# Risk Management of Highways in Pakistan using Systems Thinking Approach

By

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***This dedicated to my parents, family and friends***

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## ABSTRACT

To understand the concept of risk-management among stakeholders in Pakistan's construction industry is relatively on the very low side. This study is based on systems thinking approach to comprehend the risks related with highways during construction and how to tackle those risks. The causal loop diagram helps us in understanding the risks and their mitigation in a holistic systematic view. The analysis of the results indicates the critical risk is the financial and economic factors such as cost overruns, payment delays, other risks are design changes or errors, change orders, material and equipment resourcing, poor project planning, inadequate site management, site contamination and lack of skills and techniques. Results indicate that majority of the risks can be tackled but the issue of lack of skillfull staff in developing countries is still a dilemma. Contractors are reluctant to hire a skill full competent staff because of the high salaries and demands and also there is a shortage or non availability of skill full personels in geo graphicals areas because not many of them wants to go to such areas with such low perks given to them by the contractors. The risks caused by the skills shortage must be identified, and methods for risk management must be developed in collaboration with the whole construction sector specially in a developing country like Pakistan.

## KEYWORDS

Construction, Risk, Skills, Risk-management, Contractors.

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# Chapter 1

# Introduction

## 1.1. Background

Pakistan's National Highways are a system of toll highways owned, managed, and administered by the National Highways Authority, which is part of the Government of Telecommunications. It upholds a network of 12,131 kilometres (7,538 miles) of highways that traverse the state and offer access to key populace areas. Provincial highways, which are managed by the provinces, are not to be confused with national highways. The famed Grand Trunk Road, the Indus Highway, the Karakoram Highway, and the Makran Coastal Highway are just a few among Pakistan's national highways. In Pakistan, all national highways are prefixed with the letter 'N' (for "national"), followed by the highway's unique numerical identifier (with a hyphen in the middle), e.g. "N-5." Five digits separate each number designation, such as N-5, N-10, N-15, and so on. Planned Highways, which commence with the letter 'S' and are regulated, are not the same as National Highways. There are various dangers connected with highways that, if not adequately addressed in a timely manner, can result in significant problems for those who use them. Risk management is an approach that is becoming increasingly popular in numerous industries. Many organisations implement risk management strategies in their ventures in directive to improve accomplishment of their project and gain profitability. Risk management include identifying, assessing, and prioritising risks, as well as making effective use of capitals to reduce, monitor, and control the possibility and effect of unfavourable occurrences in the project (Hubbard, 2009). Since construction projects are typically complicated and have large expenditures, minimising the risks connected with them should be a top goal for every project manager. According to the Project Management Institute, one of the nine most important components of project commissioning is project risk management. (PMBOK, 2013). This implies a significant link between risk management and project success. While RM is regarded as the most challenging aspect of construction management, its use is encouraged in all projects to minimise undesirable outcomes. The risk management process (RMP) is a commonly used concept in the field of RM, and it consists of four basic steps: risk identification, evaluation, action, and checking (Dalgleish, 2005). Since the hazards of complex construction projects are becoming increasingly unpredictable, it is necessary to investigate the link between the risk management process and the resulting risk factors. Although earlier studies have attempted to provide answers, the complexities of hazards in the construction sector must be investigated using fresh approaches. Risk management is required, which adds to the complexity. The system thinking approach may be used to deal with complexity.

Risk is frequently cited as a manifestation of Murphy's Law (Everything that may go wrong, will go wrong.); in other confrontations, most individuals regard risk solely as a possibility for damage. Risks can arise from a variety of places, like a temporary project team composed of people from several firms, a building site, and so on. Furthermore, the size and complexity of construction supplies is growing, raising the hazards. This is in addition to the constitutional, financial, and societal circumstances under which the project is to be carried out. As described by (Brewer & Dittman, 2020) object risk as an capricious occurrence or circumstance that, if it occurs, has a positive or negative impact on at least one project objective, such as time, cost, or quality. Construction projects undergo cost and time overruns as a result of the risks. Regardless, many project managers still see quantifiable and qualitative studies as separate techniques. This intensify by what seems to be a typical perspective: quantifiable risk evaluation should be retained for larger or risky projects since establishing a quantitative approach completely incurs a substantial expense.

The risk management process (RMP) has been evaluated and researched in a number of previous studies, and it has piqued the interest of academics in the construction industry as well as project managers on the ground. RMP has never been examined using system dynamics tools and methodologies, and there has been very little work done using the system dynamic approach in the construction sector. This study seeks to evaluate risk management and measure actual and projected performance of the risk management model, along with analysing the findings to help analyse the impact on highway usage. It also intends to see the hazards as a whole, as well as the interconnections between them. The goal of this study is to apply system thinking approach to address the risk management process. A causal loop model is designed to depict and simplify the hazards associated with highways using a system thinking approach and a feedback mechanism.

### 1.2. Research Problem

The risks cause cost overruns and time delays in construction projects. Despite knowing this, many construction stakeholders continue to deal with quantitative and qualitative analysis of risk factors as isolated approaches *(Hillson & Simon, 2007).* Usually, the risks are identified and catered for mitigating either costs or time overruns. This secluded technique has failed in producing effective results for mitigating risks of construction projects. The combined effect of all project risks with their respective mitigation and their influencing factors is yet to be explored in order to put the construction projects on right track.

### 1.3. Previous studies

The construction sector is recognised for being complicated and fragmented in nature all over the world (Mohd Nawi et al., 2014). Due to the fragmented and unique nature of each project, the construction industry operates in incredibly risky environment (Sanvido et al., 1992). Considering the specific characteristics of building operations, such as extended period of time, complex procedures, a deplorable environment, financial intensity, and dynamic organisational structures, the construction sector is subjected to greater risks as compared to several other industries (Ganame & Chaudhari, 2015). Risk as an unpredictable occurrence or situation that, if it happens, has a definite or adverse impact on a venture's goal. There is a reason for a danger, as well as a consequence if it occurs (Miklosik, 2015). A risk that has not been detected cannot be monitored, relocated, or otherwise controlled, therefore it is impractical to eradicate all risks in a project (Bajaj et al., 1997). Risk management is a logical technique to give out with risk that involves inserting an important context, setting goals and aims, detecting and evaluating risks, persuading planning and decision, and monitoring and reviewing risk responses (Bing et al., 2005).

Highway construction projects carry inevitable risks (Sameh M. El-Sayegh & Mansour, 2015) . The trick is to detect the most significant risks and handle them (Barkely, 2004). (Project Management Institute, 2008) divides risk into two main categories: internal and external. Understanding the complexity of such projects, taking into account the interdependency of risks, and including diverse stakeholders in identifying major risks are all important (Ackermann et al., 2014). Construction projects begin in complex and vibrant situations, stemming in significant levels of ambiguity and risk, which are exacerbated by tight deadlines (Mulholland & Christian, 1999). Project complexity comprises of many varied interconnected parts and can be minimised in terms of isolation and mutuality (Baccarini, 1996).

Complexity science refers to a developing area of multidisciplinary understanding on the edifice, behaviour, and crescendos of change in a type of complex system known as complex adaptive systems, which are open evolutionary systems with strongly interconnected, self-organizing, and dynamic components (Anderson, 1999). Different models and frameworks are used for project complexity. (Vidal et al., 2011) provided a four-category project complexity framework that included project scale, variety, interconnectedness, and context. (Botchkarev& Finnigan, (2015) developed a “Complexity taxonomy” framework with respect to three stages of creation, project and peripheral environment. Likewise (Qazi et al., 2016) created a Project Complexity and Risk Management (ProCRiM) model that developed a unified complexity and risk management approach while investigating interdependence modelling across project complexity variables.

### 1.4. Gap in Previous Studies

The frameworks that consider risks as a component of complexity recognize the importance of interconnecting these risks together (Sohi et al., 2016), however, this interconnection is not observed in most of the models implemented for addressing complexity in construction projects (Qureshi & Kang, 2015).

Risk from the perspective of complexity has been discussed for Fast-Track projects((Rasul et al., 2021), however the impact of mitigation strategies to address this complexity in highways of Pakistan is yet to be studied.

Considering this research gap, the research objective of the study were formulated and finalized.

### 1.5. Research Questions

Following research questions has directed this research.

1. How can a system thinking approach help us in mitigating the risks faced during construction of highways in Pakistan?

### 1.6. Research Objectives

Following research objectives was identified for this study.

i. To identify risks and mitigation factors associated with highways of Pakistan.

ii. To evaluate the importance and interconnectivity of identified risks and mitigation factors using system thinking approach.

iii. To develop a framework to help in mitigation of risks causing complexity leading to improved performance during the construction of highways in Pakistan.

### 1.7. Relevence to national needs

In a developing country like Pakistan, construction industry has many basic problems that lead to risks. Here, the construction industry is behind on technology and lacks various management practices as practiced in the developed world. Risks associated with projects are seldom taken seriously. Risk management processes considered through system dynamics tools can help simplify the understanding of risks for contractors and project managers. Better understanding of project risks will also recover the value of construction industry in Pakistan.

## 1.8. Advantages

1. The research will help understand the effective implementation of project risk management.
2. It will help in identifying those complex risk factors usually ignored in construction industry.
3. It will help construction stakeholder to understand the need to explore and apply new techniques in construction industry.

## 1.9. Areas of application

The area of application is Construction Risk management and complexity.

# Chapter 2

# Literature review

## 2.1. Introduction

This chapter summarises earlier studies and works of literature on issues related to the construction sector, risk management, highway construction, factors impacting risk in highway construction, and risk mitigation in highway construction. It describes the numerous steams utilised by various researchers in published literature to aid in the development of an effective mitigation plan that can significantly reduce hazards in highway construction, particularly in emerging countries like Pakistan. The study also discusses the significance of mitigation strategy development and the application of casual loops/systems dynamic approach for development of mitigation framework is also discussed in this section.

## 2.2. Construction Industry

The construction field has long been considered one of the most vital sectors of a country's economy, especially in developed nations (Takim & Akintoye, 2002). The construction sector of a country is made up of residential, commercial, industrial, and infrastructure projects; the industry has a direct influence on the country's economic development (Marques & Berg, 2011). As countries have unique geographies and challenges, therefore, the construction industry is a complex and dynamic sector with unique challenges that needs to be tackled (Lambert et al., 2013).

The construction industry comprises of various elements, these influence the construction projects along various stages of project development a brief description of each element is mentioned below.

### 2.3. Construction organizations

There are many organisations that are responsible for the construction of various projects in a country. The goal of these companies is to provide the best possible service to the client and for the benefit of the nation (Dot et al., 2018).

Construction organizations are often categorized as governmental construction organisation or private construction organization (A. P. C. Chan et al., 2011). They are the most essential element of the industry since they perform vital activities such as planning, design, building, and maintenance of the projects developed by the industry (Shaikh, 2020).

### 2.4. The Stakeholders

The stakeholders are the people that directly affect the construction projects they can influence the goals and objectives of the project the list includes client, designer, contractor, and manufacturer (Project Management Institute, 2018). Stakeholders may have a direct impact on the complexity of building projects since they are involved from the beginning to the end, any growth in the number of stakeholders expands the number of communication channels as well as the number of impacts and relationships between them (Nielsen, 2004).

Stakeholders may be involved for only a portion of the project or have a variety of interests in the project; this element can lead to achieving the project goals and objectives difficult (Hallowell et al., 2013). As different stakeholders have varied interests, stakeholders' priorities and requirements must be classified and addressed properly in order to meet the project's goals and objectives. (Gathenya, 2013).

### 2.4.1. Characteristics of construction Industry

Due to worldwide recessions, the economic climate in the global construction sector has seen extraordinary dynamic changes since the beginning of the 1990s, prompting construction companies to focus on risk management and project management approaches (Golden et al., 2000).

The construction industry is disintegrated, which is due to the nature of the industry's operational method, Design-Bid-Build or D-B-B. This fragmentation leads to a variety of issues, including communication gaps, separation of design and construction, and poor collaboration among various stakeholders (Samiullah Sohu et al., 2020). All of these factors lead to project difficulties and increase in the overall risk connected with the project. (Sameh M. El-Sayegh & Mansour, 2015).

Many businesses found success by altering the work formula or the D-B-B Design-Bid-Build environment, which provided the construction industry more freedom in areas like risk identification and risk allocation (Nam & Tatum, 1988).

The construction industry is currently undergoing another transformation from its 1990s working methods; basic functions such as procurement methods, construction techniques, stakeholder management, and over project management are changing, as clients demand larger and more complex projects, and the risks associated with these projects are also increasing (Kangari, 1995).

Another key factor is the emergence of various alternate design and built approaches such as design-and-build contracts, as opposed to the traditional options of open competitive bidding for procuring public projects. These new approaches have seen widespread adoption and are having an impact on project managers' roles on a global scale (Bypaneni & Tran, 2018)

### 2.4.2. Project delivery methods

An effective project management delivery method is crucial in construction since it can handle various aspects of project development that can raise and increase essential project features like communication, coordination, quality, time, and costs (Gathenya, 2013). The main techniques that are used by construction organizations are as follows:

- Design Bid Build (DBB) (traditional approach)
- Design Build (DB)
- Construction Management at Risk (CMAR)
- Public Private Partnership (PPP or P3)
- Integrated-Project-Delivery (IPD)

All of the modern project delivery approaches are designed to address critical challenges such as communication gaps, cost control, and risk identification; nevertheless, they can only be used in specified suitable conditions (Ong et al., 2012).

## 2.5. Problems in construction

The two main primary sources that risks associated with them in construction projects are  time delays and cost overruns which can be caused by either design aspects or construction elements (Larsen et al., 2016). These two issues, particularly in construction, have been found to be a worldwide phenomena, and its ramifications are a topic of discussion among major project stakeholders such as owners, project managers, and contractors (Creedy et al., 2010).

### 2.5.1. Delays

Delays are defined as the execution of tasks that were specified at a certain time but will occur at a later date, time or particular period that all the concerned parties agreed prior to it happening, during the construction of the project (Tebeje Zewdu, 2016). Delays are a universal problem that can be seen in all building processes and can be observed in all construction sectors, and Pakistan is no exception (Hussain et al., 2018). Project delays are a typical occurrence, and in some situations, they are almost unavoidable (Durdyev et al., 2017). The most prominent triggers of delay identified by previous studies are:

Insufficient planning, poor site management, contractors' incompetence, subcontractors, stakeholders' financial capability, inadequate funding, lack of assurance, and interaction; improper planning, ambiguous project scope, and poor contracts (Durdyev & Hosseini, 2020).

On large scale projects, the main focus of project managers or construction managers is to try to avoid or reduce delays as much as possible; however, delays most often lead to a slew of other issues that can only be addressed by increasing costs; this scenario of delays and restoration costs eventually leads to project cost overruns; in some extreme cases, it may lead to project failure (Thomas et al., 2006).

### 2.5.2. Cost overruns

Cost overruns can arise due to number of factors, including currency exchange rate fluctuations, poor contract management, material increased prices, competitive pressures, material supply shortages, and inflation. Any of these factors might have a negative impact on the project's cost (Sepasgozar et al., 2019).

That’s why cash flow management and financial management are the key elements of the construction process without adequate fiscal capability contractors are prohibited to take part in the bidding process in many cases financial capability is a pre-requisite criterion for bidding, this rule also applies to project stakeholders such as contractors, clients and managers(Shaikh, 2020). Any project stakeholder who is incapable of financial planning poses a significant danger to the project's success (Dot et al., 2018).

A country's development is totally reliant on large-scale projects, the reasonable method for keeping projects moving forward while keeping costs and delays to a minimum is to develop new tools and techniques to mitigate delays and costs, as well as to reduce risk impacting factors and applying risk mitigation strategies to the practise of avoiding delays and developing a risk management strategy. (Samiullah Sohu et al., 2018).

Some risks can be controlled by human intervention because they are predictable and preventable in nature, but there are also unpredictable risks and uncertainties that cannot be predicted, such risks and uncertainties are most often caused by unpredictable situations and can affect the construction process on multiple levels (Taylan et al., 2014). Might include risks such as Parties' performance, complex contractual relationships, environmental difficulties and site conditions, resource availability, political chaos in the area, labour strikes, and other dangers (Larsen et al., 2016).

### 2.5.3. Risk

Risk is commonly defined as a scenario in which loss or unfavourable circumstances may occur; it is not certain and is based on a diversity of sources and uncertainties; in other arguments, most individuals only view risk as a possibility for adverse consequences, but it might just as easily be a chance for improvement (M.-T. Wang & Chou, 2003).

A Guide to the Project Management Body of Knowledge refers to risk as an "uncertainty that has a positive or negative impact…" (Project Management Institute, 2018) and risk specialists like Dr Hillson denote to risk as "it's the uncertainty that counts" (Hillson & Murray-Webster, 2017). Risk is always present due to the complicated and uncertain nature of the work that has to be done in construction projects; risk may frequently main to timetable delays or cost overruns (M.-T. Wang & Chou, 2003). Risk management is an important standpoint in project management (Sameh M. El-Sayegh & Mansour, 2015). In developing nations like Pakistan, where risk counterbalances and risk allocation methods have yet to be put into good legal practise, the potential for high-risk scenarios is greater (Ali et al., 2007).

However, the first step in reducing risk is to detect the hazards associated in a project, once possible risks have been identified, preventative measures may be implemented and this is where the risk-mitigation process begins (Sameh M. El-Sayegh & Mansour, 2015).

In project management, risk management efficacy becomes a critical characteristic. To progress the efficiency and efficacy of risk management, all parties must understand what risk is?

Without a thorough understanding of risk, including the responsibilities associated with risks, the conditions under which risk events occur, risk preferences for organisations, and risk management capabilities of everyone involved in the project, projects are doomed to face delays and cost overruns (J. H. L. Chan et al., 2012).

## 2.6. Background of risk management in construction

Risk has traditionally been disregarded or planned haphazardly in the construction industry, but in today's environment, risk management is a vital tool in project management. Effective risk management is described as the method of continually setting objectives, identifying sources of uncertainty, analysing them, and planning managerial actions (Petrovic, 2017).

This includes striving to maximise the likelihood and implications of positive events while minimising the likelihood and repercussions of negative events to project objectives risks (Square, 2000). Risk management will eventually be used as a tool to aid in the facilitation of a more advanced decision-making process that can help prevent, eliminate, and minimize risks (Kangari, 1995).

### 2.6.1. Relevence of risk in construction

This dynamic perspective on risk has resulted in the nature of specialised quantifiable and qualitative techniques to risk assessment, as well as methodologies or slants that utilize both the undesirable and optimistic aspects of risk management over time (Hillson & Simon, 2007). Despite the fact that projects that failed, could have been prevented if an evidente technique had been employed, they nonetheless fail; this appears to be due to the influence of the gap between actual and professed progress, which results in blunders not being found in a judicious method (Rodrigues, 2001).

Risks have an end date, which means they have a specific time frame in which they are expected to transpire. This is wherefore risk experts recommend project executives to re-evaluate project risks at frequent interludes to check whether something has changed (Le et al., 2009).

During the course of the project, risks may increase, diminish, or new risks may arise, as a result, if we revise the project schedule from time to time, for example, if we step up it; certain future dangers may disappear (Taylan et al., 2014). Although it may appear illogical, one may argue that, in certain conditions, project schedule acceleration could be viewed as a risk mitigation approach for various risks (Hussain et al., 2018).

Risk implications are sometimes misinterpreted as project delays, because a postponement is generally recognized as a cost bearing as this is the first-order impact. Looking at it another way, the intrinsic ambiguities mean that extensive, accurate planning can only be rationally accomplished for tasks that are urgent (Choudhry & Iqbal, 2013). As a result, activities in the detached future are exposed to unfluctuating greater degrees of indecision; by default, their forecasting will be imprecise (Y. Li et al., 2018).

### 2.6.2. Risk management methodology

The risk-management process is divided into four processes (Viswanathan et al., 2020).

- Identification and organization of the risk sources
- Risk assessment analysis
- Development of responses to risk
- Monitor and control of risk

This approach of risk management aids in the creation of a framework that can be used to identify all of the risks that may be present in a project, resulting in better decision-making and improved coordination among project participants (Thomas et al., 2006). The process can also aid in the efficient use of resources to avoid any undesirable consequences, increasing transparency through the use of risk management as a by-product in a project (Petrovic, 2017).

The risk management method also aids project planners in preparing for inevitable events or devising contingency plans to avoid difficulties through proactive actions (Aleshin, 2001).

(Loosemore et al., 2012) describes risk management as a hands-on process in which preparations are developed in advance rather than a reactive framework for when problems arise. This phrase clearly defines what true risk management entails; it is not a backward-looking or reactive process as many managers seeking to practise risk management in the construction sector portray it to be.

### 2.6.3. Risk identification

The most essential phase in the risk management process is risk identification (Siraj & Fayek, 2019). The major goal is to identify probable sources of risk and assess their influence on a specific project, rather than making future predictions or flawless risk estimations (Banaitiene & Banaitis, 2012). It is impossible to identify every risk associated in a project since the number of risks changes over time. The purpose of the risk identification process is to assess possible risks and create a solution to manage the project around the risks so that all project goals are met despite the risks involved (J. H. L. Chan et al., 2012). Risk management must be an ongoing effort due to the variable fauna of risks throughout the project life cycle (Potts & Ankrah, 2008). The early identification of risks is addressed heavily in most risk management process descriptions as identification of  risk sources can aid project planners in developing primary and secondary responses (Hanna et al., 2015). The primary responses play a critical part in the overall project success in the final stages of a project. (Sepasgozar et al., 2019).

The different methods used for risk indentation usually consists of the following:

- Checklists
- Brainstorming
- Workshops
- Expert interviews
- Analysis of diverse scenarios
- Analysis of historic data and project plans

Above methods are well-thought-out to be the most imperative aspects of the risk management process, as effective risk identification influences the precision of risk assessment (Fernandez-Dengo et al., 2013).

### 2.6.4. Risk assessment

The identification of risk is only the first step; some of the identified risks may be more significant and require further investigation; the next step is to quantify their significance before moving on to the response management stage; this entire process is referred to as the risk assessment process (Reilly et al., 2004). The objective of risk assessment and analysis is to explain prospective risks in great detail, which will help in the creation of a prioritised list of possible and likely project risks (Schieg, 2006). In general, the literature on risk assessment varies between two broad categories: qualitative and quantitative analysis (Petrovic, 2017). The former comprises interviews, checklists, and brainstorming, whilst the latter is carried out using a data-driven methodology (Banaitiene & Banaitis, 2012).

Essentially all key predictable risk variables should be quantified and analysed, as they have the ability to prolong project timelines, cause delays, reduce productivity, and raise labour costs, among other issues (Potts & Ankrah, 2008). If a project is part of a larger or set of projects, a delay in one element might cause delays or cost overruns throughout the entire project scheme. This compounding impact caused by undetected risks can have serious repercussions (Loosemore et al., 2012).

### 2.6.5. Risk response

The third phase in the risk management process indicates what actions should be performed in response to the numerous risks and threats that have been discovered and analysed before (Mahamid, 2012). The preparation of choices and actions that can simultaneously enhance opportunities and reduce risks in order to meet project objectives is characterised as the risk response planning process (Alarcón et al., 2011).

An example of a risk response that can be used to reap additional benefits in the form of opportunities as a remedy for risks is the addition of ladders in construction, which can be used to mitigate the risk of falling but can also be used to boost productivity by allowing people to access more space (Dalgleish & Cooper, 2005).

### 2.6.6. Risk register

The final phase in the risk management process is to create a risk register. It's similar to a central database, and it's utilised in the risk management process to track and identify potential threats (Dalgleish & Cooper, 2005). The register's design is determined by the preferences of the company as well as the sorts of projects and parties involved. Risk registers should keep track of risk identification indicators, risk analysis results, and associated action plans, as well as the status of each risk that has been registered (Williams, 1995).

It is critical to update and review the risk register throughout the project life cycle. The register serves a variety of purposes in the risk management process; it is a key component since it allows for the tracking and correction of progress on risk mitigation measures, as well as the identification of new risks and the closure of old ones (Potts & Ankrah, 2008).

### 2.7. Transportation sector/Highways

Roads were created without much care in previous times, and they were primarily utilised for military mobility or to increase the pace of commodities transit and were built for small size cart loads (Tran & Molenaar, 2014). Modern roads are well-planned and utilised to transport tonnes of cargo every day; they enable rapid urban expansion; they are adaptable and can allow relatively affordable movement of people and freight between cities and throughout the countryside (Gessaman & Sisler, 1976).

Roads are essential to the economies of both industrialised and developing countries, such as India, Pakistan, and Bangladesh, because they transport a vast number of commerce items and people within countries, therefore, highways contribute significantly to a country's GDP (Shaikh, 2020). Any construction activity, including highways, must deal with a variety of challenges or risks, such as natural catastrophes, construction accidents, conflicts, cost and time overruns linked to variances, wastages, political instability, and so on (Y. Li et al., 2018).

Highway construction is fraught with challenges and unforeseeable events. There are significant risks associated with highway building due to the engagement of a vast number of activities, numerous individuals from various trades, and constantly changing conditions (Sameh M. El-Sayegh & Mansour, 2015).

### 2.8. Risks factors in highway construction of Pakistan

Risk factors (RFs) are actions, conditions, and circumstances that can have a negative impact on the project and must be addressed if the project's targeted goals and objectives are to be accomplished (Rybnicek et al., 2020). As a result, any acts, conditions, or occurrences that have a negative impact on the operational capability or design of a highway project are regarded as potential risks to that highway project (Creedy et al., 2010).

To improve the risk identification process, risks in Pakistan's' construction may generally be classified into two categories: internal risks and external risks (Viswanathan et al., 2020). Internal risks are project-related risks that can be managed by the project team. External risks are those that are beyond the project team's control (Sameh Monir El-Sayegh, 2008). But these two categories of risk can be further explored and divided into many different categories such as:

**Social Risks:** These include all risks that are linked to population size, governance levels and security situations on a national and local levels. Because highway projects sometimes span long distances, the security and governance risks associated with them are particularly significant (Skitmore & Sidwell, 2006).

Same is the case with Pakistan where some areas of the country have significantly high security risks if compared to the rest of the country. Some governance-related risks commonly encountered in Pakistani highway construction include the nature of the project approval process, the outcomes of previous similar projects in the area, poor subcontractor qualification, communication and low labour productivity, and inexperienced project managers (Kog, 2019).

**Technological risks:** These risks are related to technical issues that halt the operations of the projects, these types of risks prevent contractors from managing, developing, or delivering project objectives. Some typical technological risks include defective equipment, delays in site access, equipment delivery, and poor working conditions (Nielsen, 2004).

**Economic risks:** All risks associated with project financing are classified as economic risks. These are the most common types of risks encountered throughout the world, and the same is true in Pakistan highway construction (Samiullah Sohu et al., 2020).

Cost overruns are common in Pakistani highway projects. These risks can be caused by changes in national economic policy, changes in interest rates and currency rates, inflation, and price fluctuations (Shaikh, 2020). Some experts argue that all of these risks are unavoidable due to the relatively long duration of highway project delivery, as most of these projects take 4 to 5 years to finish (Choudhry & Iqbal, 2013).

**Environmental risks:** These are the non-manageable risks found in highway construction projects these are also called as natural risks such as unfavourable climatic conditions; Also, bad environmental conditions like pollution and traffic are also considered as environmental risks to highway projects.(Boateng et al., 2012)

Pakistan is a county which possess a number of weather conditions and climatic condition so environmental risks vary from place to place some of the most common environmental risks in the country are continuous rainfall, snow, temperature and wind this risk often occur in flat or plain areas of Sindh, Punjab, and Baluchistan(Ahmed Soomro et al., 2019).

Some of the risks connected with mountainous locations, particularly Azad Kashmir and KPK, include earthquakes, floods, and land sliding; these risks have a significant impact on throughfare projects in these areas.

**Political risks:** Road network projects, Highway project and Highway projects all of these belong to a state (country) or the government, as such they are influenced heavily by government policies, this aspect of highway project often times leaves them pen to political risks.

Pakistani is seen as a country with high political unrest country in which state policy on mega-projects often change with the change of governments. As a result, many highway projects in Pakistan frequently encounter cost overruns and delays due to changes in state laws, regulations, and government policy (Zayed et al., 2008).

Highway projects are risky, yet they are critical to a country's development. In developing countries like Pakistan, incomplete highway projects represent lost economic prospects (C. Li et al., 2019). That is why it is critical for construction organizations to limit risk for roadway projects in developing countries like Pakistan (Viswanathan et al., 2020).

Table 2-1 is a list of the 34 most common risk factors which have been frequently observed in over 30 studies that were carried out in both developing and developed nations. enlists the identified factors along with frequency of occurrence.

*Table 2-1: Identified factors from literature*

| Sr. # | Identified risk factors | Frequency | Source(s) |
|---|---|---|---|
| 1 | Change orders | 13 | L. Alarcon (2011), R. Marques et al (2011),T. Zayed et al (2008), A. Chan et al (2011), M. Hastak et al (2000), N. Kartam et al (2001), Y. Yoon et al (2015), P. Gouranga (2006), M. Wang et al (2003), A. Odeh et al (2002), M. Diab et al (2017), S. Elsayegh (2008), N. Siraj et al (2019). |
| 2 | Design changes or error in design | 18 | L. Alarcon (2011), R. Marques et al (2011), A. Chan et al (2011), N. Kartam et al (2001), Y. Yoon et al (2015), G. Creedy et al (2010), D. Tran et al (2010), D. Fang et al (2004), T. Zayed etal (2008), M. Wang et al (2003), W. Tang et al (2007), A. Odeh et al (2002), I. Mahamid (2012), K. Molenaar(2005), M. Diab et al(2017), S. Elsayegh (2008), S. De Zoysa et al (2003), N. Siraj et al (2019). |
| 3 | Unclear or Ambiguous Specifications | 6 | R. Marques et al (2011), A. Chan et al (2011), Y. Yoon et al (2015), D. Tran et al (2010), D. Fang et al (2004), N. Siraj et al (2019). |
| 4 | Material and Equipment resourcing | 18 | R. Marques et al (2011), A. Chan et al (2011), M. Hastak et al (2000), N. Kartam et al (2001), Y. Yoon et al (2015), G. Creedy et al (2010), D. Tran et al (2010), |

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| | | | D. Fang et al (2004), R. Andres (2005), S. El-Sayegh et al (2008), T. Zayed et al (2008), M. Wang et al (2003), A. Chan et al (2011), S. Han (2005), N. Lee et al (2014), A. Odeh et al (2002), F. Ling et al (2010), S. Bypaneni et al (2018). |
| 5 | Poor project planning | 7 | A. Chan et al (2011), A. Chan et al (2011), A. Odeh et al (2002), R. Choudry et al (2013), I. Mahamid (2012), N. Siraj et al (2019), A. Aleshin (2001). |
| 6 | Delays in Approval of Submittals | 3 | D. Tran et al (2010), S. El-Sayegh et al (2008), F. Ling et al (2010). |
| 7 | Lack of Technology | 3 | T. Zayed et al (2008), Y. Trofimenko (2017), A. Aleshin (2001). |
| 8 | Lack of Skills/Techniques | 14 | L. Alarcon (2011), T. Zayed et al (2008), M. Hastak et al (2000), Y. Yoon et al (2015), P. Gouranga (2006),M. Wang et al (2003), W. Tang et al (2007), A. Odeh et al (2002),F. Ling et al (2010), R. Choudry et al (2013), K. Nielsen (2004), R. Barber (2004), I. Mahamid (2012), K. Molenaar (2005). |
| 9 | Delays in obtaining NOCs from Authorities | 1 | S. El-Sayegh et al(208) |
| 10 | Insufficient Right of Way | 2 | D. Tran et al (2010), S. Bypaneni et al(2018). |
| 11 | Work zone traffic control/Existing Traffic during | 3 | D. Tran et al (2010), S. Bypaneni et al (2018), N. Raju et al (2020) |

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| | Construction | | |
| 12 | Inadequate site management | 5 | F. Ling et al (2010), I. Mahamid (2012), J. Reilly et al (2004), G.Ong et al (2012) |
| 13 | Force Majeure | 13 | R. Marques et al (2011), T. Zayed et al (2008), A. Chan et al (2011),D. Fang et al (2004), S. El-Sayegh et al (2008), W. Tang et al (2007), N. Lee et al (2014), A. Thomas et al (2006), R. Choudry et al (2013), S. De Zoysa et al (2003), D. Franco-Duran et al (2016), D. Nguyen et al (2018), N. Siraj et al (2019) |
| 14 | Unforeseen Soil Condition | 12 | A. Chan et al (2011), M. Hastak et al (2000), S. El-Sayegh et al (2008), T. Zayed et al (2008), A. Odeh et al (2002), S. Bypaneni et al (2018), R. Choudry et al (2013), K. Molenaar (2005), M. Diab et al (2017), S. Elsayegh (2008), N. Siraj et al (2019) |
| 15 | Poor Coordination | 5 | S. El-Sayegh et al (2008),W. Tang et al (2007), R. Choudry et al (2013), M. Diab et al (2017), N. Siraj et al (2019) |
| 16 | Inadequate Safety Measures | 1 | R. Andres (2005) |
| 17 | Feasibility of Construction Methods | 4 | S. El-Sayegh et al (2008), W. Tang et al (2007), R. Choudry et al (2013), A. Aleshin (2001) |
| 18 | Inadequate Construction Quality | 4 | N. Kartam et al (2001), D. Tran et al (2010), S. El-Sayegh et al (2008), S. Bypaneni et al (2018), |

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| 19 | Unavailability or Shortage of materials | 3 | N. Kartam et al (2001), Y. Yoon et al (2015), N. Siraj et al (2019) |
| 20 | Rework from Poor material quality | 4 | G. Creedy et al (2010), M. Wang et al (2003), I. Mahamid (2012), N. Siraj et al (2019) |
| 21 | Payment delays | 5 | A. Odeh et al (2002), A. Thomas et al (2006), I. Mahamid (2012), D. Franco-Duran et al (2016), D. Nguyen et al (2018) |
| 22 | Poorly tailored Contract forms | 2 | S. El-Sayegh et al (2008), F. Ling et al (2010) |
| 23 | Conflict in Contract Documents | 5 | A. Chan et al (2011), S. El-Sayegh et al (2008), W. Tang et al (2007), R. Choudry et al (2013), N. Siraj et al (2019) |
| 24 | Poor communication between construction parties | 5 | W. Tang et al (2007), I. Mahamid (2012), M. Diab et al (2017), J. Reilly et al (2004), N. Siraj et al (2019) |
| 25 | Unreasonable project time frame | 1 | I. Mahamid (2012) |
| 26 | Changes in rules and regulations | 3 | R. Marques et al (2011), S. El-Sayegh et al (2008), A. Aleshin (2001) |
| 27 | Adverse weather conditions | 6 | M. Hastak et al (2000), N. Kartam et al (2001), T. Zayed etal (2008), M. Wang et al (2003), A. Akintoye (1997), N. Siraj et al (2019) |
| 28 | Site contamination | 11 | N. Kartam et al (2001), Y. Yoon et al (2015), S. El-Sayegh et al (2008), M. Wang et al (2003), W. Tang et al (2007), A. Odeh et al (2002), F. Ling et al (2010), |

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| | | | S. Bypaneni et al (2018), R. Choudry et al (2013), M. Diab et al (2017), S. Elsayegh (2008) |
| 29 | Criminal Acts | 2 | S. El-Sayegh et al (2008), N. Siraj et al (2019) |
| 30 | Bribes/ Corruption | 8 | A. Chan et al (2011), M. Hastak et al (2000), Y. Yoon et al (2015), D. Fang et al (2004), S. El-Sayegh et al (2008), F. Ling et al (2010), R. Choudry et al (2013), N. Siraj et al (2019) |
| 31 | Labour Strikes | 8 | L. Alarcon (2011), M. Hastak et al(2000), N. Kartam et al (2001), Y. Yoon et al (2015), D. Tran et al (2010), S. El-Sayegh et al (2008), K. Molenaar (2005), N. Siraj et al (2019), |
| 32 | Cost overruns | 19 | L. Alarcon (2011), R. Marques et al (2011), A. Chan et al (2011), M. Hastak et al (2000), Y. Yoon et al (2015), G. Creedy et al (2010), D. Tran et al (2010), D. Fang et al (2004), M. Wang et al (2003), W. Tang et al (2007), N. Lee et al (2014), F. Ling et al (2010), A. Akintoye (1997), R. Choudry et al (2013), M. Diab et al (2017), J. Reilly et al (2004), D. Franco-Duran et al (2016), D. Nguyen et al (2018), N. Siraj et al (2019) |
| 33 | Project and Programme Management Issues | 5 | D. Tran et al (2010), A. Odeh et al (2002), I. Mahamid (2012), D. Nguyen et al (2018), N. Siraj et al (2019) |
| 34 | Substance abuse | 1 | S. Elsayegh (2008) |

## 2.9. Risk mitigation factors in highway construction

Risk mitigation is the final step in the Risk Management Process. Risk mitigation is accomplished by either adjusting the scope of the project or reducing the possibility of detrimental events occurring (Pinto & Winch, 2016).

Implementing risk management in the early stages of highway projects lowers the likelihood of the risk event occurring; also, it is a more effective risk mitigation approach than attempting to restore the damage and repercussions after the risk has occurred (Loosemore et al., 2012). The main idea of risk mitigation is best explained though the famous idiom of

**"Prevention is better than a cure".**

Construction projects, in particular, are vulnerable to risk factors from the beginning, thus implementing risk mitigation techniques early in the construction process is greatly beneficial (Rybnicek et al., 2020). Another reason for analysing risks so early in the building project is that some risks necessitate the implementation of proper countermeasures, and if such risks can be recognised early in the project, ample time may be allocated to designing countermeasures to mitigate such severe risks (Loosemore et al., 2012).

A significant amount of future planning is required in order to identify and prevent critical risk formation; critical decisions such as project alignment or the selection of project delivery method can be influenced by risk mitigation efforts to provide better long-term results for highway projects (C. Li et al., 2019). Strategies for mitigating risks on highway projects include (Skitmore & Sidwell, 2006):

- Taking steps to reduce the project's uncertainty
- Avoiding risk by finding better ways to execute the project

- Reducing or lowering the risk's chance or impact on the project
- Risk sharing with involved project participants like contractors or insurance companies
- Accepting the risk and formulating a contingency plan
- In most severe cases abandoning the project

However, there is one crucial part that must be addressed when identifying and mitigating risks. Risk is interrelated in the same way that actions are and have an impact on one another. One risk mitigation strategy may result in the extinction of one risk, but it may also result in the development of another (Franco-Duran & Mejia A, 2016). A dynamic risk mitigation system that can account for following risks must be designed in order to prevent the creation of subsequent risks (De Zoysa & Russell, 2003).

Researchers have used various techniques for capturing the interdependent relation between highway project risks. Some of the well-known methods include

- Soft System Methodology (SSM)(Boateng et al., 2012)
- Network Theory(Project Management Institute, 2018)
- Causal Mapping (Vilventhan & Kalidindi, 2016)

However, the system thinking approach is observed to be one of the best selection for dynamic variable causal relationship mapping (Jifeng et al., 2008). This system provides users with a method for converting between qualitative expressions of dynamic mechanisms and quantitative data representation (Bayer, 2004). The system thinking approach uses a graphical influence diagram known as Casual Loop Diagram (CLD) to form the basic structure for cause and effect that shows the relationship between different variables (Rodrigues, 2001). As such system thinking approach is the most important tool to be used for developing risk mitigation strategy framework for high construction projects.

Table 2-2 is a list of the common risk mitigation strategies applied across multiple highway projects across the globe, we can use these is our study to find out which strategies can be used for casual loop diagram for risk mitigation in highway sector of Pakistan.

*Table 2-2: Mitigation factors identified from literature*

| S.R | Mitigation factors | Frequency | Sources |
|---|---|---|---|
| 1 | Detailed evaluation of total scope of work before tender | 16 | (K.V et al., 2019),(Samiullah Sohu et al., 2018),(Banobi & Jung, 2019),(N. Carbonara et al., 2015),(Viswanathan et al., 2020),(J. H. L. Chan et al., 2012),(Nunzia Carbonara et al., 2014),(Sharma & Kumar Gupta, 2020),(Hwang et al., 2017),(Mejía et al., 2020),(Witcher, 2020),(Hussain et al., 2018),(Ullah et al., 2018),(Zidane & Andersen, 2018),(Durdyev et al., 2017),(Pai et al., 2020) |
| 2 | Review of project scope, design and constructability with design | 19 | (K.V et al., 2019),(Samiullah Sohu et al., 2018),(Azis et al., 2013),(Kumar et al., 2018),(Gathenya, 2013),(N. Carbonara et al., 2015),(J. H. L. Chan et |

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| | consultants at pretender stage | | al., 2012),(Sharma & Kumar Gupta, 2020),(Hwang et al., 2017),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Witcher, 2020),(Ullah et al., 2018),(Memon et al., 2021),(Zidane & Andersen, 2018),(Durdyev et al., 2017),(Almutairi, 2016),(Pai et al., 2020),(Samiullah Sohu et al., 2020) |
| 3 | Site visits for possible risk evaluation before and after project start | 13 | (K.V et al., 2019),(Samiullah Sohu et al., 2018), (Azis et al., 2013), (Banobi & Jung, 2019), (N. Carbonara et al., 2015),(Viswanathan et al., 2020),(Ahmed Soomro et al., 2019),(Mejía et al., 2020),(Witcher, 2020),(Hussain et al., 2018),(Kog, 2019),(Ullah et al., 2018),(Almutairi, 2016) |
| 4 | Detailed tender documents for accurate project estimations | 18 | (K.V et al., 2019),(Samiullah Sohu et al., 2018), (Banobi & Jung, 2019),(Kumar et al., 2018),(Gathenya, 2013),(N. Carbonara et al., 2015),(Viswanathan et al., 2020),(J. H. L. Chan et al., 2012),(Nunzia Carbonara et al., 2014),(Rybnicek et al., 2020),(S. |

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| | | | Sohu et al., 2018),(S. Sohu et al., 2019),(Witcher, 2020),(Hussain et al., 2018),(Venkatesh & Venkatesan, 2017),(Durdyev et al., 2017),(Pai et al., 2020),(Samiullah Sohu et al., 2020) |
| 5 | Project management should schedule Frequent progress meetings | 10 | (K.V et al., 2019),(Samiullah Sohu et al., 2018), (Azis et al., 2013),(Mrs. Rani Mate & Dr. G. A. Hinge, 2015),(N. Carbonara et al., 2015),(J. H. L. Chan et al., 2012),(Sharma & Kumar Gupta, 2020),(Rybnicek et al., 2020),(Tebeje Zewdu, 2016),(Ullah et al., 2018),(Memon et al., 2021) |
| 6 | Defined timelines with highlighted Design and constructability issues | 16 | (K.V et al., 2019),(Samiullah Sohu et al., 2018), (Azis et al., 2013),(Kumar et al., 2018),(Viswanathan et al., 2020),(Nunzia Carbonara et al., 2014),(Sharma & Kumar Gupta, 2020),(Rybnicek et al., 2020),(Hwang et al., 2017),(Ahmed Soomro et al., 2019),(S. Sohu et al., 2019),(Witcher, 2020),(Hussain et al., 2018),(Kog, 2019),(Zidane & Andersen, 2018),(Pai |

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| | | | et al., 2020) |
| 7 | Design evaluation and changes are accommodated at Planning and Design stages | 17 | (K.V et al., 2019),(Samiullah Sohu et al., 2018), (Banobi & Jung, 2019),(Kumar et al., 2018),(N. Carbonara et al., 2015),(J. H. L. Chan et al., 2012),(Rybnicek et al., 2020),(Hwang et al., 2017),(Tebeje Zewdu, 2016),(Witcher, 2020),(Hussain et al., 2018),(Venkatesh & Venkatesan, 2017),(Ullah et al., 2018),(Memon et al., 2021),(Durdyev et al., 2017),(Almutairi, 2016),(Samiullah Sohu et al., 2020) |
| 8 | Designs should be implemented keeping constructability aspects | 10 | (K.V et al., 2019),(Gathenya, 2013),(N. Carbonara et al., 2015),(Rybnicek et al., 2020),(S. Sohu et al., 2019),(Kog, 2019),(Ullah et al., 2018),(Memon et al., 2021),(Pai et al., 2020),(Samiullah Sohu et al., 2020) |
| 9 | Standardization of various components and material | 9 | (K.V et al., 2019),(Gathenya, 2013),(Ahmed Soomro et al., 2019),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Mejía et al., 2020),(Witcher, |

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| | | | 2020),(Memon et al., 2021),(Almutairi, 2016) |
| 10 | Evaluate the possible changes and their impact | 8 | (K.V et al., 2019),(Mrs. Rani Mate & Dr. G. A. Hinge, 2015),(Sharma & Kumar Gupta, 2020),(Witcher, 2020),(Hussain et al., 2018),(Almutairi, 2016),(Pai et al., 2020),(Samiullah Sohu et al., 2020) |
| 11 | Effective project management plan | 15 | (K.V et al., 2019), (Azis et al., 2013),(Mrs. Rani Mate & Dr. G. A. Hinge, 2015),(N. Carbonara et al., 2015),(Sharma & Kumar Gupta, 2020),(Rybnicek et al., 2020),(Ahmed Soomro et al., 2019),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Mejía et al., 2020),(Witcher, 2020),(Kog, 2019),(Zidane & Andersen, 2018),(Samiullah Sohu et al., 2020) |
| 12 | Root cause evaluation for change orders | 12 | (K.V et al., 2019), (Banobi & Jung, 2019),(Viswanathan et al., 2020),(Nunzia Carbonara et al., 2014),(Rybnicek et al., 2020),(S. Sohu et al., 2019),(Mejía et al., |

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| | | | 2020),(Witcher, 2020),(Hussain et al., 2018),(Venkatesh & Venkatesan, 2017),(Ullah et al., 2018),(Pai et al., 2020) |
| 13 | Check Impact of design changes on the project schedule/ cost | 6 | (K.V et al., 2019),(N. Carbonara et al., 2015),(Sharma & Kumar Gupta, 2020),(S. Sohu et al., 2019),(Witcher, 2020),(Zidane & Andersen, 2018) |
| 14 | Reallocation of resources according to designs changes | 10 | (K.V et al., 2019),(Samiullah Sohu et al., 2018), (Banobi & Jung, 2019),(Kumar et al., 2018),(N. Carbonara et al., 2015),(Rybnicek et al., 2020),(S. Sohu et al., 2019),(Mejía et al., 2020),(Kog, 2019),(Ullah et al., 2018) |
| 15 | Change orders agreement before start of work | 4 | (K.V et al., 2019),(Nunzia Carbonara et al., 2014),(Witcher, 2020),(Kog, 2019) |
| 16 | Effective communication of change in designs | 13 | (K.V et al., 2019),(Samiullah Sohu et al., 2018), (Azis et al., 2013), (Banobi & Jung, 2019),(N. Carbonara et al., 2015),(J. H. L. Chan et al., 2012),(Rybnicek et al., 2020),(Tebeje Zewdu, 2016),(Mejía et al., |

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| | | | 2020),(Witcher, 2020),(Kog, 2019),(Zidane & Andersen, 2018),(Almutairi, 2016) |
| 17 | Allocation of payment based on sub-project completion | 12 | (Samiullah Sohu et al., 2018),(N. Carbonara et al., 2015),(Rybnicek et al., 2020),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Mejía et al., 2020),(Witcher, 2020),(Ullah et al., 2018),(Memon et al., 2021),(Zidane & Andersen, 2018),(Almutairi, 2016),(Pai et al., 2020) |
| 18 | Accurate predictions of site climatic conditions | 7 | (Samiullah Sohu et al., 2018),(Gathenya, 2013),(Rybnicek et al., 2020),(Ahmed Soomro et al., 2019),(S. Sohu et al., 2019),(Pai et al., 2020),(Samiullah Sohu et al., 2020) |
| 19 | Avoid sensitive political situation | 9 | (Samiullah Sohu et al., 2018),(N. Carbonara et al., 2015),(Nunzia Carbonara et al., 2014),(Rybnicek et al., 2020),(Hwang et al., 2017),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Mejía et al., 2020),(Witcher, 2020) |

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| 20 | Annal revision of legal policies | 7 | (Samiullah Sohu et al., 2018),(J. H. L. Chan et al., 2012),(Nunzia Carbonara et al., 2014),(Rybnicek et al., 2020),(Hwang et al., 2017),(Witcher, 2020),(Almutairi, 2016) |
| 21 | Acceptance of a binding and central Legal framework | 12 | (Samiullah Sohu et al., 2018),(Viswanathan et al., 2020),(J. H. L. Chan et al., 2012),(Nunzia Carbonara et al., 2014),(Sharma & Kumar Gupta, 2020) ,(S. Sohu et al., 2018),(Hwang et al., 2017),(Tebeje Zewdu, 2016),(Kog, 2019),(Ullah et al., 2018),(Zidane & Andersen, 2018),(Pai et al., 2020) |
| 22 | Proper risk allocates through dispute resolution framework | 12 | (Samiullah Sohu et al., 2018),(Gathenya, 2013),(N. Carbonara et al., 2015),(Viswanathan et al., 2020),(Sharma & Kumar Gupta, 2020),(Rybnicek et al., 2020),(S. Sohu et al., 2018),(Hwang et al., 2017),(S. Sohu et al., 2019),(Mejía et al., 2020),(Witcher, 2020),(Pai et al., 2020) |
| 23 | Delay in payment and design | 21 | (Samiullah Sohu et al., 2018),(Gathenya, 2013),(N. Carbonara et al., 2015),(J. H. |

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| | approvals should be avoided | | L. Chan et al., 2012),(Sharma & Kumar Gupta, 2020),(Rybnicek et al., 2020),(S. Sohu et al., 2018),(Hwang et al., 2017),(Ahmed Soomro et al., 2019),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Mejía et al., 2020),(Hussain et al., 2018),(Venkatesh & Venkatesan, 2017),(Kog, 2019),(Ullah et al., 2018),(Memon et al., 2021),(Zidane & Andersen, 2018),(Almutairi, 2016),(Pai et al., 2020),(Samiullah Sohu et al., 2020) |
| 24 | Changes in key posts of project should be avoided | 2 | (Samiullah Sohu et al., 2018),(Almutairi, 2016) |
| 25 | Policies should be revised on non-bias basis | 8 | (Samiullah Sohu et al., 2018),(N. Carbonara et al., 2015),(Viswanathan et al., 2020),(J. H. L. Chan et al., 2012),(S. Sohu et al., 2018),(S. Sohu et al., 2019),(Hussain et al., 2018),(Zidane & Andersen, 2018) |
| 26 | Client work done | 15 | (Samiullah Sohu et al., 2018),(Gathenya, |

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| | on regular basis | | 2013),(N. Carbonara et al., 2015),(J. H. L. Chan et al., 2012),(Nunzia Carbonara et al., 2014),(Rybnicek et al., 2020),(Hwang et al., 2017),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Mejía et al., 2020),(Venkatesh & Venkatesan, 2017),(Memon et al., 2021),(Almutairi, 2016),(Pai et al., 2020),(Samiullah Sohu et al., 2020) |
| 27 | Pre project planning | 18 | (Samiullah Sohu et al., 2018), (Azis et al., 2013),(Mrs. Rani Mate & Dr. G. A. Hinge, 2015),(Gathenya, 2013),(Nunzia Carbonara et al., 2014),(S. Sohu et al., 2018),(Ahmed Soomro et al., 2019),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Mejía et al., 2020),(Witcher, 2020),(Hussain et al., 2018),(Kog, 2019),(Ullah et al., 2018),(Zidane & Andersen, 2018),(Durdyev et al., 2017),(Pai et al., 2020),(Samiullah Sohu et al., 2020) |
| 28 | Competent staff should be hired for | 16 | (Banobi & Jung, 2019),(Mrs. Rani Mate & Dr. G. A. Hinge, 2015),(Gathenya, 2013),(N. Carbonara et al., |

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| | project | | 2015),(Viswanathan et al., 2020),(J. H. L. Chan et al., 2012),(Sharma & Kumar Gupta, 2020),(Rybnicek et al., 2020),(Ahmed Soomro et al., 2019),(Mejía et al., 2020),(Witcher, 2020),(Hussain et al., 2018),(Kog, 2019),(Durdyev et al., 2017),(Almutairi, 2016) |
| 29 | Effective site management and supervision | 14 | (Azis et al., 2013),(Gathenya, 2013),(N. Carbonara et al., 2015),(Nunzia Carbonara et al., 2014),(Sharma & Kumar Gupta, 2020),(Rybnicek et al., 2020),(Ahmed Soomro et al., 2019),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Hussain et al., 2018),(Venkatesh & Venkatesan, 2017),(Memon et al., 2021),(Pai et al., 2020),(Samiullah Sohu et al., 2020) |
| 30 | Using the past experience of project managers | 6 | (Azis et al., 2013),(Mejía et al., 2020),(Witcher, 2020) ,(Zidane & Andersen, 2018),(Durdyev et al., 2017) ,(Samiullah Sohu et al., 2020) |

| | | | |
|---|---|---|---|
| 31 | Experienced subcontractors and Contractors | 16 | (Azis et al., 2013),(Mrs. Rani Mate & Dr. G. A. Hinge, 2015),(Gathenya, 2013),(N. Carbonara et al., 2015),(Viswanathan et al., 2020),(Rybnicek et al., 2020),(Ahmed Soomro et al., 2019),(Tebeje Zewdu, 2016),(Mejía et al., 2020),(Venkatesh & Venkatesan, 2017),(Memon et al., 2021),(Zidane & Andersen, 2018),(Durdyev et al., 2017),(Almutairi, 2016),(Pai et al., 2020),(Samiullah Sohu et al., 2020) |
| 32 | Use advance technologies (BIM, pre-fabrication and 3D printing) & equipments | 9 | (Azis et al., 2013),(Mrs. Rani Mate & Dr. G. A. Hinge, 2015),(Gathenya, 2013),(Witcher, 2020),(Ullah et al., 2018),(Durdyev et al., 2017),(Almutairi, 2016),(Pai et al., 2020) |
| 33 | Frequent coordination between the parties | 11 | (Azis et al., 2013),(Mrs. Rani Mate & Dr. G. A. Hinge, 2015),(J. H. L. Chan et al., 2012),(Nunzia Carbonara et al., 2014),(Sharma & Kumar Gupta, 2020),(Rybnicek et al., 2020),(Mejía et al., 2020),(Hussain et al., 2018),(Venkatesh & Venkatesan, |

| | | | |
|---|---|---|---|
| | | | 2017),(Ullah et al., 2018) ,(Zidane & Andersen, 2018) |
| 34 | Comprehensive contract administration | 9 | (Azis et al., 2013),(Gathenya, 2013),(Viswanathan et al., 2020),(J. H. L. Chan et al., 2012),(Nunzia Carbonara et al., 2014),(S. Sohu et al., 2018),(Hussain et al., 2018),(Venkatesh & Venkatesan, 2017),(Pai et al., 2020) |
| 35 | Systematic control mechanism on projects | 14 | (Azis et al., 2013),(Mrs. Rani Mate & Dr. G. A. Hinge, 2015),(N. Carbonara et al., 2015),(Viswanathan et al., 2020),(J. H. L. Chan et al., 2012),(Nunzia Carbonara et al., 2014),(Sharma & Kumar Gupta, 2020),(Rybnicek et al., 2020),(Witcher, 2020),(Venkatesh & Venkatesan, 2017),(Ullah et al., 2018),(Zidane & Andersen, 2018),(Durdyev et al., 2017),(Almutairi, 2016) |
| 36 | Adequate project financial arrangements | 17 | (Banobi & Jung, 2019),(Kumar et al., 2018),(Gathenya, 2013),(Viswanathan et al., 2020),(Nunzia Carbonara et al., 2014),(Sharma & Kumar Gupta, |

| | | | |
|---|---|---|---|
| | | | 2020),(S. Sohu et al., 2018),(Hwang et al., 2017),(Ahmed Soomro et al., 2019),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Mejía et al., 2020),(Witcher, 2020),(Hussain et al., 2018),(Memon et al., 2021),(Durdyev et al., 2017),(Samiullah Sohu et al., 2020) |
| 37 | Consideration of owners Influence | 8 | (Banobi & Jung, 2019),(N. Carbonara et al., 2015),(J. H. L. Chan et al., 2012),(Witcher, 2020),(Hussain et al., 2018),(Venkatesh & Venkatesan, 2017),(Ullah et al., 2018),(Pai et al., 2020) |
| 38 | Close construction supervision | 14 | (Banobi & Jung, 2019),(Gathenya, 2013),(J. H. L. Chan et al., 2012),(Sharma & Kumar Gupta, 2020),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Witcher, 2020),(Hussain et al., 2018),(Kog, 2019),(Ullah et al., 2018),(Memon et al., 2021),(Zidane & Andersen, 2018),(Durdyev et al., 2017),(Almutairi, 2016) |
| 39 | Timely | 11 | (Banobi & Jung, 2019),(Gathenya, |

| | | | |
|---|---|---|---|
| | procurement and supply of materials and equipment | | 2013),(Hwang et al., 2017),(Ahmed Soomro et al., 2019),(Tebeje Zewdu, 2016),(Mejía et al., 2020),(Witcher, 2020),(Memon et al., 2021),(Durdyev et al., 2017),(Pai et al., 2020),(Samiullah Sohu et al., 2020) |
| 40 | Proposal for reasonable extension of time in project | 10 | (Mrs. Rani Mate & Dr. G. A. Hinge, 2015),(Kumar et al., 2018),(Gathenya, 2013),(N. Carbonara et al., 2015),(J. H. L. Chan et al., 2012),(Nunzia Carbonara et al., 2014),(Hwang et al., 2017),(Tebeje Zewdu, 2016),(Durdyev et al., 2017),(Almutairi, 2016) |
| 41 | Increase productivity through overtime hours, extra shifts | 5 | (Mrs. Rani Mate & Dr. G. A. Hinge, 2015),(S. Sohu et al., 2019),(Mejía et al., 2020),(Ullah et al., 2018),(Memon et al., 2021) |
| 42 | Flexible price formula for material prices | 10 | (N. Carbonara et al., 2015),(J. H. L. Chan et al., 2012),(Nunzia Carbonara et al., 2014),(S. Sohu et al., 2019),(Tebeje Zewdu, 2016),(Witcher, 2020),(Hussain et al., 2018),(Memon et al., 2021),(Almutairi, 2016),(Pai et al., |

| | | | |
|---|---|---|---|
| | | | 2020) |
| 43 | Mutual trust between the parties to the contract | 5 | (J. H. L. Chan et al., 2012),(Witcher, 2020),(Venkatesh & Venkatesan, 2017),(Ullah et al., 2018),(Memon et al., 2021) |
| 44 | Inspect quality frequently with a detailed checklist | 4 | (Hwang et al., 2017),(Mejía et al., 2020),(Witcher, 2020),(Almutairi, 2016) |
| 45 | Guaranteeing a rigorous contractor selection | 6 | (Hwang et al., 2017),(Ahmed Soomro et al., 2019),(S. Sohu et al., 2019),(Mejía et al., 2020),(Ullah et al., 2018),(Almutairi, 2016) |
| 46 | Motivate laborers through incentive programs | 4 | (Witcher, 2020),(Venkatesh & Venkatesan, 2017),(Ullah et al., 2018),(Memon et al., 2021) |

### 2.10. Systems thinking approach

The system thinking approach entails the use of diverse diagramming tools to graphically portray the structure of project systems, as well as various approaches such as casual loop diagrams and cause and effect of the overall system (Love et al., 1999). In recent times, the system thinking approach has asserted itself as an useful analytical tool for studying the dynamic interactions of several small systems into a bigger more complex system (Alasad et al., 2013).

The fundamental objective and purpose of the system thinking approach is to analyse and evaluate the effect of one variable on another. In this study, the variables are risks in highway construction. Systems thinking can be used as a tool to help with the mitigation of undesirable construction phenomena or risks/uncertainties in order to make construction processes more stable and efficient (Alasad et al., 2013).

By adopting a system-thinking approach, risk identification and mitigation in highway projects may be carried out on a bigger scale, and hazards can be managed without the concern of future risk development (Samiullah Sohu et al., 2020). This holistic approach to risk mitigation can address many challenges that arise during highway construction in underdeveloped countries such as Pakistan, where risks and their consequences are not effectively assessed, resulting in delays and cost overruns (Ali et al., 2007).

## 2.11. Causal Loop Diagram

Causal Loop Diagrams (CLDs) are regarded as an important tool for representing the causal structures of various dynamic systems. It has the advantage of allowing you to visualise theories about the causes of dynamics (Chritamara et al., 2002). Causal loops can assist in the incorporation of a comprehensive and holistic picture of various construction phenomena such as linkages, element identification, and system feedback mechanisms (Love et al., 1999).

## 2.12. How causal loop works

A causal diagram is made up of components and variables that are connected by arrows that indicate the causal relation direction between the variables. The essential causal loops are closed, making full cycles that are depicted by a loop identifier (Love et al., 1999). The causal loop diagram modelling approach is iterative in nature; even while the procedure requires steps to be completed at different stages, the elements of the system can subsequently be put together to form a complete image of the system (Jifeng et al., 2008).

The loop identifier indicates the causal feedback system's positive/ reinforcing or negative/ balancing nature (Chritamara et al., 2002). Positive causal loops imply that when the factor variable increases or decreases in one way, the next in line variable similarly increases or decreases in the same direction (Spillane et al., 2011).

Similarly, in a negative or balancing causal loop, if a variable or component increases or decreases in one direction, the corresponding effect in the loop or system is opposite and contrasting to the initial change effect (Jifeng et al., 2008).

Casual loop development assists in exhibiting significant and critical routes that define key functions such as feedbacks that can be utilised to determine the development of problems in a casual loop system (Love et al., 1999). In the closed loop or cycle, an initial increasing effect is balanced by a final reducing effect, and vice versa (Boateng et al., 2012)

# Chapter 3

# Research methodology

The methodology of current study will be discussed in this chapter. A research gap was identified after an extensive literature review which helped us in mapping out the research objectives. Afterwards, to address the research problem, studies were consulted, and system dynamics was incorporated into the methodology.

## 3.1. Research Methodology

In this study, factors obtained from extensive literature review and field survey are used as inputs to apply system thinking's approach. On the basis of their significance gained through field and literature scores, factors were arranged and shortlisted. Field data was obtained for both risk factors and mitigation strategies using a Likert scale questionnaire survey. Figure 3.1 research consists of four main phases that are illustrated in the figure below.

## 3.2. Phase 1:

In the first phase of this research, literature was consulted in detailed to find a research gap and a research problem was unearthed. Subsequently, research objectives were refined while keeping in view the research problem. Finding a research gap is a hectic process that require a thorough search both in the field and through an extensive study of literature. From the field it was identified that there are risks associated with construction of Highway Projects that need to be tackled in order for the project to be completed on time and within allocated budget. This led to an extensive review of the literature to find previous work on construction project of highways. Upon reading different research papers, research gap was narrowed down to risk factors that are associated with the construction phase of a project and mitigation strategies to counter these risks. After this narrowing down, the research gap and research objectives were finalized in this phase.

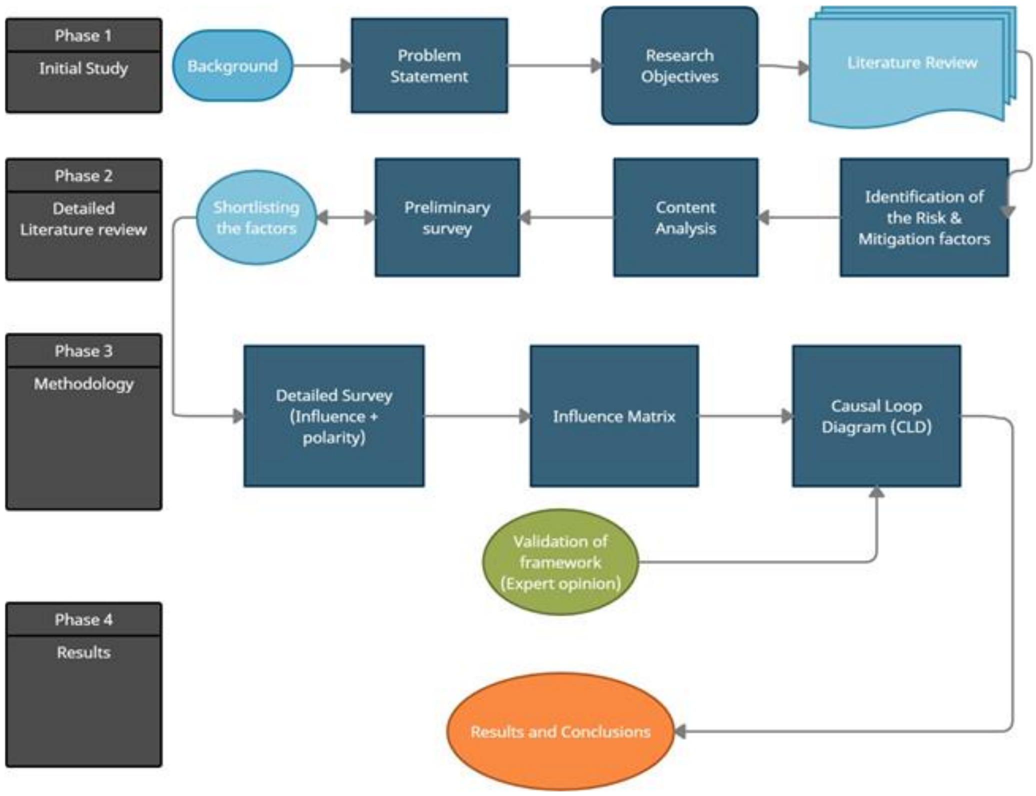


*Figure 3.1: Research methodology framework*

### 3.3. Phase 2:

In the 2nd phase, literature review was carried out to target two different line of studies. One part included studying different articles that addressed the risk factors of construction of highways and the other part included a thorough study of the literature available on risk mitigation strategies related to construction of highways. During both these parts, a separate sheet of excel was prepared to list down the identified risk and mitigation factors. The first sheet included risk factors that affected the construction of highways while the other such sheet included the mitigation strategies that will tackle the risks during construction of highways. A total of 34 risk factors were identified from literature review from 40 studies. Similarly, 43 risk mitigation factors were identified from 30 research papers. Both these factors were ranked based on normalized scores in a technique called content analysis. It included literature review and a preliminary survey. To improve the quality of the work, the literature review was substantiated with a field questionnaire survey. The survey was based on a five-point Likert scale and experts from a diverse range of backgrounds were asked to give a number from 1 to 5 to the identified factors based on their significance. (1=Very Low, 2=Low, 3=Medium, 4=High, 5=Very High). A preliminary Survey was created via Google forms. These forms were circulated online in Pakistan through LinkedIn. Due the inability of a free LinkedIn account to access the right group of people, a premium subscription was obtained for this purpose. For risk factors, a total of 30 responses were collected and were accepted in its entirety while a total of 32 responses were obtained for mitigation factors, two of which were discarded and 30 were accepted. The details of the survey respondents are in Table 3-1.

| **Qualification** | | **Years of Experience** | | **Type of Organization** | |
|---|---|---|---|---|---|
| Graduation | 16 | 0-5 | 11 | Government | 6 |
| Post-Graduation | 13 | 6-10 | 11 | Semi Government | 3 |
| PhD | 1 | 11-20 | 6 | Private | 21 |
| | | >20 | 2 | | |
| **Total Responses** | | | **30** | | |

*Table 3-1: Respondent's information (preliminary survey)*

Content analysis was performed on the factors obtained from literature and from the responses obtained from industry. The literature scores were normalized based on their total literature score. Similarly, the field data was also normalized based on their overall score.

In the next step, a one-way ANOVA Analysis was performed and p value of 1 was obtained. After ANOVA analysis a 60/40 weightage in favor of field score was adopted for both risks that can occur during the construction phase of Highways and the mitigation factors that can minimize either the probability or impact of these identified risks. The normalized score of literature review and Field score were given 50% weightage for both set of sheets. 13 risk factors out of 34 and 18 risk mitigation factors out of 46 were selected. Hence all those factors/features were selected that came above the 50% cumulative impact. Table 3-2 and 4 show the details of risk factors, respectively, including their normalized score and their ranking.

*Table 3-2: Content analysis of risk factors*

| **Risk Factors** | **50/50 Normalize score** | **Cumulative score** | **Ranking** |
|---|---|---|---|
| Material and equipment resourcing | 0.063253649 | 0.057499471 | 1 |
| Cost overruns | 0.061499542 | 0.111871518 | 2 |
| Design changes/Error in design | 0.058943304 | 0.164198576 | 3 |
| Lack of Skills/Techniques | 0.0530287 | 0.213518088 | 4 |
| Site contamination | 0.041049644 | 0.251530216 | 5 |
| Bribes/Corruption | 0.037691277 | 0.28857979 | 6 |
| Owner initiated changes | 0.041851773 | 0.325509485 | 7 |
| Poor project planning | 0.03513504 | 0.360514068 | 8 |
| Force majeure | 0.032869685 | 0.39198223 | 9 |
| Inadequate site management | 0.030022565 | 0.422896834 | 10 |

| | | | |
|---|---|---|---|
| Poor coordination | 0.030022565 | 0.453811438 | 11 |
| Delays in payment | 0.030022565 | 0.484726042 | 12 |
| Poor communication between construction parties | 0.030022565 | 0.515640646 | 13 |

Similarly, Table 3-3 shows the factors that will mitigate the risks that can happen while construction of highways.

*Table 3-3: Content analysis of mitigation factors*

| Risk mitigation factors | 50/50 Normalize score | Cumulative score | Ranking |
|---|---|---|---|
| On time payments and design decisions | 0.038366455 | 0.03545507 | 1 |
| Review of project scope, design and constructability with design consultants at pre tender stage | 0.035846294 | 0.06889401 | 2 |
| Detailed tender documents for accurate project estimations | 0.034586214 | 0.10132488 | 3 |
| Pre project planning | 0.034586214 | 0.13375576 | 4 |
| Design evaluation and changes are accommodated at Planning and Design stages | 0.033326133 | 0.16517857 | 5 |
| Adequate project financial arrangements | 0.033326133 | 0.19660138 | 6 |
| Detailed evaluation of total scope of work before tender | 0.032066052 | 0.22701613 | 7 |
| Effective project management plan | 0.030805972 | 0.25642281 | 8 |
| Effective site management and | 0.029545891 | 0.28482143 | 9 |

| | | | |
|---|---|---|---|
| supervision | | | |
| Site visits for possible risk evaluation before and after project start | 0.02828581 | 0.31221198 | 10 |
| Defined timelines with highlighted Design and constructability issues | 0.029089862 | 0.33905530 | 11 |
| Effective communication of change in designs | 0.024709581 | 0.36477535 | 12 |
| Frequent project management progress meetings | 0.024505568 | 0.38914171 | 13 |
| Use of advance technologies (BIM, pre-fabrication and 3D printing) & equipment | 0.023245488 | 0.41250000 | 14 |
| Allocation of payment based on sub-project completion | 0.024049539 | 0.43531106 | 15 |
| Acceptance of a binding and central Legal framework | 0.024049539 | 0.45812212 | 16 |
| Systematic control mechanism on projects | 0.022489439 | 0.48087558 | 17 |
| Close construction supervision | 0.022489439 | 0.50362903 | 18 |

### 3.4. Phase 3:

In this phase the primary data was collected, and the analyses were performed using several tools and techniques. The final detailed questionnaire survey was conducted through Google docs consisting of two different sections. The first section was related to professional's information and the second section was required to give their input about the strength of causal relationship and polarity between risk factors that occurs during the construction of highways and the impact of the mitigative strategies. The respondents were given options to choose two options of the five options per row. First option was to select the causal strength as Low (1), Medium (3) or High (5), and the second option was given to assign polarity as Direct or Indirect Relationship.

A total of 13 risk factors and 18 mitigation strategies were shortlisted in the final detailed survey. The aim of the survey was obtaining the causal strength and polarity of the relationships between risk factors and the impact of mitigation strategies during construction of highways. A total of 114 responses were obtained out of which 107 were considered and 7 responses were discarded. The 107 responses were utilized for further analysis. The data was compiled, and the responses were evaluated for reliability and consistency for basic statistic tools. For measuring the reliability and consistency of collected data, the Cronbach's coefficient alpha method was considered. The minimum acceptable value for Cronbach's Alpha is 0.7 (X. Wang et al., 2019). The collected data had (0.931) value for Cronbach's alpha which is considered reliable and consistent. The main sources that were used to collect data were Linkedin, Gmail, Whatsapp and all the respondents were vetted for their relevance to construction industry specially risk management as their field of knowledge.

### 3.4.1. Shortlisted factors:

The responses of the detailed survey were checked for reliability and internal consistency using basic statistical tests using SPSS ®. The data was checked for internal consistency and Reliability and Normality. To analysis the Likert scale data, an analysis technique was required. For this reason, Relative importance index (RII) method was used to rank the relationships using the significance indices as per the responses. Data collection through final questionnaire revealed 24 relationships between risk factors and their mitigation strategies. The subsequent formulation was used to reduce the test size of it (Inho & Hyo Joo, 2021), and obtain the most important causative relationships between risk factors and the impact of mitigation strategies between them.

$$\text{Relative Importance Index (RII)} = (\sum W)/(A*N)$$

where “W” is the weights assigned in Likert Scale, “A” is maximum weight assigned in the scale and “N” is the total number of respondents, and

The RII has a minimum and maximum value of 0 and 1 respectively

It is pertinent to note that to represent the structure of the system it is necessary to consider the most immediate causes instead of all influences (Series & Sterman, 2003). Therefore, the obtained responses were categorized according to their (RII), like that adopted by (Özdemir, 2010). The categories ranged from 0-2 as “very Low”, 0.2 to 0.4 as “Medium-Low”, 0.4 to 0.6 as “Medium, 0.6 to 0.8 as “Medium-High” and 0.8 to 1 as “Very High”. In this research, only those relationships were considered for future study that had an RII value ≥ 0.8. The RII values for factors are in Table 3-4. Only these relationships were weighed as the most important or most immediate for further analysis using systems thinking. For better understanding the factors are named with legends.

*Table 3-4: RII of shortlisted factors*

| ***Shortlisted factors*** | | | | | |
|---|---|---|---|---|---|
| ID | **Risk Factors** | **ID** | **Impact of mitigation strategies** | **Polarity** | **Relative Importance Index** |
| F1 | **Material & Equipment Resourcing** | A4 | Pre project planning | - | 0.862928348 |
| | | A6 | Adequate project financial arrangements | - | 0.819314641 |
| F2 | **Cost overruns** | A7 | Detailed evaluation of total scope of work before tender | - | 0.81619937 |
| | | A13 | Allocation of payment based on sub-project completion | - | 0.81308411 |
| | | A12 | Use of advance technologies and equipment | + | 0.80373831 |
| | | A14 | Close construction supervision | - | 0.90031152 |
| F3 | **Design changes or error in design** | A2 | Review of project scope, design and | - | 0.85669781 |

| | | | | | |
|---|---|---|---|---|---|
| | | | constructability with design consultants at pre tender stage | | |
| | | A1 | On time payments & design decisions | - | 0.806853582 |
| | | A11 | Defined timelines with highlighted Design and constructability issues | - | 0.838006230 |
| | | A12 | Use of advance technologies and equipment | - | 0.890965732 |
| F4 | **Lack of Skills/Techniques** | A12 | Use of advance technologies and equipment | + | 0.825545171 |
| F5 | **Change Orders** | A4 | Pre planning | - | 0.844236760 |
| | | A2 | Review of project scope, design and constructability with design consultants at pre tender stage | - | 0.813084112 |
| | | A7 | Detailed evaluation of total scope of | - | 0.800623052 |

| | | | | | |
|---|---|---|---|---|---|
| | | | work before tender | | |
| F6 | **Site contamination** | A4 | Pre planning | - | 0.822429906 |
| | | A10 | Site visits for possible risk evaluation before and after project start | - | 0.803738317 |
| F7 | **Bribes/Corruption** | A9 | Effective site management and supervision | - | 0.803738317 |
| F8 | **Poor Project planning** | A4 | Pre planning | - | 0.850467289 |
| | | A10 | Site visits for possible risk evaluation of the project | - | 0.822429906 |
| | | A8 | Effective project management plan | - | 0.813084112 |
| F9 | **Inadequate site Management** | A4 | Pre planning | - | 0.803738317 |
| | | A8 | Effective project management plan | - | 0.884735202 |
| | | A9 | Effective site management and supervision | - | 0.809968847 |
| F10 | **Delays in payments** | A1 | On time payments & design decisions | - | 0.9003115264 |
| | | A6 | Adequate project | - | 0.8068535825 |

| | | | | | |
|---|---|---|---|---|---|
| | | | financial arrangements | | |
| | | A13 | Allocation of payment based on sub-project completion | - | 0.9065420560 |
| | | A14 | Close construction supervision | - | 0.8255451713 |

### 3.5. Phase 4:

The last phase of this research was to develop the causal loop diagram. The shortlisted 27 relationships (as illustrated in the above table) were used for developing the causal loop diagram. The causal loop was developed using VENSIM® software. The process of developing CLD was a trial and error, repetitive and frequentative practice where all variables were connected to each other in relation and arranged using professional method. Ten factors of risk were shortlisted in the 27 relations, were used as top variables and the mitigation strategies related to other variables (impact of mitigation strategies on risk factors during construction of highways) along the trend of their impact. Either a negative or positive polarity is carried by each arrowhead, indicating an inverse or direct relation with the next variable in the loop, respectively. The closed chains of cause and effect known as feedback loops were identified as reinforcing or balancing loop.

#### 3.5.1. Demographics of survey:

The detailed Questionnaire survey was intended to target Construction industry professionals such as Project managers, construction managers, contracts specialists, Design specialists and others from different regions of Pakistan. 35% of the respondents had a master's degree, followed by 3% Doctorate and 54% respondents had bachelor's degree and 7% were diploma holders. In terms of years of experience, 12% respondents has 1 year of experience, 43 % respondents had 2-5 years of experience, 27% had 6-10 years of experience, 13.2% respondents had 11-15 experience, 3% had 16-20 years of experience while 1.8% respondents had >20 years of experience.

Most of the respondents belonged to Contractors and subcontractors, followed by 10% belonging to consultants and 9% of them belonged to clients. Majority of the respondents are contractors because they are available during the execution of the projects.

### 3.5.2. Regional categories of responses:

All 107 responses were from Pakistan as it was targeted for construction specialist that are involved in construction projects of highways. Respondent's demographics are in Table 3-5.

*Table 3-5: Information of respondents (main survey)*

| **Table 6 - Frequency distribution of primary survey responses** | | |
|---|---|---|
| **Profile** | **Frequency** | **Responses** |
| **Total Responses 107** | | |
| **Field of Work** | | |
| Design Engineer | 13 | 11.4% |
| Infrastructure Manager | 3 | 2.6% |
| Construction manager | 12 | 10.5% |
| Project manager | 14 | 12.3% |

| | | |
|---|---|---|
| Transportation engineer | 4 | 3.5% |
| Project engineer | 5 | 4.4% |
| Site engineer | 51 | 44.7% |
| Inspection officer | 2 | 1.8% |
| Contract Manager | 3 | 7% |
| Safety officer | 2 | 1.8% |
| **Years of Experience** | | |
| 0 to 1 | 14 | 12.3% |
| 2 to 5 | 49 | 43% |
| 6 to 10 | 31 | 27.2% |
| 11 to 15 | 15 | 13.2% |
| 16 to 20 | 3 | 2.6% |
| >**20** | 2 | 1.7% |
| **Educational Background** | | |
| Diploma | 8 | 7% |
| Bachelors | 62 | 55.4% |
| Masters | 40 | 35% |
| Doctorate | 3 | 2.8% |

# Chapter 4

# Analysis and Results

This chapter presents and explains the results and analysis of models developed using systems thinking approach in this research. The CLD developed with all its reinforcing and balancing loops is explained here with all its variables and loops.

## 4.1. Development of causal loop diagram

The CLD is based on findings from survey conducted in this research and illustrates a total of five (5) significant reinforcing and balancing loops, as shown in the Figure 4. The reinforcing loops are designated with 'R' while balancing loops are designated with 'B'. The CLD consists of two types of variables: risk factors and their mitigation strategies during construction of highways in Pakistan. All the loops are identified and explained below.

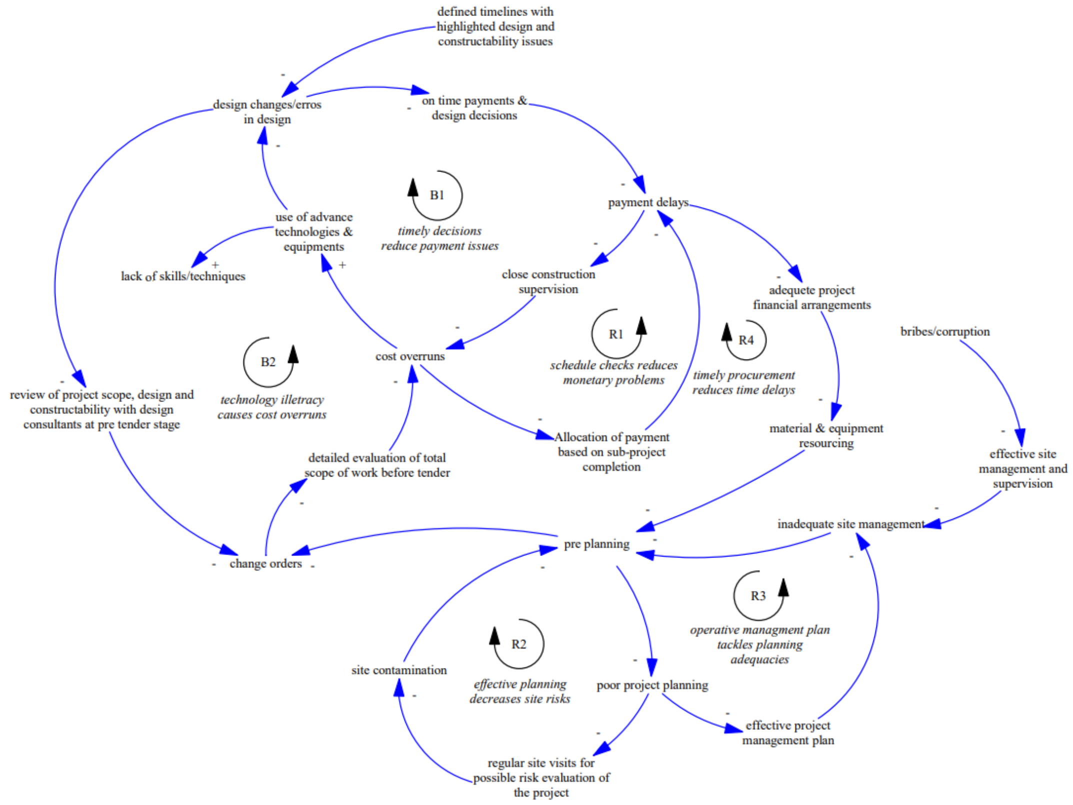


*Figure 4.1: Causal Loop Diagrams*

## 4.2. Reinforcing loop R1 (Schedule checks reduces monetary problems):

It implies that the continuous supervision of construction works ensures that the project is in accordance with the contract documents, the fewer cost overruns there will be. The more the project is divided into sub- categories, the less the payment delays will be, therefore, reducing the monetary problems.

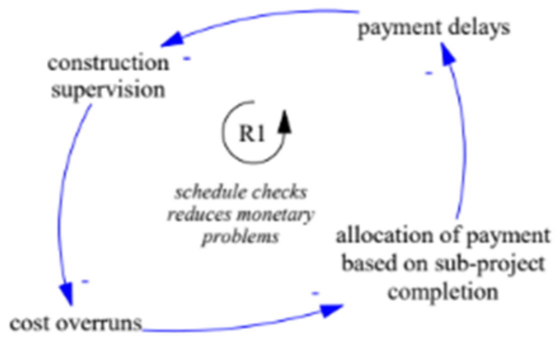


*Figure 4.2: Reinforcing loop R1*

### 4.3. Reinforcing loop R2 (Effective planning decreases site risks):

It implies that more effective pre planning of the project is done, the less the site risks will occur. The more frequent site visits for possible risks evaluation of the project the less site issues and planning issues there will be.


*Figure 4.3: Reinforcing loop R2*

### 4.4. Reinforcing loop R3 (Operative Management plan tackles planning adequacies):

It indicates that a good operative management plan at pre planning stages reduces the planning and management adequacies during the project. Hence, more effective project management plan, the less site management issues.


*Figure 4.4: Reinforcing loop R3*

### 4.5. Reinforcing loop R4 (Timely procurement reduces time delays):

R4 indicates that having adequate financial arrangements and with pre project planning the risk of material and equipment resourcing can be minimized. Pre project planning can decrease change orders and with detailed evaluation the cost overruns and change orders can be reduced.

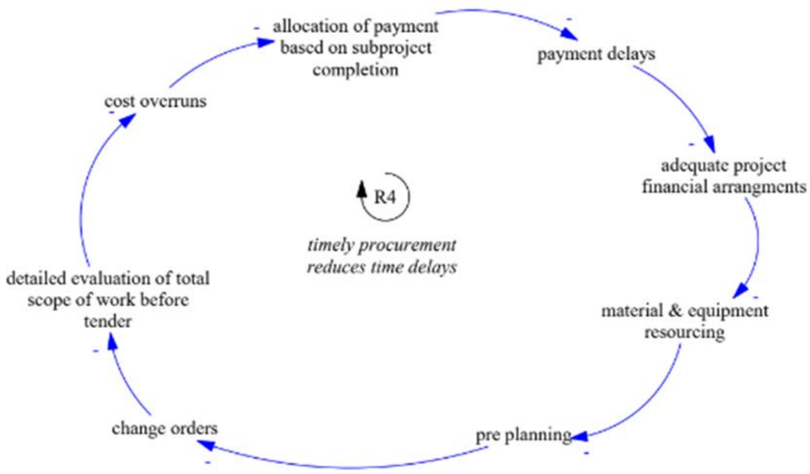


*Figure 4.5: Reinforcing loop R4*

### 4.6. Balancing loop B2 (Technology illetracy causes cost overruns):

B1 loops indicates that the detailed review of project scope and constructability by project design consultants before bidding stage can result in less change orders regarding scope of work, thereby, limiting the chances of cost overruns. The identified equipment for the execution of project such as the machinery for pre-fabricated parts can reduce the clashes arising due to design errors. Although the use of advance equipment is to efficiently execute the project, but the lack of required technological expertise in developing countries causes cost overruns. This is because most of the expensive equipment bought for better execution is not used by workers and thus the purchasing cost goes into sunk costs.

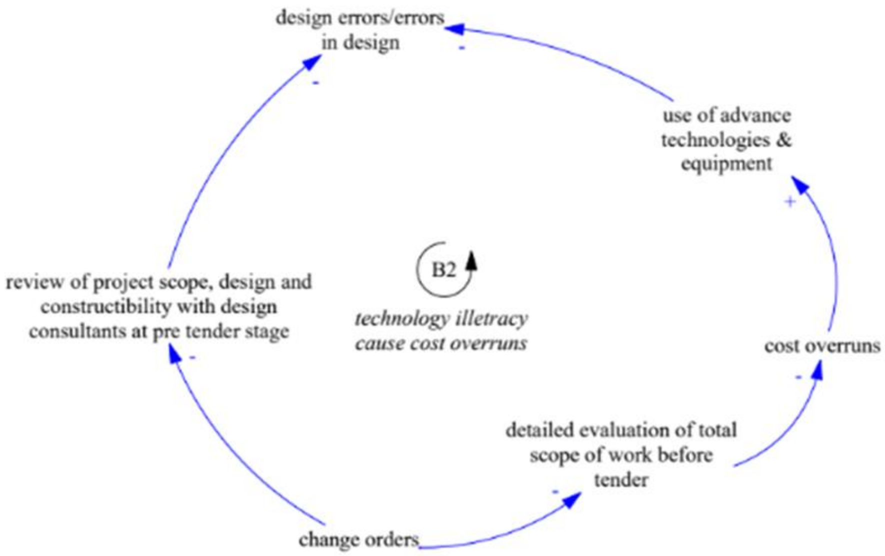


*Figure 4.6: Balancing loop B1*

### 4.7. Balancing loop B1 (Timely decisions reduces payment issues):

It indicates that on time payments and design decisions can decrease the payment delays. The continuous supervision of project can decrease payments delays as well as the cost overruns that occurs during construction. It also indicates the increase in cost overruns due to usage of advance equipment and technology but a decrease in design errors.

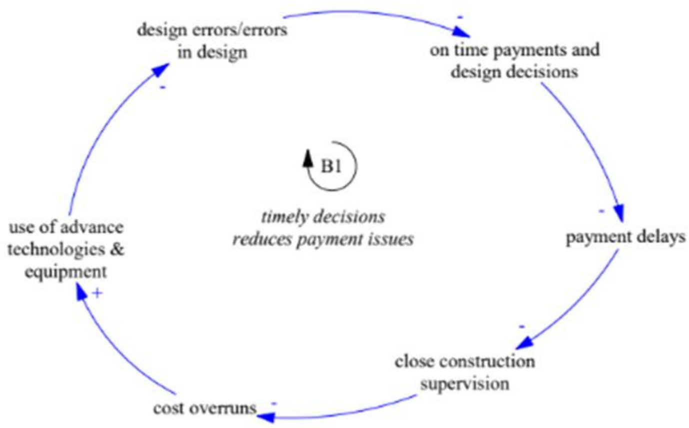


*Figure 4.7: Balancing loop B2*

# Chapter 5

# Conclusion

## 5.1. Discussion

The causal loop diagram reflects the holistic view of complex risk components interacting with its mitigation strategies that can be applied during the construction of highways. The CLD is developed to show the impact of mitigation strategies on risks as the risks are complex, it is necessary to show the interconnectivity of components in a whole system for better understanding. The most critical risk factors that effects a project are lack of skills/techniques, cost overruns, design errors, change orders, poor project planning, bribes, inadequate site management, site contamination, payment delays and material and equipment resourcing. The best mitigation strategies to tackle these risks are detailed evaluation of total scope of work, review of design, scope and constructability with design consultants at pre tender stage, pre project planning, effective project management plan, effective site management and supervision, on time payments and design decisions, allocation of payment based on sub-project completion, close construction supervision, use of advanced technology and equipment and regular site visits for possible risk evaluation of the project. As there are multiple stakeholders involved in project like client, consultants, contractors, and sub-contractors, therefore, it creates a complex relationship that needs to be addressed through systems thinking approach.

Skills are the necessary abilities that can be adequatly applied in a specific condition for a specific purpose, and a lack of skill occurs when an organistion is unable or have difficulty filling vacancies for a specific work, or specialized skill are needed for that specific work, at current levels of salary and working conditions, and location. Shortages in a field are often for skilled and experienced people, as well as relatively low overall unemployment. A job post may be designated as having a shortage even if it does not have a scarcity in all specialties and may only have a shortfall in certain geographical locations.Changes in technology that result in new processes and skill needs sometimes lag behind retraining. When there is an adequate supply of competent workers, but companies are still unable to attract and recruit sufficient acceptable personnel, this is due to industry, profession, or employer characteristics such as comparatively low salary, bad working conditions, unpleasant working hours, negative image of the industry, unsuitable location, inefficient recruiting, incorrect advertising, and so on. Skill shortage lists often exclude skills that need only a short length of training or experience to learn. The risks caused by the skills shortage must be identified, and methods for risk management must be developed in collaboration with the whole construction sector.

Starting with the client and working down the supply chain with consultants, contractors, suppliers, and institutions, the industry must stand up and be counted collectively. The mystery must be removed from the sector, and we must educate what is relevant to knowledge and comprehension of how construction works, and facilities operate. Instead of a magic wand, an innovative strategy is required. As an industry, we must accept responsibility for our skill shortages and work together to find acceptable solutions. We must avoid the rising threat of increasing expenses, deteriorating quality, and greater on-site accidents. Skills scarcity should not be viewed as an issue; nonetheless, in a solution-oriented sector, we are concerned with finding answers. We must continue to address the issue and not wait until it is too late.

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