
G3F1	0.327	77	0.000	0.741	77	0.000
G3F2	0.253	77	0.000	0.791	77	0.000
G3F3	0.242	77	0.000	0.800	77	0.000
G3F4	0.256	77	0.000	0.788	77	0.000
G3F5	0.277	77	0.000	0.841	77	0.000
G3F6	0.351	77	0.000	0.788	77	0.000
G3F7	0.312	77	0.000	0.834	77	0.000
G3F8	0.274	77	0.000	0.793	77	0.000
G3F9	0.275	77	0.000	0.787	77	0.000
G3F10	0.284	77	0.000	0.789	77	0.000
G4F1	0.241	77	0.000	0.882	77	0.000

NVAA factors	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
G4F2	0.297	77	0.000	0.829	77	0.000
G4F3	0.233	77	0.000	0.853	77	0.000
G4F4	0.273	77	0.000	0.825	77	0.000
G4F5	0.285	77	0.000	0.825	77	0.000
G4F6	0.276	77	0.000	0.850	77	0.000
G5F1	0.277	77	0.000	0.841	77	0.000
G5F2	0.276	77	0.000	0.786	77	0.000
G5F3	0.253	77	0.000	0.820	77	0.000
G5F4	0.272	77	0.000	0.831	77	0.000
G6F1	0.319	77	0.000	0.805	77	0.000
G6F2	0.302	77	0.000	0.823	77	0.000
G6F3	0.258	77	0.000	0.788	77	0.000
G6F4	0.267	77	0.000	0.780	77	0.000
G6F5	0.254	77	0.000	0.858	77	0.000
G6F6	0.242	77	0.000	0.834	77	0.000
G6F7	0.225	77	0.000	0.823	77	0.000
G7F1	0.269	77	0.000	0.812	77	0.000
G7F2	0.281	77	0.000	0.842	77	0.000
G7F3	0.287	77	0.000	0.820	77	0.000
G7F4	0.262	77	0.000	0.829	77	0.000
G7F5	0.275	77	0.000	0.810	77	0.000
G7F6	0.287	77	0.000	0.817	77	0.000
G8F1	0.244	77	0.000	0.791	77	0.000
G8F2	0.305	77	0.000	0.803	77	0.000
G8F3	0.275	77	0.000	0.815	77	0.000

a. Lilliefors Significance Correction

Normality Test of Mitigation Strategies

Mitigation strategies	Kolmogorov-Smirnov ^a			Shapiro-Wilk		
	Statistic	df	Sig.	Statistic	df	Sig.
S1	0.282	77	0.000	0.792	77	0.000
S2	0.268	77	0.000	0.778	77	0.000
S3	0.297	77	0.000	0.795	77	0.000
S4	0.269	77	0.000	0.828	77	0.000
S5	0.257	77	0.000	0.796	77	0.000
S6	0.248	77	0.000	0.802	77	0.000
S7	0.292	77	0.000	0.799	77	0.000
S8	0.256	77	0.000	0.789	77	0.000
S9	0.251	77	0.000	0.844	77	0.000
S10	0.262	77	0.000	0.822	77	0.000
S11	0.265	77	0.000	0.805	77	0.000
S12	0.285	77	0.000	0.828	77	0.000
S13	0.298	77	0.000	0.774	77	0.000
S14	0.283	77	0.000	0.763	77	0.000

S15	0.295	77	0.000	0.836	77	0.000
S16	0.244	77	0.000	0.826	77	0.000
S17	0.262	77	0.000	0.798	77	0.000
S18	0.255	77	0.000	0.802	77	0.000
S19	0.288	77	0.000	0.765	77	0.000
S20	0.249	77	0.000	0.869	77	0.000
S21	0.306	77	0.000	0.827	77	0.000
S22	0.267	77	0.000	0.810	77	0.000
S23	0.337	77	0.000	0.809	77	0.000
S24	0.313	77	0.000	0.815	77	0.000

a. Lilliefors Significance Correction

Correlation matrix for Different groups

For group 1

	G1F1	G1F2	G1F3	G1F4	G1F5	G1F6	G1F7
G1F1	1.000	.486**	.532**	.307**	.419**	.240*	.264*
G1F2	.486**	1.000	.307**	.288*	.253*	.372**	.271*
G1F3	.532**	.307**	1.000	.383**	0.128	0.090	.298**
G1F4	.307**	.288*	.383**	1.000	.262*	0.111	0.135
G1F5	.419**	.253*	0.128	.262*	1.000	.244*	.227*
G1F6	.240*	.372**	0.090	0.111	.244*	1.000	0.148
G1F7	.264*	.271*	.298**	0.135	.227*	0.148	1.000

For G2

	G2F1	G2F2	G2F3	G2F4	G2F5	G2F6	G2F7	G2F8
G2F1	1.000	.554**	.407**	.417**	.239*	-0.015	-0.087	-0.168
G2F2	.554**	1.000	.395**	.305**	.278*	0.056	0.183	.238*
G2F3	.407**	.395**	1.000	.489**	.408**	0.102	0.073	0.114
G2F4	.417**	.305**	.489**	1.000	.621**	0.083	-0.043	0.142
G2F5	.239*	.278*	.408**	.621**	1.000	0.152	0.100	0.188
G2F6	-0.015	0.056	0.102	0.083	0.152	1.000	.554**	.403**
G2F7	-0.087	0.183	0.073	-0.043	0.100	.554**	1.000	.444**
G2F8	-0.168	.238*	0.114	0.142	0.188	.403**	.444**	1.000

For Group 3

	G3F1	G3F2	G3F3	G3F4	G3F5	G3F6	G3F7	G3F8	G3F9	G3F10
G3F1	1.000	.584**	0.180	.235*	0.149	-0.091	.229*	.422**	.264*	0.123

G3F2	.584**	1.000	.501**	.510**	.447**	0.192	.355**	.562**	.476**	.316**
G3F3	0.180	.501**	1.000	.615**	.503**	0.103	.377**	.355**	.441**	.294**
G3F4	.235*	.510**	.615**	1.000	.274*	.291*	.344**	.313**	.257*	0.183
G3F5	0.149	.447**	.503**	.274*	1.000	.306**	.360**	.439**	.536**	.389**
G3F6	-0.091	0.192	0.103	.291*	.306**	1.000	.359**	0.164	.252*	-0.035
G3F7	.229*	.355**	.377**	.344**	.360**	.359**	1.000	.364**	.577**	0.223
G3F8	.422**	.562**	.355**	.313**	.439**	0.164	.364**	1.000	.453**	.398**
G3F9	.264*	.476**	.441**	.257*	.536**	.252*	.577**	.453**	1.000	.276*
G3F10	0.123	.316**	.294**	0.183	.389**	-0.035	0.223	.398**	.276*	1.000

For Group 4

	G4F1	G4F2	G4F3	G4F4	G4F5	G4F6
G4F1	1.000	.550**	.406**	0.213	.422**	0.131
G4F2	.550**	1.000	.686**	0.157	.367**	.324**
G4F3	.406**	.686**	1.000	.292**	.501**	.503**
G4F4	0.213	0.157	.292**	1.000	.348**	0.034
G4F5	.422**	.367**	.501**	.348**	1.000	.437**
G4F6	0.131	.324**	.503**	0.034	.437**	1.000

For G5

	G5F1	G5F2	G5F3	G5F4
G5F1	1.000	.518**	.544**	.526**
G5F2	.518**	1.000	.369**	.547**
G5F3	.544**	.369**	1.000	.459**
G5F4	.526**	.547**	.459**	1.000

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Correlation
is
significant
at the 0.01
level (2-
tailed).

For **G6**

	G6F1	G6F2	G6F3	G6F4	G6F5	G6F6	G6F7
G6F1	1.000	.425**	0.157	.302**	0.223	.243*	0.170
G6F2	.425**	1.000	.274*	.336**	0.163	.335**	0.207

G6F3	0.157	.274*	1.000	.732**	0.021	.419**	.481**
G6F4	.302**	.336**	.732**	1.000	0.073	.497**	.465**
G6F5	0.223	0.163	0.021	0.073	1.000	-0.037	-0.097
G6F6	.243*	.335**	.419**	.497**	-0.037	1.000	.580**
G6F7	0.170	0.207	.481**	.465**	-0.097	.580**	1.000

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Correlation
is
significant
at the 0.01
level (2-
tailed).

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Correlation
is
significant
at the 0.05
level (2-
tailed).

For **G7**

	G7F1	G7F2	G7F3	G7F4	G7F5	G7F6
G7F1	1.000	.440**	.466**	0.107	.443**	.288*
G7F2	.440**	1.000	.736**	.395**	.234*	.321**
G7F3	.466**	.736**	1.000	.414**	.297**	.306**
G7F4	0.107	.395**	.414**	1.000	.452**	.288*
G7F5	.443**	.234*	.297**	.452**	1.000	.489**
G7F6	.288*	.321**	.306**	.288*	.489**	1.000

For **G8**

	G8F1	G8F2	G8F3
G8F1	1.000	.579**	.465**
G8F2	.579**	1.000	.649**
G8F3	.465**	.649**	1.000

Correlation Matrix for Different Strategies

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10	S11	S12	S13	S14	S15	S16	S17	S18	S19	S20	S21	S22	S23	S24
S1	1.000	.671**	0.174	.294**	.443**	.453**	.288*	.289*	.273*	.477**	.442**	.338**	.360**	.289*	.327**	.403**	.360**	.553**	.393**	0.130	0.163	0.211	0.083	0.053
S2	.671**	1.000	.369**	.396**	.285*	.388**	.396**	0.212	.281*	.435**	.248*	.440**	.309**	.246*	.250*	.377**	.308**	.473**	.324**	0.151	.294**	.298**	0.094	0.203
S3	0.174	.369**	1.000	.345**	0.039	0.134	.394**	0.056	0.178	0.032	0.011	.349**	0.175	0.146	0.174	.231*	.233*	0.103	0.100	0.029	0.178	0.050	-0.056	0.068
S4	.294**	.396**	.345**	1.000	0.117	.227*	.406**	.351**	.552**	.290*	0.205	.371**	.238*	0.201	.392**	.299**	0.188	.305**	0.162	.387**	.386**	.228*	.442**	.309**
S5	.443**	.285*	0.039	0.117	1.000	.641**	.305**	.531**	.232*	.236*	.464**	.228*	.396**	.416**	.368**	.532**	.433**	.550**	.304**	0.211	.275*	0.180	.231*	0.097
S6	.453**	.388**	0.134	.227*	.641**	1.000	.442**	.458**	.257*	.388**	.473**	.425**	.388**	.565**	.470**	.533**	.402**	.570**	.348**	0.218	.462**	.430**	.247*	.377**
S7	.288*	.396**	.394**	.406**	.305**	.442**	1.000	.258*	0.217	0.208	0.118	.369**	.262*	.374**	.365**	.302**	.292*	.275*	0.167	0.191	.373**	0.023	0.029	0.157
S8	.289*	0.212	0.056	.351**	.531**	.458**	.258*	1.000	.333**	.287*	.537**	.233*	0.214	.293**	.302**	.391**	.413**	.370**	.225*	.263*	.429**	.296**	.294**	0.217
S9	.273*	.281*	0.178	.552**	.232*	.257*	0.217	.333**	1.000	.396**	0.135	.255*	0.148	0.087	.275*	.262*	0.175	.260*	0.003	.402**	.399**	0.153	.418**	0.150
S10	.477**	.435**	0.032	.290*	.236*	.388**	0.208	.287*	.396**	1.000	.321**	.383**	.374**	0.223	.256*	.376**	0.186	.402**	.239*	0.132	.258*	.352**	.233*	.247*
S11	.442**	.248*	0.011	0.205	.464**	.473**	0.118	.537**	0.135	.321**	1.000	.444**	.392**	.432**	.433**	.510**	.450**	.405**	.391**	0.061	.252*	.265*	0.058	0.156
S12	.338**	.440**	.349**	.371**	.228*	.425**	.369**	.233*	.255*	.383**	.444**	1.000	.645**	.546**	.415**	.440**	.402**	.450**	.414**	0.209	.402**	.429**	0.101	.367**
S13	.360**	.309**	0.175	.238*	.396**	.388**	.262*	0.214	0.148	.374**	.392**	.645**	1.000	.592**	.422**	.448**	.336**	.434**	.497**	.430**	.353**	.451**	0.183	.235*
S14	.289*	.246*	0.146	0.201	.416**	.565**	.374**	.293**	0.087	0.223	.432**	.546**	.592**	1.000	.459**	.364**	.394**	.404**	.454**	0.210	.313**	.471**	0.112	.365**
S15	.327**	.250*	0.174	.392**	.368**	.470**	.365**	.302**	.275*	.256*	.433**	.415**	.422**	.459**	1.000	.406**	.327**	.506**	.388**	0.221	.420**	.293**	0.180	.261*
S16	.403**	.377**	.231*	.299**	.532**	.533**	.302**	.391**	.262*	.376**	.510**	.440**	.448**	.364**	.406**	1.000	.492**	.560**	.283*	.239*	.305**	.237*	0.171	.276*
S17	.360**	.308**	.233*	0.188	.433**	.402**	.292*	.413**	0.175	0.186	.450**	.402**	.336**	.394**	.327**	.492**	1.000	.487**	.353**	0.101	0.191	0.138	0.071	0.113
S18	.553**	.473**	0.103	.305**	.550**	.570**	.275*	.370**	.260*	.402**	.405**	.450**	.434**	.404**	.506**	.560**	.487**	1.000	.378**	0.136	.304**	.393**	.244*	.403**
S19	.393**	.324**	0.100	0.162	.304**	.348**	0.167	.225*	0.003	.239*	.391**	.414**	.497**	.454**	.388**	.283*	.353**	.378**	1.000	0.162	0.126	.242*	0.020	0.160
S20	0.130	0.151	0.029	.387**	0.211	0.218	0.191	.263*	.402**	0.132	0.061	0.209	.430**	0.210	0.221	.239*	0.101	0.136	0.162	1.000	.503**	0.202	.524**	.284*
S21	0.163	.294**	0.178	.386**	.275*	.462**	.373**	.429**	.399**	.258*	.252*	.402**	.353**	.313**	.420**	.305**	0.191	.304**	0.126	.503**	1.000	.394**	.297**	.486**
S22	0.211	.298**	0.050	.228*	0.180	.430**	0.023	.296**	0.153	.352**	.265*	.429**	.451**	.471**	.293**	.237*	0.138	.393**	.242*	0.202	.394**	1.000	.275*	.668**
S23	0.083	0.094	-0.056	.442**	.231*	.247*	0.029	.294**	.418**	.233*	0.058	0.101	0.183	0.112	0.180	0.171	0.071	.244*	0.020	.524**	.297**	.275*	1.000	.448**
S24	0.053	0.203	0.068	.309**	0.097	.377**	0.157	0.217	0.150	.247*	0.156	.367**	.235*	.365**	.261*	.276*	0.113	.403**	0.160	.284*	.486**	.668**	.448**	1.000

**Correlation is significant at the 0.01 level (2-tailed).

*Correlation is significant at the 0.05 level (2-tailed).

APPENDIX-D

Data Validation Form for Factors and Mitigation

Respected Sir/ Madam,

I am Sudin Raj Shrestha, MSc. in Construction Management student, and this form is part of my Master's thesis titled **“Perception of Stakeholders towards Non-Value Adding Activities in Nepalese Hydropower Construction.”**

“Non-Value Adding Activities (NVAAs)” are waste causing activities involve work that consumes resources, time or space but does not add value to the product or service.

This form represents the first stage of expert consultation, conducted prior to the questionnaire survey, and you are being approached as an expert to validate the factors relating to Non-Value Added activities identified from existing literature. The factors included in this form have been identified through a comprehensive review of literatures on NVAAs in construction industry. The literature sources reviewed are listed in the references below.

Based on a synthesis of the literatures, the identified NVAA factors have been systematically categorized by the researcher into eight major groups:

1. Procurement related factors
2. Construction site related factors
3. Design and documentation related factors
4. Material handling, transportation and storage related factors
5. Management related factors
6. Workers/Labors related factors
7. Environment and Other external factors
8. Equipment and machinery related factors

Also, the mitigation measures for NVAA reduction have also been identified from the literatures.

You are kindly requested to **tick the factors relevant to the Nepalese hydropower sector** and **cross out those you consider irrelevant** in our context. You can **add other significant factors** that are missing in this form.

Groups	Factors	Source	Relevancy	Additional Factors (if any)
			(Yes/ No)	
Procurement related factors	1. Ordering errors	R2, R3, R5, R6, R15		
	2. Incorrect estimation	R2, R3		
	3. Favoring expensive materials	R2, R6, R16		
	4. Waiting for replacement	R3, R4, R8, R10, R11, R16, R18		
	5. Suppliers' errors	R3, R6, R7		
	6. Different estimation methods	R2, R10, R15		
	7. Poor procurement schedule	R2, R6, R9, R18		
	8. Material price changes	R2		
Construction site related	1. Rework	R2, R3, R5, R6, R7, R10, R11		
	2. Wrong construction methods	R2, R3, R5, R6, R17, R18		
	3. Poor control and supervision	R2, R3, R5, R7, R15, R18		
	4. Lack of coordination between Client, Contractors and Consultant	R2, R3, R5, R17, R18		
	5. Ineffective planning and scheduling	R5, R7, R17, R18		
	6. Poor waste management	R1, R3, R5		
	7. Excess materials on construction site	R2, R10		
	8. Accidents due to negligence	R2, R7, R18		
	9. Materials misuse	R5, R12		
Design and Documentation related	1. Design changes	R2, R3, R5, R6, R7, R9, R17, R18		
	2. Lack of knowledge about construction techniques during design activities	R2, R6		
	3. Complex designs	R2, R3, R5, R6, R17		
	4. Construction drawing errors	R2, R5, R10, R17		
	5. Poor communication between parties	R2, R3, R6		

	6. Incomplete contract documents	R2, R3, R6, R7, R12, R17		
	7. Poor site layout	R2, R13, R18		
	8. Contractors non involvements	R2, R5		
	9. Inexperienced design team	R2, R17, R18		
	10. Error in specifications	R2, R3, R5, R6, R17, R18		
	11. Last minute client requirement resulting in rework	R2, R3		
Material handling, transportation and storage	1. Over production	R2, R4, R8, R10, R11, R12, R16, R18		
	2. Improper handling of materials	R1, R2, R3, R5, R6, R9, R10, R15, R18		
	3. Defects	R1, R2, R4, R5, R8, R10, R12, R16, R18		
	4. Poor quality control and inspection	R2, R3, R7, R12, R15, R18		
	5. Accidents during handling and transportation	R1, R2, R3, R6, R7		
	6. Material damage during transportation	R1, R2, R4, R5, R6, R8, R11, R16		
	7. Unnecessary inventory	R4, R5, R10, R15, R16, R18		
Management related	1. Excessive control	R2, R12		
	2. Lack of control on construction materials	R1, R2, R12		
	3. Poor planning and controlling	R3, R12		
	4. Lack of waste management plans	R1, R2, R3, R7, R15		
	5. Lack of management commitment	R1, R7		

Workers/Labors related	1. Workers errors in construction	R3	
	2. Poor attitudes of workers	R3, R5, R9, R15	
	3. Insufficient training	R3, R18	
	4. Poor workmanship	R2, R3, R16, R18	
	5. Excessive overtime for workers	R2, R3, R10, R18	
	6. Lack of experience	R2, R3, R5, R18	
	7. Shortage of skilled workers	R1, R2, R3, R7, R13, R18	
Environment and other external factors	1. Severe weather condition	R2, R3, R6, R7, R13, R17, R18	
	2. Protests/strikes	R2	
	3. Political instability	R2, R3	
	4. Safety costs	R10	
	5. Unpredictable local conditions	R2, R3	
	6. Theft and vandalism	R1, R2, R3, R6, R7, R9, R12	
Equipment and machinery	1. Inappropriate Equipment	R2, R3, R13, R18	
	2. Equipment malfunction and breakdown	R2, R3, R5, R7, R10, R18	
	3. Inadequate equipment on site	R3	

Mitigation measures:

Measures	Source	Relevancy (Yes/No)	Additional measures (if any)
Adoption of proper site management techniques	R2		
Accurate and good specifications of materials	R2		
Proper storage of materials on site	R2		
Recycling of waste materials on site	R2		
Minimizing design changes	R2		
Good coordination among personnel	R2		
Proper material handling	R2		

Use of more efficient construction equipment	R2	
Encourage reuse of waste materials	R2	
Early and prompt scheduling of deliveries	R2	
Use of experienced personnel	R2	
Site quality management system	R19	
Effective strategic planning	R19	
Proper project planning	R19	
Frequent project meetings	R19	
Proper emphasis on learning from experience	R19	
Clear information and communication channel	R19	
Training programs for site management staff	R2, R19	
Proper project scheduling	R19	
Site inspections and audits by the government	R19	
Regular safety meetings with safety personnel	R19	
Quality Control monitoring team.	R19	
State and local regulations monitoring team	R19	
Quality control enforcement team	R19	

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Thank you for your time and consideration.

Name of the Expert:

Designation:

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Signature:

APPENDIX-E

KII Form for Experts

ANNEX-1: ACCEPTANCE LETTER



SUDIN SHRESTHA <080mscom021.sudin@pcampus.edu.np>

[IOEGC18] Editor Decision

1 message

Dr. Pradeep Shrestha <ioegc17@gmail.com>

Mon, Apr 27, 2026 at 7:55 AM

To: SUDIN RAJ SHRESTHA <080mscom021.sudin@pcampus.edu.np>, Mahendra Raj Dhital <mrhdhital@ioe.edu.np>

SUDIN RAJ SHRESTHA, Mahendra Raj Dhital:

We have reached a decision regarding your submission to 18th IOE Graduate Conference, "Assessment of Waste Factors due to Non-Value-Adding Activities and Evaluation of Mitigation Strategies in Hydropower Construction Projects in Nepal".

Our decision is to: Accept Submission

With Warm Regards,
IOEGC-18 Editorial Team

 **B-ioegc18-review comment-969.pdf**
290K

ANNEX-2: ORIGINALITY REPORT

PAPER NAME

Assessment of Waste Factors due to Non-Value Adding Activities and Evaluation of Mitigation Strategies in Hydropower Construction Projects in Nepal

AUTHOR

Sudin Raj Shrestha

WORD COUNT

19139 Words

CHARACTER COUNT

104250 Characters

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