TRIBHUVAN UNIVERSITY

INSTITUTE OF ENGINEERING

PULCHOWK CAMPUS

THESIS NO.: 080/MSCoM/007

"Development and Assessment of a Safety Performance Index in Hill Road Construction: Case Study of Mid-Hill Highway in Kavrepalanchowk District"

By

Bhuwan Aryal

A THESIS

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

DEPARTMENT OF CIVIL ENGINEERING

LALITPUR, NEPAL

APRIL 2026

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DECLARATION

I hereby declare that the thesis submitted to the Department of Civil Engineering under the title "Development and Assessment of a Safety Performance Index in Hill Road Construction: Case Study of Mid-Hill Highway in Kavrepalanchowk District" in partial fulfilment of the requirement for the Master of Science in Engineering in Construction Management degree. The work was completed under the supervision of Assistant Professor Mahendra Raj Dhital and Associate Professor Nagendra Bahadur Amatya. The content of this thesis is entirely my own, with the exception of referenced and acknowledged consulted materials.

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CERTIFICATE OF THESIS APPROVAL

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ABSTRACT

Safety of the work force is of utmost importance in the construction sector. This thesis, ”Development and Assessment of a Safety Performance Index in Hill Road Construction: Case Study of Mid-Hill Highway in Kavrepalanchowk District.” sets out on a thorough journey to address the issue of construction safety. The main goal of the thesis is to develop a safety performance index and apply it to evaluate construction site safety through a case study.

The factors affecting the safety of workers in Hill-Road construction were identified through comprehensive literature review and contextualized with relevance to our scenario. Based on the sample space calculated, a section of the mid hill highway in Kavrepalanchowk district was chosen for survey. Then the questionnaire survey was launched for the stakeholders from whom relevant data regarding safety could be collected. The data collected was organized and tested for reliability. The data was analyzed for the formulation of the Safety Performance Index (SPI) equation based on literature. The developed SPI equation was then used to evaluate the safety performance of workers as a case study for any one construction site.

Six major factors and thirty sub-factors that would affect safety were identified for this study. An evaluation of the safety performance of workers was conducted for one project using the developed SPI equation. It uses leading indicators, such as the perception of workers, safety inspections, training, and meetings for health and safety, and the environment of the organization for worker safety. It checks how closely the industry complies with safety standards and safety implementation at hill road construction sites. The assessed project has moderately unsafe safety performance, and the result corresponds with actual situations of the project on sites, which proves the capacity of the SPI equation developed.

Keywords: safety performance, safety performance index, safety factors, equation, leading indicators,

ACKNOWLEDGEMENTS

This research has been a result of continual support and guidance from different people without whom the study would have not been complete. I would like to express my heartfelt gratitude to the Institute of Engineering (IOE) and the Pulchowk Campus for providing a wonderful opportunity to carry out thesis work as partial fulfillment of the Master of Science in Construction Management.

I would like to thank my thesis co-supervisors Asst. Prof. Mahendra Raj Dhital and Assoc. Prof. Nagendra Bahadur Amatya for continual support and guidance throughout the course. Their valuable efforts and assistance for preparing this thesis were priceless.

Also, I would like to convey sincere thanks to all faculty members, constructional professionals from different organization, engineers, contractors and workers for helping me in collection of data.

I also express gratitude to the participants who allocated their time to share their invaluable insights through survey forms and interviews.

I am also indebted to my family, friends, and other coworkers for their unwavering support, inspiration, and encouragement during my study.

Bhuwan Aryal 080/MSCoM/007

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

OSH	Occupational SafetyHealth
DOR	Department of Roads
PPE	Personal protective equipment
MS	Mean Score
RII	Relative Importance
SPI	Safety Performance Index
PI	Performance Index
ILO	International Labour Organization
NEC	Nepal Engineering Council
FCAN	Federation of Contractor Association of Nepal
SOP	Standard Operating Procedures
PPMO	Public Procurement Monitoring Office
NRSC	Nepal red cross society
NOSHA	Health and safety training in Nepal
TRIR	Total Recordable Incident Rate
LTIR	Lost Time Incident Rate
EMR	Experience Modification Rate
SPSS	Statistical Package for Social Science
TTM	Total trimmed mean
DOI	Department of Industry
SCC	Special Condition of Contract
SBD	Standard Bidding Document
GCC	General Condition of Contract
GDP	Gross Domestic Product
HSE	Health Safety Environment
FIDIC	International Federation of Consulting Engineers

CHAPTER 1. INTRODUCTION

This chapter introduces about the study,its background and objectives.The significance of this study and its scope and limitations are also discussed in this chapter.

1.1 Background

Safety, which includes social, psychological, and physical well-being, is widely described as the state of being shielded from damage, injury, or loss (Hale, 1987). Safety in construction projects particularly refers to the well-being, safety, and health of personnel engaged in on-site tasks.

One of the main drivers of Nepal's economic growth, the construction sector contributes significantly to both employment and national investment. In a mountainous nation like Nepal, infrastructure development—especially road building—is crucial for enhancing accessibility, trade, and regional connection.

Building hill roads, like the Mid-Hill Highway, is essential to connecting isolated areas. However, because of the challenging terrain, erratic geology, landslides, and severe weather, these projects are extremely complicated. These difficulties greatly raise the possibility of mishaps and hazardous working circumstances.

One of the riskiest industries in the world is Construction sector. The International Labour Organization (ILO) estimates that work-related illnesses and accidents claim the lives of about 2.93 million workers per year. Compared to other industries, construction workers in Nepal are three to six times more likely to be involved in an accident.

In recent years, Nepal's road infrastructure has grown significantly. Safety management procedures, however, have not advanced as quickly. On many construction sites, safety precautions like PPE use, training, equipment upkeep, and monitoring are not properly implemented.

Furthermore, the lack of safety barriers, steep slopes, and small carriageways make hill roads especially hazardous. According to studies, run-off-road incidents frequently cause serious injuries and fatalities on steep roads.

Conventional safety assessment techniques focus on reactive lagging indications (accidents, injuries). Leading indicators that emphasize prevention are becoming more and more necessary. Consequently, creating a Safety Performance Index (SPI) offers a proactive and quantitative way to evaluate safety performance.

Safety Performance Indicators (SPIs) have been utilized in international contexts to quantify safety levels and direct methods for development (Hinze et al., 2013; Patil & Patil, 2014). An SPI creates a composite index that represents overall safety performance by combining several quantifiable indicators, such as site management, safety training, supervision, and the use of personal protective equipment (PPE). Similar study has been done on construction in Nepal, but no comparable model has been created for projects involving the construction of hill roads, where dangers and working conditions are very different.

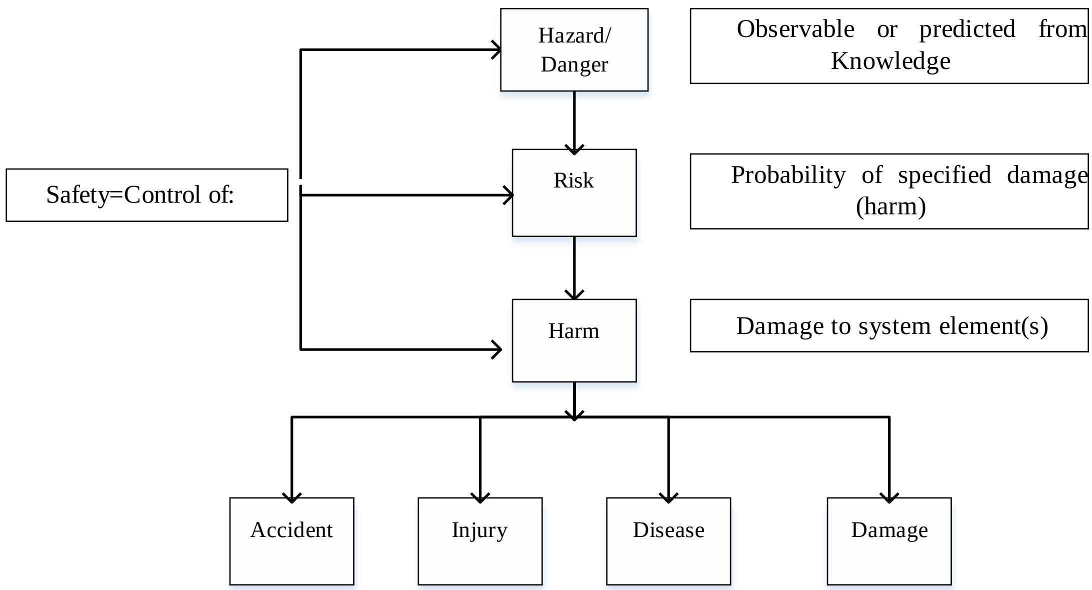


Figure 1.1:Concept of Safety

1.2 Statement of Problem

Due to steep slopes, delicate geological conditions, and the use of high-risk construction techniques like drilling and blasting, construction of roads in Nepal's hilly regions poses special safety challenges. In Nepal's road construction industry, there is virtually no systematic monitoring of occupational safety performance despite the high-risk environment (Pokharel, 2018).

The majority of projects only use verbal reports and qualitative audits for safety assessments, which are unreliable and subjective. Furthermore, current government regulations, such as the Road Safety Audit Manual (1997) and OHS Guideline 2080, place a strong emphasis on safety protocols but lack quantitative assessment frameworks to gauge actual performance (DoR, 2023).

Because of this disparity, project managers and legislators find it challenging to:

- Assess the effectiveness of on-site safety procedures
- Evaluate how well contractors or sites perform &
- Determine the main causes of subpar safety results.

Because of this, mishaps and dangerous behaviors continue, especially in hill road developments with little control.Consequently, it is necessary to:

1. Determine which safety performance indicators (SPIs) are most important for construction of hill roads;
2. Create a composite SPI model using suitable weighting methods (such as RII); and
3. Use the model to assess actual safety performance in a road construction project that is currently underway.

By developing a quantitative, evidence-based framework for safety assessment that can assist both project-level monitoring and the advancement of national policy, this research seeks to close this gap.

The graph below from ILO (2022) shows fewer accidents in 2015 and 2019, respectively, as a result of the COVID pandemic and the economic embargo.

Table 1.1:Occupational Accident Data

Occupational accident during the last 10 fiscal year					
SN	**Fiscal year**	**Accidents**			
		Minor	**Major**	**Fatal**	**Total**
1	2010/11	53	11	5	69
2	2011/12	37	0	2	39
3	2012/13	25	5	3	33
4	2013/14	20	10	6	36
5	2014/15	22	5	6	33
6	2015/16	25	0	3	28
7	2016/17	21	5	6	32
8	2017/18	36	11	4	51
9	2018/19	14	3	3	20
10	2019/20	38	7	8	53

1.3 Objectives

The primary objective of this study is to Development and Evaluation of a Safety Performance in Hill Road Construction: Case Study of Mid-Hill Highway in Kavrepalanchowk District. Whereas, the secondary objectives are as follows:

- To prioritize and rank safety factors based on their relative importance.
- To create a composite SPI model .
- To assess on-site safety performance using field data from the Kavrepalanchok segment of the Mid-Hill Highway.

1.4 Importance of the Study

This study advances safety management techniques in Nepal's road construction sector. The following succinctly describes its significance:

- **Creating a Measurable Safety Instrument:** According to Hinze et al. (2013), the SPI offers a methodical, quantitative framework for evaluating safety during the construction process, enabling project teams to pinpoint flaws and monitor advancements.

- **Support for National Guidelines:** By operationalizing the OHS Guideline 2080's provisions into quantifiable performance indicators, the model improves policy implementation (DoR, 2023).
- **Better Decision-Making:**Project managers can better allocate resources to prevent accidents by using RII-based weighting to determine the most important safety considerations.
- **Practical Relevance:**By enabling contractors, consultants, and government organizations to compare project performance, the SPI model enhances accountability and transparency (Patil & Patil, 2014).

Contribution to Academics:

The work provides a foundation for future research in Nepal and other similar regions worldwide by extending earlier SPI research from building construction to the understudied field of hill road construction.

1.5 Scope and Limitations

This study's objective is restricted to evaluating safety performance during hill road project construction, with a particular case study of the Mid-Hill Highway in Kavrepalanchok District. In order to assess on-site safety performance, the study entails collecting pertinent safety indicators, calculating their relative importance using the Relative Importance Index (RII) approach, and creating a composite Safety Performance Index (SPI). The indicators, which span topics including environmental conditions, organizational management, and human factors, are developed through a review of the literature, expert consultation, and field observations. These variables are integrated by the SPI model using weighted scoring, and the outcomes are used to categorize safety performance into groups like Good, Moderate, and Poor.

The study does have some drawbacks, though. The conclusions may not be as broadly applicable to all road development projects in Nepal because it is limited to a particular case study site. The study only looks at occupational safety during the construction phase; post-construction and vehicle safety are not taken into account. A certain amount of subjectivity may be introduced because data collecting depends on field observations and expert views. The established SPI does not take into consideration temporal fluctuations or predicted accident modeling; instead, it depicts the safety condition throughout the data collection period. The number of responders and observation days may also be limited by time, money, and accessibility to remote locations. Notwithstanding these drawbacks, the study offers a solid basis for the creation of a uniform quantitative framework for assessing safety performance in hill road construction projects throughout Nepal.

CHAPTER 2. LITERATURE REVIEW

In the context of hill road construction projects, this chapter examines the literature on the ideas of safety, occupational health, and safety performance measurement. It contains analyses of previous research, national and international safety regulations, and frameworks for measuring safety performance. The chapter also covers methods for creating a Safety Performance Index (SPI), safety-related policies, and variables affecting road construction safety.

2.1 Labour and Labour Safety

The term "labor" describes the human resources actively involved in the construction process, from engineers and site supervisors to unskilled laborers, all of whom work together to finish road projects. Because workers typically work in high-risk environments including steep terrain, unstable slopes, and heavy machinery zones, labor safety, also known as occupational safety, is crucial in the road construction industry.

By reducing occupational dangers and guaranteeing a safe working environment, the idea of labor safety aims to shield employees from harm, disease, or death (Hale, 1987). Landslides, slope collapse, machinery overturns, blasting accidents, and exposure to dust and noise are among the special risks that workers in hill road construction confront (ADB, 2012). In these situations, effective safety management necessitates ongoing monitoring, supervision, and awareness in addition to basic compliance.

Many people are employed in Nepal's road construction industry, many of whom come from rural areas. The majority of these workers are unpaid contractors with no access to protective gear, little safety awareness, and little training (Pokharel, 2018). In addition to being vital for humanitarian reasons, ensuring their safety is also essential for keeping project schedules on track and minimizing financial damages from mishaps.

2.2 Occupational Health

Occupational Health and Safety (OHS) is concerned with maintaining a safe workplace, preventing accidents, and safeguarding the health of employees. OHS includes physical, chemical, biological, ergonomic, and psychosocial risk factors, according to Saiyed et al. (2006). While ergonomic dangers include exhaustion from repetitive jobs and extended work hours, physical risks in road construction are more common and include falls, car crashes, and accidents from machinery.

OHS's ergonomic component falls into one of the following categories:

- **Physical ergonomics:** Exposure to equipment vibrations, poor body posture, and heavy lifting.
- **Cognitive ergonomics:** Human error brought on by exhaustion, inattention, or low awareness.
- **Organizational ergonomics:** low motivation, poor cooperation, and poor communication (Saiyed et al., 2006).

In hill road construction, effective OHS management reduces workplace accidents and promotes a safety culture that puts prevention above reaction.

2.3 Labour Safety Measures: National

Road projects and other construction-related occupational safety are governed by a number of laws, regulations, and institutional structures in Nepal. Important clauses consist of:

a) **Occupational Health and Safety Guideline for Road Infrastructure Development and Management, 2080 (DoR, 2023)**

   This is the most up-to-date and thorough road construction safety guideline, released by the Department of Roads (DoR). It outlines the duties of supervisory engineers, consultants, and contractors with regard to worker safety. Safety planning, the supply of personal protective equipment (PPE), the placement of signage, the availability of first aid, emergency response, and incident reporting are all highlighted in the guideline. This study aims to fill that gap by providing a quantitative framework for performance evaluation.

b) Labour Act, 2074 (2017)

The main piece of legislation pertaining to workers' rights and safety in Nepal is the Labour Act.

- Chapter 12 requires companies to uphold health and safety standards at work.
- Employer responsibilities for safety training, reporting accidents, and providing protective gear are outlined in Sections 68–73.
- On building sites, Section 74 mandates the establishment of Safety and Health Committees.

The implementation of occupational safety requirements in all construction projects is based on these regulatory provisions.

c) Public Health Service Act, 2075 (2018)

Authorities are required by Section 44 to put safety precautions in place for workers in high-risk construction zones. In order to prevent occupational injuries and guarantee worker welfare, it places a strong emphasis on adhering to national standards.

d) Standard Specifications for Road and Bridge Works (DoR, 2020)

The technical basis for all road projects in Nepal is this document. It mandates that contractors maintain sufficient site safety, offer first aid supplies, control traffic while building is underway, and guarantee environmental preservation. Additionally, the contract requires all laborers to have access to PPE and safe work procedures.

e) Constitution of Nepal (2015)

According to Part 3, Clauses 29 and 34 of the Constitution, employment, fair compensation, and workplace safety are essential rights. It guarantees social security to all employees and places a strong emphasis on safeguarding against workplace abuse.

Despite these legislative frameworks, there is still a lack of a quantifiable safety monitoring system, insufficient inspection, and lax enforcement.

Therefore, the goal of this study is to make a contribution by creating an SPI that complies with current regulations while incorporating quantitative evaluation capabilities.

2.4 Labour Safety Measures: International

Frameworks for workplace safety are provided by a number of international organizations and standards:

- ILO Convention No. 155 (Occupational Safety and Health, 1981) places a strong emphasis on worker engagement, preventive measures, and national OSH programs.
- An organized method for risk-based safety management and ongoing improvement is offered by ISO 45001:2018 (Occupational Health and Safety Management Systems).
- OSHA Standards (USA) specify safety procedures for a number of sectors, including construction, with an emphasis on PPE, hazard control, and accident reporting.
- Proactive risk assessment and safety audits are encouraged by EU-OSHA and British Safety Council frameworks.

This study adapts these international recommendations, which provide methodological insights for creating performance-based safety evaluation systems, to the hill road setting of Nepal.

2.5 Safety Performance and its Index

The efficiency of safety management techniques in reducing workplace risks and upholding a secure workplace is referred to as safety performance (Hinze et al., 2013). It gauges how well safety regulations, practices, and training initiatives are carried out in the construction industry.

By merging several performance indicators into a single score, a Safety Performance Index (SPI) is a composite indicator that measures the general degree of safety at a construction site (Patil & Patil, 2014). The SPI method converts qualitative characteristics of safety, like management commitment or training quality, into quantifiable numbers. It aids in tracking progress over time, comparing performance across projects, and identifying areas that require improvement.

2.6 Safety Performance Measurement Approaches

Safety performance measurement is a multifaceted process that considers various indicators such as incident rates, near-miss reporting, compliance with safety regulations, safety training, and the use of personal protective equipment (PPE), among others (Sawacha et al., 1999). These indicators collectively help in assessing the overall safety condition of construction sites.

Traditionally, safety performance has been measured using common metrics such as Total Recordable Incident Rate (TRIR), Lost Time Injury Rate (LTIR), and Experience Modification Rate (EMR) (Client & Group, 2013). These are categorized as **lagging indicators**, as they are reactive in nature and evaluate safety performance based on past incidents and accidents. Such measures rely on historical data, including the number of fatalities, injury frequency, severity rates, and lost workdays, and are therefore considered failure-focused. Reactionary analysis involves examining these past records to identify weaknesses in safety processes and management systems (Sgourou et al., 2010).

However, the effectiveness of lagging indicators is often limited due to inadequate reporting systems and incomplete accident data, which is a common issue in construction projects. To overcome these limitations, **leading indicators** are increasingly used as proactive and preventive measures (Xu et al., 2023). Leading indicators focus on current safety practices and behaviors that can help prevent accidents before they occur.

These predictive measures include observation of site conditions, safety inspections, health, safety, and environment (HSE) meetings, training programs, and audits. By emphasizing ongoing activities such as compliance monitoring and worker participation, leading indicators support continuous improvement in safety performance and contribute to accident prevention.

Safety assessment can also be conducted based on the perception of workers, as adopted by (Andi, 2008). This approach evaluates safety performance through qualitative and behavioral indicators. Some key indicators include:

- **Safety perception surveys**, which assess the level of compliance with safety regulations, effectiveness of safety training, and overall awareness among workers (Andi, 2008).
- **Employee participation**, representing the extent to which workers are actively involved in safety-related activities such as hazard identification and reporting.
- **Management commitment**, which reflects the degree of importance given to safety by management through policies, supervision, and enforcement practices (Teo et al., 2005).
- **Safety culture**, defined as the collective values, attitudes, and behaviors of individuals within an organization that determine how safety is perceived, prioritized, and implemented (Abueltayf, 2022).

These indicators form the basis for evaluating safety performance in a proactive manner and are particularly useful in developing models such as the Safety Performance Index (SPI).

2.7 Factors Affecting Safety Performance in Hill Road Construction

HUMAN FACTOR (H)

Sub-factor	Key References
PPE usage	(Abdelhamid & Everett, 2000), (Choudhry & Zahoor, 2016), (ILO, 2022)
Safety awareness	(Tam et al., 2004), (Teo et al., 2005), (Andi, 2008)
Worker fatigue	(Siva et al., 2014), (Usukhbayar & Choi, 2020)

Sub-factor	Key References
Skill competency	(Sawacha et al., 1999), (Islam et al., 2019)
Safety compliance	(Choudhry & Zahoor, 2016), (Shrestha et al., 2022)

ORGANIZATIONAL FACTOR (O)

Sub-factor	Key References
Safety culture	(Teo et al., 2005), (Abueltayf, 2022)
Site supervision	(Zahoor et al., 2017), (Ng et al., 2005)
Hazard communication	(Tam et al., 2004), (Priyadarshani et al., 2014)
Emergency preparedness	(ILO, 2022), (Giri, 2020)
Safety resources	(Priyadarshani et al., 2014), (Ng et al., 2005)

PHYSICAL FACTOR (Ph)

Sub-factor	Key References
Slope stability	(Giri, 2020), (Usukhbayar & Choi, 2020)
Weather condition	(Usukhbayar& Choi, 2020), (Shrestha et al., 2022)
Equipment safety	(Abdelhamid & Everett, 2000), (Siva et al., 2014)
Site access	(Siva et al., 2014), (Choudhry & Zahoor, 2016)
Material handling	(Choudhry & Zahoor, 2016), (ILO, 2022)

PROCEDURAL FACTOR (Pr)

Sub-factor	Key References
Work procedures (SOP)	(Wu et al., 2015), (Ng et al., 2005)
Permit system	(FIDIC, 2017), (PPMO SBD Nepal, GCC Clause 24)
Work sequencing	(Sawacha et al., 1999), (Tam et al., 2004)
Incident reporting	(Abdelhamid & Everett, 2000), (ILO, 2022)
Safety inspection	(Sgourou et al., 2010), (Shrestha & Shrestha, 2019)

REGULATORY FACTOR (R)

Sub-factor	Key References
Legal compliance	(ILO, 2022), Labour Act 2074 (Nepal)
Environmental regulation	Environmental Protection Act (Nepal), (Giri, 2020)
Labour compliance	Labour Act 2074, Constitution of Nepal (2015)
Construction permits	Public Procurement Act, PPMO (Nepal)
Authority inspection	(Shrestha & Shrestha, 2019), Department of Labour Nepal

TECHNOLOGICAL FACTOR (T)

Sub-factor	Key References
Safety devices	(Choudhry & Zahoor, 2016), (Wu et al., 2015)
Modern equipment	(Islam et al., 2019), (El-Nagar et al., 2015)
Communication tools	(Teo et al., 2005), (Wu et al., 2015)

Sub-factor	Key References
Protective structures	(Giri, 2020), DoR Specifications Nepal
Stabilization technology	DoR Nepal Guidelines, (Usukhbayar& Choi, 2020)

2.8 Quantitative Models for Developing Safety Performance Index Past Studies on Factors affecting Safety

Relative Importance Index $RII = \frac{\sum W}{AN} = \frac{1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}{AN}$

where, n1, n2, n3, n4, n5 represent the number of respondents for very low,low, moderate, high and very high levels of safety respectively.

Mean score

The data obtained from the survey questionnaire underwent analysis using the Mean Score (MS) method, as implemented (Ng et al., 2005).

$$MS = \frac{\sum f * s}{N} (1 \le MS \le 5)$$

Where,f=frequency of the responses rating each main factor

s= score given to each main factor by respondent

N=total number of responses

Relative importance

$$\boldsymbol{RI = \frac{MS}{\sum MS}}$$

Where,MS is mean score

CHAPTER 3. METHODOLOGY

This chapter discusses the research method that is used to achieve the research objectives. The topics discussed in this chapter are research approach, research design, study area, population size, sample size calculation ,statistical tools and tests, methods of data collection, data analysis, model development. This chapter gives an overall organization of the study.

To achieve the objectives of the study, asystematic literature review was done initially to get the detailed overview of the study's background and previous research conducted within the scope of the study. The identified research questions necessitated the need of study for safety in construction sector primarily the hill road. Technical reports, journal articles, and thesis works are also included as existing literature to expand the possibility of encompassing all materials related to the topic of this study.

3.1 Research Methodology

This thesis includes the following structured process listed sequentially below:

- The first step involves formulating a research question and selecting a research topic. This is succeeded by identifying a research challenge, formulating research objectives, and outlining the research strategy.
- The second step is literature review to identify factors affecting safety in hill road construction and their relation with safety performance with respect to workers which is reinforced and validated with the help of Experts opinions and interviews.
- The third step is creating the sample and the questionnaire. The survey is primarily based on research studies from (Wu et al., 2015), (Ng et al., 2005) and (Abdalfatah et al., 2023), with the necessary modifications and contextualization relevant to the Nepalese construction industry scenario. It was done with the help of expert consultation. Prior to the actual field survey, the questionnaire underwent additional pre-testing (pilot survey)to ensure that the questions are not biased.

- The fourth step includes data collection through Structured questionnaire survey administered to different stakeholders involved in hill road construction projects and especially to contractors and workers who are directly involved in construction. The questionnaire was then coded and data analysis using Statistical Package for Social Science(SPSS) software and MS Excel, data visualization and analysis tool.
- After the analysis the safety performance equation is developed based on mean weightage of safety factors as discussed in literature review.
- The next phase includes application of model using a case study to evaluate safety performance of hill road construction site in Kavrepalanchowk district.
- And finally, the last phase includes interpretation and discussion of results with conclusion and recommendation.

3.2 Research Design

The conceptual framework in which research is carried out is called the research design. It gives a general overview of how this study will be conducted in order to accomplish the aforementioned goals.

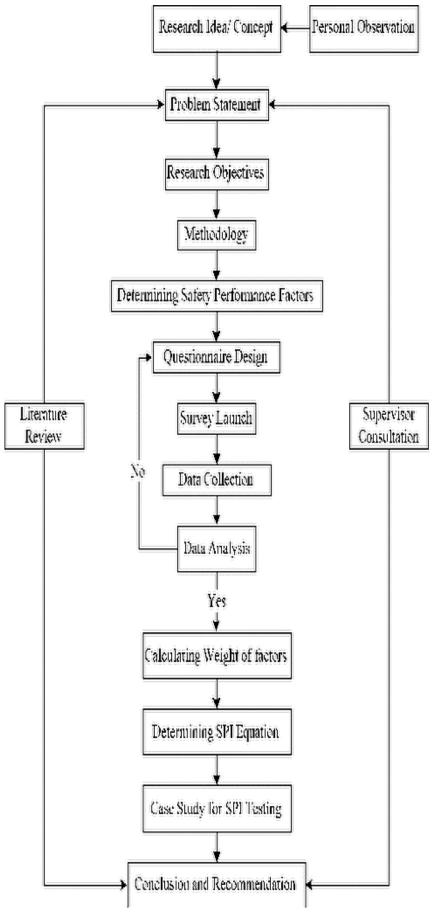


Figure 3.1:Research design flow chart

3.3 Study area

Although equally available to other hill-road construction sectors, the study limited itself to hill road sector only with following criterion.

Nature	criteria	Location
Hill road construction project	Mid hill highway	Kavrepalanchowk

3.4 Study Population, Sample Selection and Sample size

In this study, population means all the Hill-Road Construction Sites. The collection of data is done through stakeholders involved in these construction sites. The stakeholders include Project manager, Contractor, Worker, Supervisors, Safety Officials, Engineers involved in those construction sites. Random sampling was done to avoid biasness in the data collection which is presented in section 4.2.2. Also, for a case study one project is selected in random manner. The population here is large. Sample size determination is based on the literature (Cochran, 1977).

3.4.1 Sample size

The parties related to the contractors would be subjected to participate in questionnaire survey. The sample size for the study represented will calculated based on the following formula

$$n_o = \frac{z^2pq}{e^2}$$

....Equation 3.1

Where,

n_0=the first estimate of sample size

z =significant value of z at desired confidence

p=the proportion of characteristics being measured in target population

$$q = 1 - p$$

e=standard error

Assuming the population size is large

From

....Equation 3.1, Calculation:

Here for 90% confidence level; z= 1.64; e=0.1 and p=0.5, q=0.5

n_0= (1.64*1.64*0.5*0.5)/ (0.1*0.1)=67.24 i.e. 68nos

Therefore, sample size is taken as 68 as per calculation.

3.5 Research data Collection

3.5.1 Primary data Collection

It aims to collect firsthand information. Here in this research original information is gathered directly from survey. For this particular study, data is collected using a questionnaire survey administered through online forms and on-site data collection involving interviews. The questionnaire survey was administered in two phases. The first was for the formulation of safety performance equation. Later was done as a case study to evaluate the value of safety performance index (SPI) for the selected construction sites.

3.5.2 Secondary data Collection

It includes published literatures, study reports, journals, articles, websites, magazines, records etc. relevant to the study. Identification of safety factors in this thesis is primarily done using this method of data collection. Later validated in context of Nepal through expert opinion and pilot survey.

3.6 Data Analysis

Microsoft Excel and the Statistical Package for Social Science (SPSS) program have been used to analyze, summarize, categorize, and tabulate the data and information gathered from both primary and secondary sources. Various descriptive statistical tools have been used to visualize and understand the data. The overall research matrix is given below to understand how data is analyzed.

3.6.1 Research Matrix

Objective	Data Required	DataSource	Tools	Expected Outcomes
Prioritize safety factors based on severity and importance	• Factors affecting safety. • Standard set of questions	• client • consultant • contractor • Academicians • Safety officials and authorities • Workers	Questionnaire	Based on mean score(MS) and relative importance Index(RII) the ranking and priority order of safety factors.
To develop a model to measure performance of safety in construction	• Prioritized safety factors (main factors and sub factors)with the relative importance index(RII) • Frequency distribution and rating weightage for each factor	• client • consultant • contractor • Academicians • Safety officials and authorities • Workers	Mathematical equation of Safety performance index (SPI) mathematical relation of Relative importance suggested by literature review Performnce index (PI)	Mathematical model to measure safety performance.
To apply safety performance model to evaluate safety performance of construction sites as a case study	Outcomes of first three objectives, and literature review. Safety performance equation.	Outcomes from above mentioned objective	Observation and interview specific to construction site	Comparable numerical values of Safety performance index.

3.6.2 Descriptive Statistics

It is helpful in representing data in such a way that can be visualized through graphs, charts and tables. Demographic data here in this research has been analyzed through descriptive statistics.

3.6.3 Reliability Statistics

Reliability or internal consistency of the survey data has been measured through Cronbach's alpha(α). It uses statistics to determine consistency among the collected data of same characteristics (Hinton,2014). Represented by alpha with the value between 0 and 1. Higher value indicates higher consistency among data.The range is well depicted in given table below.

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

$\sum s^2y$=Sum of variance associated with theitem

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

Table 3.1: Cronbach's Alpha

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

Table 4.2:Result of Cronbach's alpha

Variables	**Values**	**Result**
Number of scale item(k)	30	Very good consistency
Sum of variance associated with the item ($\Sigma s^2 y$)	10.463	
Variance associated with the observed total score($s^2 x$)	64.173	
Cronbach's alpha(α)	0.866	

3.6.4 Relative Importance Index Analysis

Relative importance can be used to Likert scale to assess the relative importance of different factors or variables. Based on this relative importance the variables here referred as safety factors can be ranked.

$$\boldsymbol{RII} = \frac{\sum \boldsymbol{W}}{\boldsymbol{AN}}$$

$$= \frac{\boldsymbol{1n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}}{\boldsymbol{AN}}$$

Where n1 , n2 , n3 , n4 , n5 represent the number of respondents for very low, low, moderate, high and very high levels of safety respectively.

3.6.5 Formation of Safety Performance Index (SPI) Equation

SPI is based on the weightage of mean for given safety factor. Mean is calculated for 5% trimmed data to eliminate outlier to remove extreme values. Outliers may skew the data so that five percent of data (extreme values) i.e. highest and lowest values are trimmed to compute trimmed mean which is more accurate than traditional mean (Wilcox & Keselman, 2003).

3.6.6 Mean score

The data obtained from the survey questionnaire underwent analysis using the Mean Score (MS) method, as implemented by (Ng et al., 2005).

$$\boldsymbol{MS = \frac{\sum f * s}{N} \ (1 \leq MS \leq 5)}$$

where,f=frequency of the responses rating each main factor

s= the score given to each main factor by respondent

N=total number of the responses

Equations:

$$\text{Weight of Human Factor(WH)} = \frac{TMH}{TTM}$$

$$= \frac{TMH}{TMH + TMO + TMPh + TMPr + TMR + TMT}$$

$$Weight\ of\ Organizational\ Factor = \frac{TMO}{TTM}$$

$$= \frac{TMO}{TMH + TMO + TMPh + TMPr + TMR + TMT}$$

Similar for other factors Physical factor(W_{Ph}), Procedural factor(W_{Pr}), Regulatory Factor (W_R) and Technological Factor (W_T).

Where,TTM: Total trimmed mean(5%) of all factor categories TM_H: Five percent trimmed mean for Human factor

TMO: Five percent trimmed mean for Organizational factor TM_{Ph}: Five percent trimmed mean for Physical factor TM_{Pr}: Five percent trimmed mean for Procedural factor TM_R: Five percent trimmed mean for Regulatory factor TM_T: Five percent trimmed mean for Technological factor

$SPI=W_H.H+W_O.O+W_{Ph}.Ph+W_{Pr}.Pr+W_R.R+W_T.T$

Where, H, O, Ph, Pr, R, T are compensative coefficient for respective factors.

CHAPTER 4. RESULTS AND DISCUSSIONS

The methods and analysis covered in chapter three are used in this chapter to analyze and evaluate the data that was gathered. Excel was used to import the gathered data in order to perform descriptive statistics. Additionally, tables, bar graphs, and pie charts were used to display the data and the outcomes.The results are organized according to the three research objectives:

- **Section 4.1**-Results for RO1- To prioritize and rank safety factors based on their relative importance.
- **Section 4.2**-Results for RO2- To create a composite SPI model.
- **Section 4.3**-Results for RO3- To assess on-site safety performance using field data from the Kavrepalanchok segment of the Mid-Hill Highway.

4.1 To prioritize and rank safety factors based on their relative importance.

This section addresses the first research objective: To prioritize and rank safety factors based on their relative importance.

4.1.1 Finalized Safety Factors from Expert Consultation

As a result of the factors affecting safety identification process described in Chapter 3 which involved literature review followed by expert consultation to contextualize factors for Kathmandu Valley, a total of 6 major risk factors and 30 sub-factors were finalized. These are presented below.

Main Factors	Sub-Factors
Human Factor (H)	Use of Personal Protective Equipment (PPE)
	Safety training and awareness
	Fatigue and work hours

	Experience and competency
	Safety compliance behavior
Organizational Factor (O)	Safety policy and culture
	Supervision and monitoring
	Communication of hazards
	Emergency preparedness
	Resource allocation
Physical Factor (Ph)	Road geometry and slope stability
	Weather conditions
	Machinery and equipment safety
	Site layout and access
	Materials handling
Procedural Factor (Pr)	Standard operating procedures (SOPs)
	Permit-to-work system
	Work scheduling and sequencing
	Incident reporting and investigation
	Safety audits and checklists
Regulatory Factor (R)	Compliance with national safety laws
	Environmental and slope regulations

	Labor law compliance
	Permits and approvals for hill roads
	Inspection and enforcement
Technological Factor (T)	Safety technology
	Modern machinery and automation
	Communication tools
	Protective structures
	Innovative construction methods

4.1.2 Response Rate

Table 4.1:Respondent Data

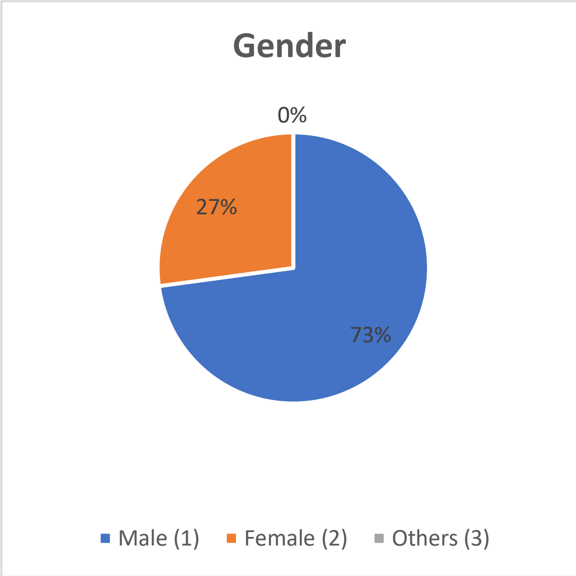
Total Response received	70
Physical form	70
Project Manager (1)	6
Site Engineer (2)	12
Site Sub Engineer (3)	13
Consultant (4)	11
Contractor (5)	17
Others (labors, supervisors, Equipment Operators)	11

4.1.3 Demographic data

- **Gender**

Table 4.2:Gender Profile

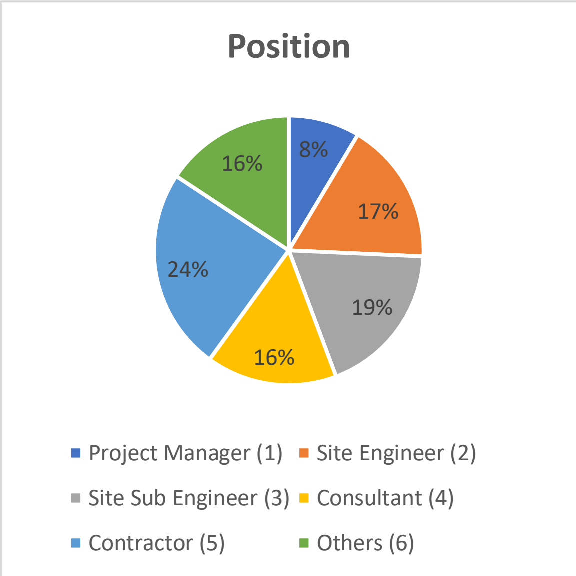
Male	51
Female	19
Others	0
Total	**70**



- **Job Title**

Table 4.3: Job Title

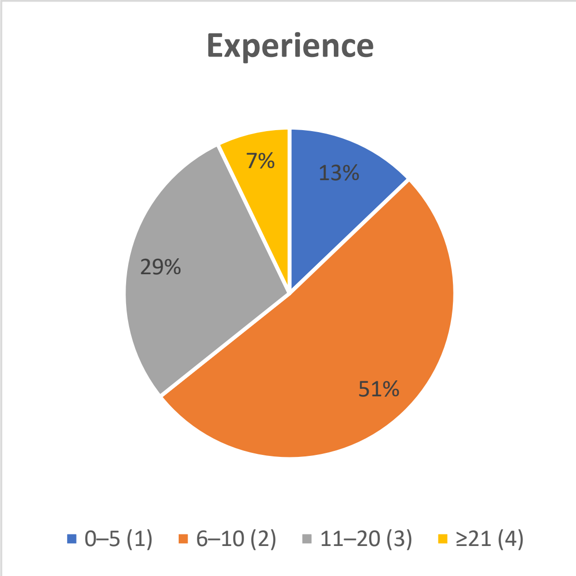
Project Manager (1)	6
Site Engineer (2)	12
Site Sub Engineer (3)	13
Consultant (4)	11
Contractor (5)	17
Others (6)	11



- **Experience**

Table 4.4: Experience

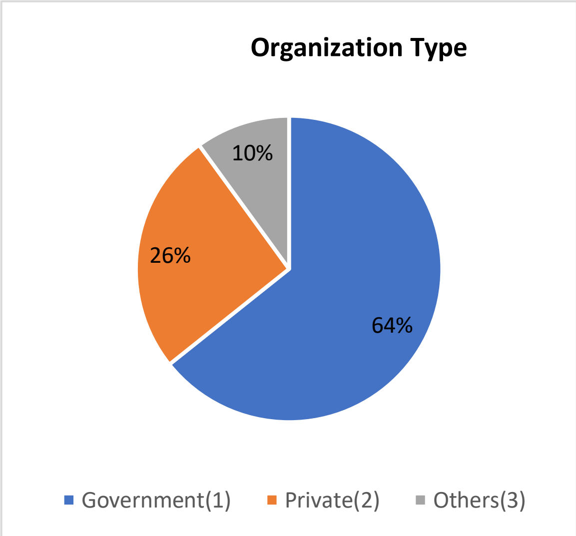
0–5 (1)	9
6–10 (2)	36
11–20 (3)	20
≥21 (4)	5



- **Organization Type**

Table 4.5: Organization Type

Government(1)	45
Private(2)	18
Others(3)	7



4.1.4 Ranking of Factors

Ranking of the factors are based on the relative importance index as discussed in chapter three. Road geometry and slope stability, Use of personal protective equipment (PPE) and Protective structures ranks top three. Similarly, Fatigue and work hours, Materials handling, and Safety technology are least important factors compared to other factors.

Table 4.6: Ranking of Factors

Code	Sub Factors	RII	Rank
Ph1	Road geometry and slope stability	0.949	1
H1	Use of Personal Protective Equipment (PPE)	0.937	2
T4	Protective structures	0.926	3
R1	Compliance with national construction safety laws	0.914	4
Ph3	Machinery and equipment safety	0.9	5
Pr4	Incident reporting and investigation	0.897	6
H2	Safety training and awareness	0.889	7
H4	Experience and competency	0.886	8
T2	Modern machinery and automation	0.88	9
O1	Safety Policy and culture	0.877	10
H5	Safety compliance behaviour	0.874	11
Pr1	Standard operating procedures(SOPs)	0.874	11
R2	Environmental and slope stability regulations	0.874	11

O2	Supervision and Monitoring	0.869	14
Pr5	Safety audits and checklists	0.851	15
Pr3	Work scheduling and sequencing	0.829	16
T3	Communication tools	0.826	17
Ph2	Weather condition	0.823	18
Ph4	Site Layout and access	0.820	19
O3	Communications of hazards	0.811	20
R4	Permits and approvals for hill road construction	0.809	21
O4	Emergency preparedness	0.806	22
R5	Inspection and enforcement by authorities	0.806	22
R3	Labor law compliance	0.794	24
Pr2	Permit-to-work system	0.791	25
O5	Resource Allocation	0.783	26
T5	Innovative construction methods	0.783	26
H3	Fatigue and work hours	0.774	28
Ph5	Materials handling	0.769	29

T1	Safety technology	0.746	30

4.1.5 Cronbach's alpha (α) Reliability Analysis

Reliability test for 30 safety performance indicators were conducted in Excel and the result is represented in table below.The Cronbach's alpha with value 0.866 suggests the data set has very good reliability.

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

Table 4.7:ResultofCronbach'salpha

Variables	Values	Result
Number of scale item(k)	30	Very good consistency
Sum of variance associated with the item ($\Sigma s^2 y$)	10.463	
Variance associated with the observed total score($s^2 x$)	64.173	
Cronbach's alpha(α)	0.866	

Discussions: The prioritization of safety factors for hill road construction in Nepal reveals a significant emphasis on managing the physical environment and immediate worker protection, as evidenced by **Road Geometry and Slope Stability (Ph1)** achieving the highest importance ($RII = 0.949$). This primary ranking reflects the unique geomorphological challenges of the region, where landslides and steep gradients are inherent risks that practitioners view as the most critical threats to safety. The subsequent high rankings of **Use of PPE (H1)** ($RII = 0.937$) and **Protective Structures (T4)** ($RII = 0.926$) indicate a reliance on tangible, defensive measures to mitigate these environmental hazards. Furthermore, the strong positioning of **Compliance with National Construction Safety Laws (R1)** ($RII = 0.914$) suggests that the regulatory framework, including the Labour Act 2074, is becoming a central pillar of site management. Interestingly, "soft" factors such as **Fatigue and Work Hours (H3)** and **Materials Handling (Ph5)** were ranked among the least important, hinting at a possible normalization of high-stress work conditions or a cultural focus that prioritizes technical engineering solutions over human-centric risk management. These findings are supported by a robust data set from 70 experienced respondents—primarily from the government sector—and validated by a **Cronbach's Alpha of 0.866**, which confirms very good internal consistency and reliability for the 30 sub-factors analyzed. Overall, the discussion highlights that while the industry is highly proficient at identifying high-impact physical and legal risks, there remains an opportunity to elevate the perceived importance of modern safety technology and human fatigue management to achieve a more holistic safety culture.

4.2 To create a composite SPI model.

The graphs and equation below show the weight of factors as determined by (El-Nagar et al., 2015).

<u>Equations:</u>

$$\text{Weight of Human Factor(WH)} = \frac{TMH}{TTM}$$

$$= \frac{TMH}{TMH + TMO + TMPh + TMPr + TMR + TMT}$$

$$WeightofOrganizationalFactor = \frac{TMO}{TTM}$$

$$= \frac{TMO}{TMH + TMO + TMPh + TMPr + TMR + TMT}$$

Similar for other factors Physical factor (W_{Ph}), Procedural factor (W_{Pr}), Regulatory Factor (W_R) and Technological Factor (W_T).

Where, TTM: Total trimmed mean (5%) of all factor categories TM_H: Five percent trimmed mean for Human factor

TMO: Five percent trimmed mean for Organizational factor TMPh: Five percent trimmed mean for Physical factor TMPr: Five percent trimmed mean for Procedural factor TMR: Five percent trimmed mean for Regulatory factor TMT: Five percent trimmed mean for Technological factor

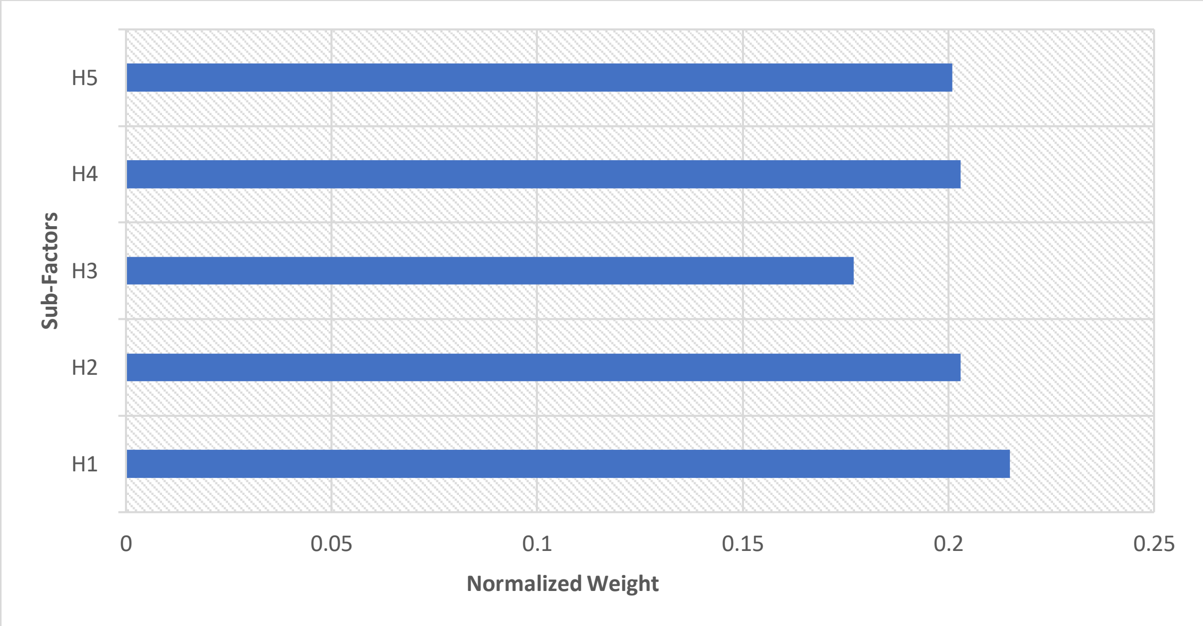
$$\mathbf{SPI = W_H.H + W_O.O + W_{Ph}.Ph + W_{Pr}.Pr + W_R.R + W_T.T}$$

Where , H, O, Ph, Pr, R, T are compensative coefficient for respective factors.

Human Factor(H): From the table and chart below, it can be seen that five factors under human category accounts for worker related safety factors whose sum of normalized weight is 1. Five factors have their different weightage. Among the human categorical factor, Use of personal protective equipment (PPE) ranks first and consequently safety training and awareness and Experience and competency ranks second and third respectively.

Table 4.8:Rankingof Human factor

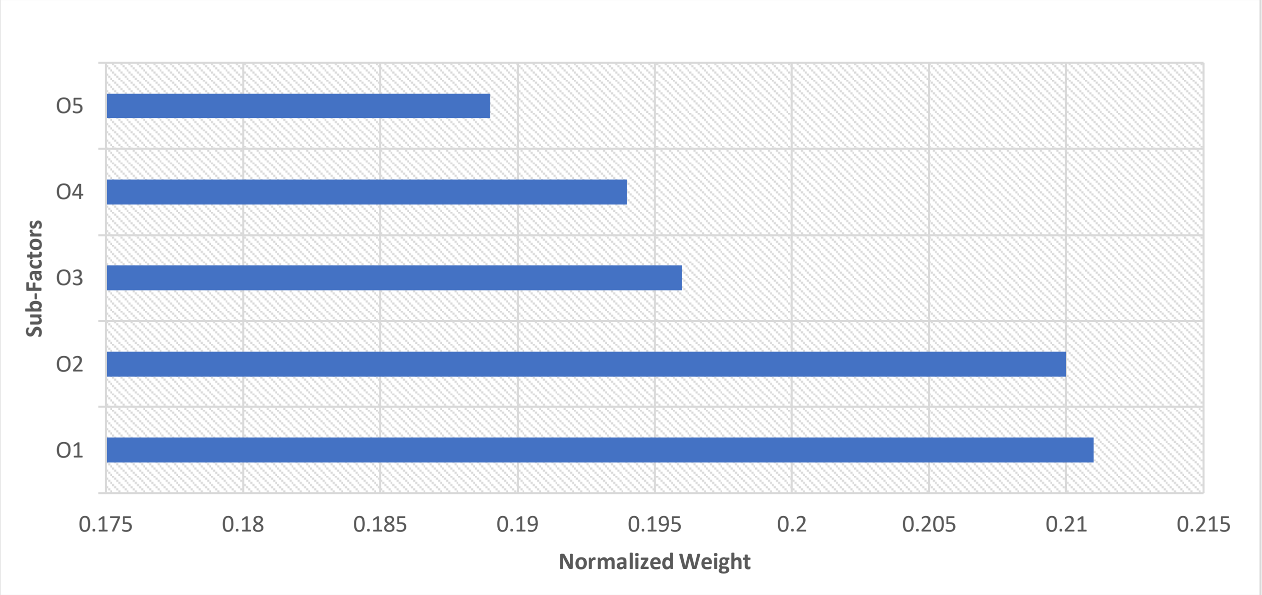
Code	Human Facors	Mean	Normalized weight	Rank
H1	Use of Personal Protective Equipment (PPE)	4.706	0.215	1
H2	Safety training and awareness	4.441	0.203	2
H4	Experience and competency	4.441	0.203	3
H5	Safety compliance behavior	4.382	0.201	4
H3	Fatigue and work hours	3.868	0.177	5
H=0.215H1+0.203H2+0.177H3+0.203H4+0.201H5				



Organizational Factor(O): From the table and chart below, it can be understood that Safety policy and culture ranks firstwith Supervision and monitoring and Communication of hazards on second and third respectively. The value of organizational categorical factor can be evaluated from the given equation below.

Table 4.9:Ranking of Organizational Factor

Code	Organizational Factors	Mean	Normalized weight	Rank
O1	Safety policy and culture	4.382	0.211	1
O2	Supervision and monitoring	4.353	0.21	2
O3	Communication of hazards	4.059	0.196	3
O4	Emergency preparedness	4.029	0.194	4
O5	Resource allocation	3.926	0.189	5
O=0.211O1+0.210O2+0.196O3+0.194O4+0.189O5				

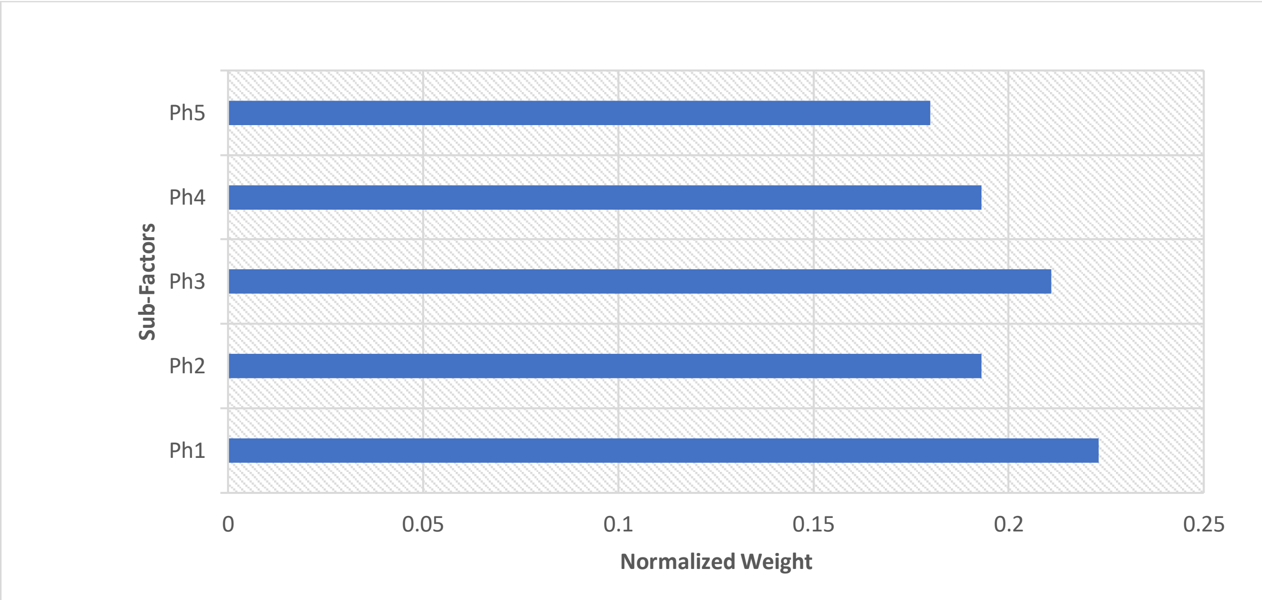


Physical Factors(Ph): From the table and chart below, it can be understood that Road geometry and slope stability ranks first with machinery and equipment safety and weather conditions on second and third respectively. The value of physical categorical factor can be evaluated from given equation below.

Table 4.10:Ranking of Physical Factor

Code	Physical Factors	Mean	Normalized weight	Rank
Ph1	Road geometry and slope stability	4.765	0.223	1
Ph3	Machinery and equipment safety	4.515	0.211	2
Ph2	Weather conditions	4.118	0.193	3
Ph4	Site layout and access	4.118	0.193	4

Ph5	Materials handling	3.838	0.18	5
Ph=0.223Ph1+0.193Ph2+0.211Ph3+0.193Ph4+0.180Ph5				

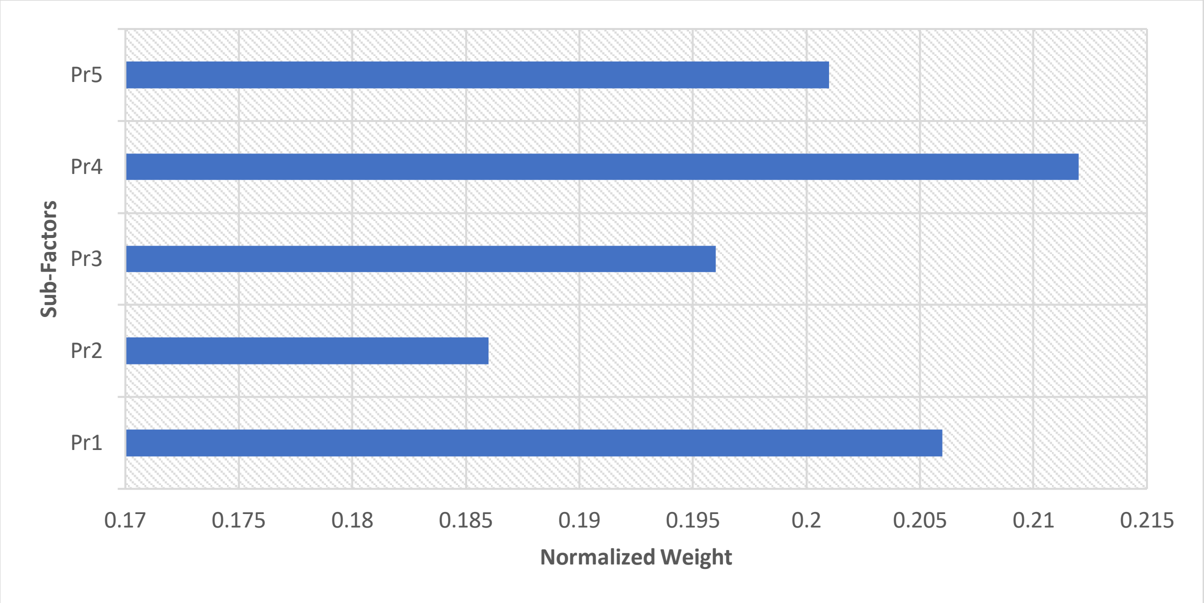


Procedural Factor(Pr): From the table and chart below, it can be understood that incident reporting and investigation ranks first with Standard Operating Procedures (SOPs) and Safety audits and checklists on second and third respectively.The value of procedural categorical factor can be evaluated from the given equation below.

Table 4.11:Ranking of procedural factors

Code	Procedural Factors	Mean	Normalized weight	Rank
Pr4	Incident reporting and investigation	4.5	0.212	1
Pr1	Standard operating procedures (SOPs)	4.382	0.206	2
Pr5	Safety audits and checklists	4.265	0.201	3
Pr3	Work scheduling and sequencing	4.162	0.196	4

Pr2	Permit-to-work system	3.956	0.186	5
Pr=0.206Pr1+0.186Pr2+0.196Pr3+0.212Pr4+0.201Pr5				

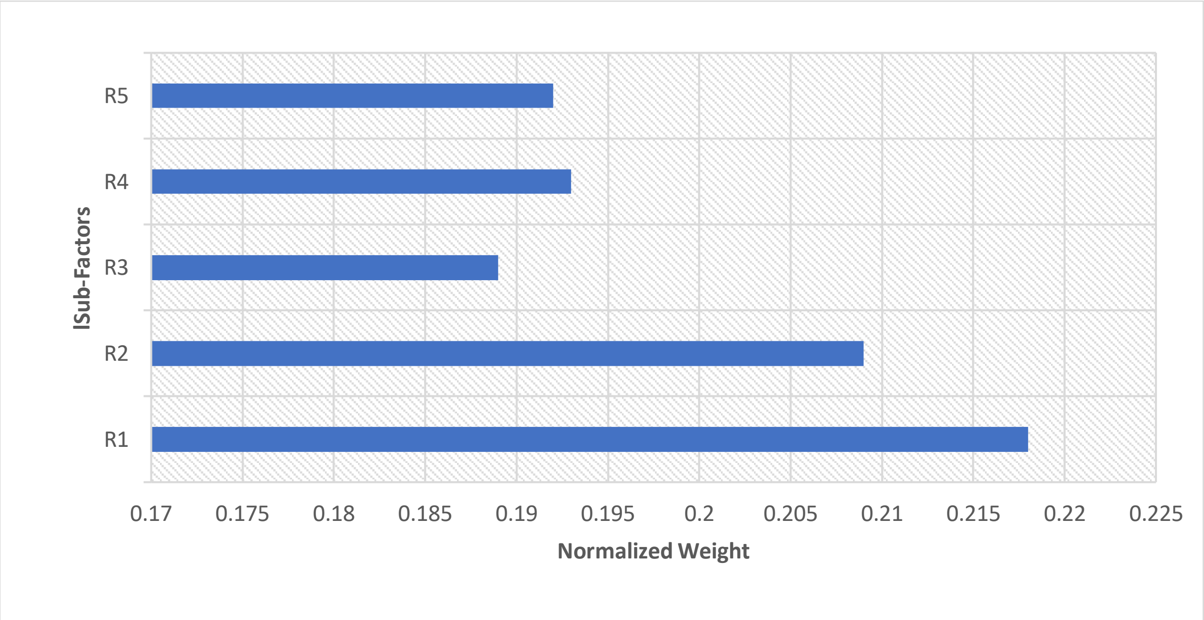


Regulatory Factor(R): From the table and chart below, it can be understood that Compliance with national construction safety laws ranks first with Environment and slope stability regulations and Permits and approvals for hill road construction on second and third respectively. The value of Regulatory categorical factor can be evaluated from the given equation below.

Table 4.12:Ranking of Regulatory Factor

Code	Regulatory Factors	Mean	Normalized weight	Rank
R1	Compliance with national construction safety laws	4.574	0.218	1
R2	Environmental and slope stability regulations	4.382	0.209	2

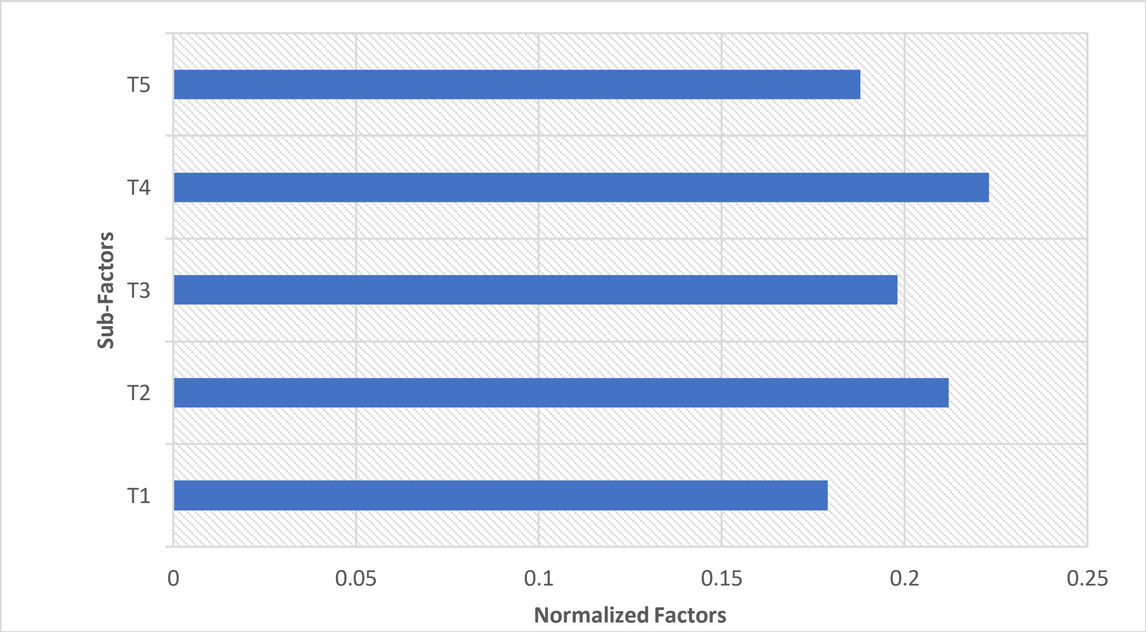
R4	Permits and approvals for hill road construction	4.044	0.193	3
R5	Inspection and enforcement by authorities	4.029	0.192	4
R3	Labor law compliance	3.971	0.189	5
R=0.218R1+0.209R2+0.189R3+0.193R4+0.192R5				



Technological Factor(R): From the table and chart below, it can be understood that Protective structures ranks first with Modern machinery and automation and Communication tools on second and third respectively.The value of Technological categorical factor can be evaluated from the given equation below.

Table 4.13:Ranking of technological factors

Code	Technological Factors	Mean	Normalized weight	Rank
T4	Protective structures	4.647	0.223	1
T2	Modern machinery and automation	4.412	0.212	2
T3	Communication tools	4.132	0.198	3
T5	Innovative construction methods	3.912	0.188	4
T1	Safety technology	3.721	0.179	5
T=0.179T1+0.212T2+0.198T3+0.223T4+0.188T5				



While other factors also have the relative importance as shown in graph and equation.

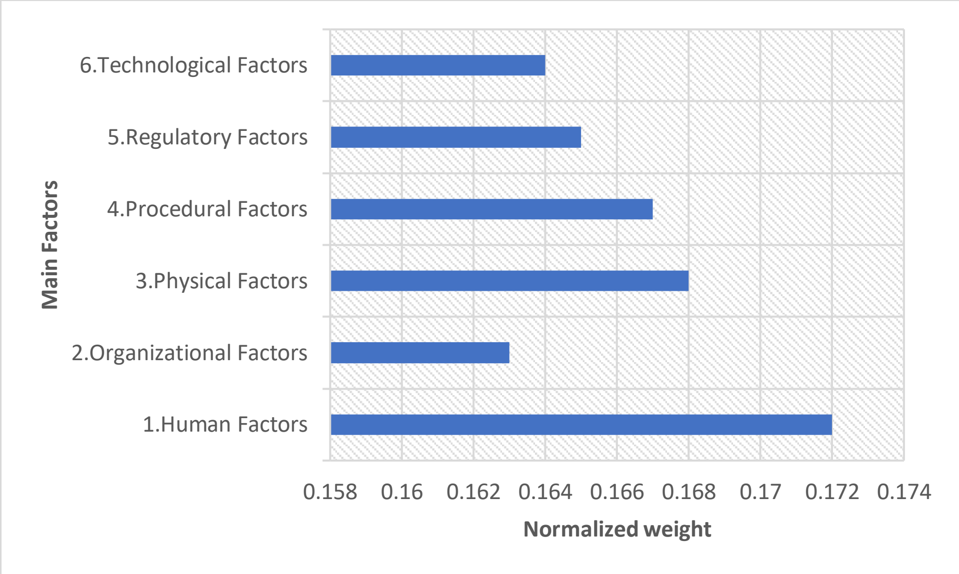
Table 4.14:Weight of Safety Factors

Categories	Mean (5% trimmed mean)	Weight	Sub Factors
Human Factor	4.368	0.172	H1,H2,H3,H4,H5
Organizational Factor	4.15	0.163	O1,O2,O3,O4,O5,
Physical Factor	4.271	0.168	Ph1, Ph2, Ph3, Ph4, Ph5
Procedural Factor	4.253	0.167	Pr1, Pr2, Pr3, Pr4, Pr5
Regulatory Factor	4.200	0.165	R1, R2, R3, R4, R5
Technological Factor	4.165	0.164	T1, T2, T3, T4, T5

The SPI equation:

SPI=0.172H+0.163O+0.168Ph+0.167 Pr+0.165R+0.164T

From the above result, it can be concluded that all six categories Human, Organizational, Physical, Procedural, Regulatory and Technological factors have significant impact according to the weightage as shown in equation above. These categorical variables in the equation also depends on sub factors as shown in equations and graphs above. Their consideration should be given to achieve safety at the construction site.



Discussions: The development of the composite Safety Performance Index (SPI) model underscores a holistic approach to safety management in hill road construction, where the integration of various factor weights provides a comprehensive metric for site evaluation. By utilizing a 5% trimmed mean to normalize weights—a methodology adapted from **El-nagar et al. (2015)**—the model minimizes the influence of extreme outliers and highlights that all six major categories maintain a relatively balanced impact on overall safety, with normalized weights ranging from **0.163** to **0.172**. The **Human Factor (H)** emerged as the most influential category with a weight of **0.172**, driven largely by the high significance of **Use of PPE (H1)**, which possesses a normalized sub-weight of **0.215**. Within the **Physical Factor (Ph)** category, **Road geometry and slope stability (Ph1)** was identified as the premier sub-factor with a weight of **0.223**, validating its critical role in the precarious terrain typical of Nepalese hill roads. Similarly, the **Technological Factor (T)** is dominated by **Protective structures (T4)** at a weight of **0.223**, while **Regulatory Factor (R)** is led by **Compliance with national construction safety laws (R1)** with a weight of **0.218**. The resulting composite equation, $SPI = 0.172H + 0.163O + 0.168Ph + 0.167Pr + 0.165R + 0.164T$, serves as a mathematical framework where each coefficient acts as a compensative value, ensuring that improvements in specific sub-factors like **Incident reporting (Pr4)** or **Safety policy (O1)** directly contribute to the overall safety score. Ultimately, this model demonstrates that achieving optimal safety at construction sites requires simultaneous attention to both the high-weighted physical and human elements, as well as the supporting organizational and procedural structures that form the foundation of the safety index.

4.3 To assess on-site safety performance using field data from the Kavrepalanchowk segment of the Mid-Hill Highway.

Each major factor, namely Human (H), Organizational (O), Physical (Ph), Procedural (Pr), Regulatory (R), and Technological (T), in the developed Safety Performance Index (SPI) model is evaluated within a normalized range of 0 to 1 based on its level of implementation and influence on site safety conditions. The assigned values represent the extent to which safety practices are effectively adopted at the construction site.

The evaluation of each factor is carried out through a structured checklist where individual sub-factors are scored according to predefined criteria ranging from poor to excellent performance. These scores are then aggregated using weighted equations to obtain the corresponding factor values.

The scoring ranges and criteria are developed based on established methodologies in construction safety performance evaluation, adapted from previous studies such as Abdalfatah et al. (2023) and El-Nagar et al. (2015), and further refined through expert consultation to suit the context of hill road construction in Nepal.

Thus, the values of variables used in the SPI equation are determined from the observed site conditions and survey responses using the evaluation tables provided below.

Table 4.15:Evaluation table for case study

Evaluation Score	1	0
Use of Personal Protective Equipment (PPE) (H1)	Yes	No
Safety training and awareness (H2)	Yes	No

Supervision and monitoring (O2	Yes	No
Emergency preparedness (O4)	Yes	No
Site layout and access (Ph4)	Yes	No
Standard Operating Procedures (SOPs) (Pr1)	Yes	No
Permit-to-work system (Pr2)	Yes	No
Compliance with national construction safety laws (R1)	Yes	No
Safety technology (T1)	Yes	No
Protective structures (T4)	Yes	No

Table 4.16:Evaluation table for case study

Evaluation Factor	**0 (Low/Poor)**	**0.5 (Moderate)**	**1 (High/Effective)**
Experience and competency (H4)	Low	Moderate	High
Safety policy and culture (O1)	Weak	Moderate	Strong
Communication of hazards (O3)	Poor	Moderate	Effective
Resource allocation (O5)	Inadequate	Moderate	Adequate

Machinery and equipment safety (Ph3)	Poor	Moderate	Good
Materials handling (Ph5)	Unsafe	Moderate	Safe
Work scheduling and sequencing (Pr3)	Poor	Moderate	Well-planned
Safety audits and checklists (Pr5)	Rare	Occasional	Regular
Inspection and enforcement (R5)	Rare	Occasional	Frequent
Communication tools (T3)	Poor	Moderate	Effective

Table 4.17:Evaluation table for case study

Evaluation Factor	**0**	**0.25**	**0.5**	**0.75**	**1**
Fatigue and work hours (H3)	Very High	High	Moderate	Low	None
Safety compliance behavior (H5)	Never	Sometimes	Often	Usually	Always
Road geometry and slope stability (Ph1)	Very Poor	Poor	Moderate	Good	Excellent
Weather conditions (Ph2)	Severe	High	Moderate	Low	None
Incident reporting and investigation (Pr4)	None	Weak	Moderate	Good	Excellent
Environmental and slope regulations (R2)	None	Low	Moderate	Good	Full
Labor law compliance (R3)	None	Low	Moderate	Good	Full

Permits and approvals (R4)	None	Partial	Moderate	Good	Complete
Modern machinery and automation (T2)	None	Limited	Moderate	Good	Advanced
Innovative construction methods (T5)	None	Limited	Moderate	Good	Advanced

4.3.1 Level of Safety Performance

The classification of Safety Performance Index (SPI) into different performance levels is based on established practices in safety performance evaluation and indexing approaches adopted in previous studies such as Mouleeswaran (2014), Dam (2018), and Abdalfatah et al. (2023). The ranges are generalized and adapted to provide a clear interpretation framework suitable for hill road construction projects.

Table 4.18:SPI classification Table

%SPI	**0-20%**	**21%-40%**	**41%-60%**	**61%-80%**	**81%-100%**
Level of safety performance	Extremely Unsafe	Unsafe	Moderately Unsafe	Safe	Extremely Safe

The developed model is derived from established studies and previously published literature, including works by Abdalfatah et al. (2023), El-Nagar et al. (2015), and Dam (2018), which are widely recognized in the field of construction safety. The model has been suitably adapted to reflect the specific conditions and practices of the Nepalese context, thereby eliminating the requirement for additional validation. Furthermore, a case-based application has been carried out to assess the effectiveness of the Safety Performance Index (SPI) within an actual construction site.

Table 4.18: Calculation of safety performance index

Category	Factors	Value Project Selected	Data collection data
H	H1	0.67	Direct Site Observation
	H2	0.125	Interview
	H3	0.25	Interview
	H4	0.82	Direct Site Observation
	H5	0.25	Interview
Compensation coefficient for **Human Category (H)**		**0.43**	
O	O1	0.25	Interview
	O2	0.75	Interview
	O3	0.5	Interview
	O4	0	Interview
	O5	0.25	Interview
Compensation coefficient for **Organizational Category(O)**		**0.356**	
Ph	Ph1	0.5	Interview
	Ph2	0.25	Interview
	Ph3	0.25	Interview
	Ph4	0.5	Interview
	Ph5	0.5	Interview
Compensation coefficient for **Physical Category (Ph)**		**0.399**	
Pr	Pr1	0.25	Interview
	Pr2	0.375	Interview
	Pr3	0.25	Interview
	Pr4	0.875	Interview
	Pr5	0.375	Interview
Compensation coefficient for **Procedural Category (Pr)**		**0.431**	
R	R1	0.625	Interview
	R2	0.625	Interview
	R3	0.25	Interview
	R4	1	Interview
	R5	0.25	Interview

Compensation coefficient for **Regulatory Category (R)**		**0.555**	
T	T1	0.25	Interview
	T2	0.5	Interview
	T3	0.5	Interview
	T4	0.75	Interview
	T5	0.25	Interview
Compensation coefficient for **Technological Category (T)**		**0.464**	

⯁Final SPI Calculation

SPI= = 0.172(0.43) + 0.163(0.356) + 0.168(0.399) + 0.167(0.431) + 0.165(0.555) + 0.164(0.464)

☞**SPI ≈ 0.439**

⯁Final Result

☞**SPI = 0.439 → Moderately Unsafe / Average Safety Level**

Discussions: The on-site safety performance assessment conducted for the Kavrepalanchok segment of the Mid-Hill Highway reveals a critical gap between theoretical safety frameworks and practical field implementation, resulting in a final Safety Performance Index (SPI) of **0.439**. This score categorizes the project's safety level as **"Moderately Unsafe,"** falling within the 41%–60% performance range established by methodologies adapted from **Mouleeswaran (2014)** and **Abdalfatah et al. (2023)**. The detailed evaluation across the six major factors highlights that while the **Regulatory Category (R)** achieved the highest compensative coefficient of **0.555**—driven by full compliance in obtaining construction permits (**R4 = 1.0**) and moderate environmental adherence (**R2 = 0.625**)—the **Organizational (O)** and

Physical (Ph) categories significantly lagged with coefficients of **0.356** and **0.399**, respectively. A major point of concern is the complete absence of **Emergency Preparedness (O4 = 0)** and the low implementation of **Safety Policy and Culture (O1 = 0.25)**, suggesting that administrative safety management is reactive rather than proactive on this segment. Furthermore, human factors such as **Safety Compliance Behavior (H5 = 0.25)** and **Safety Training (H2 = 0.125)** were scored poorly despite relatively high worker **Experience and Competency (H4 = 0.82)**, indicating that specialized skills are not being effectively translated into safe work habits. The site's physical safety is also compromised by poor **Machinery Safety (Ph3 = 0.25)** and challenging **Weather Conditions (Ph2 = 0.25)**, which are inherent risks in Nepalese hill road construction. Ultimately, the weighted aggregation of these coefficients into the SPI equation ($SPI \approx 0.439$) underscores that despite meeting basic legal requirements, the project requires immediate intervention in organizational resources and safety training to move from a moderately unsafe status to a safe classification.

CHAPTER 5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The primary objective of this study was to develop and assess a Safety Performance Index (SPI) model for evaluating safety performance in hill road construction, using a case study of the Mid-Hill Highway in Kavrepalanchok District. This objective has been successfully achieved through a systematic and structured approach.

5.1.1 Conclusions for RO1: To prioritize and rank safety factors based on their relative importance.

Firstly, key safety indicators relevant to hill road construction were identified through an extensive review of literature and contextualized to Nepal. These indicators were categorized into six major groups: human, organizational, physical, procedural, regulatory, and technological factors, each consisting of relevant sub-factors affecting safety performance. The prioritization of these factors using stakeholder responses revealed that human-related aspects such as PPE usage and worker experience are relatively strong, whereas safety training, fatigue management, and compliance behavior require significant improvement.

5.1.2 Conclusions for RO2: To create a composite SPI model.

Secondly, a composite SPI model was developed by assigning appropriate weightages to the identified factors using analytical methods. The model integrates multiple dimensions of safety into a single measurable index, providing a systematic and quantitative framework for evaluating construction safety performance.

5.1.3 Conclusions for RO3: To assess on-site safety performance using field data from the Kavrepalanchowk segment of the Mid-Hill Highway.

Thirdly, the developed SPI model was applied to a selected hill road construction site under the Mid-Hill Highway project in Kavrepalanchowk District. The calculated SPI value of 0.439 indicates a moderately unsafe level of safety performance. This result highlights that although certain safety practices such as basic PPE usage, supervision, and regulatory compliance are present, there are considerable deficiencies in procedural implementation, safety training, emergency preparedness, and technological adoption.

Overall, the study confirms that safety performance in hill road construction is influenced by a combination of human behavior, management practices, site conditions, and regulatory enforcement. The developed SPI model proved to be effective in identifying critical gaps and quantifying safety performance. Therefore, it can serve as a practical tool for stakeholders to monitor, evaluate, and improve safety conditions in hill road construction projects in Nepal.

5.2 Recommendations

Based on the objectives and findings of this study, the following recommendations are proposed:

Firstly, with respect to the identification and prioritization of safety factors, it is recommended that project authorities focus on the most critical weak areas identified in the study. Particular attention should be given to improving safety training, fatigue management, and safety compliance behavior among workers, as these human factors significantly influence overall safety performance. Additionally, awareness programs should be strengthened to enhance worker participation and safety culture at construction sites.

Secondly, regarding the developed SPI model, it is recommended that the model be adopted as a routine safety assessment tool in hill road construction projects. The SPI framework can be used by engineers, contractors, and project managers to regularly monitor safety performance, identify critical deficiencies, and prioritize corrective actions based on quantified results.

Thirdly, based on the application of the SPI model in the case study, several practical improvements are recommended. Proper implementation of procedural measures such as permit-to-work systems, incident reporting mechanisms, and structured safety inspections should be ensured. Organizational aspects such as supervision, communication, and resource allocation must also be strengthened to improve enforcement of safety practices on site.

Furthermore, technological and regulatory improvements are necessary to enhance overall safety performance. The adoption of modern safety technologies, improved communication tools, and safer construction methods should be encouraged. Regulatory bodies should also strengthen inspection and enforcement mechanisms to ensure compliance with existing safety laws and standards.

Finally, for future research, it is recommended that the SPI model be extended to other infrastructure sectors such as hydropower, tunnels, and irrigation projects to test its wider applicability. Incorporating lagging indicators such as accident records and integrating economic analysis of safety investments would further improve the robustness and practical relevance of the model.

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APPENDIX A: QUESTIONNAIRE FOR EVALUATION OF SAFETY PERFORMANCE INDEX

Identification of Key Indicators, Development of a Composite Safety Performance Index, and Evaluation of Safety Performance in Hill Road Construction: Case Study of the Mid-Hill Highway in Kavrepalanchok District

Section I: Demographics

1. Name: ……………………………………………………………………

2. Gender:

- ○ Male
- ○ Female
- ○ Other

3. Which sector do you work in?*

- ○ Government
- ○ Private
- ○ Others

5. What is your job role?

- ○ Project Manager
- ○ Site Engineer
- ○ Site Sub- Engineer
- ○ Consultant
- ○ Contractor
- ○ Others

8. How many years of experience do you have in road or pavement construction?

- ○ 1–5
- ○ 6–10
- ○ 11–20
- ○ 21 or more

Section II: Constructional Practice Factors

Below are the main factors related to construction practices, along with their sub-factors identifies in the study. Please asses the impact level for each sub-factor under a given main factor. Rate its importance on the 1-5 scale defined below.

There are no right or wrong answers-just your honest opinions.You will answer one question (or set of related sub-questions) at a time; after each, simply enter your response. Use the following 5-point Likert scale for all sub-factor ratings: 1=Irrelevant, 2=Not so important, 3=Important to some extent, 4=Significant, 5=Extremely important.

Main Factors	Sub-Factors	1	2	3	4	5
Human Factor (H)	Use of Personal Protective Equipment (PPE)					
	Safety training and awareness					
	Fatigue and work hours					
	Experience and competency					
	Safety compliance behavior					
Organizational Factor (O)	Safety policy and culture					
	Supervision and monitoring					
	Communication of hazards					
	Emergency preparedness					
	Resource allocation					

Physical Factor (Ph)	Road geometry and slope stability					
	Weather conditions					
	Machinery and equipment safety					
	Site layout and access					
	Materials handling					
Procedural Factor (Pr)	Standard operating procedures (SOPs)					
	Permit-to-work system					
	Work scheduling and sequencing					
	Incident reporting and investigation					
	Safety audits and checklists					
Regulatory Factor (R)	Compliance with national safety laws					
	Environmental and slope regulations					
	Labor law compliance					
	Permits and approvals for hill roads					
	Inspection and enforcement					
Technological Factor (T)	Safety technology					
	Modern machinery and automation					
	Communication tools					
	Protective structures					

	Innovative construction methods					

APPENDIX B: QUESTIONNAIRE FOR CASE STUDY

Identification of Key Indicators, Development of a Composite Safety Performance Index, and Evaluation of Safety Performance in Hill Road Construction: Case Study of the Mid-Hill Highway in Kavrepalanchok District

SECTION A: BINARY QUESTIONS (YES / NO)

(Score: Yes = 1, No = 0)

Q1. Are workers using Personal Protective Equipment (PPE) properly on site? (H1)
☐ Yes (1) ☐ No (0)

Q2. Have workers received safety training and awareness programs? (H2)
☐ Yes (1) ☐ No (0)

Q3. Is proper supervision and monitoring carried out at the site? (O2)
☐ Yes (1) ☐ No (0)

Q4. Is emergency preparedness (first aid, evacuation plan) available? (O4)
☐ Yes (1) ☐ No (0)

Q5. Is site layout and access properly managed for safety? (Ph4)
☐ Yes (1) ☐ No (0)

Q6. Are Standard Operating Procedures (SOPs) available and followed? (Pr1)
☐ Yes (1) ☐ No (0)

Q7. Is a permit-to-work system implemented for risky activities? (Pr2)
☐ Yes (1) ☐ No (0)

Q8. Is the project compliant with national construction safety laws? (R1)
☐ Yes (1) ☐ No (0)

Q9. Are safety technologies (alarms, warning systems) used? (T1)
☐ Yes (1) ☐ No (0)

Q10. Are protective structures (barriers, retaining walls, guardrails) provided? (T4)
☐ Yes (1) ☐ No (0)

SECTION B: THREE-LEVEL QUESTIONS (0 – 0.5 – 1)

Q11. How would you rate worker experience and competency? (H4)
☐ Low (0) ☐ Moderate (0.5) ☐ High (1)

Q12. How would you rate safety policy and culture of the organization? (O1)
☐ Weak (0) ☐ Moderate (0.5) ☐ Strong (1)

Q13. How effective is communication of hazards to workers? (O3)
☐ Poor (0) ☐ Moderate (0.5) ☐ Effective (1)

Q14. How adequate is resource allocation for safety (budget, manpower)? (O5)
☐ Inadequate (0) ☐ Moderate (0.5) ☐ Adequate (1)

Q15. What is the condition of machinery and equipment safety? (Ph3)
☐ Poor (0) ☐ Moderate (0.5) ☐ Good (1)

Q16. How safe are material handling practices? (Ph5)
☐ Unsafe (0) ☐ Moderate (0.5) ☐ Safe (1)

Q17. How effective is work scheduling and sequencing? (Pr3)
☐ Poor (0) ☐ Moderate (0.5) ☐ Well-planned (1)

Q18. How frequently are safety audits and checklists conducted? (Pr5)
☐ Rare (0) ☐ Occasional (0.5) ☐ Regular (1)

Q19. How often do authorities inspect and enforce safety? (R5)
☐ Rare (0) ☐ Occasional (0.5) ☐ Frequent (1)

Q20. How effective are communication tools used on site? (T3)
☐ Poor (0) ☐ Moderate (0.5) ☐ Effective (1)

SECTION C: FIVE-LEVEL QUESTIONS (0 – 1 SCALE)

Q21. What is the level of worker fatigue due to working hours? (H3)
☐ Very High (0)
☐High (0.25)
☐ Moderate (0.5)
☐Low (0.75)
☐None (1)

Q22. How often do workers comply with safety procedures? (H5)
☐ Never (0)
☐ Sometimes (0.25)
☐ Often (0.5)

☐ Usually (0.75)
☐ Always (1)

Q23. How would you rate road geometry and slope stability? (Ph1)
☐ Very Poor (0)
☐ Poor (0.25)
☐ Moderate (0.5)
☐ Good (0.75)
☐ Excellent (1)

Q24. What is the impact of weather conditions on safety? (Ph2)
☐Severe (0)
☐High (0.25)
☐ Moderate (0.5)
☐Low (0.75)
☐None (1)

Q25. How effective is incident reporting and investigation? (Pr4)
☐ None (0)
☐ Weak (0.25)
☐ Moderate (0.5)
☐ Good (0.75)
☐ Excellent (1)

Q26. How well are environmental and slope regulations followed? (R2)
☐ None (0)
☐ Low (0.25)
☐ Moderate (0.5)
☐ Good (0.75)
☐ Full (1)

Q27. What is the level of labor law compliance? (R3)
☐ None (0)
☐ Low (0.25)
☐ Moderate (0.5)
☐ Good (0.75)
☐ Full (1)

Q28. What is the status of permits and approvals for construction? (R4)
☐ None (0)
☐ Partial (0.25)
☐ Moderate (0.5)
☐ Good (0.75)
☐ Complete (1)

Q29. What is the level of use of modern machinery and automation? (T2)

☐ None (0)
☐ Limited (0.25)
☐ Moderate (0.5)
☐ Good (0.75)
☐ Advanced (1)

Q30. What is the level of use of innovative construction methods? (T5)

☐ None (0)
☐ Limited (0.25)
☐ Moderate (0.5)
☐ Good (0.75)
☐ Advanced (1)

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We have reached a decision regarding your submission to 18th IOE Graduate Conference, "Identification of Key Indicators and Development of a Composite Safety Performance Index for Hill Road Construction".

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With Warm Regards,
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59504 Characters

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