School of Design and Built Environment

# Valuation of risk and complexity attributes causing delays in Australian Transport infrastructure projects for optimal contingency Estimation

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# Chapter 1: Introduction

## 1.1 Research Background

Owners (especially government owners), project managers, and contractors often find themselves at odds following the owner's decision to build due to misunderstandings and tensions caused by cost overruns. Cost overruns are more often than people would think, even though it is easy to convince yourself that both are equally possible. This is especially problematic for highway buildings, where huge cost overruns have become the norm for many projects. Average over the previous seventy years, the real cost of building significant transportation infrastructure in the United States is 28% greater than the initial estimates. Similarly, studies suggest that highway projects in Australia (especially in Queensland) often experience major cost overruns over quite extended periods. Ten percent of projects with budgets exceeding $1 million (AUD), according to the Roads Implementation Program 2004-05 Reports (RIP) from the Queensland Department of Main Roads (2005), had overruns of over 10 percent on scheduled estimates (Love, 2015).

From the perspective of the owner, highway project cost overruns may have a significant effect on program budgeting. According to the findings of one research, highway organizations must devote significant resources to determining the best course of action for the development of highways in the future. The public, the press, and legislators all take swift action if there is a change to the declared building program, which lays out how highway monies are to be spent over time (Islam, 2021). Highway agencies lose credibility and waste effort justifying deviating from the official schedule when this happens. However, a highway organization's reputation may be improved if it provides accurate program estimates, particularly during the decision-to-build phase.

Furthermore, the amount of project risk contingency in estimates greatly affects the financial consequences for project owners. An excessive amount of contingency may have negative consequences, such as encouraging wasteful spending, making the project unfeasible and leading to its cancellation, or tying up resources that might be used for other endeavors. However, if the allocation is too little, it might lead to an unrealistic financial situation and poor performance. Due to the widespread acceptance of uncertainties in the public sector, budget submissions may often exclude cushions for unforeseen challenges, making it impossible to properly plan for the potential for failure (Ammar, 2022).

Though research linking owner risks in highway construction to actual final costs is expected to provide useful and straightforward applications to estimate techniques, very little has been done in this area. While models have been developed to predict the final cost of competitively bid highway construction projects using only the low bid as input (using techniques such as simple linear regression), little work has been done to identify the risk factors of specific highway project types and their relationship to budget cost overrun. In addition, there is a paucity of studies that examine the relationship between the different types of highway projects and the risks faced by owners, and the amount of money such projects end up costing in the end. By pinpointing problem areas and incorporating systems into program budgeting methods, owners may generate more accurate project budget estimates by addressing the root causes of persistent cost overruns. Project cost fluctuation or cost expansion is the consequence of several interconnected variables, all of which carry some degree of uncertainty (Antunes, 2015). Any cost-estimating system may be made better by identifying the root causes of building cost overruns and focusing on those areas.

A study aims to address the gaps and flaws in the existing literature by analyzing the potential causes of highway project cost overruns. In addition to replacing the existing ad hoc methods, this article intends to provide a more clear risk contingency allocation framework for comprehensive highway projects. There are two main goals. The first step is to examine past causes that contributed to project cost overruns and project characteristics to see whether doing so will result in more precise owner budget projections in the future by allowing for recognized cost overrun drivers (Andersson, 2017).

When the actual result of an event or action will most likely depart from the estimated or anticipated value, people say that the outcome is risky or uncertain. The construction industry is especially vulnerable because of the numerous unknowns that arise during project execution and have a direct and dramatic impact on the timeline and budget. Projects awarded based on competitive bidding add to the inherent economic risk associated with the construction industry. “Most highway infrastructure projects in the United States, Australia, Canada, New Zealand, Sweden, the United Kingdom, and the United States use a delivery method called the "traditional model," sometimes known as the "Design-BidBuild" method (DBB) (Islam, 2019). This implies that a procurement contract is a first bid for the design/engineering services, and then a separate contract is submitted for the actual construction or physical works that will be based on those services. The conventional DBB approach has been criticized for its lack of innovation, long completion timeframes, and excessive cost overruns”. Since the owner is responsible for most of the costs and hazards associated with the design and construction processes, there need to be improved procedures in place to guarantee the owner's satisfaction, speedy project completion, and economical answers.

The sums spent on highway building are affected by several different variables. Researchers in Newfoundland discovered that the prices of individual contracts varied widely depending on the time of year, geographical region, project type, length of the contract, and total contract value. Besides the cost of raw materials, another study found that the annual volume of contracts put up to bid (the "bid volume") also has a significant role in determining project budgets. Primary causes of cost overruns are hypothesized to be poor project management due to “the control of internal resources, poor labor relations, and low productivity, unrealistic estimates, the technical complexity of the project, and external risk (due to changes in the scope of a project and changes in the legal, economic, and technological environments) (because of the uncertainties involved)” (Love, 2018). The quality of the engineering designs used in a project may have a significant impact on the total price tag, and vice versa if the results from those designs are less than ideal.

Overruns in both budget and time are common in transportation infrastructure projects. Examples that have received extensive coverage in both popular media and scholarly journals include Boston's Big Dig, the Channel Tunnel, and the Jubilee Extension Line. Despite the complexity and size of these initiatives, even moderately sized ones might see significant cost increases. It has been reported that “in the US state of Massachusetts, over 50% of road and bridge construction projects went over budget and 33% were not completed on time. When looking at projects with a contract value of more than AU$1m, the Queensland Department of Main Roads (2005) discovered that 10% had gone over budget by that amount”. Only 48% of the reviewed Australian infrastructure projects were completed on time, under budget, and to specifications (Santoso, 2020). The potential negative impact on economies, the generation of widespread taxpayer anxiety, and the destabilization of a government's political position make infrastructure project cost overruns a constant source of concern for leaders throughout the world.

It is common practice to include design and cost contingencies to lessen the blow of any unexpected cost increases or delays. However, it seems that this kind of backup plan does not go far enough in protecting you against budget and time overruns. The cost certainty that government customers need has not been achieved by even the use of "reference class forecasting," which sets a project in a statistical range of outcomes for specified project categories. Edinburgh's Tram and Airport Rail Link in Scotland is a prime example since its delivery has been plagued by cost and time overruns. Project costs were originally expected to be oE320 million. After taking into account “all of the distributional data, the reference class projection arrived at an 80th percentile value of oE' 400 million based on a reference class of comparable rail projects. The estimated final cost of the unfinished project is above $1 billion (Derakhshanfar, 2021). Contractual claims and disagreements with the infrastructure building contractor over changes to the specification, inadequate design, and substandard design work have greatly increased the project's cost and pushed back its completion date (Auditor General for Scotland and the Accounts Commission, 2011)".

From the time a decision is made to construct until contracts are granted, there will be significant fluctuations in both cost and schedule estimates. A project's initial feasibility budget is often adjusted when new details about the project, and the client's needs, become clear throughout the design phase. In addition, it is possible that design flaws and omissions may not be uncovered until the building has already begun, leading to costly rework. Data analysis shows that rework is the leading cause of schedule and budget overruns in the building and engineering industries (Lee, 2017).

There is an unlimited variety of possible outcomes for 'random continuous variables' like rework, budget, and time overruns. To estimate the likelihood of budget overruns, the Normal distribution (sometimes known as the Gaussian distribution) PDF has traditionally been utilized because of its symmetry at the mean, the Normal distribution is inappropriate for modeling left- or right-skewed data. It is plausible that heavy-tailed distribution models, such as the Generalized Logistic or the Cauchy, are the most appropriate for describing cost-overrun data, even if the data itself is symmetric. With so many possible statistical distributions, trying to fit an empirical distribution to data may be challenging. An erroneous choice of statistical distribution may lead to misleading probabilities, which in turn can have a severe impact on decision-making and, ultimately, results (Kim, 2018).

Budget increases, cost increases, and cost growth are all synonyms for the dreaded cost overrun. A cost overrun should be differentiated from "cost escalation," which describes an expected increase in a projected cost due to variables like inflation. In construction, a cost overrun occurs when actual expenses exceed budget projections. The potential cost overrun is measured against the original budget established at the 'decision to construct.' A project's final construction costs are its total recorded expenses. The difference between the contract value (i.e., at the time of award) and the actual construction value (i.e., at the time of practical completion) has been proposed as an alternate definition and reference point for establishing a cost-overrun in a study (Chapman, 2016). Cost-overrun percentages stated in the normative literature vary greatly due to the contradiction between the definitions offered.

While several studies have tried to put a dollar value on budget overruns, fewer have looked at the likelihood of time overruns. Overrunning a timeline may be referred to as several different things, including delays, schedule growth, or time overruns. When the time frame agreed upon before construction began is exceeded, it is called a schedule overrun and was not included in the original contract price. There is a lot of literature on what leads to budget and time overruns. Projects still tend to incur cost and schedule increases, as well as contractual claims and conflicts, notwithstanding the abundance of gathered information concerning overrun causes (Love, 2016).

Since changes in project scope are inevitable in the building and engineering industries, contractors often include a construction contingency in their contracts. However, what is not taken into consideration are the mistakes and omissions in the design and construction that necessitate redoing the job. Rework is the "unnecessary effort to redo a process or activity that was incorrectly implemented the first time," as described by the Oxford English Dictionary. Errors, alterations, and omissions in the design phase usually lead to rework during construction, sometimes after a considerable delay. Strategic choices made by senior management or key decision-makers, which provide the circumstances for the adoption of incorrect project structures, procedures, practices, and technology, are identified as the root causes of rework (Deep, 2022).

There is a widespread problem with transportation infrastructure projects being over budget and behind time. Empirical research shows that cost overruns are a major cause of dissatisfaction among project stakeholders. For these reasons, budget overruns are a major source of worry for governments across the globe. They may have a detrimental effect on an economy, provoke widespread disquiet among taxpayers, and undermine the legitimacy of the ruling party in power. An example of a project that went over budget and then is Boston's Big Dig, also known as the Central Artery project. Initially estimated to cost $2.6 billion, the final price tag was $14.6 billion and the project ran seven years late (Islam, 2022).

Transport-related research has often solely focused on identifying the source and 'cost' of overruns that develop in road, rail, bridge, and tunnel construction, despite the monetary and social ramifications of late projects. Thirty percent of all road and bridge projects end up being late, and cost overruns are another common issue. Overrunning deadlines may have a devastating effect on a project's productivity and the team's bottom line. As a result, they need to be taken into account while analyzing problems with project efficiency. A timetable slippage in the procurement of a toll road, for instance, would reduce income, which would be unacceptable to financial markets, which value precision, predictability, and high returns on investment. It is important to note that cost and time overruns are not always exclusive of one another. The two conditions—cost overruns and on-time completion—are not mutually exclusive (Melaku Belay, 2021). While much of the literature has focused on cost and time overruns, it is important to note that broader evaluation techniques (such as whole-life costing and cost-benefit analysis) can be used to determine whether the additional cost can result in greater benefits (value), or whether greater initial investment in capital costs can reduce life-cycle costs.

There is a large corpus of research that looks at what goes wrong during the building and engineering management of transportation infrastructure, and why it goes over budget and behind time. However, sufficient knowledge of, or insights into, the underlying determinants of late delivery and cost overruns, especially in the transportation industry, have not typically resulted from this effort. As an alternative to an "inside view," which emphasizes meticulously planned activity, this literature argues that an "outside view" (i.e., dependence on precedent) is necessary to understand the overrun phenomena. There is an argument that optimism bias and purposeful misrepresentation lead to erroneous cost projections when just one perspective is considered (Amadi, 2017).

Stakeholders' tendency to overstate advantages and underestimate costs are related to optimism bias. Strategic misrepresentation, on the other hand, is when the costs and dangers of a project are intentionally understated for strategic, economic, or political reasons. Due to the belief that "results are determined solely by their actions and those of their organizations," optimism bias and strategic distortion in cost estimating lead to an underestimation of the risks and uncertainties associated with the predictions. Overruns in both time and money might result from poor planning, a deterioration in relations between the customer and contractors, and implementation issues (Välilä, 2020). Yet, this may be oversimplifying a subject that calls for more investigation. Overruns may have both positive and negative effects, and those who take either the "inside" or "outside" stance on this topic have valid arguments in support of their positions.

Overruns in transport infrastructure projects are explored in terms of their quantification and how project features (size and kind) impact their importance, before a fair explanation of their causes is provided. Some scholars, due to their prominence in the planning and transportation literature, have their body of work dissected in detail. Construction and engineering management literature often rely on data collected at the time the project was being completed, so it is important to keep this in mind. This is because the political climate, economic climate, technological climate, and construction methods used on each project were all similar at the time (Eshun, 2021).

When it comes to a country's GDP, the construction industry plays a pivotal role, and the transportation sector plays a key role within that. Highways, important intercity roads, toll roads, and other key roadways, such as bridges, ducts, and tunnels, are all part of the road network. These are very important in terms of the advancement of society and the economy, as well as the spread of population and the growth of cities and towns, and the improvement of living conditions in general. The growth of a road network has far-reaching consequences for many spheres, including economic expansion, the attraction of foreign investment, and the volume of both local and international tourists. All construction projects have many of the same dangers that might lead to cost overruns in road building. However, their effects on road projects vary according to a horizontal extent, design, mode of execution, and influence on neighboring facilities (Tepeli, 2021). Projects to build a road network are more likely to have cost overruns than other types of construction work because of their high initial investment, massive size, extended duration, and unique site characteristics. Everything from ports and airports to industries and institutions is interconnected by the country's road network.

A cost overrun is an amount by which actual costs exceed budgeted ones, as assessed in the local currency at a constant price and relative to a standard benchmark. A cost overrun is a difference between the planned budget and the actual costs of a building project. Internal variables including project size, length, complexity, location, design, and cost estimating technique, as well as external issues like inflation, taxes, and regulations, may all contribute to budget overruns. Developing a country's gross domestic product via a well-connected system of roads is a long-term investment that pays off. As a result, the nation would benefit monetarily from increased efficiency in road network building achieved via the use of cost-effective alternatives (Yuan, 2020).

Roughly 90% of transportation network projects have cost overruns due to higher-than-expected final expenses. Cost overruns have been a common problem for many high-profile transportation projects across the globe. The Central Artery/Tunnel in Boston, also referred to as the "Big Dig," was the most costly roadway project in the United States. Starting in 1991, its development lasted until 2007, resulting in an 11 billion dollar, or 275%, cost overrun.

Based on the results of this research, it is clear that infrastructure projects, such as road construction in Norway, road construction in the United States, and transport infrastructure in Australia, often experience major cost overruns. Over 250 transportation projects across 15 nations were included in a study of budget overruns. According to another research, there is an 86% chance that the final expenditures would exceed the projected ones for any given project. The percentage of overrun costs relative to the original estimate is highest (45%) for rail projects and lowest (20%) for road projects. The cost overruns for European projects were less than their North American counterparts (Abeysekara, 2021). Numerous studies have studied project cost performance, although almost all of them have focused on industrialized nations. The cost overrun results from projects in the United States, Australia, and Europe that could not be transferred to Africa because of the vast differences in culture and government. Investment in the expansion of the nation's road network is crucial to economic development because of the sector-wide and overall benefits it provides (Ayub, 2019).

Some researchers analyzed data from 258 projects with a combined value of US $9 billion to identify the factors that lead to cost overruns in transportation infrastructure projects. They were concerned with how long projects took and how big they were. Cost overruns were shown to (a) be significantly influenced by the length of the implementation stage, and (b) grow by an average of 4.64% every year from the time the decision to construct is made until operations commence. They also found that bigger projects, especially those involving bridges and tunnels, are more likely to have cost overruns (Makovšek, 2018). The primary causes of budget overruns for Australian roadway projects have been determined. Changes in design, tender prices, quality standards, unanticipated circumstances, and the need to replace materials that are not up to par are all examples of these types of variables. Findings from a statistical analysis of road building expenditures in Norway during 1992–1995 confirmed a positive correlation between these two variables. The results showed that there was a difference between the budgeted amount and the total amount spent, by a mean of 7.9%. Design revisions, latent conditions, permits, and regulations were shown to be the most prevalent causes of cost overruns for Canadian road construction (Al Nahyan, 2019).

Budget overruns, delays, and public opposition are typical in transportation infrastructure projects. In the Netherlands, for instance, it typically takes 11 years for a decision to be made about a new piece of infrastructure. Nevertheless, budget overruns of 40% are not uncommon and may even approach 80% in extreme cases. The efficacy, efficiency, and legality of infrastructure development have been hotly disputed in the Netherlands since the 1970s, therefore this conclusion is not new. European research from a decade earlier found comparable findings (Osei-Kyei, 2022). This ongoing debate shows how difficult it is to find a rapid solution to the problem of infrastructure development's inherent complexity.

The failure of such initiatives has prompted several investigations on the nature of infrastructure development's difficulties, as well as potential remedies to these issues. To better understand why projects work the way they do, we need more and better infrastructure development assessment, as emphasized by the Netherlands Institute for Transport Policy

Analysis (KiM). In contrast, determining "what" rather than "that" is the root cause is a more complex task. In other words, it is far simpler to see trends in things like cost overruns and time delays than it is to determine the causes of such problems. So far, most project evaluations have used a "before and after" approach, ignoring the impact that local circumstances have on the evolution of infrastructure projects. Since the complexity of policy systems is not adequately taken into account by the most popular evaluation methods, they hinder policy learning (Amoah, 2020). In a similar vein, researchers noted that present assessments, in addition to being conducted on a sporadic basis, also suffered from methodological inadequacies that stem from a discordance between how infrastructure development projects are conceptualized and the evaluation techniques used. That is why it is important to have assessment methods that can properly assess the complexities of infrastructure projects.

Although it is important for evaluation approaches to include the context of projects to account for the impact of unique circumstances, this does not need an exclusive emphasis on single-N (population) in-depth analyses. After all, the purpose of assessment is to enhance infrastructure-building practice, which necessitates generalization; analyzing repeating patterns demands looking at more than just one situation or example (Ganbat, 2020). As will be demonstrated in the next section, there seems to be tension between the need for specificity in context and broad applicability. However, when comparing cases across contexts, the current standard approaches typically fail to account for contextual factors.

To describe a project in the realm of physical infrastructure as complicated is to imply that it will be difficult to complete. Complexity, however, is not only a statement about the time and work required to finish a job; nor is it a universal truth. In reality, it is a complex idea with many facets. The word "infrastructure development" refers to the process of making changes to an already existing system. “It is the relationship between three-dimensional units (such as rooms, buildings, and assemblages of buildings), two-dimensional units (such as the layout or distribution of the three-dimensional units across a given space), and linear units that largely determines the layout in a built environment, for example (such as transport networks linking the three-dimensional units)”. Together, they provide a syntax that is specific to that area (Yassien, 2020). Some features are situation-specific, such as challenging ground conditions that would make building a road to a future suburb prohibitively costly, while others are universal in instances of infrastructure development (such as suburbanization and subsequent commuter travel patterns). This means that a developer working on infrastructure who wants to make a change in a particular scenario must deal with a custom-built syntax that incorporates both global and locale-specific factors.

The local built environment is shaped through time by the interplay between generic and specific features, making it one of a kind in its particularity while retaining certain recognizable traits. Considering the people who make up a constructed area, including those who live there, work there, commute there, and visit there for leisure, makes planning for that region's infrastructure even more difficult. Properties of a subunit (such as a street) mirror those of the whole (such as a district), but not to the degree that both levels are perfect replicas of one another. In this way, the local constructed order is a product of the interplay between universal and localized aspects of the physical and social environment (De Marco, 2021). As a result, those responsible for building the necessary infrastructure must address a region that is distinct from others while sharing many characteristics in common. Developing infrastructure in urban settings, therefore, is not as simple as applying universal planning, construction, or management standards to a given place; rather, they must be tailored to the specifics of the location. To know how a project should be carried out and what causes particular results, it is crucial to study the unique combination of local variables and generic trends that characterize urban regions.

Several factors are highlighted by this viewpoint. To begin, infrastructure is built in response to a unique combination of local circumstances and general patterns that is unique to each site. Two, it shows that we know very little about the causal links between site-specific variables and generic changes outside of that particular time and location. Therefore, by definition, case-specific causal interactions are those that are known just for a certain location. True, due to their one-of-a-kind character, created systems imply that other systems are formed differently, even though their emergent order may be comparable (Rui, 2018). To conclude, every developed place has an emergent aspect, which suggests it has evolved through time. In other words, it is a consequence of preceding alterations and occurrences, which are path-dependent. When these three ideas are combined, the piece reveals an appreciation for urban environments as intricate networks.

### 1.2 Research problem

Supply chains in all industries would collapse without the Logistics Sector. Transportation providers are vital to the success of businesses in every sector, from healthcare and tourism to manufacturing and industry. People say traffic jams will always be an issue, but others disagree. The Brookings Institution has observed that congestion is a direct result of individuals attempting to go to work and school at the same time. That is not a terrible thing in and of itself. People working and studying together, simultaneously, is likely beneficial to our society as a whole. Traffic will likely grow as a result. Despite popular belief, traffic delays are likely preventable in most urban areas, particularly those with a dense metropolitan population. Certain urban areas indeed handle traffic more efficiently than others. Meanwhile, the cost of living is quite high in most major urban areas. For many previously disadvantaged groups, this further pushes members to the outskirts of cities, increasing inequality. Every year, the typical American wastes 17 hours looking for a parking spot. Some cities, like Washington, DC, San Francisco, and Los Angeles, have far higher rates. Drivers are not the only ones negatively affected by parking issues; businesses suffer as well. It is impossible to do grocery shopping, see a doctor, or go to work on time if vehicles can not find a place to park. Local governments have expressed frustration with this location, and it may contribute to pollution levels as motorists sit idly waiting for a parking place.

Large fleet operation expenses are on the increase. Since fuel accounts for about 60% of a fleet's budget, price increases in this area are likely the primary cause. Nonetheless, the price of gas is hardly the only concern. The price of labor and the cost of general upkeep are both rising. Necessities like new tires and auto components have also gone up in price. Sadly, the customer ends up footing the bill for these charges. Fleet owners are less inclined to develop their company in ways that may improve the city's transportation because of the expensive expense of doing so. While irritating, transportation issues may be solved, particularly by resourceful urban planners. The digital tools available via Remix may be used to assist cities in developing practical public transportation networks that meet the actual, measurable demands of the city's population.

### 1.3 Research questions and objectives

The main question of the study is to examine the valuation of risk and complexity attributes causing delays in Australian Transport infrastructure projects for optimal contingency Estimation. In addition to this the study also focuses on:

- What are the risk and complexity factors causing delays in Urban transport projects in Australia?
- What are the risk and complexity factors based on risk criticality in terms of likelihood and magnitude of impact?
- What are latent variables (factors) among these risk and complexity attributes that are causing delays?

- What are the predictors in terms of risk and complexity attributes Urban Transport Infrastructure projects towards overall project delay?

Research objectives

The main aim of the study is to examine the valuation of risk and complexity attributes causing delays in Australian Transport infrastructure projects for optimal contingency Estimation. In addition to this the study also focuses on:

- Identify the risk and complexity factors causing delays in Urban transport projects in Australia.
- Rank the risk and complexity factors based on risk criticality in terms of likelihood and magnitude of impact.
- Determine latent variables (factors) among these risk and complexity attributes that are causing delays.
- Determine the predictors in terms of risk and complexity attributes in Urban Transport Infrastructure projects toward overall project delay?

**1.4 Contribution of the study**

The main contribution of the study it examines the risk and complexity factors causing delays in Urban transport projects in Australia and the risk and complexity factors based on risk criticality in terms of likelihood and magnitude of impact. The study is also useful in the future as it focuses on latent variables (factors) among these risk and complexity attributes that are causing delays. Lastly, it focuses on the predictors in terms of risk and complexity attributes Urban Transport Infrastructure projects toward overall project delay.

**1.5 Delimitation and Limitations**

While doing the research the study research faced some research limitations in the study. The time allotted to complete the task was not enough for the researcher hence it created to time limitation. Secondly, the researcher faced knowledge limitations as there is limited data available on the internet.

## Chapter 2: Literature Review

### 2.1 Introduction

All across the world, transportation projects have a tendency to go above their original budget and contract value. Construction prices can end up being greater than anticipated because of inaccurate contingency cost estimates. According to the findings, it seems that the methods utilized to prepare for the possibility of cost overruns in transportation projects have been unsuccessful. Both deterministic systems like expert-judgment and probabilistic ones like the Reference Class Forecasting (RCF) have ignored the difference between risk and uncertainty in reality. Often, the phrase "contingency" is used to denote monetary outlay, typically as a percentage of the overall budget. During the planning phase of a project, customers and contractors may often put aside money above and above the initial budget to cover any unanticipated expenses. In this essay, the authors focus exclusively on the client's cost contingency. To account for things like estimate-related uncertainty and the possibility of making a few small mistakes or overlooking certain information, this sum has been set aside. Nevertheless, a cost contingency is not meant to cover things like sudden changes in the project's scope, strikes by workers, bad weather, rising costs (such those for materials and labor), or fluctuations in the value of the dollar.

There are two settings that spring to mind when thinking about risk and uncertainty. How do people decide in risky situations when people know all the available options, potential outcomes, and likelihoods? To put it another way: (a) you will need to use your statistical brain. When making choices in conditions of ambiguity, however, it is important to think about what to do when part of the available options, effects, and probabilities are not known. Simply said, the odds of a danger can be calculated in advance, however the same cannot be said for uncertainty. This means that people may enhance the cost performance of transport projects "by managing contingency funds in a more cost-effective way," by properly estimating risk and better tolerating uncertainty.

Researchers examine the prevalent methods for estimating the cost overrun for a transportation project against this background. Researchers are aware that several articles have been written critiquing and proposing other approaches to cost contingency planning. Unfortunately, the methodologies that have been widely disseminated lack a decision-making theory as a foundation, with the exception of RCF. Due to this theoretical deficiency, they are unable to appropriately factor in risk and uncertainty while making judgments about the transportation project's budget.

**2.2 Overruns in transportation infrastructure projects**

According to Odeck, (2021) in order to keep up with the demands of a rising population and maintain a competitive edge in a global economy, it is necessary to invest in various modes of transportation. If a country wants to take advantage of the development and investment opportunities presented by demographic shifts and expanding global demand for its goods and services, it must spend more in its transportation infrastructure.

According to Keizur, (2021) a cost overrun is the percentage difference between the ultimate cost of the project and the estimate established at full funds authorization after accounting for inflation. Overruns in this case are defined as the difference between the permitted original project cost and the actual final expenses spent, after taking into account expenditures owing to escalation clauses. In spite of a great deal of study, budget overruns continue to be a common issue. As it is currently impossible to verify whether or not a collection of events or propositions can be verified and whether or not their causal links can be recognized as true, preventing cost overruns is impossible without first solving this problem. This article provides a short overview of the relevant literature and argues for the necessity to create a probabilistic theory of cost overrun causation so that effective measures may be created to guarantee the timely and successful delivery of transportation projects.

Odeck, (2019) pointed out that the overruns in both budget and time frame are common in transportation infrastructure projects. Boston's Big Dig, the Channel Tunnel, and the Jubilee Extension Line are all instances that have received extensive coverage in the media and scholarly publications. Such projects are complicated and large in scale, but even smaller projects may have significant cost overruns. Governments throughout the globe worry about infrastructure project overruns because they may have a detrimental effect on the economy, generate substantial uneasiness among taxpayers, and destabilize a government's political position.

According to Kermanshachi, (2020) it is common practice to include design and cost contingencies in order to soften the blow of, or even avoid, cost overruns. Nevertheless, it seems that such backup plans do not provide enough safety net against budget and time overruns. “The cost certainty that Government customers seek has not been achieved by the use of "reference class forecasting," which sets a project in a statistical range of outcomes for specified project categories. One example is the Edinburgh Tram and Airport Rail Connection in Scotland, both of which encountered delivery delays and cost overruns”. The project's original budget was $320 million, and a buffer of oE40 million was included in. Upon consideration of all distributional data, a reference class estimate based on comparable rail projects showed an 80th percentile value of oE' 400 million (such as Docklands Light Rail). It has been estimated that more than oE' 1 billion will be needed to finish this unfinished project. Overruns in both budget and time have been caused by contractual claims and conflicts with the infrastructure construction contractor due to changes in specification, inadequate design, and poor design work (Auditor General for Scotland and the Accounts Commission, 2011).

Love, (2019) analyzed that from the time a decision is made to construct until contracts are granted, there will be significant fluctuations in both cost and time estimates. The budget determined at the feasibility stage is adjusted when new information about the project's needs, especially those of a customer, becomes available throughout the design phase. It is also possible that design flaws or omissions may not be uncovered until construction has already begun, leading to expensive redesign. Rework is the single largest cause of cost and schedule overruns in building and engineering projects, according to empirical studies.

Pham, (2020) stated that in addition to "budget increase," "cost increase," and "cost growth," the phrase "cost overrun" is often used. Nevertheless, it is important to differentiate a cost overrun from "cost escalation," which describes an expected increase in a planned cost owing to variables like inflation. When building expenses exceed initial estimates, this is known as a cost overrun. To estimate any potential cost increases, the budget at the 'determination to construct' stage is employed here. True construction expenses are those that have been tallied and accounted for as of the project's conclusion.

Abeysekara, (2021) analyzed that although several studies have tried to put a dollar value on budget overruns, fewer have looked at the likelihood of time overruns. Overruns in time or resources are sometimes known as delays, schedule growth, or time overruns. For a project to be considered behind schedule, the time frame agreed upon prior to the start of construction has to be extended beyond the initial contract duration given at contract award. Reasons for budget and time overruns have been studied and analyzed at length. There has been a lot of research on the causes of cost and schedule overruns, yet projects still often face these issues, along with contractual claims and disputes.

According to Kermanshachi, (2019) as changes in project scope are inevitable in the building and engineering industries, contractors often include a construction contingency in their contracts. But, without taking into consideration design and construction mistakes and omissions that need more labor. Rework is the "unnecessary effort to redoing a process or activity that was incorrectly implemented the first time," according to the Oxford English Dictionary. Common causes of rework include last-minute design tweaks, alterations, and omissions that only become apparent during construction. Strategic choices made by senior management or key decision-makers, the report claims, are the root causes of rework because they create the environment in which ineffective project structures, procedures, practices, and technologies are adopted.

### 2.3 Landscape of overruns in transport infrastructure projects

According to Odeck,(2021) transportation infrastructure projects often experience delays and cost overruns. Several case studies have shown that cost overruns are a major reason why stakeholders are not happy with the final product. Governments throughout the globe worry about cost overruns because they may harm economies, make taxpayers nervous, and undermine the legitimacy of the ruling party in power. The Big Dig, also known as Boston's Central Artery project, is a well-known example of a project that went over budget. Originally estimated to cost $2.6 billion, the project ended up costing $14.6 billion, seven years later than expected.

Keizur, (2021) stated that “the overruns in road, rail, bridge, and tunnel construction are often the main focus of transport-related research, despite the financial and societal consequences of late projects”. In addition, schedule overruns are common, causing delays in the completion of 30% of road and bridge projects. Overrunning deadlines may have a devastating effect on a project's productivity and the team's bottom line. These should, therefore, be taken into account while analyzing problems with project performance. Capital markets demand precision, reliability, and high returns on investment, thus a timetable overrun in the procurement of, say, a toll road via a PPP would be unacceptable. On the other hand, cost and time overruns are not always exclusive of one another. The two conditions—cost overruns and on-time completion—are not mutually exclusive. While much of the literature has focused on the effects of cost and schedule overruns, it is important to note that broader evaluation techniques can be used to determine whether the additional cost can result in greater benefits (value), or whether a greater initial investment in capital costs will result in lower life-cycle costs.

According to Odeck, (2019) the reasons for budget and time overruns in transportation infrastructure's development and engineering management have been the subject of much research. Whilst this research has helped, in general, it has not developed a sufficient knowledge of, or offered insights into, the underlying determinants of late delivery and cost overruns, especially in the transportation industry. There was a consensus in this literature that the overrun phenomena is best explained by taking a "outside view," or learning from past experiences, rather than a "inside view," or acting in accordance with predetermined plans. It is believed that optimism bias and purposeful misrepresentation lead to erroneous cost projections when just one perspective is considered.

Kermanshachi, (2020) analyzed that when stakeholders overestimate the advantages and underestimate the costs, this is known as optimism bias. Strategic misrepresentation, on the other hand, involves intentionally underestimating project costs and hazards for political, economic, or strategic reasons. Due to the belief that "results are determined solely by their own actions and those of their organizations," optimism bias and strategic deception in cost estimating both lead to an underestimation of the risks and uncertainties associated with the predictions. Overruns in both time and money might result from poor planning, strained relations between the client and contractors, and a failure to adequately prepare for the project's execution. Yet, this may be oversimplifying a subject that calls for more investigation. Both the 'inside' and 'outside' perspectives on the root causes and knock-on effects of overruns are supported by valid arguments and evidence.

Pham, (2020) stated that the quantification of overruns and the ways in which project factors (size and kind) impact their importance are examined prior to offering a balanced explanation of overrun causation for transport infrastructure projects. “Particular attention is paid to a few studies that have played a significant influence in the planning and transportation literature. Construction and engineering management literature often incorporates data from the same period of time, so that the politics, economy, technology, and building practices of each project are comparable”.

Abeysekara,(2021) analyzed that a cost overrun may also be referred to as an expenditure overrun, an expense growth, or a budget rise. Nevertheless, it is important to differentiate a cost overrun from cost escalation, which refers to an increase in projected costs above what was originally planned for owing to things like inflation. The term "cost escalation" refers to an increase in projected construction costs that is not attributable to changes in the scope of the project. Nonetheless, a plethora of other explanations for budget overruns have been disseminated. As defined by the study's authors, a cost overrun occurs when the project's final expenses are more than the original estimate was. An overrun in this case is the difference between the approved baseline project cost and the actual final expenses spent, net of any escalation clauses.

Kermanshachi, (2019) pointed out that the economic, political, managerial, and psychological factors all contribute to transportation infrastructure projects being late and over budget, as seen from the outside by the external perspective of project economics. By contrast, what is considered from the inside is limited to the standards for project management established by businesses, academics, and governments. The inside perspective is concerned with technical matters, such as the detection of scope creep, modification orders, poor planning, and missing information in the contract. It has been estimated that change orders are responsible for anywhere from 20% to 50% of delivery delays and expense overruns. However, studies have revealed that the cost to redo a construction project due to mistakes or omissions in the contract documents may be anywhere from 5 to 20 percent of the total contract price. Obviously, projects will be in a better position to accomplish their objectives if change orders and rework are reduced.

According to Chadee, (2021) the scale of change orders and modifications is commonly accepted as a factor in cost overruns in planning and transportation practice. The research, however, reveals that these factors alone may not completely explain for mistakes in predicting and infrastructure delivery. "It is striking that this long standing pattern [of cost overruns], which appears to prevail worldwide, continues unabated despite major improvements in the technical capacity for cost estimation," highlighting this issue and suggesting its causes lie in the realm of politics rather than engineering or accounting. No studies attempting to quantify the influence of politics and optimism bias on overruns have tested the veracity of these anecdotes. The interference of politics is an intractable problem that can not be addressed with methods like RCF alone. As a result, decision-makers in government, business, NGOs, and the community need to be aware of them and, more importantly, must ensure that appropriate project delivery strategies are put in place, externalities are taken into account, and realistic forecasting is made so that expectations for deliverables can be met.

Rokicki, (2022) pointed out that the difficulty of executing transportation infrastructure projects should not be minimized by assuming that cost and schedule overruns can be explained exclusively by an outside perspective. It was found that a more complete picture of cost and time overruns can be gleaned by approaching the problem from multiple angles, including the perspective of those involved in the project as well as those who observe it from the outside; this should also include consideration of the “engineering, management, complexity, geographic, and political factors” that play into each individual project. Policymakers' explicit strategic choices may have a negative effect on the project's governance and delivery approaches. While transactional data suggests that optimism bias and strategic deception do account for a considerable contribution to time and expense overruns of transportation infrastructure projects, evidence implying that these are the only causes for overruns is deceptive.

According to Mahmud, (2020) variations in the normative literature may be traced back to the different starting points utilized to calculate cost increases. Inadequate site studies at the decision-to-build point in time may lead to cost overruns and scope changes in the early phases of a project owing to feedback from stakeholders. As a result, the contract award is proposed as a more reliable benchmark that more closely represents the true cost to build an asset. Cost overruns between the time of the final "go/no-go" decision and when the contract is finally awarded are another area that needs more investigation. Several projects are said to have similar risk profiles for cost overruns, which inspired the creation of RCF, according to the literature on transportation and planning. Again, the evidence is limited because of insufficient numbers of people surveyed and because the data was gathered in an era with different technologies, procurement practices, and governance structures. “As project delivery techniques and teams vary in quality, resources, and composition, and since the behaviors of all dynamic systems are dependent on their initial conditions, it is difficult, if not impossible, to predict a result based on previous experience alone. The knowledge and skills gained by a project team during one endeavor may not be directly applicable to another”.

Al Heet, (2020) analyzed that the current advances in project delivery and technology, based on suggestions offered in several government studies, add momentum to improve the performance of transportation infrastructure projects. BIM has been a focus point for mitigating whole-life-cycle costs because to the utilization of relationship contracting, in particular IPD, and developments in technology. Increased efficiency and improved cost and schedule predictability may result from combining IPD (or variations thereof) with BIM. BIM is being utilized in an increasing number of projects to guarantee budgetary and scheduleary stability. The new field of study in transportation infrastructure research should examine not just optimism bias and strategic deception, but also the ways in which design, construction, and organizational and technical advancements may enhance the efficacy of projects.

### 2.4 Risk Factors Leading To Cost Overrun In The Delivery Of Highway Construction Projects

According to Ammar, (2022) project cost variation after the owner's decision-to-build is a common cause of tension among owners (particularly government owners), project managers, and contractors, and the issue of cost overrun is a global phenomena, especially in the construction sector. In spite of the fact that it is reasonable to assume that both cost overruns and underruns occur at about the same rate, cost overruns actually happen more often. In the highway building industry in particular, this has resulted in huge cost overruns in the past. Average over the previous seventy years, the real cost of building significant transportation infrastructure in the United States is 28% greater than the initial estimates. Similarly, studies have shown that highway projects in Australia (especially in Queensland) often have major cost overruns over quite extended time periods. For instance, the Queensland Department of Main Roads (2005) found that 10% of projects with budgets exceeding $1 million (AUD) had exceeded by more than 10% on budgeted estimates.

Rajput, (2020) pointed out that from the perspective of the owner, highway project cost overruns may have a significant effect on program budgeting. It has been suggested that transportation agencies should invest heavily on forethought and preparation of future highway construction initiatives. If there is a shift in the allotted amount of highway financing specified in the construction program, the public, the press, and the politicians are quick to respond. As a result, transportation agencies lose credibility and must spend extra time explaining their actions when they deviate from the official schedule. Yet, if a highway organization can provide accurate program estimates, particularly during the decision-to-build phase, the agency's reputation will improve.

According to Susanti, (2021) moreover, project owners' bottom lines are profoundly affected by the degree to which estimates account for the possibility of adverse events. Too much of a safety net might lead to wasteful spending, make the project unfeasible and lead to its cancellation, or tie up resources that could be used for other endeavors. Yet, if the provision for contingencies is too little, it might create an artificial financial climate that leads to subpar performance. There is a trend in certain parts of the public sector to eliminate contingency provisions in budget submission since they are generally accepted as truths, leaving little room for anticipating project risk.

Asiedu, (2020) pointed out that "few research has directly compared owner risks in highway development to actual final pricing, but it is expected that links in construction cost data may be formed that may be advantageous and readily adaptable to estimate methodologies. While simple linear regression has been used to create models that can predict the final cost of competitively bid highway construction projects using only the low bid as input (Williams et al., 1999), there has been relatively little research into identifying the risk factors of specific highway project types and their relationship to budget cost overrun". There is also a lack of data connecting the dots between the various kinds of highway projects and owner project risks and actual cost overruns. When owners have a firm grasp on what is causing recurring cost overruns, they can zero in on the most pressing issues and integrate cost-control mechanisms into their program planning processes for more accurate cost projections moving forward. As was said, the cost of a project might fluctuate or increase for a number of reasons, all of which include some degree of risk. If you want to make your cost estimating system better, one of the first things you should do is analyze the factors that lead to construction projects going over budget.

According to Mahmud, (2021) when the actual result of an event or action will most likely depart from the estimated or anticipated value. One reason this occurs so often in the construction industry is because there are so many unknowns during project execution that may have a consequential impact on both time and money spent. Projects awarded based on competitive bidding add to the inherent economic risk associated with the construction industry. The 'conventional technique,' also known as Design-BidBuild, is often employed for highway infrastructure projects in the USA, AU, CA, NZ, SE, UK, and GB (DBB). This means that a procurement contract for the design/engineering services will be filed ahead of time, followed by a separate procurement contract for the actual construction or physical works. Although the classic DBB approach has been used for many years, it has been criticized for its stale ideas, long completion times, and excessive costs. Since the owner is responsible for most of the costs and dangers associated with the design and construction processes, there should be more stringent guidelines to follow in order to guarantee that the owner's requirements are being met in a timely manner and that the best possible solutions are being offered at a reasonable price.

Oyieyo, (2020) stated that the highway construction prices are affected by several variables. Researchers in Newfoundland discovered that the prices of individual contracts varied widely depending on time of year, geographical region, project type, length of contract, and total contract value. A research found that the input price of materials is exactly as sensitive to changes in the annual total number of contracts tendered (the so-called bid volume). A lack of control over internal resources, poor labor relations, and low productivity are the four main causes of cost overruns, followed by technical complexity, unrealistic estimates, and external risk (caused by changes in the project's scope and the legal, economic, and technological environments) (because of the uncertainties involved). On the other hand, some academics argue that factors unique to the project's design and scope, such as the degree of uncertainty surrounding the project's objectives, the complexity of the design, and the overall size of the undertaking, are the most influential in determining an accurate cost estimate. Calahorra-Jimenez, (2020) pointed out that the quality of the engineering designs used in a project may have a significant impact on the final price tag, and vice versa if the results from those designs are less than ideal. Thirty percent of architectural and engineering projects, according to their study, fail to meet their budget and deadline goals. Few cases have been documented where engineering designs are so thorough that a project might be completed to the precise specifications detailed in the original design documentation. Many issues encountered on building sites may be traced back to poor design decisions made at the outset.

### 2.5 Understanding and researching complexity with Qualitative In transportation infrastructure Projects

According to Cantelmi, (2021) budget overruns, delay, and public opposition are typical in transportation infrastructure projects. In the Netherlands, for instance, it typically takes 11 years for infrastructure decisions to be made. Yet, it is very uncommon for projects to have cost overruns of at least 40% and even as high as 80%. This is not a new discovery; a research in Europe from ten years ago found the same thing, and in the Netherlands, questions about the efficacy, efficiency, and legality of infrastructure expansion have been raised since at least the 1970s. This ongoing debate shows how difficult it is to find a rapid solution to the underlying complexity of infrastructure development, which has persisted over the years.

Jayasuriya, (2019) pointed out that he failure of such initiatives has prompted several investigations on the nature of infrastructure development's difficulties, as well as potential remedies to these issues. Examples include calls for greater and better assessment of infrastructure development from groups like the Netherlands Institute for Transport Policy Analysis (KiM), which highlights the need to better understand why projects function the way they do. To evaluate 'what' causes, as opposed to 'that' causes, is more challenging. In other words, it is simpler to see trends in cost overruns and delays than it is to pin down the causes of such problems. In the past, evaluating projects has mostly included comparing "before" and "after" states, ignoring the impact of local circumstances on infrastructure projects. As the complexity of policy systems is not adequately taken into account by the most popular evaluation methods, they hinder policy learning. It was also noted by KiM that present assessments suffered from methodological inadequacies, which are linked to the discordance between how infrastructure development projects are interpreted and the evaluation procedures applied because infrastructure projects are so intricate, we require assessment techniques that can properly measure their success.

Santika,(2019) stated that while it is important for evaluation approaches to include the context of projects in order to account for the impact of unique circumstances, this does not need an exclusive concentration on single-N in-depth analyses. For all, the purpose of assessment is to enhance infrastructure building practice, which necessitates some degree of generality; analyzing repeating patterns entails looking beyond the specific context of a single example. As will be seen in the next section, there seems to be tension between the needs for specificity and those for generality. One problem with the current gold standard approaches is that they often fail to account for context when comparing cases from different locations. Nonetheless, it is difficult to generalize from extensive case studies.

According to Mikkelsen, (2021) the term "complex" is often used to denote the perceived difficulty of an infrastructure project. On the other hand, complexity is not equivalent to, or even a measure of, the amount of work required to execute a project. As it turns out, the idea has several facets. Expanding a system's underlying framework is, in principle, what infrastructure development entails. Three-dimensional units (such as rooms, buildings, or assemblages of buildings) interact with two-dimensional units (such as the layout or distribution of the three-dimensional units throughout a given space) and linear units (such as transit networks) to establish the layout of a constructed area. All of these parts come together to form a syntax that is specific to a certain domain and was built specifically for it. Certain features are context-dependent, such when the cost of building a road to an upcoming suburb is sky-high because of the terrain's extreme difficulty, while others are common to all kinds of infrastructure projects. To make changes in a particular scenario, an infrastructure developer must work with a custom-built syntax that incorporates both global and context-specific factors.

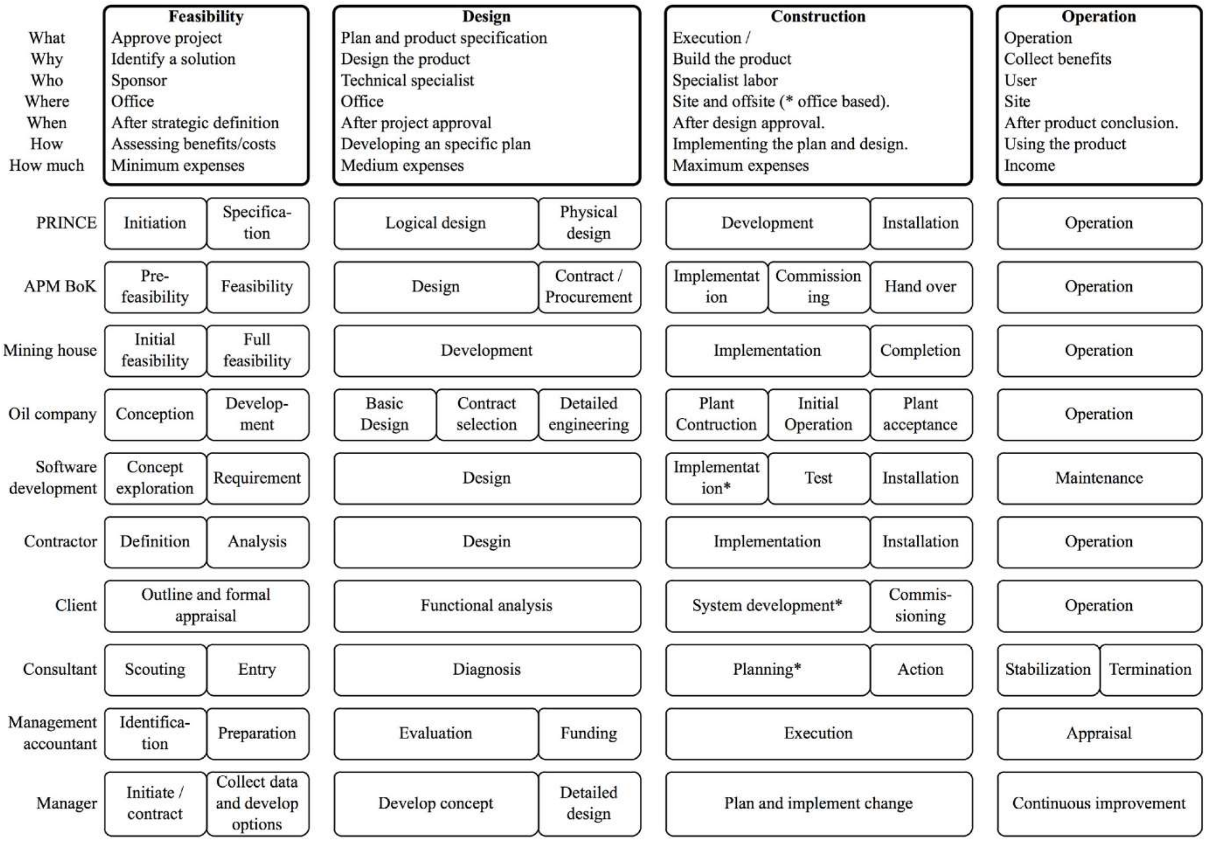
Afzal, (2021) analyzed that as time passes, the local built environment develops its own distinct characteristics as a result of the interplay between generic and specialized features. Consideration of the people who make up a built area, including those who live there, work there, commute there, and visit there for leisure, adds another layer of complexity to the problem, as their activities have a direct impact on the kinds of infrastructure that are currently in place and will be needed in the future. Properties of a subunit (e.g. a street) mirror qualities of its whole (e.g. a district), but not to the degree that both levels are identical replicas of each other. In this way, the local constructed order is a product of the interplay between universal and localized aspects of the physical and social environment. As a result, those responsible for building the necessary infrastructure must contend with a region that is distinct from others yet sharing many characteristics in common. Building infrastructure in urban settings, therefore, is not as simple as applying universal planning, construction, or management standards to a given place; rather, they must be tailored to the specifics of the location. Understanding exante how a project should be implemented and understanding ex post what leads to particular results requires intensive study of the unique combination of local variables and general trends that characterizes built-up places.

Karlsson, (2020) pointed out that many key factors are highlighted by this viewpoint. First, infrastructure development happens within a unique context comprised of a variety of local situations and general patterns. Second, this highlights the reality that our understanding of the mechanisms connecting local factors to global trends is limited, if at all. So, by definition, casespecific causal interactions are those that are known just for a certain location. Due to their singularity, created systems imply that other systems have distinct constituents, even though their emergent orders are comparable. Finally, every constructed place has an emergent character, which suggests it has evolved through time. That is, it is the final outcome of path-dependent changes and occurrences in the past.

### 2.6 Research gap

There are various risk that are related with the transport infrastructure project such as cost, delay in completion, incompetent contractors, environmental risk, loss of paper work etc that create major contributing factor to project delay. In addition to this project implementation is considered as fundamentally risky because it include lack of suitable technique to address that has lead to a unwanted results because of execution of transportation projects. While conducting this research, the study mainly focus on large scale transport infrastructure project performance by including best practices that estimate the cost in transport infrastructure project so that the various papers highly focus on probabilistic contingency estimation only. Hence it can be said that here is knowledge gap because it is only talking about the cost related problems that causing delays in in Australian Transport infrastructure projects**.**

## 2.7 Theoretical Contribution




According to Osuizugbo, (2020) one may deduce the technical qualities of building from the knowledge of what it is. In this study, construction refers to more than just civil engineering and architecture; it also includes activities such as erecting, erecting, establishing, and assembling. With skilled labor, construction brings an idea to life by realizing its design. This process involves thinking through the product's intended purpose, as well as its technical needs and constraints. Developing a product to meet an overarching business objective. While prototyping as a completed product is beyond the scope of this research, it may be included as a deliverable or stage of the project, such as during the design process. Goals for a prototype are to put it through its paces in the real world to see how well it performs and where it can be improved before the full release. The completed outcome of the project is final and unchangeable, unlike any prototypes that may have been created. Products from the project may be used in a prototype or other special structure if the standards are followed. Examples of construction industry output include computer programs, water and gas distribution systems, transportation infrastructure, residential and commercial structures, and even oil wells. In conclusion, the study's concept of construction applies to a wide range of project deliverables, both in terms of their technical backlogs and their domains of application.

Brandão, (2021) analyzed that the presence of a technical backlog also adds a level of routine to the process. Due to the specialist nature of the work required, the project manager will most likely work on other endeavors that have a similar technological basis. A business specializing in offshore oil well construction, for instance, is less likely to branch out into road construction in the future. Here, the repetition is happening across other projects of a similar kind, on a horizontal plane. Repetition may also exist inside a project, as in the building of several identical apartments, stories of a building, or storage containers for oil. These procedures show one kind of repetitiveness, a vertical one, in action: the repeating of operations inside a single project.

Liu, (2020) stated that ten distinct project management frameworks were examined to better comprehend construction's many domains of application and its function in the project life cycle. Many project-driven techniques are shown in Figure 1 organized into four phases clustered by essential criteria. The feasibility phase entails a series of activities designed to zero in on the most effective means of achieving the project sponsor's stated business objective. Processes like this should also evaluate the feasibility of implementing the chosen solution and producing the accompanying project output. During the second phase, known as "design," members of the project and technical teams analyze the findings from the feasibility study. With the best solution in mind, the teams create design requirements and project plans that detail the steps necessary to create the final product. The subsequent step (building) entails constructing the product in accordance with the technical specifications and in accordance with the management strategies established in the previous phase. After the project is complete, the user receives the end result (the operation) and uses it to create value and advance the business's objectives. While it is not technically part of a project's life cycle, operation is often the milestone that signals its completion.

According to Guo, (2022) depending on the location of the primary stakeholders involved in each of the project's three phases (feasibility, design, and construction), the project may move to a new site each time. First, it is driven by strategic need, and second, feasibility studies are conducted in the home territory of the project's potential financial backer. At this point, management is aware that the status quo cannot provide a necessary condition for the company's continued success. As a result, upper management has sanctioned a special effort to fulfill this unmet company need, kicking off the project. After a project is underway, the sponsor is responsible for deciding which investment strategy and solution will provide the greatest results. Feasibility studies are usually conducted as part of standard operating procedure inside an organization.

Kim, (2021) pointed out that while the primary reason for the project's existence is the inability of ordinary operations to meet a particular business need, the sponsor often lacks the in-depth technical understanding necessary for the project's or product's design. So, a third-party expert may need to be brought in to develop the technical aspects, gather all requirements, and plan and design the project product through to its eventual implementation because of this, the design phase often involves a handoff from the project sponsor's office to that of a third party, with the two sets of offices maintaining constant communication with one another. Hence, stakeholders have less of an impact than they did before. The same line of thinking that underlies technological progress may be applied to the building phase, where trade specialists or contractors are often needed to carry out each step of the construction plan.

According to De Bot, (2020) there is often no history of cooperation between the firms or teams involved, making the present project the main thing binding them together. Where the action of the completed project takes place is a critical business choice. Nonetheless, the project's work packages might be made in a variety of locations. The work packages are broken down and given to suppliers in accordance with the project's procurement management strategy, with the majority of the work being done in the supplier's facilities rather than the project owner's. Stakeholders' weight is cut one more. The manufacturing facility is crucial since it is here that the majority of the manpower and materials required to complete the project's output are amassed. The bulk of the budget goes into this resource convergence, and it discloses any mistakes or inconsistencies in the plan produced in earlier phases of the project. Magill, (2022) pointed out that time, quality, and safety in manufacturing are just a few of the benefits that are often cited. The most significant advantage of off-site manufacturing, paradoxically, is not having the work done on-site. The top three responses in the ranking of advantages, according to significance and probability, link directly or indirectly to the decrease of activities on-site. From most to least important, these advantages are: reducing the need for on-site operations; clearing out workspace congestion; and facilitating communication between different trades.

According to Tetik, (2021) on-site manufacturing in the construction industry has unique logistical challenges. In contrast to manufacturing, where the placement of a plant is determined by the fulfillment of strategic logistic objectives related to product distribution and supplier connection, the location of a construction site is entirely dependent on the demands of the end user. "the delivery is to a temporary location, without permanent facilities for handling material," which is a logistical nightmare. The temporary warehouse makes it harder to utilize the most efficient delivery routes and establish contacts with the most wanted suppliers, which in turn slows down the development of an effective supply chain. Supply chain efficiency might be substantially hampered by geographical factors. Many non-technical limitations may be imposed, depending on the site's location. Building a skyscraper in the middle of the city, for instance, could need adhering to zoning laws. Schedules and rules for transporting cargo, delivering and dispatching materials, and extra safety precautions may be required owing to the closeness of people. Schimanski, (2021) pointed out that however, building in remote areas often has difficulties sourcing and transporting necessary materials due to large distances from suppliers and inadequate or nonexistent transportation methods. Long distances from favored suppliers sometimes increase expenses to the point where the chain becomes untenable, pushing executors to work with different sources. As prior involvements facilitate the development of both product and process expertise through lessons gained, new parties are more likely to undergo a longer learning curve than regular partners over the course of a project.

According to Wang, (2020) the supply chain is very important in the construction sector because of the vast quantities of components needed for manufacturing. During the building phase in particular, the raw materials must arrive in the precise quantity and in the right order since the onsite warehouse is too small to store large quantities. Coordination of arrivals and wait times is crucial to avoiding warehouse and assembly line bottlenecks. When picking operations may be slowed down due to an excess of materials, less warehouse space may be available for cargo handling, which might affect how materials flow to the manufacturing line. Cutting off the manufacturing line's food supply is more urgent since it might cause the line, or a section of it, to shut down.

Chen, (2019) pointed out that short-term refers to the time period in which output is driven by forces that are relatively constant. More work is needed to boost production since more capital is not an option. Core features of the creation of projects are scope, budget, and schedule limitations, i.e., constant parameters that limit the quantity of work, the addition of funds, and the time period in which the project is executed. In the case of projects, when a small number of items need to be manufactured, the timeframe, budget, and total number of items to manufacture (scope) are all known in advance. The estimates of these limits are not often practical, despite being clearly and explicitly mentioned in the project scope. In contrast, during a lengthy production run, both the production end and total units to create are unknown, necessitating reliance on projections and market circumstances. Upstream oil production rigs, for example, often have extraction targets in mind depending on the oil potential. Despite this, the reservoir will continue to be mined for oil until either all of the oil is gone or it becomes economically prohibitive to do so.

According to Maury-Ramírez, (2022) since the number of units to be produced is assumed to remain constant during a short production run, the average cost (cost/units) is more reliable than it is during a longer production cycle. At first, for the same investment, the long run (forecasted units) has more uncertainty than the short run (precise units). On the other hand, in the long term, output might exceed expectations, leading to a cheaper per-unit average. Short-run manufacturing also has higher per-unit costs than long-run production since there are fewer units to manufacture because of this disproportionate exposure to risk in the event of unit variation, short-run production is more vulnerable to disruptions. With the same risk probability, a greater risk effect results in a larger anticipated value. Overall, the risk is smaller in short-run manufacturing, but greater precision is needed since the value is concentrated in the individual pieces. Hence, even a little shift in labor costs might have a significant impact on output and the bottom line.

By their very nature, projects are temporary, self-contained endeavors with an endpoint. Even if the end of a project is universally agreed upon, there is some disagreement regarding when it really begins. Upon delivery of the product to the customer, the project is considered complete. Documentation and official closure of the project constitute any further actions. The system (in this case, the project) is provided with a number of sequential on and off switches to account for the beginning and conclusion of each stage, deliverable, or activity. Disruptions like this lead to a splintering of efforts. This disintegration suggests many transitory states, i.e., a brief period during which the system is either adjusting to a state change or reacting to a disruption, such as immediately after the effect of a danger. Such changes may influence the production state, shifting it from steady to unstable.

## Chapter 3: Research Methodology

### 3.1 Introduction/Research Methodology

Research is a methodical investigation in which data are gathered and analyzed with the help of statistical tools to answer the question being studied. To understand research, you need to know that it looks at several things that show how well luxury trains work in India's infrastructure. A research methodology is a plan for how to set up, run, and finish the research. It is also called the "scientific method" because it shows the right way to do a study (Mackenzie & Knipe, 2006). It is also called a clustering procedure. (Somekh & Lewin) It is a way to solve problems that are mostly made up of ideas, theories, and ways of doing things (2005). The researcher must follow the instructions, methods, approaches, and designs for the study to be done (Rajasekar, Philominathan & Chinnathambi, 2013). So, research methodology is an important part of figuring out how to solve a problem and making sure it is solved. In this study, different methods were used to figure out what role luxury trains play and how important they are in promoting infrastructure in India (Rajasekar, Philominathan & Chinnathambi, 2013). In the current research methodology chapter, each step is taken to reach the goal and purpose of the research.

In other words, a research methodology is a set of tools and methods that help the researcher find the right facts for the study (Rajasekar, Philominathan, and Chinnathambi, 2013; Peffers, Tuunanen, Rothenberger, and Chatterjee, 2007). It is also known as a process because it helps the researcher honestly get the best data. With the help of research methodology, the researcher usually takes a mixed approach that includes both qualitative and quantitative methods. This helps the researcher figure out how happy customers are when they use and travel on India's most luxurious trains. We will use a questionnaire to get information about this data so that it can be looked at. The data collection method also includes the study, which looks at different approaches, philosophies, and research principles. This will help the researcher pick the right variable, which will help them make the right choice. Also, the research approach and strategy are split into two parts: qualitative and quantitative research methods, which depend on the properties of the chosen variable (Quinlan, Babin, Carr & Griffin, 2019). In the study, there is also a description of a way to do research. The two main ways to look at research are from a positivist and an interpretive point of view. All of these ways are based on research, experiments, theories, and investigations. Looking at the data is a part of the research method. It helps the researcher figure out what the data means by showing it in a way that fits with a theme, like pie charts, bar diagrams, charts, and tables of facts. Use the other way to analyze statistical data for more accurate and useful results (Bogdan & DeVault, 2015).

### 3.2 Research Paradigm

A research paradigm is the set of ideas and assumptions that the researcher gathers so that the research study can be done well. It gives the researcher a structure so that he or she can make good decisions about how to run the different parts of the research study (Guerra-Santin & Tweed, 2015). It has been found that the research paradigm is the main way that the different facts and figures about the research study can be collected, evaluated, and interpreted. The research paradigm is the set of natural beliefs and assumptions that the researcher has (Griffin, Lall, Bruce, Withers, Finnegan, Lamb & PreFIT Study Group, 2018). This set of beliefs that the researcher has gives the research study a direction and structure. It is important to find out all the facts about the research study so that it can be done clearly. Most people agree that it is based on three main parts: ontology, epistemology, and methodology. The main focus of the ontology parts of the research paradigm is to cover the reality parts of the research study by figuring out what reality is. The main focus of the epistemology part of the research paradigm was to cover the reasoning parts of the research study by figuring out how you know something (Dang & Pheng, 2015). The methodology part of the research paradigm focused on the process part of the study by figuring out how to find out what you want to know.

But it turns out that there are two more parts to the research paradigm: the positivism research paradigm and the interpretivism research paradigm (Camic, Rhodes & Yardley, 2003). The positivist research approach is a scientific method of research that effectively analyzes facts and numbers based on the researcher's beliefs and assumptions. It is the process of gathering facts and information through experimentation, observation, and a reason-based evidence research study. It helps prove that the facts and numbers about the cause and effect of relationships in nature are correct (Murry Jr & Hammons, 1995). It is the most common and well-known way to do a research study, and it is effective at explaining the different facts. It is also known for making predictions based on what people think will happen (Wiek & Lang, 2016). Positivism is a way of doing research that uses a deductive method, making hypotheses, testing those hypotheses, and using mathematical equations, calculations, extrapolations, terminologies, etc. to gather facts in a good way. It involves using mathematical ideas and formulas to guess the results that have been gathered from different sources (Welman, Kruger & Mitchell, 2005). The study was found to be objective, and the facts and figures were looked at using a deductive method. After looking at all the facts and numbers, the results are things that can be seen in the real world and can be shown in a number format. Also, it was found that the research paradigm was independent and not affected by human actions (Peffers, Tuunanen, Rothenberger & Chatterjee, 2007). It took a quantitative approach and used statistical methods to show how the data was analyzed clearly. The ontology part of the positivism research paradigm depends a lot on real and clear philosophies that are found to be independent and self-governing. It has been found that a lot depends on the fact that reality is one and alone (Tokuhiro, Ruggles & Pointer, 2015). The epistemological assumption of the positivist research paradigm is that the truth can be evaluated and estimated. It focused on getting facts and information that could be figured out with numbers and shown statistically. The methodology part of the positivist research paradigm has to do with how the study is done, such as with experimental, observational, survey, etc. methods (Griffin, Lall, Bruce, Withers, Finnegan, Lamb & PreFIT Study Group, 2018). By using these methods, the researcher was able to gather many different facts and pieces of information in a good way.

Interpretivism research paradigm is found to be the subjective method of research approach that collects all the facts and figures about the research study in a natural way (Taylor, Bogdan & DeVault, 2015). It does not follow a specific research structure and tries to find out more about a research study by taking into account the different views, opinions, and attitudes of socially constructed communities. The study of research is found to be both qualitative and inductive. In addition, it involves using different methods, such as unframed interviews, observations, and content analysis, to look at the collected data in a clear way (Sullivan-Bolyai, Bova & Singh, 2014). When this paradigm is used to gather data, it is found that the process is less structured. Getting different pieces of information requires a lot of time and several different sources. The ontology part of the interpretivism paradigm is based on the fact that truth has many different sides and is very subjective. It could be said that the facts are fixed and that most of the time, they are linked to different social areas of the community. The epistemological assumption of the interpretivism approach is that learning is a natural part of life (Griffin, Lall, Bruce, Withers, Finnegan, Lamb & PreFIT Study Group, 2018). The methodological assumptions are based on both scientific research and the personal experiences of the people.

In the current research study, the researcher used a positive paradigm as an empirical method to do the research (Sjoberg & Nett, 1997). With the help of the positive research paradigm, the researcher was able to do the research right by quantitatively analyzing the facts and numbers. This paradigm also let the researcher analyze and make sense of the facts and information mathematically by putting the data in a statistical format so that the facts and figures could be laid out in a precise way. The ontology part of the research paradigm made sure that the truth could only be proven by observing it (Simonsohn, Nelson & Simmons, 2017). It will also help to look at the data in an unreliable way so that research can be done well. The epistemology of the positivist approach said that the assumptions that are taken into account in the research study can be shown using different signs and signals so that people can learn and understand a lot about the research study. The positivist research paradigm made it possible to do research quantitatively by taking into account all of the assumptions and beliefs made by the research and coming up with results that are based on numbers and are accurate (Griffin, Lall, Bruce, Withers, Finnegan, Lamb & PreFIT Study Group, 2018).

### 3.3 Research Strategy

The research design is the process that is billed as the blueprint or framework structure of the different approaches, tools, and techniques that the researcher uses to do the proposed research in a good way. The research design gives the research study a set of rules and guidelines that are used to carry out the research process. It seems to focus on answering the "How" part of the researcher's question. Every researcher is likely to feel overwhelmed by several questions, such as which paradigm to choose, which approaches to choose for the research study, how to collect data, what the sample size should be, etc (Silverman, 2016). The design of the research gives the researcher a good place to answer all of his or her questions. The research design gives the researcher a well-organized, systematic framework in which all the information needed to do the research study is laid out in a structured way. It could be called the most important part of the research study because it gives a good foundation for the different ways of doing research. The research study's design is in charge of giving all the information, minutes, and details about the study. It has also been found that the research design is responsible for giving detailed information about the different research methods, such as experimental, survey, correlational, semi-experimental, review, etc., that need to be taken into account when doing a research study (Griffin, Lall, Bruce, Withers, Finnegan, Lamb & PreFIT Study Group, 2018). It is also responsible for giving information about the different research designs, such as experimental design, research problem, descriptive case study, etc., that need to be thought about to do the research study well. The main parts of the research design are that it is neutral, reliable, valid, and generalizable. The parts of the research design are what give the research study a clear structure so that the different parts of the research study can be carried out in the right way. Neutrality has to do with the way the research was done and how the results were found to be free of any kind of bias. The main goal of the research design is to spread uniformity across the whole study paper (Scandura & Williams, 2000). It seems to put a lot of emphasis on getting a deep understanding of the final scores and giving interpretations based on the analysis of several sources. The research design in which the research process is carried out over and over again is called the "reliability factor." It uses a questionnaire and other methods to do the research study so that the results can be more accurate. The Validity factor is the use of different tools and methods to do the investigations in the right way. Most of the research study depends on the goals that were set in the research study. The term "generalization factor" refers to a type of research design in which a large number of people are taken into account (Rogers & Kincaid, 1981). A small number of people in the sample would not be enough to do this kind of research.

Most of the time, the word "research" refers to the gathering of new information. Research is often defined as the critical and practical testing of a hypothesis about a possible relationship between parameters to learn something new. People often think of research in the social sciences as a way to find and use the knowledge that was not known before to solve practical or social problems.

In an empirical study of a phenomenon the following steps are followed are:

➢ Observation - An in-depth look at a current event that leads to a statement of the problem and the right research questions.

➢ Hypothesis - A temporary explanation or solution to a problem that is based on assumptions about the relationships between the parameters.

➢ Experimentation - The plan for the study is to test and systematically prove the hypothesis.

➢ Induction - A formal, abstract view of the experimental data that leads to a valid conclusion about the theory.

**3.4 Research Approach**

The approach to research consists primarily of a set of guidelines for conducting studies. In addition to providing the information that will be used to conduct the study, this procedure also provides the methods and procedures that will be employed (Creswell, 2014). Methods can be categorized as qualitative, quantitative, or mixed (Mohajan, 2017). In the quantitative method, the vast majority of data is represented numerically and analyzed mathematically. Positivist-aligned analytical instruments and techniques that aid in the formation and testing of research hypotheses are also included (Mohajan, 2017). Qualitative research, on the other hand, is consistent with the interpretive paradigm in that it calls for the researcher to zero in on a particular problem, which is then modified and explored through the use of a sophisticated collaborative method of data collection (Creswell, 2014). Subjective responses from respondents are used to compile data for this approach. The thoughts, feelings, attitudes, behaviors, and opinions of respondents are thus included in a well-organized format (Kothari, 2014). Informal interviews will be used to collect data for this qualitative study, which will be analyzed to shed light on or describe the current situation (Techno, 2016). Finally, a mixed approach combines qualitative and quantitative techniques to gain insight into the research question (Clark and Creswell) (2011).

Due to its reliance on comparisons made at various points throughout the investigation, the deductive method produces more reliable results in this study. A large amount of data is gathered, and then the researcher selects the most relevant data and samples. Potential benefits of deductive research include the ability to measure the ideas, generalize the results, and specify the connection among research variables.

### 3.5 Data Collection

The term "data collection method" refers to the procedures and processes involved in amassing the necessary information and statistics for conducting a research study (Griffin, Lall, Bruce, Withers, Finnegan, Lamb & PreFIT Study Group, 2018). It is common knowledge that data plays a crucial role in any study and provides the foundation for disseminating findings. It is the first thing you should do because it sets the tone for the whole study. Its purpose is to furnish the arguments and conclusions that underpin the development of a study's theoretical framework. Proper data collection from a variety of sources is essential for arriving at valid conclusions that support the research's stated aims (Mies, 1983). For a more accurate assessment of the various facts and information and clearly defined results, it is necessary to conduct the process of the data collection method. The process is broken down even further into two distinct categories—the primary method of data collection and the secondary method of data collection—based on the specific data collection techniques that are put into play.

Using first-hand accounts and documents to compile information is known as "primary data collection" (Merriam, 2002). It is a term for the unique strategy the researcher will use to gather information. Neither printed nor digital, audio, or video content about the topic of the study can be found anywhere. This may be the very first edition or draft of the work in question. Several methods, processes, and tools can be used to gather the fundamental data. Methods like surveys, exams, classroom observations, interviews, diaries, and notebooks are used. It is important to remember that different procedures and methodologies are used for collecting different types of data (Merriam, 1998). Tools and techniques, such as closed-ended questionnaires, etc., that can produce quantitative results are recommended for use, such as when collecting data in the quantitative form. Tools and techniques such as open-ended questionnaires, journals, interviews, diaries, classroom observations, etc. that could provide qualitative results are recommended for gathering qualitative data. Moreover, it is discovered that the survey method, in conjunction with questionnaires, can be used to collect primary data. When it comes to gathering data of a quantitative nature from firsthand sources, the survey method is widely considered to be among the most effective methods (McCusker & Gunaydin, 2015).

Secondary data collection is the practice of gathering information from previously existing sources. Refers to a strategy for gathering data in which the researcher draws from existing literature and studies. Secondary data collection entails gleaning information from sources that have already been established by other researchers, academics, and thinkers (Mackenzie & Knipe, 2006). It is the practice of assembling information and data from sources that have already been processed, examined, and investigated. Secondary information can be collected from a wide variety of periodicals, articles, newspapers, books, etc. These options are seen as cheap ways to gather information. Information could be gathered rapidly from secondary sources. Utilizing several digital and social media platforms, as well as other online resources, it was discovered that secondary data could be gathered. It has been discovered that a wealth of information on a wide range of topics is readily available across many digital platforms; this information can be accessed by searching for relevant keywords on a variety of search engines (including Google, etc.) and perusing relevant websites (Griffin, Lall, Bruce, Withers, Finnegan, Lamb & PreFIT Study Group, 2018). Facts and figures gathered from primary sources can be analyzed with the help of information gleaned from other sources.

The researcher used a secondary data collection strategy for this study. By switching to the second method, the researcher was able to compile information useful from a wider range of secondary sources. The researcher was able to collect and analyze the data adequately by drawing on a wide range of secondary sources (Litosseliti, 2018). In addition, it includes anywhere from 100 to 200 separate observations culled from primary sources. Criteria based on the ratio of a sample size to the number of variables have also been proposed, with values ranging from 2 to 20. The recommended minimum number of observations per variable to avoid computational difficulties is 10.

**3.6 Sampling technique**

Convenience sampling, expert opinion sampling, and quota sampling are all examples of non-probability methods. For factor analysis, even a small sample size is necessary. It has been suggested that between 100 and 200 observations be used in the study (Guadagnoli and Velicer, 1988). Criteria based on the ratio of a sample size to the number of variables have also been proposed, with values ranging from 2 to 20. For ease of computation, a minimum of 10 observations per variable is recommended.

### 3.7 Data Analysis Method

In a research study, data analysis is the process of quantifying and evaluating the various numeric facts and figures gathered through primary sources. Analyzing data entails evaluating information gathered through observation, interviews, surveys, and other means of gathering information, and then presenting the results in a statistical format. Quantitative data is gathered with the help of numerical or graphical instruments. This is done so that a reasonable conclusion can be drawn from the gathered data (Kothari, 2004). Results from the data analysis procedure show that this also helps the researcher check and double-check the accuracy of the responses participants provided. In addition, the researcher can see if the answers participants provide make sense with the questions they were asked. Analysis of administrative policies is also made possible through this method of data collection and processing. Furthermore, it enables the researcher to restrict the data collection and required data range gaps in the research study. The research's data analysis method, meanwhile, adequately conveys the study's factual data and boosts the study's significance and practicality (Holloway, 1997). Various techniques, including p-value, Correlation, descriptive, and Anova, will be employed.

**Test of normality:**

Test for normality is not applicable for ordinal data because it assumes that the data follows a continuous distribution, such as a normal distribution. Ordinal data, on the other hand, represents categories or ranks with a relative order but does not have a fixed unit of measurement or equal intervals between categories. Since ordinal data does not meet the assumptions of normality, conducting tests such as the Shapiro-Wilk test, Kolmogorov-Smirnov test, or other normality tests is not appropriate. These tests are designed for continuous data that can be measured on a numeric scale. Instead, when analyzing ordinal data, it is more suitable to use statistical methods specifically designed for ordinal variables. These methods include non-parametric tests like the Mann-Whitney U test, Kruskal-Wallis test, or ordinal regression models. These tests and models consider the ordinal nature of the data and provide appropriate inferential analysis.

**Multicollinearity**

Multicollinearity is a factual peculiarity that happens when at least two indicator factors in a relapse model are exceptionally connected, prompting swelled standard blunders and unsound evaluations of the relapse coefficients. Ordinal information are a kind of downright information where the qualities address requested classifications or levels, and they can be numeric or non-numeric. When the predictor variables in ordinal regression models are highly correlated with one another, multicollinearity can occur, making it difficult to interpret the model results and make accurate predictions. In ordinal data, failing to make the assumption of multicollinearity can result in inaccurate estimates of the regression coefficients and compromise the statistical analysis's validity and dependability. Regression models with ordinal data must therefore check for multicollinearity and address it by removing highly correlated predictor variables or employing regularization techniques, for example.

Identifying the predictive impact of critical risk and complexity factors on the delay as a whole?

Ordinal logistic regression, also known as ordinal regression, is used on multiple variate data to determine which of the independent variables—risk and complexity attributes—have a significant impact on the project's overall delay because the dependent variable—Overall delay—is ordinal and based on a Likert scale (Christensen, 2015). It is possible to interpret it as an explanation of the logistic regression model, which is applicable to dichotomous dependent variables and allows for multiple response categories (Agresti, 2003). Assume that Y is an ordinal variable (the dependent variable) and that J are categories (risk and complexity attributes). The cumulative probability of Y being greater than or equal to specific category j =1, 2....J-1 is then represented by P(Yj). Additionally, P(YJ) = 1, as the sum of probabilities for each attribute's effect on the overall delay is one. Since P(Y>J) = 0 and the sum of the probabilities of events affecting cannot exceed more than the existing attributes, the odds of being less than or equal to a particular category can be defined as (P(Yj))/(P(Y>j)) 3.1 for j=1,2,...J-1. The expression for the log odds, which is also known as the logit, is log (P(Y)J)/(P(Y>J))=logit(P(Y)J). 3.2 The model applies to data that satisfy the proportional odds assumption (POA). An illustration of this is as follows. If the proportions of the statistical population that would respond to the questions using a Likert scale of "Very low," "Low," "Average," "High," and "Very High" are p1, p2, p3, p4, and p5, then the logarithm of the odds of responding in particular ways is as follows:

“Very low,” log p1/(p1+p2+p3+p4+p5), 0; “Low,” log (p1+p2)/(p3+p4+p5); “Average,” log (p1+p2+p3)/(P4+p5); “High,” log(p1+p2+p3+p4)/p5; 3; The POA is that the terms that are incremented to each of these loga

Ordinary least squares are not used to estimate the coefficients of linear regression.

They are normally assessed utilizing greatest probability which implies they are worried about fitting the right dispersion to the information. We want to locate it in a way that makes it as likely as possible to observe the weights we measured.

Instances of multiordered reaction classifications incorporate security appraisals, reviews in light of conclusions, state spending on government projects and so on…

Understanding of relative chances model

To decipher the model, we first need to comprehend the activities of the relative chances model.

The mathematical formulation of the proportional odds model is given by logit(P(Yj)=j-iXi 3.3 0.1 Let's take the dependent variable as Y, the independent variable as X, and are the slope and intercept coefficients, respectively. Let J be the categories of the dependent model, and M be the independent variables, which are the risk and complexity attributes (in this set, j=5 and M=16).

P=1/(1+e(0+1X+.)) 3.4 is the solution to the probability equation, and the independent variables are X1, X2.

**p-value:**

The p-esteem is an examination and measurement of how much certainty there exists against the invalid speculation with more modest worth of p-esteem, the more proof. In this project, the null hypothesis is rejected if the p-value is less than 0.2.

When a p-value is less than 0.05, it is typically regarded as significant, and the null hypothesis is rejected. In this instance, the value is significantly lower, and any risk with a probability greater than 80% is considered significant. This is mostly done to account for all the noise in the data based on the information about the participants. Any bias is expected to be taken into account because the participants come from a variety of roles, qualifications, and backgrounds.

**3.8 Ethical Considerations**

So that the study can be conducted properly, it is important to give due consideration to ethical concerns (Choy, 2014). It is an essential part of the study and facilitates the proper execution of the research procedure. The researcher meticulously laid out a solid foundation of ethical considerations, ensuring that no problems or roadblocks would arise during the course of the research process. Before beginning the study, the researcher made sure to acquire all necessary permissions and permits (Camic, Rhodes & Yardley, 2003). To ensure that no problems would arise during the course of conducting the research study, the researcher made sure to acquire all necessary permits from the relevant authorities in advance. Respondents had been briefed on the study's aims, and informed consent had been obtained before they were asked to take part. The researcher has given their word to the participants that no one will learn who they are or what they said. Respondents were assured by the researcher that they would not be subjected to any form of harassment, both mental and physical and that they could discontinue participation in the study at any time if they did so (Bryman & Bell, 2014).

# Chapter 4: Data analysis

## 4.1 Introduction

The purpose of this chapter is to answer the critical questions posed by this thesis project using descriptive and inferential statistics and publish the results. Once the demographic analysis of the survey data is completed by pictorially depicting aspects of work experience, roles and age statistical analysis is implemented. In order to determine the critical risk and complexity factors Relative Importance Index (RII) is used. In the next section, Factor analysis is used to analyse the underlying correlations among risk and complexity attributes and to determine the principal components of the data. Principal Component Analysis is used to condense several attributes of data into few factors. In the final section a predictive model is developed using Multiple Regression Model based on ordinal data in order to predict the behaviour of dependent variable (Overall delay) based on independent variables. In the finishing section we implement the above methodology on a toy model.

### 4.2 Establish data for further analysis

The initial set of risk and complexity attributes causing delay in construction infrastructure projects were derived after extensive literature review. The list contained results of major risk and complexity attributes causing delays in construction projects. The next task was to refine this list so as to only include attributes relevant to transport infrastructure projects. As the author of this thesis at the time of the writing was working for Road and Maritime services (RMS), a NSW government agency responsible for road, bridge and maritime across NSW state the author was able to conduct informal interviews with Project Manager and Directors working in RMS who have had an average experience of 7-10 years' experience in road construction and management. The format of the interview would typically be a discussion for 10-15 mins which begins by the author giving the context and aim of the discussion which is to refine the list to transport project. Then the author reads the attributes from the comprehensive list and the PM/PD would respond with Yes/No basis, Yes meaning the attribute is relevant for transport infrastructure project and No means otherwise. The author conducted 10 interviews with respondents and based on the frequency of Yes/No's for each attributes the attributes were selected or dismissed. Once done, the result was used in questionnaire survey to rank the risk and complexity attributes based on their overall impact to project delay.

### 4.3 Demographic Analysis

Out of 200 respondents 108 participants responded which brings us to a response rate of 54%. Of the 108 respondents 5 were considered redundant (missing data) and hence we essentially have 102 respondents. As represented in Table 1 of the 102 respondents 87 were Project Owners/clients who was responsible for the funding of the project. 7 of them were general Contractors who were the EPC contractors responsible for overall engineering and construction of the project. and 8 of the respondents were consultants who had more of an advisory role within the business.

Table 1: General information about the participants

| Variables | Frequency | % |
|---|---|---|
| **Employee Type** | | |
| *Project Owner/Client* | 87 | 85.29 |
| *General Contractor* | 7 | 6.86 |
| *Consultant* | 8 | 7.84 |
| **Degree Type** | | |
| *Bachelors* | 32 | 31.37 |
| *Masters* | 65 | 63.73 |
| *Doctoral* | 5 | 4.90 |
| **Experience (in years)** | | |
| *0-5 years* | 10 | 9.80 |
| *5-10 years* | 65 | 63.73 |
| *>10 years* | 27 | 26.47 |
| **Role** | | |
| *Project Engineer* | 6 | 5.88 |
| *Project Manager* | 77 | 75.49 |
| *Project Director* | 19 | 18.63 |

Education, of the 102 respondents 32 has a Bachelor's degree, 65 of them a Master's degree and rest 5 of them a doctoral degree. As 102 respondents 10 of them had 0-5 years' experience, 65 of the respondents had 5-10 years' experience and rest has greater than 10 years of experience. As mentioned, 102 respondents 6 of them were in a Project Engineer role, 77 in a Project Manager role and 19 of them in Project Director role.

### 4.4 Rankings results

To check the reliability of the data, Reliability test based on Cronbach's alpha was implemented. The coefficient of reliability normally ranges between 0 and 1. The closer the value of Cronbach's alpha is to 1 the higher the reliability. As shown in table 4.2, the Cronbach's alpha is 0.85 with 102 variables. There is a high consistency for dataset for which the Cronbach's alpha is more than 0.7(Hair et al, 1998)

| Cronbach's alpha | Standardized Cronbach's alpha | Mean | s.d |
|---|---|---|---|
| 0.85 | 0.86 | 3.4 | 0.38 |

Table 4.2 Cronbach's alpha

Relative index analysis was used to rank the criteria according to their relative importance. Below table shows the ranking for each category using relative index analysis. As stated in the

Table 3 below risk and technical complexity issues due to delay from design and scope changes has a RII score of 0.81 is one of first rankings risk and complexity attributes. Scope creep due to specification change and design error or rework is a common occurrence in Transport infrastructure projects and its occurrence in the construction phase would have a significant impact on cost and schedule. On a similar level, with RII score of 0.81 is risk and complexity factors caused due to insufficient investigations and site conditions. Underground latent conditions especially finding utilities below the ground which were not part of the original design is a regular occurrence causing public sector millions of dollars every year. It's mainly due to insufficient survey work done during initial phase the project which is the root cause. Also, with a score of 0.81 is risk due to delay from property acquisitions caused by stakeholder opposition, design change and legal dispute. Stakeholder opposition occurs mainly due to fear of loss of emotional entity which has been their living place for long time. Also occurs due the price difference in market price and price offered by the public agency leading to legal dispute equating to cost overruns and schedule delays.

Risk due to delay from constructability issues caused from high traffic areas and night works comes in second place with a RII score of 0.77. It's extremely hard to work in high traffic areas especially during peak hours as any kind of hindrance to traffic would cause massive congestion. Hence this leads to time constraints which would impact the cost and schedule of the project.

Risks due to delay arising from improper decisions due to lack of senior management experience, lack of team cohesion and composition comes in the third place with a RII score of 0.68. Decision makers hold the key to the project and any bad decision especially during the construction phase of the project can have a massive impact of the cost and schedule of the project.

Risk and complexity issues due to delay arising from outstanding environmental issues comes in fourth place with a RII score of 0.66. With depleting ozone layer and increasing greenhouse effects environmental issues are at the forefront of current issues. Any projects which has a probability of doing any harm to the environment and its surroundings would likely have a many third party approval bodies which would create massive delays.

Risk and structural complexity issues due to delay from poor contractual agreements among diverse stakeholders often leading to conflict and mistrust among stakeholders comes in fifth place with RII score of 0.65. Poor contractual agreements without any clause to the risk and reward allocation between client and contractor can lead to clash and mistrust among parties involved. This would lead to delays as contractors are not provided with all the information to carry on the project which would lead to massive cost and schedule impacts.

| Risk Item No | Item | RII | N | Mean | SD | Ranking |
|---|---|---|---|---|---|---|
| R04 | Risk and technical complexity issues due to delay from design and scope changes | 0.81 | 102 | 4.06 | 0.781 | 1 |
| R01 | Risk and temporal complexity caused due to delay from insufficient investigations and site conditions(Utilities, rocks etcâ€¦) | 0.81 | 102 | 4.03 | 1.029 | 1 |
| R02 | Risk due to delay from property acquisitions caused by stakeholder opoosition, design change and legal dispute | 0.81 | 102 | 4.03 | 0.917 | 1 |
| R03 | Risk due to delay from constructibility issues caused from high traffic areas and night works | 0.77 | 102 | 3.84 | 0.714 | 2 |

| | | | | | | |
|---|---|---|---|---|---|---|
| R14 | Risk due to delay arising from improper decisions causing from senior management experience, lack of team cohension and composition | 0.68 | 102 | 3.42 | 0.588 | 3 |
| R05 | Risk and temporal complexity due to delay arising from outstanding enviromental regulations | 0.66 | 102 | 3.31 | 0.675 | 4 |
| R08 | Risk and structural complexity due to delay from poor contractual agreements often leading to conflict and mistrust among stakeholders | 0.65 | 102 | 3.27 | 0.616 | 5 |
| R06 | Risk due to delay in Project approvals with other institutions, third parties and approval bodies | 0.65 | 102 | 3.25 | 0.713 | 5 |
| R07 | Risk due to delay in accessing  job site due to community and council objections | 0.63 | 102 | 3.15 | 0.695 | 6 |
| R10 | Risk due to delay arising fron using improper procurement methods or other procurement related issues | 0.62 | 102 | 3.09 | 0.599 | 7 |
| R13 | Risk due to delay arising from lack of skilled resources or skills shortage | 0.61 | 102 | 3.05 | 0.651 | 8 |
| R09 | Risk and directional complexity due to Delay arising from change in government laws, regulations and other political factors | 0.61 | 102 | 3.03 | 0.682 | 8 |

| | | | | | | |
|---|---|---|---|---|---|---|
| R11 | Risk due to delay stemming from lack of safety measures | 0.60 | 102 | 3.01 | 0.589 | 9 |
| R12 | Risk due to delay arising from lack of funding issues | 0.59 | 102 | 2.94 | 0.672 | 10 |
| R16 | Risk due to delay from using obsolete construction methods | 0.59 | 102 | 2.93 | 0.693 | 10 |
| R15 | Risk due to delay from bad weather of climatic conditions | 0.58 | 102 | 2.91 | 0.631 | 11 |

Table 4.3 Ranking of risk and complexity attributes

Risk due to delay in project approvals with other institutions, third parties and approval bodies is also on the fifth place with a RII score of 0.65. Depending on the project's location, complexity and other factors approvals from third party bodies may be required especially with respect to environmental and utilities. This may take some time depending on the quality of the support documents and the complexity involved, namely the variety and complexity of the project which has an impact on cost and schedule.

Risk in access job sites due to community and council objections is in the sixth place with a RII score of 0.63. Some of the job sites might be a place of gathering or a playground for the community and their loss might have a negative impact. This would eventually to community objections to work on the job site and might take several rounds of consultation before a consensus in found.

Risks due to delay arising from improper procurement methods or other procurement related issues is on the seventh place with a RII score of 0.62. Due to outsourcing nowadays it's common to manufacture materials overseas and hence overseas procurement would always take a long lead time. Hence proper procurement methods are extremely important such that the fastest and cheapest options are executed.

Risks due to delays from lack of skilled resources or skilled shortage is on the eight places with a RII score of 0.61. Since the project complexity is gradually increasing hence the skill required are becoming more specialized and demand for skilled labour has never been higher. Lack of skilled labour often cause rework leading to cost and schedule overruns.

Risk and complexity due to delay arising from change government laws, regulations and other political factors is also on the eight places with a RII score of 0.61. Although government laws may change often, some sudden disruptions such as COVID 10 pandemic can cause changes in government laws which can lead to lockdowns or change in political leadership which can lead to cancellation of funding can cause overruns of cancellation of the project.

Risk due to delay stemming from lack of safety measures is on the ninth place with a RII score of 0.60. Australia has very stringent workplace safety laws compared to other countries but in spite of this there are fatalities at construction sites across the country. This can lead to stoppage of works and can cause cost and schedule overrun.

Risk stemming from funding issues is in tenth place with a RII score of 0.59. Funding issues are depended on the objectives of the organisation, priority of the leadership amongst others. Any delay in funding can cause cost and schedule overruns

Risk due to delay from using obsolete construction methods is on the tenth-place ith a RII score of 0.59. Construction without using modern methods such as BIM and other digital tools can considerably reduce the productivity of the project.

Risk due to bad weather or climatic conditions can cause severe delays and is in last place with a RII score of 0.58.

### 4.5 Principal Component Analysis (Factor analysis):

Factor analysis (PCA) was implemented using the statistical software R to determine the underlying latent correlations among variables/attributes and also to reduce the number of variables to minimum factors. The minimum number of variables required for factor analysis should be around 6-10 variables. (de Winter, 2009; Tabachnick, 2007}. For data set in this thesis, the sample size was 102 and the number of attributes/variables was 16 giving us a strong ratio of 6.3.

#### 4.5.1 Factor Analysis Test Parameters

**Kaiser-Meyer-Olkin Measure of Sampling Adequacy**

The is a statistic that indicates the portion of variance in your variables caused by underlying factors. Values close to 1.0 generally indicate that a factor analysis may be useful with your data and if less than 0.5 not very useful the current output in table 4 showed a value of 0.84 which confirmed that data has a good sampling factor to conduct factor analysis.

```
Kaiser-Meyer-Olkin factor adequacy
Call: KMO(r = X)
Overall MSA =  0.84
MSA for each item =
investigations       property      construct          scope    environment      approvals      community     contractual     government
          0.61           0.70           0.74           0.77           0.82           0.64           0.81           0.91           0.87
   procurement         safety        funding          skill     management        climate       obsolete
          0.92           0.88           0.84           0.89           0.83           0.80           0.92
>
```

Table 4.4 KMO measure of sample adequacy

**Bartlett's test of sphericity**

Bartlett’s Test of sphericity tests if the underlying data or correlation matrix is an identity matrix, which would indicate that your variables are not related and therefore unsuitable for structure detection. Values with significance values less than 0.5 indicate that a factor analysis may be useful with your data. The current output in table 5 showed a p value of 0.00 which confirmed that the test was statistically significant, and the data was suitable for factor analysis.

```
$p.value
[1] 1.722773e-92
```

Table 4.5 Bartlett’s test

```
Importance of components:
                          Comp.1    Comp.2    Comp.3     Comp.4     Comp.5     Comp.6     Comp.7     Comp.8     Comp.9    Comp.10
Standard deviation     2.4250338 1.3508453 1.3180541 1.07195642 0.96885159 0.88938660 0.80906752 0.73247030 0.68591870 0.61972280
Proportion of Variance 0.3675493 0.1140489 0.1085792 0.07181816 0.05866709 0.04943803 0.04091189 0.03353205 0.02940528 0.02400352
Cumulative Proportion  0.3675493 0.4815982 0.5901774 0.66199556 0.72066265 0.77010068 0.81101257 0.84454462 0.87394990 0.89795342
                          Comp.11   Comp.12    Comp.13    Comp.14    Comp.15    Comp.16
Standard deviation     0.59931893 0.5699235 0.52734619 0.51517415 0.47300332 0.42605018
Proportion of Variance 0.02244895 0.0203008 0.01738087 0.01658778 0.01398326 0.01134492
Cumulative Proportion  0.92040237 0.9407032 0.95808404 0.97467182 0.98865508 1.00000000
>
```

Table 4.6 Proportion of variance

As shown from the above table 6, the first **four** components have eigenvalues greater than 1 and hence considered for further analysis. Together they explain more than 50% of the variance. It is also important to note that all 16 components explain 100% of the variance.

### 4.5.2 Scree Plot

The scree plot on figure 7 graphed the eigenvalue against the number of initial factors so as to support a particular eigenvalue cut-off level. The component from fourth component factor flattened indicating the successive factors where accounting for a smaller variance. From the scree plot, only the first *four* component points warranted further investigation.

Due to graphical limitation in R only 10 components are shown.

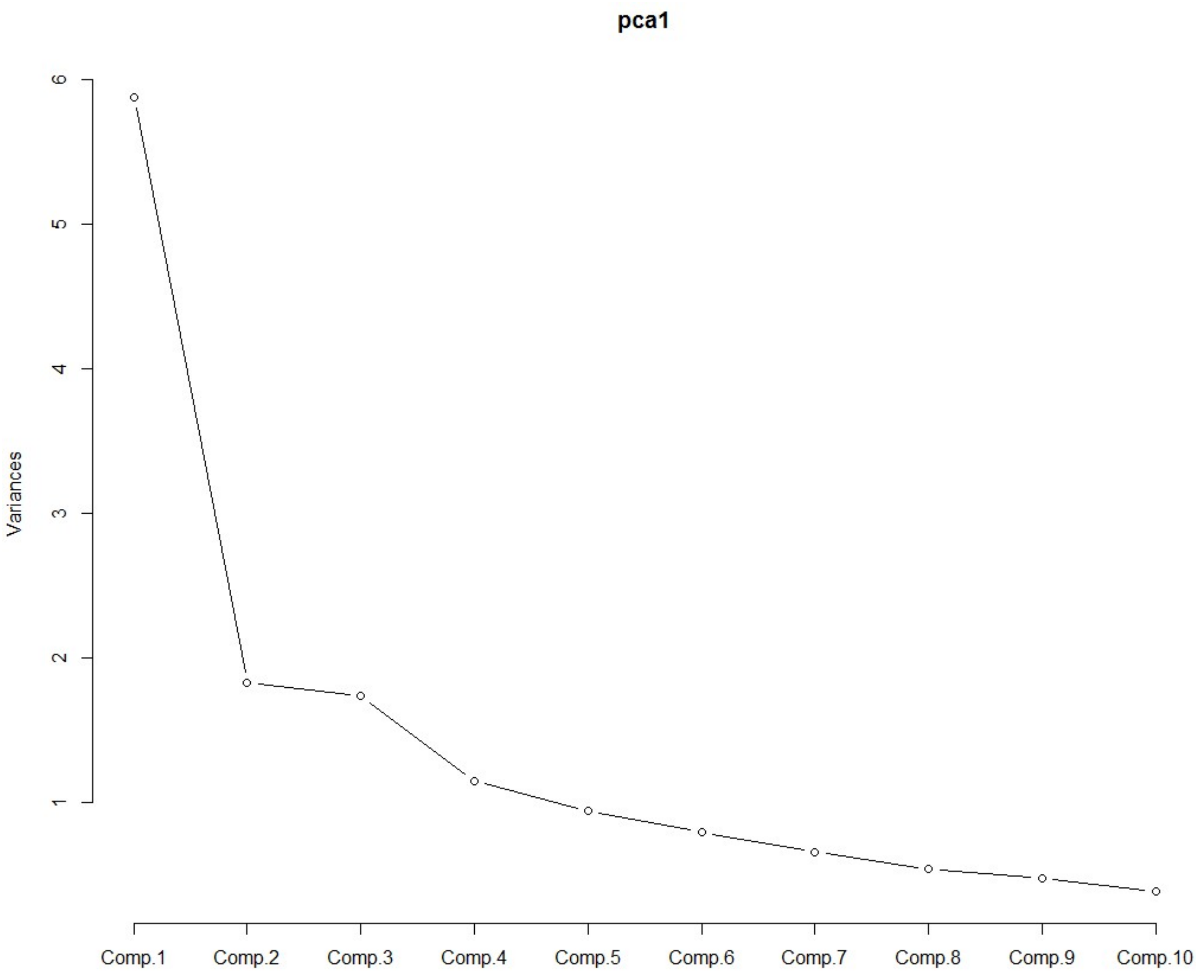



Figure 4.5 Scree Plot of eigenvalues

### 4.5.3 Loading of Various Components

Factor analysis(FA) was performed based on the varimax method as shown in table 8 and 9. It was noted the loading matrix established 4 component groups for 16 delay variables as supported by scree plot. The cut-off of 0.3 for the loadings (Tabachnick, 2007) is selected as cut-off for this analysis.

Loadings:

| | Factor1 | Factor2 | Factor3 | Factor4 |
|---|---|---|---|---|
| investigations | | | 0.538 | 0.171 |
| property | | 0.149 | 0.628 | |
| construct | 0.162 | 0.123 | 0.342 | 0.335 |
| scope | 0.225 | | 0.587 | 0.148 |
| environment | 0.205 | 0.272 | 0.315 | 0.720 |
| approvals | | 0.856 | | 0.160 |
| community | 0.294 | 0.769 | 0.100 | |
| contractual | 0.323 | 0.561 | 0.302 | 0.142 |
| government | 0.592 | 0.368 | | 0.342 |
| procurement | 0.694 | 0.309 | 0.137 | 0.137 |
| safety | 0.821 | | | 0.214 |
| funding | 0.580 | 0.204 | | 0.256 |
| skill | 0.790 | | 0.231 | -0.110 |
| management | 0.457 | 0.246 | 0.331 | -0.271 |
| climate | 0.772 | | | |
| obsolete | 0.667 | 0.276 | 0.159 | 0.124 |

| | Factor1 | Factor2 | Factor3 | Factor4 |
|---|---|---|---|---|
| SS loadings | 4.029 | 2.171 | 1.570 | 1.082 |
| Proportion Var | 0.252 | 0.136 | 0.098 | 0.068 |
| Cumulative Var | 0.252 | 0.388 | 0.486 | 0.553 |

Table 4.6 Loadings of various components

| | Factor1 | Factor2 | Factor3 | Factor4 |
|---|---|---|---|---|
| SS loadings | 4.029 | 2.171 | 1.570 | 1.082 |
| Proportion Var | 0.252 | 0.136 | 0.098 | 0.068 |
| Cumulative Var | 0.252 | 0.388 | 0.486 | 0.553 |

```
Test of the hypothesis that 4 factors are sufficient.
The chi square statistic is 91.8 on 62 degrees of freedom.
The p-value is 0.0083
>
```

Table 4.7 Cumulative loadings and p value

### 4.5.4 Classification into factors

| Attributes Codes | Factor 1 | Factor 2 | Factor 3 | Factor 4 |
|---|---|---|---|---|
| Investigations | | | 0.538 | 0.171 |
| property | | 0.149 | 0.628 | |
| construct | 0.162 | 0.123 | 0.342 | 0.335 |
| scope | 0.225 | | 0.587 | 0.148 |
| environment | 0.205 | 0.272 | 0.315 | 0.72 |
| approvals | | 0.856 | | 0.16 |
| community | 0.294 | 0.769 | 0.1 | |
| contractual | 0.323 | 0.561 | 0.302 | 0.142 |
| government | 0.592 | 0.368 | | 0.342 |
| procurement | 0.694 | 0.309 | 0.137 | 0.137 |
| safety | 0.821 | | | 0.214 |
| funding | 0.58 | 0.204 | | 0.256 |
| skill | 0.79 | | 0.231 | -0.11 |
| management | 0.457 | 0.246 | 0.331 | -0.271 |
| climate | 0.77 | | | |
| obsolete | 0.667 | 0.276 | 0.159 | 0.124 |

Table 4.8 Loadings of various components

**Table illustrating the loadings of various components**

- **A. Component Group 1** – Delay from change in government laws, regulations and political factors, Delay from use of improper procurement methods and other procurement issues,delay from lack of safety measures, lack of funding issues, skill shortage, poor decisions made by senior management, bad weather and climatic issues, use of obsolete methods in construction is grouped under Component group 1. The common theme among these attributes are the fact that they are all highly sensitive to external forces or factors. Hence they are named as **External factors**
- **B. Component Group 2** –Delay in project approvals from third party institutions, delay due to community and council objections and delay due to poor contractual agreements are generally concerned with internal matters of the organisation and have very less external influence. Hence they are grouped as **Internal factor.**

- **C. Component Group 3** – Delay due to insufficient investigations mainly around utilities below ground, property acquisitions caused by stakeholder opposition, design change and legal dispute, delay due to design and scope changes and constructability issues are grouped under Component group 3. There attributes are mainly related to the design section of the project and hence named as **Design Factor**.
- **D. Component Group 4** – Delay due to environmental regulations especially with historical or sacred aboriginal sites is listed as the last attributes and named as **Environmental factor.** However based on the criteria of determining the optimal solution factor as explained in next paragraph tis factor is **rejected.**

  Based on well researched and cited Factor analysis guidelines such as (Costello, 2005 ) and (Watkins, 2018) include the following criteria for optimal factor solution.

  1. Each factor must only contain items explaining 10% of the variance in its respective factor
  2. Each factor is recommended to have at least three item loadings(FA fails this criteria)
  3. All factors must be interpretable.
  4. Final factor has no items that cross load on multiple factors with same magnitude.

These groupings can be summarised in the table below:

| Component Group | Component Name | Factor Description | Included/Excluded |
|---|---|---|---|
| Group 1 | Delay from change in government laws, regulations and other political factors | External factors | Included |

| | | | |
|---|---|---|---|
| Group 1 | Delay from use of improper procurement methods and other procurement issues | External factor | Included |
| Group 1 | Delay from lack of safety measures | External factor | Included |
| Group 1 | Delay from lack of funding issues | External factor | Included |
| Group 1 | Delay from skill shortage | External factor | Included |
| Group 1 | Delay from poor decisions made by senior management | External factor | Included |
| Group 1 | Delay from bad weather and climatic issues | External factor | Included |
| Group 1 | Delay from use of obsolete methods in construction | External factor | Included |
| Group 2 | Delay in project approvals from third party institutions | Internal factor | Included |
| Group 2 | Delay from community and council objections | Internal factor | Included |
| Group 2 | Delay due to poor contractual agreements | Internal factor | Included |
| Group 3 | Delay due to insufficient investigations | Design related factor | Included |
| Group 3 | Delay due to property acquisitions caused by stakeholder opposition, design changes, legal dispute | Design related factor | Included |
| Group 3 | Delay due to design and scope changes | Design related factor | Included |

| | | | |
|---|---|---|---|
| Group 3 | Delay due to constructability issues | Design related factor | Included |
| Group 4 | Delay due to environmental regulations | Environmental factor | Excluded as it fails to satisfy Optimal factor criteria. |

Table 4.9 Table Components of Factor Analysis

**4.6 Ordinal Logistic Regression (Multiple)**

Ordinal regression, is a type of regression analysis used for predicting the ordinal variable. i.e variable whose values exists as a ordered scale where only relative ordering between different values is significant . In this case as the dependent variable ("overall delay") is ordinal-based on a Likert scale we would proceed with ordinal regression for multiple independent variables. The main objective is to find the relationship between dependent variable (Overall delay) and independent variable (risk and complexity attributes) based on a best fit line.

The risk and complexity attributes are coded into keyword format in order to make it easy for analysis in R software as shown in table 4.10

| **Risk and complexity Item No** | **Item** | **Code** |
|---|---|---|

| | | |
|---|---|---|
| R04 | Risk and technical complexity issues due to delay from design and scope changes | scope |
| R01 | Risk and temporal complexity caused due to delay from insufficient investigations and site conditions (Utilities, rocks etc…) | investigations |
| R02 | Risk due to delay from property acquisitions caused by stakeholder opposition, design change and legal dispute | property |
| R03 | Risk due to delay from constructability issues caused from high traffic areas and night works | construct |
| R14 | Risk due to delay arising from improper decisions causing from senior management experience, lack of team cohesion and composition | management |
| R05 | Risk and temporal complexity due to delay arising from outstanding environmental regulations | environment |
| R08 | Risk and structural complexity due to delay from poor contractual agreements often leading to conflict and mistrust among stakeholders | contractual |

| | | |
|---|---|---|
| R06 | Risk due to delay in Project approvals with other institutions, third parties and approval bodies | approvals |
| R07 | Risk due to delay in accessing job site due to community and council objections | community |
| R10 | Risk due to delay arising from using improper procurement methods or other procurement related issues | procurement |
| R13 | Risk due to delay arising from lack of skilled resources or skills shortage | skill |
| R09 | Risk and directional complexity due to Delay arising from change in government laws, regulations and other political factors | government |
| R11 | Risk due to delay stemming from lack of safety measures | safety |
| R12 | Risk due to delay arising from lack of funding issues | funding |
| R16 | Risk due to delay from using obsolete construction methods | obsolete |
| R15 | Risk due to delay from bad weather of climatic conditions | climate |

Table 4.10 Coded Risk and Complexity attributes

### 4.6.1 Assumptions for ordinal regression based on current dataset

Part of the process involves checking to make sure that the data you want to analyse can actually be analysed using ordinal regression. Generally the data should pass four assumptions for ordinal regression to give you a valid result.

Assumption 1: Dependent data should be measured at ordinal level. In this case the dependent variable (overall delay) is based on a Likert scale of 1-5 and hence on an ordinal level.

Assumption 2: Independent variable should be continuous or categorical. In this case the independent variables (risk and complexity variables) are treated as categorical variables with no ordering even though they are based on a Likert scale.

Assumption 3: There is no multicollinearity. When there is a high correlation between two or more independent variables, _multicollinearity occurs. This leads to problems with understanding which independent variable is contributing to the explanation of the dependent variable and technical issues in calculating an ordinal regression. Based on the correlation plot in figure 8 between dependent and independent variables there is no high correlation between the variables.

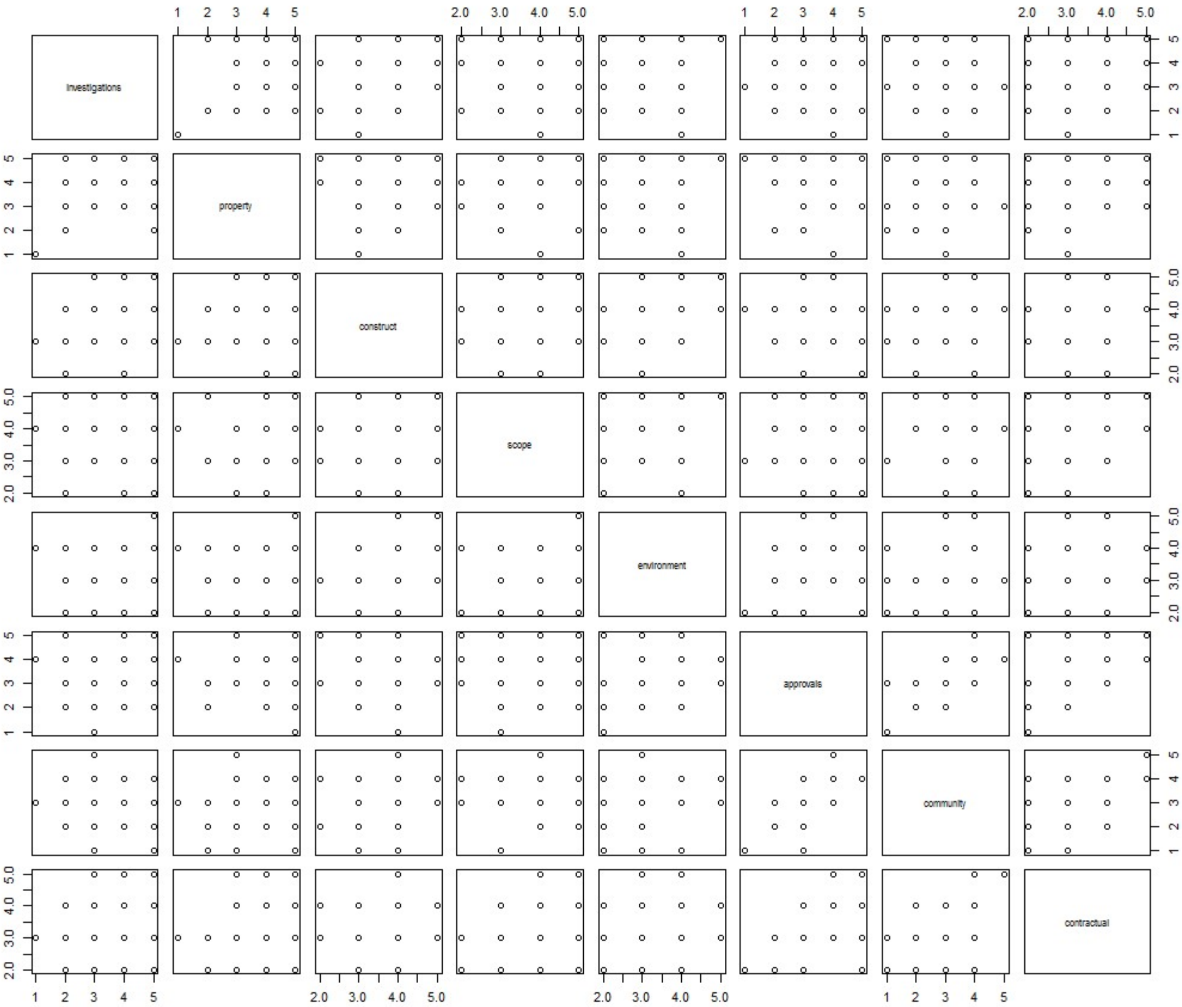



Figure 4.6 Correlation plot among independent variables

Assumption 4: The assumption of proportional odds means that each independent variable has an identical effect at each cumulative split of the ordinal dependent variable. In this project we are assuming the dataset satisfies the proportional odds assumption.

### 4.6.2 Analysis of the model.

The dataset is a multi-class ordered dependent variable with categories based on a 5 point Likert scale and 16 risk and complexity attributes which are the independent variables.

**Initial Setup**

For the initial setup the data is read from the output CSV file using the read.csv command in R. since the dependent variable is ordinal that output variable was converted from factor to the ordered variable using the as. ordered command.

data$overall_delay<-as. ordered(data$overall_delay)

In the output above, we get the information about

- Model equation
- The regression coefficients with their values, standard errors and t value.
- Estimates for three intercepts
- Residual deviance and AIC, which are used in comparing the performance of different models

O**utput**:

We now fit the ordinal regression model using  relevant libraries in R language. The output below

This shows the coefficients and intercepts along with the t value. T value is used to calculate the sample mean to null hypothesis. Since we are only interested in variables which are statistically significant predictors to dependent variable we focus our attention to the next illustration.

Coefficients:

| | Value | Std. Error | t value |
|---|---|---|---|
| property | 0.4371 | 0.2990 | 1.462 |
| scope | 0.6970 | 0.3648 | 1.911 |
| community | -0.6907 | 0.3601 | -1.918 |
| safety | 1.0902 | 0.5462 | 1.996 |
| climate | -0.9509 | 0.5028 | -1.891 |

Intercepts:

| | Value | Std. Error | t value |
|---|---|---|---|
| 3\|4 | -0.0658 | 1.7305 | -0.0380 |
| 4\|5 | 4.6178 | 1.8306 | 2.5226 |

Residual Deviance: 132.3129
AIC: 146.3129

Table 4.11 Coefficients and intercepts of Ordinal regression model

Since the significance value is at 80%, all values less than 0.2 p value are considered as shown in figure below

As we see below risk due to delay from property acquisitions, scope changes, community complaints, safety issues and climate factors are statistically significant and have an effect on overall predictability of the dependent variable.

| | Value | Std. Error | t value | p value |
|---|---|---|---|---|
| property | 0.4370595 | 0.2989806 | 1.46183214 | 0.144 |
| scope | 0.6970461 | 0.3647869 | 1.91083103 | 0.056 |
| community | -0.6907359 | 0.3601240 | -1.91805047 | 0.055 |
| safety | 1.0902401 | 0.5461970 | 1.99605652 | 0.046 |
| climate | -0.9508915 | 0.5028310 | -1.89107583 | 0.059 |
| 3\|4 | -0.0658071 | 1.7305150 | -0.03802746 | 0.970 |
| 4\|5 | 4.6177632 | 1.8305584 | 2.52259810 | 0.012 |

>

Table 4.12 p-value of model coefficients

The null hypothesis for this project is there is no relation between risk and complexity variables and overall delay of the project. The null hypothesis is rejected if the attributes have a p-value of greater than 0.2. In this case there are four attributes namely delay from property acquisitions(p-value of 0.144), delay from scope creep(p-value of 0.056), delay due to community objections to a project(0.055) and delay from safety concerns(0.046) which are all within the threshold value of 0.2 and hence considered statistically significant. Hence the null hypothesis is rejected.

### 4.6.3 Interpretation of Proportional Odds Model

In R's polr formula the ordinal logistic regression is parametrized as "

$$Logit\ [P(Y<=j)] = \alpha_j - \sum \beta_i X_i \qquad 4.1$$

Y = dependent variable

j=categories of the dependent variable

α=Y intercept

i=risk and complexity attributes

β=X intercept

X=value of X attribute

The complete estimated model for can be written as:

$$logit[P(Y \leq 3)]=4.61-(0.43*property)-(0.69*scope)-(-0.69*community)-(1.09 * safety)-(-0.95*climate)$$

4.2

This is the log odds of having a cumulative probability score of average impact or lesser on risk and complexity attributes. In this model delay from property acquisition, scope changes, community, safety and climate are statistically significant and obtained by iteration.

$$logit[P(Y \leq 4)]=-0.06-(0.43*property)-(0.69*scope)-(-0.69*community)-(1.09*safety)-(-0.95*climate) \quad 4.3$$

This is the log odds of having a cumulative probability score of "high" or lesser impact on risk and complexity attributes.

Interpreting the odds ratio:

The coefficients can be interpreted as follows:

- For one unit increase in property price, we expect about 0.437 increase in expected value of the overall delay in log odds scale, given that all other variables in the model are held constant.
- For every one unit increase in the scope changes, we expect about 0.697 increase in expected value of the overall delay in log odds scale, given all other variables in the model are held constant.
- For every one unit decrease in the customer complaints, we expect 0.690 decrease in the expected value of the overall delay in log odds scale, given all other variables in the model are held constant.

- For every one unit increase in the safety incidents, we expect 1.09 increase in the expected value of overall delay in log odds scale, given all other variables are held constant.
- For every one unit decrease in climate/bad weather conditions, we expect 0.95 decrease in the expected value of the overall delay in log odds scale, given all other variables are held constant.

Intercepts:

Mathematically the intercept 3|4 or average| high corresponds to logit[P(Y≤3)]. It can be interpreted as log of odds of impact of delay on project success being "average" versus impact being "high" or "very high" is -0.06.

The intercept 4|5 or high|very high corresponds to logit[P(Y≤4)]. It can be interpreted as log of odds of impact of delay on project success being "average" or "high" versus "very high" is 4.61.

**4.7 Mathematical computation using a toy model:**

By using the intercept and slope values on model data we can estimate the desired probabilities in the following manner using sample summary data. Let's say we want to predict the probability corresponding to each instance of the score as follows

Delay due to Property acquisitions: 4-high impact

Delay due to scope changes: 4-high impact

Delay due to Customer complaints: 3-medium impact

Delay due to Safety incidents=4-high impact

Delay due to Weather conditions=3-medium impact

The probability corresponding to **average** impact will be calculated as:

$Logit[P(Y\leq3)] =4.61-(0.43*4)-(0.69*4)-(-0.69*3)-(1.09 *4)-(-0.95*3)$

$Logit[P(Y\leq3)]=0.69$

$P(Y\leq3)]=exp(0.69)/(1+exp(0.69))=0.66$

$P(Y\leq3)=P(Y=3)=0.66$.

This shows that the probability of independent Risk and complexity attributes having a positive "medium" impact on overall delay is 66% in this instance.

The probability of "high" impact on overall delay can be calculated as:

$Logit[P(Y\leq4)]=-0.06-(0.43*4)-(0.69*4)-(-0.69*3)-(1.09*4)-(0.95*3)$

$Logit[P(Y\leq4)=-3.98$

$P(Y\leq4)=exp(-3.98)/(1+exp(-3.98)$

$P(Y\leq4)=0.018$

$P(Y=4) =P(Y\leq4)-P(Y\leq3) =0.018-0.66=-0.64$

This shows that the probability of independent Risk and complexity attributes having a negative "high" impact on overall delay is 64% in this instance

The probability of having a "very high" impact on overall delay can be calculated as:

$P(Y\leq5) =1-P(Y\leq4)$

$P(Y\leq5) =1.65$

This shows that the probability of independent Risk and complexity attributes having a positive "very high" impact on overall delay is 165% in this instance

**4.8 Chapter Summary**

The purpose of this chapter was to conduct empirical analysis to answer the research questions relevant to this thesis using statistical techniques. This was carried out in a manner as summarised below.

- Identify project risk and complexity factors causing delays in Urban transport infrastructure projects. This was achieved by studying relevant literature of delay risks in construction projects. As the papers from an Australian context was scant a global perspective was adapted and a list was created outlining set of unique risk and complexity attributes causing delays in construction projects.
- Rank the risk and complexity factors according to their criticality (Likelihood and magnitude of impact) based on the survey questionnaire. Once the comprehensive list was created, a questionnaire survey was created using Qualtrics survey system and distributed among participants using social media website LinkedIn and also work emails to colleagues of author. A ranking system known as Relative Importance Index (RII) was used to score and rank the risk and complexity attributes.
- Identify the latent variables based on regression coefficients among critical risk and complexity attributes using Principal Component Analysis (PCA). Factor Analysis was used to determine the latent relations among attributes to determine the factors with a goal reducing the size of the attributes to a few key factors. This would help decision makers in highlighting key factors for risk allocation. Although initially there were four factors one of the factors were rejected as there was only one item which lead to not satisfying the optimal factor allocation criteria.

- Construct a predictive model based on multiple ordinal regression analysis to determine the correlation between overall delay to the project and risk and complexity attributes. A we had to work with ordinal data which was based a likert scale , Multiple Ordinal Linear Regression was used as the tool to derive a predictive relationship between overall delay and risk and complexity attributes which was refined using the iteration process. The final model showed the relationship between overall delay and safety, community, property, scope and climate.

Chapter 5 follows and discusses the research findings in fulfilment of the research objectives and documents its contribution to original research and suggesting areas of future research.

# Chapter 5: Discussion

## 5.1 Introduction

The objective of this chapter is to address the pivotal inquiries presented by this thesis undertaking through the utilization of descriptive and inferential statistics, and subsequently disseminate the findings. Upon completion of the demographic analysis of the survey data, the graphical representation is utilized to depict various aspects of work experience, roles, and age, followed by the implementation of statistical analysis. The Relative Importance Index (RII) is employed to ascertain the criticality of risk and complexity factors. The subsequent section employs Factor Analysis as a means of scrutinizing the fundamental correlations that exist among risk and complexity attributes, to identify the principal components of the data. Principal Component Analysis (PCA) is a statistical technique employed to reduce the dimensionality of data by extracting a smaller number of factors that capture the majority of the variation in the original attributes. The concluding segment of the study involves the construction of a predictive model utilizing the Multiple Regression Model approach, which is founded on ordinal data. The objective of this model is to forecast the conduct of the dependent variable (Overall delay) by taking into account the independent variables. The methodology described above is applied to a toy model in the finishing section.

### 5.2 Discussion of the collected facts and data

**Establish data for further analysis**

The risk and complexity attributes that lead to delays in construction infrastructure projects were initially identified through a comprehensive review of relevant literature. The inventory comprised outcomes of significant risk and intricacy characteristics that result in the postponement of construction projects. Subsequently, the subsequent objective entailed the process of honing down the aforementioned inventory to encompass solely those characteristics that are pertinent to transportation infrastructure initiatives. The author of this thesis, during the time of writing, was employed by Road and Maritime Services (RMS), a government agency in NSW that holds responsibility for road, bridge, and maritime operations throughout the state. As a result of this employment, the author was able to conduct informal interviews with Project Managers and Directors who possessed an average of 7-10 years of experience in road construction and management within RMS. The standard protocol for conducting the interview entails a discourse lasting approximately 10-15 minutes, initiated by the author who provides an overview of the discussion's purpose and objectives, namely the enhancement of the transportation project list. Subsequently, the author proceeds to extract the attributes from the all-encompassing list, and the Project Manager (PM) or Project Director (PD) would provide a binary response of either "Yes" or "No", indicating the relevance of the attribute to the transport infrastructure project. The researcher conducted a series of 10 interviews with participants, utilizing a frequency-based approach to determine the inclusion or exclusion of various attributes based on the number of affirmative and negative responses received. After completion, the outcome was employed in a survey questionnaire to prioritize the risk and complexity characteristics according to their comprehensive influence on project postponement.

**Demographic Analysis**

The response rate of the study was 54%, as 108 out of 200 participants responded to the survey. Out of the total number of respondents, which was 108, a subset of 5 individuals were deemed redundant due to incomplete data. Therefore, the effective sample size for the study is 102 respondents. Table 1 illustrates that out of the 102 respondents, 87 were Project Owners/clients who held the responsibility of financing the project. Seven individuals held the position of general contractors, serving as the engineering, procurement, and construction (EPC) contractors accountable for the project's comprehensive engineering and construction. Eight of the participants held the position of consultant, assuming primarily an advisory capacity within the organization. In the realm of education, out of a total of 102 participants, 32 individuals possess a Bachelor's degree, 65 individuals hold a Master's degree, and the remaining 5 individuals have attained a doctoral degree. Out of the 102 respondents, 10 of them reported having 0-5 years of experience, while 65 respondents reported having 5-10 years of experience. The remaining respondents reported having more than 10 years of experience. As indicated, the study involved 102 participants, with 6 occupying the position of Project Engineer, 77 serving as Project Managers, and 19 holding the title of Project Director.

To assess the dependability of the data, a reliability test utilizing Cronbach's alpha was employed. The range of the coefficient of reliability typically falls between 0 to 1. A higher degree of reliability is indicated by a value of Cronbach's alpha that approaches 1. Table 4.2 displays a Cronbach's alpha of 0.85 for a set of 102 variables. According to Hair et al. (1998), datasets with a Cronbach's alpha greater than 0.7 exhibits a high level of consistency. The methodology employed for prioritizing the criteria was relative index analysis. This approach involved assigning a rank to each criterion based on its relative significance. The table presented below displays the rankings for each category utilizing the relative index analysis method. According to Table 3, the risk and technical complexity issues arising from delays in design and scope changes have a high RII score of 0.81, making it one of the top-ranked risk and complexity attributes. The phenomenon of scope creep, which arises from changes in specifications and design errors or rework, is frequently observed in transport infrastructure projects. Its manifestation during the construction phase can have a substantial effect on both cost and schedule. Similarly, it can be observed that risk and complexity factors may arise as a result of inadequate investigations and site conditions, as evidenced by an RII score of 0.81. The identification of subterranean latent conditions, particularly the discovery of utilities that were not included in the initial design, is a frequent issue that results in significant financial losses for the public sector annually. The primary reason for this issue can be attributed to inadequate survey efforts conducted during the project's initial phase, which serves as the underlying cause. Furthermore, a risk with a score of 0.81 arises from delays in property acquisitions resulting from stakeholder opposition, design modifications, and legal disputes. Stakeholder opposition primarily arises from apprehension regarding the potential loss of an emotional entity that has served as their place of residence for a significant duration. Legal disputes resulting in cost overruns and schedule delays may arise due to the price differential between the market price and the price offered by the public agency.

The constructability issues arising from high-traffic areas and night works are identified as the second most significant risk, with an RII score of 0.77. Working in high-traffic areas can be particularly challenging, especially during peak hours, as any obstruction to traffic flow can result in significant congestion. Consequently, this results in temporal limitations that could affect both the budget and timeline of the project. The third highest risk, as indicated by an RII score of 0.68, pertains to the potential consequences of delayed actions resulting from inadequate decision-making due to factors such as insufficient senior management experience, inadequate team cohesion, and suboptimal team composition. The individuals responsible for making decisions are crucial to the success of a project, particularly during the construction phase. Poor decision-making during this stage can significantly affect both the cost and timeline of the project. The fourth-ranked concern, as indicated by an RII score of 0.66, pertains to the potential risks and complexities that may arise from delays caused by unresolved environmental matters. The current environmental concerns are prominently centered around the depletion of the ozone layer and the intensification of greenhouse effects. Projects that pose a potential risk to the environment and its surroundings are likely to encounter significant delays due to the involvement of multiple third-party approval bodies. The fifth-ranked issue, with an RII score of 0.65, pertains to the risks and structural complexities that arise from delays caused by inadequate contractual agreements among heterogeneous stakeholders. Such delays often result in conflicts and a lack of trust among the stakeholders. Insufficient contractual agreements that lack provisions for risk and reward allocation between the client and contractor have the potential to result in conflict and a breakdown of trust among the parties involved. Insufficient provision of information to contractors can result in project delays, leading to significant cost and schedule impacts.

The fifth most significant risk, as indicated by an RII score of 0.65, pertains to potential delays in project approvals from external institutions, third-party entities, and regulatory bodies. Approval from third-party entities may be necessary for projects, particularly regarding environmental and utilities considerations, depending on factors such as location and complexity. The duration of this process is contingent upon the caliber of the accompanying materials and the intricacy of the undertaking, specifically the diversity and intricacy of the project, which has implications for both the budget and timeline. The RII score for the risk associated with accessing job sites in the face of community and council objections is 0.63, placing it in sixth position. The closure of certain job sites may result in the loss of a communal gathering place or recreational area, potentially leading to adverse effects. This could potentially lead to community dissent regarding the execution of the project on the worksite and may necessitate multiple rounds of deliberation before a consensus is reached. The seventh-ranked risk, as determined by a Relative Importance Index (RII) score of 0.62, pertains to delays caused by inadequate procurement methods or other procurement-related concerns. In contemporary times, outsourcing has become a prevalent practice in which materials are often manufactured abroad, resulting in a prolonged lead time for overseas procurement. Therefore, it is imperative to implement appropriate procurement techniques to ensure the expeditious and cost-effective execution of operations. The eighth position on the RII score chart, with a score of 0.61, pertains to the potential hazards arising from delays caused by a dearth of proficient personnel or a scarcity of skilled labor. As the complexity of the project is progressively escalating, the requisite skills are becoming more specialized, and the demand for skilled labor has reached unprecedented levels. The absence of a proficient workforce frequently results in the need for additional work, which in turn leads to financial and temporal excesses.

The eighth position in the RII score is attributed to the risk and complexity that ensues from delays caused by changes in government laws, regulations, and other political factors. The dynamic nature of government laws coupled with unforeseen events such as the COVID-19 pandemic can result in significant alterations to the legal framework, including the imposition of lockdowns and changes in political leadership. These changes can have far-reaching consequences, such as the cancellation of funding, project overruns, or even the termination of the project altogether. The RII score of 0.60 places the risk associated with delay resulting from inadequate safety measures in the ninth position. Despite Australia's rigorous workplace safety regulations in comparison to other nations, fatalities continue to occur at construction sites throughout the country. This phenomenon has the potential to impede progress and result in financial and temporal inefficiencies. The RII score of 0.59 places the risk associated with funding issues in the tenth position. The allocation of funds is contingent upon various factors, including the goals of the organization, the hierarchy of priorities established by leadership, and other relevant considerations. The occurrence of cost and schedule overruns can be attributed to any delay in funding. The utilization of outdated construction methods poses a risk of moderate significance, as indicated by its RII score of 0.59, placing it in the tenth position. The absence of contemporary techniques like Building Information Modeling (BIM) and other digital tools in construction can significantly diminish the efficiency of the project. The RII score of 0.58 indicates that risk associated with unfavorable weather or climatic conditions can result in significant delays.

**Principal Component Analysis (Factor analysis)**

The present study employed principal component analysis (PCA) through the use of the statistical software R. The aim was to identify the latent correlations that exist among variables/attributes and to minimize the number of variables by extracting the essential factors. Typically, a minimum of 6-10 variables is recommended for conducting factor analysis. The sources cited in the text are De Winter (2009) and Tabachnick (2007). The present study employed a data set comprising 102 observations and 16 attributes/variables, resulting in a robust ratio of 6.3.

**Factor Analysis Test Parameters**

**Kaiser-Meyer-Olkin Measure of Sampling Adequacy**

A statistical measure exists that quantifies the proportion of variability in a given set of variables that can be attributed to latent factors. A value of 1.0 or close to it typically suggests that the data may benefit from a factor analysis, whereas a value less than 0.5 indicates limited usefulness. As indicated in Table 4, the observed value of 0.84 confirms that the data has a favorable sampling factor for conducting a factor analysis.

**Bartlett's test of sphericity**

Bartlett's Test of Sphericity is employed to examine whether the correlation matrix or the underlying data conforms to an identity matrix. This is indicative of the absence of any relationship between the variables, rendering them unsuitable for the detection of structure. Values with significance levels below 0.5 suggest that factor analysis could be a valuable tool for analyzing your data. The results presented in Table 5 indicate a statistically significant outcome with a p-value of 0.00, thereby confirming the suitability of the data for factor analysis.

**Scree Plot**

Figure 7 displays a scree plot that plots the eigenvalue against the number of initial factors, which is utilized to substantiate a specific eigenvalue cut-off threshold. The fourth component factor exhibited a flattened trend, signifying that the subsequent factors accounted for a diminishing amount of variance. Based on the scree plot, it was determined that only the initial four component points were deemed worthy of additional examination. The application of factor analysis (FA) was carried out utilizing the varimax method, as demonstrated in Tables 8 and 9. The loading matrix was observed to have established four component groups for a set of 16 delay variables, which was corroborated by the scree plot. In this analysis, a cut-off of 0.3 for the loadings, as recommended by Tabachnick (2007), has been utilized. Component Group 1 pertains to the delay that may arise due to alterations in government laws, regulations, and political factors. Component group 1 encompasses various factors that contribute to delays in construction projects, including but not limited to utilization of inadequate procurement methods, procurement-related challenges, absence of safety measures, insufficient funding, shortage of skilled labor, suboptimal decisions made by senior management, unfavorable weather and climatic conditions, and employment of outdated construction techniques. The shared characteristic among these attributes is their susceptibility to external forces or factors. Therefore, they are designated as external factors.

The second component group, which includes project approval delays from third-party institutions, delays caused by community and council objections, and delays resulting from inadequate contractual agreements, primarily pertains to internal organizational matters and is minimally influenced by external factors. Therefore, they are classified as internal factors. Component Group 3 encompasses various factors that contribute to delays in construction projects, including insufficient investigations related to underground utilities, stakeholder opposition leading to property acquisition delays, legal disputes, design and scope changes, and constructability issues. The aforementioned attributes are primarily associated with the design component of the project and are therefore referred to as Design Factors. The fourth component group pertains to delays caused by environmental regulations, particularly those related to historical or sacred aboriginal sites. This attribute is denoted as the Environmental factor and is positioned as the final item in the list. However, upon evaluation of the criteria for determining the optimal solution factor, as elaborated in the subsequent paragraph, this factor has been deemed unsuitable.

The inclusion of specific criteria for an optimal factor solution is based on well-researched and cited guidelines for factor analysis, as outlined by Costello (2005) and Watkins (2018). Each factor should exclusively comprise items that account for 10% of the variance in their corresponding factor. It is recommended that each factor should possess a minimum of three item loadings. All factors must be capable of being interpreted. The ultimate variable exhibits no instances of item overlap across multiple factors with equivalent levels of significance.

**Ordinal Logistic Regression (Multiple)**

Ordinal regression is a statistical technique utilized to predict an ordinal dependent variable through regression analysis. A variable can be considered as having an ordered scale in which the relative ordering between different values is the only significant factor. Given that the dependent variable, "overall delay," is ordinal and measured on a Likert scale, an appropriate statistical approach would involve conducting ordinal regression with multiple independent variables. The primary aim of this study is to establish a correlation between the dependent variable, namely Overall delay, and the independent variable, which comprises risk and complexity attributes, using regression analysis to determine the best-fit line. Table 4.10 presents the coding of risk and complexity attributes in keyword format, which facilitates their analysis in R software.

**Assumptions for ordinal regression based on the current dataset**

A crucial aspect of the procedure entails verifying the suitability of the data for analysis via ordinal regression. To obtain a valid outcome from ordinal regression, it is typically necessary for the data to satisfy four underlying assumptions. Hypothesis 1: It is postulated that data that is reliant on other variables ought to be assessed at the ordinal level. The present study employs a Likert scale ranging from 1 to 5 to measure the dependent variable of overall delay, which is situated at the ordinal level of measurement. Assumption 2 posits that the independent variable must either be continuous or categorical in nature. The present study treats the independent variables, namely the risk and complexity variables, as categorical variables devoid of any ordinality, despite their origin from a Likert scale. Assumption 3 posits the absence of multicollinearity. Multicollinearity arises when there exists a strong correlation among two or more independent variables. This gives rise to issues about comprehending the independent variable that is accountable for elucidating the dependent variable, as well as technical complications in the computation of an ordinal regression. The correlation plot depicted in Figure 8 indicates that there exists no significant correlation between the dependent and independent variables.

Following the owner's choice to construct, project managers, contractors, and owners (particularly government owners) often find themselves at odds because of miscommunications and tensions brought on by cost overruns. Even though it is simple to persuade oneself that all scenarios are equally likely, cost overruns occur more often than one may imagine. In highway construction, where significant cost overruns have become the norm for many projects, this is particularly troublesome. The actual cost of constructing key transportation infrastructure in the United States is 28% more than the original projections, on average during the last 70 years. Similar research indicates that highway construction projects in Australia, particularly in Queensland, often incur significant cost overruns over periods that are fairly lengthy. According to the Roads Implementation Program 2004-05 Reports (RIP) from the Queensland Department of Main Roads (2005), 10% of projects with budgets over $1 million (AUD) experienced overruns of more than 10% on planned estimates (Love, 2015).

From the owner's viewpoint, program budgeting may be significantly impacted by cost overruns on highway projects. According to the results of one study, highway organizations need to invest a lot of money in figuring out the optimal strategy for future highway growth. If there is a modification to the proclaimed construction program, which specifies how highway funds are to be spent over time, the public, the press, and lawmakers all move quickly (Islam, 2021). When this occurs, highway authorities lose trust and spend unnecessary time defending timetable deviations. However, providing accurate program estimates, especially during the decision-to-build phase, may boost a transportation organization's image.

The financial impact on project owners is also significantly influenced by the amount of project risk contingency included in estimates. An excessive quantity of contingency may have unfavorable effects, like increasing wasteful expenditure, rendering the project unworkable and resulting in its cancellation, or tying up resources that may be utilized for other projects. However, if the allocation is too little, it might result in a shaky performance and an impossible financial condition. Budget submissions may often leave out provisions for unanticipated difficulties due to the broad acceptance of uncertainty in the public sector, making it difficult to adequately prepare for the possibility of failure (Ammar, 2022).

Though it is anticipated that research connecting owner risks in highway construction to real final prices would provide practical and simple applications to estimate approaches, relatively little has been done in this field. Little research has been done to pinpoint the risk factors of particular highway project types and their connection to budget cost overrun. Models have been developed to predict the final cost of competitively bid highway construction projects using only the low bid as input (using techniques like simple linear regression). Additionally, few studies look at the connection between the risks owners take when undertaking various roadway improvements and how much money such projects ultimately wind up costing. Owners may produce more accurate project budget estimates by addressing the reasons for ongoing cost overruns by identifying problem areas and introducing systems into program budgeting techniques. Several interrelated factors that are all subject to some degree of uncertainty result in project cost volatility or cost growth (Antunes, 2015). By identifying the main reasons for construction cost overruns and concentrating on those areas, any cost-estimating system may be improved.

By examining the possible reasons for cost overruns in highway projects, the research seeks to fill in the gaps and weaknesses in the current body of knowledge. This article aims to give a clearer risk contingency distribution methodology for extensive highway projects in addition to replacing the current ad hoc techniques. There are two major objectives. To determine if taking into account known cost overrun drivers would lead to more accurate owner budget estimates in the future, the first step is to look at prior factors that led to project cost overruns as well as project characteristics (Andersson, 2017).

People refer to an outcome as hazardous or uncertain when they believe that the actual outcome of an event or action will most likely differ from the expected or anticipated value. The many unknowns that develop during project execution and have a direct and significant influence on the timeframe and budget make the construction sector particularly susceptible. The economic risk that is already there in the construction sector is increased by projects that are selected based on competitive bidding. The "traditional model," sometimes referred to as the "Design-BidBuild" technique (DBB), is the delivery mechanism used for the majority of highway infrastructure projects in the United States, Australia, Canada, New Zealand, Sweden, the United Kingdom, and the United States (Islam, 2019). This suggests that a procurement contract serves as an initial offer for design/engineering services, and another contract is subsequently presented for the actual construction or physical works that would be based on those services. The traditional DBB method has come under fire for being unoriginal, taking a long time to complete, and having large cost overruns. There must be enhanced systems in place to ensure the owner's satisfaction, quick project completion, and cost-effective solutions since the owner bears the majority of the expenses and risks involved with the design and construction processes.

Several factors influence the costs associated with developing new highways. According to Newfoundland researchers, the costs of individual contracts vary significantly based on the season, location, project kind, duration, and overall contract amount. Another research discovered that, in addition to the price of raw materials, the quantity of yearly contracts placed up for bid (the "bid volume") also has a considerable effect on establishing project budgets.

Poor project management, which is attributed to "the control of internal resources, poor labor relations, and low productivity, unrealistic estimates, the technical complexity of the project, and external risk (due to changes in a project's scope and changes in the legal, economic, and technological environments) (because of the uncertainties involved)" are thought to be the main causes of cost overruns (Love, 2018). A project's final cost may be significantly influenced by the caliber of the engineering designs employed, and vice versa if the outcomes of those designs are subpar.

In projects involving transportation infrastructure, schedule, and budget overruns are frequent occurrences. Examples include the Channel Tunnel, the Jubilee Extension Line, and Boston's Big Dig, all of which have gotten substantial attention in both scientific publications and popular media. Even modestly large efforts might see considerable cost increases due to the complexity and magnitude of these activities. According to a survey, 33% of road and bridge building projects in the US state of Massachusetts were delayed and over 50% went over budget. The Queensland Department of Main Roads (2005) found that 10% of projects with contract values of more than AU$1m had gone over budget by that sum. Only 48% of the Australian infrastructure projects that were examined were finished on schedule, under budget, and by specifications (Santoso, 2020). Infrastructure project cost overruns are a perennial cause of worry for governments throughout the globe due to the possible negative effect on economies, the production of broad taxpayer fear, and the instability of a government's political position.

There is a substantial body of study that examines what goes wrong during the engineering management and construction of transportation infrastructure, as well as the reasons why it goes over budget and behind schedule. However, this endeavor has often not yielded adequate knowledge about or insights into the underlying causes of late delivery and cost overruns, particularly in the transportation business. This literature contends that to comprehend the overrun phenomenon, an "outside view" (i.e., reliance on precedent) is required as an alternative to an "inside view," which emphasizes precisely planned action. When just one viewpoint is taken into account, there is a claim that optimism bias and deliberate misrepresentation cause inaccurate cost forecasts (Amadi, 2017).

Optimism bias is associated with the propensity for stakeholders to overestimate benefits and undervalue disadvantages. On the other hand, strategic misrepresentation occurs when a project's costs and risks are purposefully underestimated for tactical, financial, or political considerations. Optimism bias and strategic distortion in cost estimates cause an underestimating of the risks and uncertainties related to the projections because of the assumption that "results are determined solely by their actions and those of their organizations." Poor planning, a decline in the relationship between the client and the contractors, and implementation problems may cause overruns in both time and money (Välilä, 2020). However, this could be oversimplifying a topic that needs further research. Overruns might have both beneficial and bad impacts, and both "inside" and "outside" stances on the subject are supported by strong reasons.

Before a fair explanation of their reasons is given, overruns in transport infrastructure projects are investigated in terms of their quantification and how project characteristics (size and type) affect their relevance. Some academics have their bodies of work meticulously scrutinized because of their significance in the planning and transportation literature. It is crucial to bear in mind that most of the data used in construction and engineering management literature were gathered at the time the project was finished. This is because each project's building methodologies, and political, economic, and technical environments were comparable at the time (Eshun, 2021).

The transportation sector is a crucial component of the construction industry, which is crucial to a nation's GDP. The road network includes highways, crucial intercity routes, toll roads, and other vital thoroughfares such as bridges, ducts, and tunnels. These are crucial for the development of society and the economy, as well as for population increase, the expansion of cities and towns, and the general improvement of living circumstances. A road network's development has far-reaching effects on a variety of areas, including economic growth, the attraction of foreign investment, and the number of both domestic and foreign visitors. There are various risks common to all construction projects that might result in cost overruns while developing roads. However, depending on their horizontal extent, design, method of implementation, and impact on nearby facilities, their consequences on road projects might vary (Tepeli, 2021). Road construction projects are more prone than other kinds of construction projects to have cost overruns because of their large initial investment, enormous size, prolonged duration, and distinctive site features. The nation's road system connects everything, from enterprises and institutions to ports and airports.

A cost overrun is the difference between actual costs and anticipated costs, calculated in the local currency at a fixed rate and in comparison to a predetermined benchmark. The discrepancy between a construction project's intended budget and actual expenses is known as a cost overrun. Budget overruns may be caused by internal factors like project size, duration, complexity, location, design, and cost estimation methodology as well as external factors like inflation, taxes, and regulations. A well-connected road network is a long-term investment that increases a nation's gross domestic product. As a consequence, using cost-effective options would boost road network development efficiency, which would provide financial benefits to the country (Yuan, 2020).

Approximately 90% of transportation network projects have cost overruns as a result of higher-than-anticipated closing costs. Cost overruns have been a frequent issue for several well-known transportation projects all around the world. The "Big Dig," also known as the Central Artery/Tunnel in Boston, was the most expensive transportation project in the country. Its construction, which began in 1991 and continued until 2007, cost an additional $11 billion, or 275% more than originally anticipated.

According to the study's findings, significant cost overruns are a common occurrence in infrastructure projects including road construction in Norway, road building in the United States, and transport infrastructure in Australia. In a study of budget overruns, almost 250 transportation projects from 15 different countries were considered. Another study found that the odds of the actual costs for any particular project exceeding the budgeted ones being exceeded were 86%. In comparison to the initial estimate, the proportion of expenses that exceeded expectations was largest (45%) for rail projects and lowest (20%) for road projects. European projects saw fewer cost overruns than their North American equivalents (Abeysekara, 2021). Project cost performance has been the subject of several studies, although practically all of them have concentrated on developed countries. The expense overrun is the consequence of programs in the US, Australia, and Europe that were unable to be transplanted to Africa due to the profound cultural and governmental differences because of the advantages, it brings to the whole industry, investing in the country's road network growth is essential for economic development (Ayub, 2019).

The interaction of general and special aspects throughout time has molded the local built environment, giving it uniqueness while keeping certain recognizable characteristics. Planning for a region's infrastructure is made considerably more challenging when taking into account the people that inhabit it, including those who live, work, commute, and visit for fun. A street's characteristics reflect those of a district's overall characteristics, but not to the extent that both levels are exact duplicates of one another. In this approach, the interaction between universal and localized elements of the physical and social environment results in the locally built order

(De Marco, 2021). As a consequence, people in charge of creating the required infrastructure must focus on a location that differs from others while having a lot in common. Therefore, creating infrastructure in urban contexts requires that planning, building, and management standards be specifically adapted to the area rather than just being applied to a particular spot. Studying the distinctive confluence of local characteristics and general trends that defines metropolitan areas is vital to understanding how a project should be carried out and what generates specific outcomes.

This perspective highlights several elements. To begin with, infrastructure is created in response to a special fusion of regional patterns and site-specific conditions. Two, it demonstrates how little we understand about the causes of genetic changes that occur outside of that given time and place and site-specific characteristics. Case-specific causal interactions are therefore by definition those that are only known for a particular place. True, even if their emergent order may be equivalent, constructed systems suggest that other systems are generated differently because of their unique nature (Rui, 2018). In conclusion, every developed location has a characteristic that has emerged through time. In other words, it is a result of earlier changes and events that are path-dependent. The sculpture exhibits respect for urban areas as sophisticated networks when these three concepts are put together.

Transportation projects often exceed their initial budget and contract value all around the globe. Inaccurate contingency cost estimates might result in higher construction costs than expected. The results suggest that the strategies used to anticipate potential cost overruns in transportation projects have not been effective. The distinction between risk and uncertainty, in reality, has been disregarded by probabilistic systems like Reference Class Forecasting (RCF) as well as deterministic ones like expert judgment. The word "contingency" is often used to refer to a monetary expenditure, usually expressed as a percentage of the entire budget. Customers and contractors often set aside funds over and above the planned budget during the planning stage of a project to pay for any unforeseen costs. The writers of this article only discuss the client's cost contingency. This amount has been put aside to cover items such as estimate-related uncertainty, the potential for a few tiny errors, or missing some information. A cost contingency, however, is not intended to cover things like unforeseen changes in the project's scope, worker strikes, inclement weather, increased prices (such as those for materials and labor), or changes in the value of the dollar.

When considering risk and uncertainty, two situations come to mind immediately. How do individuals make decisions in dangerous circumstances when they are aware of all their alternatives, possible outcomes, and likelihoods? In other words: (a) you'll need to use your statistical knowledge. However, it is crucial to consider what to do when some of the potential alternatives, impacts, and probabilities are unknown while making decisions in ambiguous situations. Simply said, it is possible to predict the likelihood of a hazard, but not the probability of uncertainty. This indicates that individuals may improve the cost-effectiveness of transportation projects "by managing contingency funds more cost-effectively," by accurately evaluating risk, and by better tolerating uncertainty.

In light of this, researchers look at the standard techniques for calculating the cost overrun for a transportation project. Researchers are aware of the many papers criticizing and suggesting other ways to cost contingency planning. Unfortunately, except for RCF, none of the commonly used approaches include a decision-making theory at their core. They are unable to properly account for risk and uncertainty when making decisions regarding the transportation project's budget as a result of this theoretical flaw.

Transportation projects worldwide have a proclivity to exceed their initial budget and contractual value. Inaccurate contingency cost estimates can result in construction prices exceeding initial projections. Based on the results, it appears that the strategies employed to anticipate potential cost overruns in transportation initiatives have not yielded favorable outcomes. Deterministic systems, such as expert judgment, and probabilistic systems, such as Reference Class Forecasting (RCF), have failed to acknowledge the distinction between risk and uncertainty in actuality. Frequently, the term "contingency" is employed to signify financial expenditure, commonly expressed as a proportion of the total budget. In the project planning phase, it is common for both customers and contractors to allocate additional funds beyond the initial budget to account for unforeseen expenses. The authors of this essay concentrate solely on the cost contingency of the client. A contingency has been allocated to accommodate for factors such as uncertainty associated with estimation and the potential occurrence of minor errors or omissions in the information. However, it should be noted that a cost contingency is not intended to account for unforeseen circumstances such as abrupt alterations in the project's scope, labor strikes, inclement weather, escalating expenses (such as those related to materials and labor), or fluctuations in currency exchange rates.

Keizur (2021) defines cost overrun as the percentage disparity between the final cost of a project and the initial estimate established at full funds authorization, taking into account the effects of inflation. In this context, overruns refer to the variance between the authorized initial budget of a project and the ultimate actual expenditures incurred, inclusive of any costs resulting from escalation clauses. Despite extensive research, the occurrence of budget overruns persists as a prevalent concern. The challenge of preventing cost overruns is contingent upon the ability to establish the verifiability of a set of events or propositions and the recognition of their causal links as true. At present, this remains an unresolved issue. The present article offers a brief survey of the pertinent literature and advocates for the development of a probabilistic framework for explaining the causes of cost overruns. This is deemed necessary to devise efficacious strategies that can ensure the prompt and successful completion of transportation projects.

According to Keizur (2021), there is a tendency for transport-related research to prioritize the overruns in road, rail, bridge, and tunnel construction, despite the significant financial and societal implications of project delays. Furthermore, it is a prevalent occurrence for schedules to exceed their allotted time, resulting in delays in the finalization of approximately 30% of road and bridge construction endeavors. Exceeding project deadlines can potentially have a detrimental impact on both the productivity of the project and the financial outcome of the team. Hence, it is imperative to consider these factors when scrutinizing issues about project efficacy. The capital markets necessitate exactitude, dependability, and elevated returns on investment. Consequently, any delay in the procurement of a toll road through a public-private partnership would be deemed unacceptable. Conversely, it is not uncommon for cost and time overruns to occur concurrently. The simultaneous occurrence of cost overruns and on-time completion is a plausible scenario. The existing body of literature has predominantly concentrated on analyzing the implications of cost and schedule overruns. However, it is crucial to acknowledge that more comprehensive assessment methodologies can be employed to ascertain whether the supplementary expenses can yield higher advantages (value). Alternatively, it can be determined whether a higher primary capital investment can lead to reduced life-cycle costs.

Ammar (2022) asserts that the occurrence of project cost variation after the owner's decision to build is a frequent source of tension among owners, particularly those in government positions, project managers, and contractors. The issue of cost overrun is a global phenomenon, particularly prevalent within the construction industry. Despite the reasonable assumption that cost overruns and underruns occur at a similar frequency, empirical evidence suggests that cost overruns are more prevalent. In the realm of highway construction, this phenomenon has historically led to significant financial excesses. On average, over the past seventy years, the actual cost of constructing significant transportation infrastructure in the United States has exceeded the initial estimates by 28%. Likewise, research has indicated that highway initiatives in Australia, particularly in Queensland, frequently experience significant budgetary excesses over prolonged durations. As per the findings of the Queensland Department of Main Roads in 2005, it was observed that approximately 10% of projects with a budget of over $1 million (AUD) had surpassed the budgeted estimates by more than 10%.

As per Cantelmi's (2021) findings, transportation infrastructure projects commonly encounter issues such as budget overruns, delays, and public opposition. In the Dutch context, the process of making infrastructure decisions is known to take an average of 11 years. However, it is a rarity for projects to experience cost overruns exceeding 40% and in some cases, even reaching up to 80%. The aforementioned observation is not novel; a study conducted in Europe a decade ago yielded analogous results, and in the Netherlands, concerns regarding the effectiveness, productivity, and legitimacy of infrastructure enlargement have been brought up since at minimum the 1970s. The persistent complexity of infrastructure development has been a challenging issue, as evidenced by the ongoing debate regarding the difficulty of finding a prompt resolution.

According to Jayasuriya (2019), the lack of success of these endeavors has led to numerous inquiries into the challenges associated with infrastructure development, as well as potential solutions to address these challenges. The Netherlands Institute for Transport Policy Analysis (KiM) has advocated for enhanced and superior evaluation of infrastructure development. This entails a deeper comprehension of the underlying mechanisms that govern the performance of such projects. Distinguishing the causal factors of a phenomenon, rather than simply identifying their existence, presents a greater level of difficulty. Stated differently, it is comparatively less complex to identify patterns in the escalation of expenses and project timeline extensions, as opposed to determining the underlying factors that contribute to these issues. Historically, project evaluation has predominantly entailed contrasting the preimplementation and post-implementation conditions, with little consideration given to the influence of contextual factors on infrastructure projects. The insufficiency of prevalent evaluation methods to account for the intricacy of policy systems impedes policy learning. Kim has observed that current evaluations are deficient in methodology, which is attributed to the discrepancy between the interpretation of infrastructure development projects and the evaluation procedures employed. Given the complexity of infrastructure projects, it is imperative to employ assessment techniques that can accurately gauge their efficacy.

According to Santika (2019), incorporating project context into evaluation methods is crucial for capturing the effects of distinct circumstances. However, this does not necessitate a sole focus on in-depth analyses of individual cases. The primary objective of the assessment is to improve the practice of infrastructure development, which requires a certain level of generality. Examining recurring patterns involves considering factors beyond the particular context of a singular instance. As demonstrated in the following section, there appears to be a conflict between the requirements for precision and those for comprehensiveness. A limitation of contemporary gold standard methodologies is their tendency to overlook contextual factors when conducting cross-regional case comparisons. However, drawing broad conclusions from comprehensive case studies can be challenging.

As per Mikkelsen's (2021) assertion, the terminology "complex" is frequently employed to connote the perceived intricacy of an infrastructure undertaking. Conversely, the level of complexity does not necessarily correspond to, nor serve as a metric for, the magnitude of effort entailed in carrying out a given project. The concept comprises multiple aspects. Infrastructure development involves the expansion of a system's fundamental framework. The spatial arrangement of a constructed area is established through the interplay between three-dimensional units, such as rooms, buildings, or assemblages of buildings, and two-dimensional units, such as the layout or distribution of the three-dimensional units within a given space.

Additionally, linear units, such as transit networks, also contribute to the overall layout of the constructed area. The integration of these constituent elements culminates in the development of a syntax that is exclusive to a particular field and has been tailored to its unique requirements. Some characteristics of infrastructure projects are contingent upon the specific context in which they are implemented, such as the exorbitant expenses associated with constructing a roadway to a forthcoming residential area due to the challenging topography. Conversely, other features are universally applicable across various types of infrastructure initiatives. To effect modifications within a given context, an infrastructure developer must engage with a bespoke syntax that integrates both universal and situation-specific variables.

# Chapter 6: Conclusion

## 6.1 Major Findings

The decision to construct by the owner often results in conflicts between project managers, contractors, and owners (especially government owners) due to misunderstandings and tensions arising from cost overruns. Despite the ease with which one may convince oneself that all possibilities are equally plausible, it is a fact that cost overruns occur with greater frequency than commonly perceived. The prevalence of significant budget overruns has become a customary occurrence in numerous construction projects, posing a significant challenge, particularly in the context of highway construction. On average over the past seventy years, the initial projections for the cost of constructing essential transportation infrastructure in the United States are 28% lower than the actual cost incurred. Empirical evidence indicates that Australian highway projects, particularly in Queensland, are frequently associated with significant cost overruns and delays. According to Love (2015), the Roads Implementation Program 2004-05 Reports by the Queensland Department of Main Roads revealed that a proportion of 10% of projects that had costs exceeding $1 million (AUD) encountered overruns that exceeded 10% of the planned estimates.

Despite the anticipated practical applications of estimating approaches, there has been a dearth of research on the correlation between owner risks in highway construction and the eventual project costs. Although models have been constructed utilizing techniques such as simple linear regression to anticipate the ultimate expenses of competitively bid highway construction projects solely based on the low bid, there has been a relatively limited amount of research conducted to recognize the risk factors of particular highway project categories and their correlation to budget cost overrun. Insufficient research exists regarding the correlation among different types of roadway projects, the hazards that proprietors assume, and the eventual expenses associated with said projects. By incorporating systems into program budgeting processes to address the underlying causes of repeated cost overruns, owners can potentially obtain more accurate project budget estimates. This approach involves identifying problematic areas and implementing appropriate measures to mitigate them. The variability in project costs or cost escalation can be attributed to a multitude of interconnected factors, each characterized by a varying degree of ambiguity (Antunes, 2015). Identifying the underlying factors responsible for the escalation of construction expenses and implementing appropriate remedial measures has the potential to enhance the efficacy of cost estimation mechanisms.

According to popular belief, an event or action may result in hazardous or unclear outcomes when the actual consequence deviates from the expected or anticipated value. The construction industry is particularly vulnerable due to the inherent complexity of building projects and the potential emergence of numerous variables during their implementation. The construction industry inherently entails economic risk, which is further compounded by the awarding of projects through competitive bidding. The "traditional model," commonly referred to as the "Design-Bid-Build" approach (DBB) (Islam, 2019), is the predominant method employed for highway infrastructure projects in several countries, including the United States, Australia, Canada, New Zealand, Sweden, and the United Kingdom. To clarify, the procurement contract pertains to the solicitation of design and engineering services, while the construction contract pertains to a separate solicitation that is contingent upon the aforementioned design and engineering services. The conventional Design-Bid-Build (DBB) approach has been criticized for purportedly being ineffective, exhibiting sluggish advancement, and experiencing significant cost escalation. Given that the proprietor assumes the majority of the financial and operational liabilities associated with the design and construction process, it is imperative to establish more rigorous procedures to guarantee the proprietor's satisfaction, expedite project completion, and minimize expenses.

Several variables impact the amount of expenditure allocated toward roadway infrastructure. A study conducted by researchers in Newfoundland revealed that contract pricing exhibited significant variability about factors such as seasonality, geographical location, project type, contract duration, and total contract value. An additional study has demonstrated that the annual quantity of contracts that are made available for competitive bidding, commonly referred to as the "bid volume," significantly impacts the determination of project expenses, even when accounting for the expenses associated with raw materials. The occurrence of cost overruns is believed to be attributed to inadequate project management, which can be attributed to various factors such as suboptimal management of internal resources, unfavorable labor relations, reduced productivity, impractical estimates, intricate technical aspects of the project, and external risks arising from changes in the project's scope, legal, economic, and technological environments, which are often accompanied by uncertainties. (Love, 2018). The utilization of high-quality engineering designs can significantly impact the cost of a project, either positively or negatively. Conversely, low-quality engineering designs may also have a similar effect on project cost.

The phenomenon commonly referred to as the feared cost overrun is alternatively identified as budget rise, cost increase, or cost growth. The term "cost escalation" refers to an expected increase in projected costs due to various factors such as inflation, whereas "cost overrun" denotes an actual excess in costs. The phenomenon of actual building costs exceeding the initially estimated costs is commonly referred to as a "cost overrun." The estimation of overrun costs is conducted concerning the initial budget established during the decision-making phase of the construction project. The aggregate documented expenses of a project constitute the definitive construction costs. Chapman (2016) has proposed an alternative approach to defining and determining cost overruns. This approach involves calculating the difference between the contract value, which is determined at the time of award, and the actual construction value, which is determined at the time of practical completion. The normative literature reports varying percentages of cost overruns, which can be attributed to inconsistent definitions provided.

Transportation infrastructure projects are frequently plagued by the problems of overspending and delays. Empirical studies suggest that cost overruns are a significant cause of dissatisfaction among project stakeholders. Governments worldwide express significant concern regarding budget overruns. The potential consequences of their actions include negative impacts on the economy, public dissatisfaction due to the perceived wastage of tax funds, and a loss of credibility for the ruling government. The Central Artery project, also known as The Big Dig, in Boston serves as a notable illustration of a project that exceeded its budgetary allocation and then surpassed it further. According to Islam (2022), the project's initial budget was $2.6 billion, however, the final cost amounted to $14.6 billion, resulting in a delay of seven years.

The phenomenon of optimism bias is associated with the inclination of stakeholders to overemphasize the potential advantages and downplay the potential drawbacks. Strategic misrepresentation is a phenomenon whereby the costs and risks associated with a project are intentionally downplayed to achieve strategic, economic, or political objectives. The determination of results is contingent upon the actions of individuals and their respective organizations. However, the presence of optimist bias and strategic distortion in cost estimates may lead to an underestimation of potential negative outcomes associated with projected forecasts. Insufficient planning, deteriorating customer-contractor relations, or implementation issues may lead to time and cost overruns (Välilä, 2020). It is possible that this assertion may be overly reductionist, and thus necessitates further scholarly inquiry. Individuals who hold either an "inside" or "outside" perspective regarding the issue of overruns can provide compelling justifications for their respective positions, as both approaches can yield advantageous or disadvantageous outcomes.

The construction industry plays a pivotal role in contributing to a nation's gross domestic product, with the transportation sector serving as a critical component thereof. The transportation infrastructure comprises primary expressways, crucial interurban conduits, levied thoroughfares, and other indispensable passageways such as overpasses, conduits, and subterranean passages. These factors are essential for the advancement of society and the economy, the growth of population and urbanization, and the overall improvement of individuals' quality of life. The expansion of transportation infrastructure has significant implications in various domains, including the expansion of the economy, the attraction of international investments, and the influx of tourists from both local and distant regions. The hazards that have the potential to escalate the cost of road construction are analogous to those that can augment the cost of any other construction undertaking. The impact of road projects can vary depending on several factors, including their horizontal scope, design, implementation method, and effects on nearby facilities (Tepeli, 2021). Road-building projects are more susceptible to cost overruns compared to other types of construction work due to their significant initial investment, extensive scope, prolonged duration, and distinctive site characteristics. The transportation infrastructure of the country comprises a network of roads that serve as a vital link between various ports, airports, industries, and institutions. It is a common occurrence for transportation network initiatives to exceed their initial budgetary projections. Numerous transportation initiatives of great prominence across the globe have experienced noteworthy increases in expenses beyond their initial budget. The Central Artery/Tunnel of Boston, commonly referred to as the "Big Dig," holds the distinction of being the most costly highway infrastructure undertaking in the annals of the United States. The development of the project commenced in 1991 and persisted until 2007, culminating in a cost overrun of 11 billion dollars, which represents a 275 percent increase.

A cohort of specialists analyzed 258 distinct transportation infrastructure undertakings, with a cumulative value of $9 billion, to ascertain the factors that lead to budgetary overruns. The concerned parties expressed apprehension regarding the magnitude and duration of the undertakings. The findings indicate that the duration of the implementation stage has a significant impact on cost overruns, as evidenced by (a), while (b) demonstrates that cost overruns tend to increase by an average of 4.64 percent per year from the point of construction decision to the commencement of operations. According to Makovek's (2018) findings, it was demonstrated that larger-scale projects, such as those about bridges and tunnels, exhibited a greater propensity for experiencing cost overruns. Several primary factors have been identified as the root cause of cost overruns observed in highway projects in Australia. Variables encompass a range of factors such as redesign iterations, alterations in pricing within tenders, modifications in quality requirements, unforeseen events, and the necessity of substituting substandard materials. Empirical evidence from a statistical analysis of Norway's road construction expenditures between 1992 and 1995 has demonstrated a positive correlation between these two variables. The research indicates that the realized expenses were 7.9% below the projected expenses. The study conducted by Al Nahyan (2019) on the subject of cost overruns in road construction projects in Canada revealed that the primary factors responsible for such overruns were design modifications, concealed conditions, permits, and regulations.

**6.2 Recommendations**

- Conduct a thorough risk assessment to identify and analyze the potential risks and complexities associated with the project. The assessment process should take into account various factors such as geological circumstances, environmental impact, regulatory hindrances, stakeholder administration, and project interdependencies. The identification and quantification of risks can enhance the precision of your contingency planning.

- An examination of data from completed transport infrastructure projects in Australia can provide insight into the types of hazards and challenges that have contributed to project delays in the past. The present research endeavor aims to facilitate the anticipation of potential future events by drawing upon empirical observations and to provide valuable perspectives on specific risk factors that hold significant prominence within the context of Australia.
- Solicit external perspectives and evaluations about your risk and complexity assessment. It is recommended to engage professionals with expertise in the transportation infrastructure sector in Australia to validate your risk evaluation and offer guidance. Certain hazards may have been overlooked; however, with their expert guidance, we can ensure that the assessment is conducted with the utmost comprehensiveness.
- Conduct a sensitivity analysis to assess the potential impact of various variables on the schedule of your project. To accomplish this task, it is imperative to conduct an analysis of the potential effects that altering specific risk factors could have on the overall project schedule. One may evaluate potential contingencies by considering their likelihood and potential consequences, and by quantifying the impact of their complexity.
- Develop a range of scenarios that encompass all possible outcomes, considering the different levels of risk and complexity that may arise during the implementation of the project. It is recommended to incorporate the potential impacts of various risks on the project schedule within each scenario. By estimating contingencies for each possible outcome, one can increase preparedness for unforeseen delays and account for a range of potential results.

- Develop a comprehensive approach to monitor and document potential hazards that may emerge during the project's duration. In the event of alterations to the project's scope, external factors, or potential hazards, it is imperative to conduct a thorough review and subsequent update of the risk and complexity assessment. By remaining vigilant toward possible hazards, it is possible to make prompt modifications to one's estimates for contingency planning.

**6.3 Limitations**

The efficacy of road infrastructure initiatives in Australia is contingent upon a precise assessment of risk and intricacy attributes. Nonetheless, this approach is subject to limitations that could impede efficiency and hinder the attainment of optimal contingency projections. Transportation infrastructure initiatives are intricate and fraught with risk due to their inherent unpredictability. The intricacies of stakeholders, disciplines, supplier chains, and environmental linkages in such projects can be quite complex. The challenges associated with defining and quantifying hazards and complexity can result in inaccuracies in estimation. Insufficient preparation for unforeseen events can result in delays and cost overruns. The lack of comprehensive historical records and established benchmarks for past endeavorposees significant obstacles. Accessing relevant data and information about the previous success of a project is imperative for making precise predictions regarding potential risks and challenges. Obtaining commensurate data for suitable evaluation can pose a difficulty as numerous transportation infrastructure projects are unique in nature. The absence of reliable benchmarks may result in uncertainties when calculating contingencies, leading to potential delays as the project team seeks additional information or expert opinions to make informed decisions.

The intricacy of stakeholder involvement and decision-making processes is a contributing factor to the postponement of optimal contingency evaluations. Transport infrastructure projects often involve the participation of various public and private entities as well as community members. Consensus on risk assessment and contingency estimation can prove challenging due to divergent objectives, perspectives, and risk thresholds among stakeholders. Possible academic rewrite: The occurrence of delays can be attributed to the need for extensive deliberations, bargaining, and authorizations, especially when there are divergent interests or tensions among the parties involved. Moreover, the dynamic nature of project environments and external factors may pose challenges in accurately assessing risks and complexities. External factors, such as regulatory changes, economic fluctuations, or natural disasters, may significantly impact the magnitude and complexity of the project beyond the team's jurisdiction. It is imperative to continuously reassess and modify contingency evaluations as unforeseen variables may arise at any point during the project's duration. Failure to account for these dynamic situations could result in delays and inadequate contingency planning. Furthermore, the estimation procedure could experience a deceleration due to a scarcity of proficient individuals possessing expertise in risk assessment and complexity valuation. Professionals involved in managing transportation infrastructure projects and conducting risk assessments are required to possess a comprehensive understanding of the domain, as well as project management and risk assessment methodologies. Nonetheless, there is typically a greater need for these specialists than the available pool, leading to potential setbacks in the evaluation procedure. The need to identify suitable expertise or invest in the education of current personnel may impede the progress of project teams.

### 6.4 Further research

Accurately assessing the risk and complexity attributes holds significant importance for the efficient and timely execution of transportation infrastructure ventures in Australia. Subsequent research endeavors will persist in prioritizing the exploration of enhanced methodologies for approximating probabilities, as the discipline progresses. Enhanced accuracy in forecasting potential delays and cost overruns in such projects could be facilitated by researchers who allocate more focus toward evaluating risk and complexity factors. Future research will primarily concentrate on developing advanced models and frameworks to evaluate the intricacy and risk associated with transportation infrastructure projects. To scrutinize vast quantities of data and identify significant risk indicators and complexity traits, these models are expected to employ advanced data analytics techniques such as machine learning and artificial intelligence. By analyzing historical project data and considering contextual factors such as geography, project scale, and stakeholder involvement, researchers have the potential to create more comprehensive frameworks that accurately capture the nuances of individual projects.

Future research will explore the incorporation of risk and complexity assessment into project management methodologies. Conventional project management methods often exhibit inaccuracies in contingency planning due to the perceived differentiation between risk and complexity. Incorporating risk and complexity appraisal into project management methodologies may enhance the efficacy of resource allocation, scheduling, and risk mitigation determinations. The consolidation process will enable project managers to engage in more comprehensive planning and make more accurate risk assessments, thereby reducing the incidence of costly delays and additional expenses. An essential domain for future research is the analysis of the impact of novel technologies on the evaluation of risk and complexity in transportation infrastructure projects. The utilization of advanced technologies such as the Internet of Things (IoT), remote sensing, and real-time data collection can potentially offer valuable insights into project dynamics and enable the prompt identification and mitigation of risks. These tools can be utilized by researchers to develop novel approaches for assessing project risks and complexities, thereby enabling more accurate contingency planning for risk and complexity and yielding superior end outcomes.

Additional research is required to investigate the accomplishments and shortcomings of previous transportation infrastructure endeavors. Undertaking an in-depth analysis of both successful and failed projects through the examination of case studies is a helpful approach to comprehending the primary risk and complexity factors that contribute to project delays. The dissemination of information by researchers can assist project managers and stakeholders in making informed decisions and adopting effective strategies to mitigate delays and enhance contingency estimates. Future research on the valuation of risk and complexity attributes in Australian transport infrastructure projects will concentrate on advanced models and frameworks that integrate risk and complexity valuation into project management methodologies. This will involve leveraging emerging technologies and identifying best practices. The implementation of these initiatives is expected to benefit the transportation infrastructure sector in Australia by enhancing risk assessment, reducing project timelines, and improving the overall quality of the final deliverables.

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