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THE FINAL MASTER'S THESIS

Rizikos valdymas didelio masto infrastruktūros projektuose: Kočio metro geležinkelio projekto Keralio valstijoje atvejo analizė	***Risk Management In Large-Scale Infrastructure Projects: A Case Study Of The Kochi Metro Rail Project In Kerala***

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SUMMARY

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INTERNATIONAL PROJECT MANAGEMENT STUDY PROGRAMME

SREELAKSHMI SASIKUMAR

RISK MANAGEMENT IN LARGE-SCALE INFRASTRUCTURE PROJECTS:

A CASE STUDY OF THE KOCHI METRO RAIL PROJECT IN KERALA

Supervisor – Dr. Birutė Miškinienė, Managing Director of Vilnius University Business School
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Developing nations frequently encounter issues related to planning, coordination amongst stakeholders, management of finances and risks, and other aspects when carrying out large-scale infrastructure works. The Kochi Metro Rail Project implemented in Kerala, India, is a perfect example to analyze risk management practices, theoretical foundations, practical applications, and contextual challenges. The study is focused on analyzing risk management frameworks, detecting the major risks, evaluating the effectiveness of the mitigation measures, and giving suggestions for improvements in future projects.

A qualitative case study method was implemented using secondary sources such as Detailed Project Reports, KMRL annual reports, audit reports, Environmental and Social Impact Assessments, and media articles. Content analysis and triangulation helped to identify the risk events, patterns, and outcomes in the financial, operational, human-resource, safety, scheduling, and documentation areas. Among the findings, there was effective management of operational and human-resource risks that was in line with the standards of PMBOK, ISO 31000, and PRINCE2. On the contrary, financial planning, scheduling, land acquisition, revenue diversification, and documentation were all done poorly, which in turn led to cost escalations, delays, and interrelated risks. The recommendations consist of conducting independent audits, improving land acquisition and financial strategies, developing revenue

diversification, and building up risk reporting to ensure the future infrastructure projects in India are efficient, reliable, and successful.

SANTRAUKA

VILNIAUS UNIVERSITETO VERSLO MOKYKLA 2024–2026

TARPTAUTINIS PROJEKTŲ VALDYMAS

SREELAKSHMI SASIKUMAR

RIZIKOS VALDYMAS DIDELIO MASTO INFRASTRUKTŪROS PROJEKTUOSE: KOČIO METRO GELEŽINKELIO PROJEKTO KERALOS VALSTIJOJE ATVEJO ANALIZĖ

Vadovas – dr. Birutė Miškinienė, VU Verslo mokyklos generalinė direktorė Magistro darbas (projektas) buvo parengtas Vilniuje, 2025 m.

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I šsivysčiusios šalys dažnai susiduria su problemomis, susijusiomis su planavimu, suinteresuotųjų šalių koordinavimu, finansų ir rizikų valdymu bei kitais aspektais įgyvendinant didelio masto infrastruktūros projektus. Keralos valstijoje, Indijoje, įgyvendintas Kochi metro geležinkelio projektas yra puikus pavyzdys, leidžiantis analizuoti rizikos valdymo praktiką, teorinius pagrindus, praktines taikymo sritis ir kontekstinius iššūkius. Tyrimo tikslas – analizuoti rizikos valdymo sistemas, nustatyti pagrindines rizikas, įvertinti taikomų rizikos mažinimo priemonių efektyvumą ir pateikti pasiūlymus, kaip pagerinti ateities projektų valdymą.

Tyrimui buvo pasirinktas kokybinis atvejo analizės metodas, naudojant antrinius šaltinius, tokius kaip Detalizuotos projekto ataskaitos (DPR), KMRL metinės ataskaitos, audito ataskaitos, aplinkos ir socialinės įtakos vertinimai bei žiniasklaidos straipsniai. Turinys buvo analizuojamas ir trianguliuojamas, siekiant identifikuoti rizikos įvykius, pasikartojančius modelius ir rezultatus finansų, veiklos, žmogiškųjų išteklių, saugos, tvarkaraščių ir dokumentacijos srityse. Tyrimo rezultatai parodė, kad veiklos ir žmogiškųjų išteklių rizikos buvo valdomos efektyviai, laikantis PMBOK, ISO 31000 ir PRINCE2 standartų.

Tuo tarpu finansų planavimas, tvarkaraščių laikymasis, žemės įsigijimas, pajamų diversifikavimas ir dokumentacija buvo vykdomi nepakankamai, dėl ko kilo išlaidų padidėjimas, vėlavimai ir tarpusavyje susijusios rizikos. Pasiūlymai apima nepriklausomų auditų vykdymą, žemės įsigijimo ir finansų strategijų gerinimą, pajamų diversifikavimą bei rizikos ataskaitų rengimą, siekiant užtikrinti ateities infrastruktūros projektų efektyvumą, patikimumą ir sėkmę Indijoje.

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To my boyfriend, thank you for always believing in me, encouraging me when things got tough, and being my constant source of motivation. Your patience and support made this journey much easier and more meaningful.

I am also grateful to my family and friends for their understanding and encouragement along the way.

LIST OF ABBREVIATIONS

ALARP – As Low As Reasonably Practicable
BIM – Building Information Modeling
CAG – Comptroller and Auditor General of India
COSO – Committee of Sponsoring Organizations of the Treadway Commission
DPR – Detailed Project Report
EIA – Environmental Impact Assessment
ERM – Enterprise Risk Management
ESIA – Environmental and Social Impact Assessment
GDP – Gross Domestic Product
ICT – Information and Communication Technology
IRGC – International Risk Governance Council
ISO – International Organization for Standardization
ISO 31000 – Risk Management Guidelines
ISO/IEC – International Organization for Standardization / International Electrotechnical Commission
IT – Information Technology
KMRL – Kochi Metro Rail Limited
LSIP / LSIPs – Large-Scale Infrastructure Project(s)
PAC – Public Accounts Committee
PMBOK – Project Management Body of Knowledge
PMI – Project Management Institute
SDGs – Sustainable Development Goals
UN – United Nations

INTRODUCTION

Relevance of the Topic

It is an evergreen notion that the development of infrastructure remains instrumental to improving mobility, building economic activity, and improving urban life standards in today's rapidly changing world (Foster, Gorgulu, Straub, & Vagliasindi, 2023). In addition to reducing traffic congestion, curbing environmental degradation, and cleaning up inefficiencies in urban mobility, good planning of infrastructure projects also sustains transport systems and provides other essential public services for the day-to-day activities of citizens. But similar to a coin, it also has two sides, one which showcases the benefits, while the other, the inevitable risks, mainly technical, financial, environmental, social, and political challenges. These risks, if left unsolved, could result in disputes among the stakeholders, cost overruns, delays, and sometimes, outright failures. Hence, it has become compulsory to manage these inherent risks to ensure the successful completion of infrastructure projects (Goswami, 2024). Thereby, risk management serves to reduce costs as well as to prevent delays and ensure that objectives outlined for projects are well achieved.

The strong reasons that claim the facilitation of stakeholder engagement, urban planning, and long-term economic gains, infrastructure projects also support social development. In order to manage uncertainties and sustain project progress, large-scale projects especially those with numerous stakeholders need proactive risk governance. Project managers can make evidence-based decisions, allocate resources effectively, evaluate alternatives clearly, and foster stakeholder trust with the help of a clear risk management framework. In order to investigate the use and efficacy of risk management techniques in a major urban transit project, this study focuses on the Kochi Metro Rail Project (KMRL) in Kerala, India.

According to the Kochi Metro Official website, the Kochi Metro Rail Project is a historic urban transportation project that aims to improve connectivity, promote sustainable mobility, and reduce traffic in one of India's fastest-growing cities. KMRL has been acknowledged for its engineering skills, as well as its socially responsible and environmentally friendly operations, since it opened in 2017. Kochi Metro, like other big metro projects, faced a number of risks during the planning, land acquisition, and construction phases. These risks included stakeholder opposition, financial constraints, land acquisition conflicts, and challenges in coordinating between public and private sectors (Castelblanco, Guevara, Mesa, & Flores, 2020). This project is a great way to learn how to use risk management techniques successfully in India's infrastructure.

Over the past two decades, India has witnessed rapid infrastructure development driven by urbanization, population growth, and government initiatives to improve transportation, housing, and energy systems. Urban mass transit systems have gained prominence in addressing traffic congestion, pollution, and increasing demand for efficient mobility. The Kochi Metro Project stands as one of the most advanced urban rail projects in Kerala, aiming to transform urban transportation while exemplifying sustainable development practices.

Kochi, as one of the most congested cities in Kerala, and it has been experiencing a surplus in four-wheel transportation. Almost 30,000 new cars were registered every year in the city, and an unprecedented estimate of 200,000 across the whole Ernakulam district. According to the article Times of India 2025, this has led to traffic congestion and frustration among the public, especially the daily commuters.

The repercussions were longer travel times, worsening traffic congestion, higher fuel consumption, and deteriorating air quality. To illustrate the environmental impact of increasing vehicle emissions, a study conducted by the Centre for Science and Environment (CSE) found that NO_2 levels increased by 539 percent during specific periods when compared to lockdown baselines in 2020. This, in turn, highlights the necessity of a mass rapid transit systems, such as the Kochi Metro, which provide a dependable, high-capacity, low-pollution substitute for traditional road transportation, as highlighted by the ongoing traffic and pollution issues. The novelty of this research lies in the fact that it is an in-depth case study of a large-scale metro project in India, especially from a particular state called Kerala, an area that has received limited attention in the existing literature.

Problematics

Developing countries' large-scale infrastructure projects are usually faced with doubtful planning, coordination among stakeholders, and so on. India has urban metro systems such as Delhi and Hyderabad that are studied a lot, while the Kochi Metro Rail Project in Kerala has not been the focus of much rigorous academic research, especially concerning the impact of risk management practices on project outcomes (Sinha, 2021).

The main risk in the Kochi Metro is land acquisition and resettlement. The Social Due Diligence Report for Kochi Metro Phase II clearly mentions AIIB's ESS 2 standard (Involuntary Resettlement), thus showing that displacing people, disrupting their livings and disputes overcompensation are very serious issues (AIIB, 2024). The report also points out that to prevent these risks, there will have to be strong and fair way for people to report it and community involvement (AIIB, 2024). Besides that, the Project's Environmental Impact Assessment (EIA) for Phase II identifies ecological and social dangers, such as disruption of wildlife and change in land use due to the building of an elevated viaduct (Kochi Metro Rail Ltd, 2020). Apart from risks associated with land, there are financial and technical uncertainties that add to the fragility of the project. An assessment of risk using fuzzy-FMEA on elevated metro projects in India showed that among the topmost threat categories economic risks (especially cost overruns) and physical risks are (Amrutha & Kranti Kumar, 2023). What is more, the long-term financing of the Kochi Metro is heavily reliant on land-value capture and real-estate cross-subsidisation, which brings along the risks related to real estate markets and policy stability (Sinha, 2021). The combination of the institutional and academic insights shows that there is a knowledge gap which is still present: the project documents acknowledge the presence of several types of risks erning situation in Kochi regarding those risks. The understanding of which governance mechanisms are successful, which are unsuccessful, and how they could be made better in future phases or similar urban rail projects is thereby diminished.

Thesis Aim

The project intends to give a wide-ranging assessment of the risk management of the large-scale infrastructure projects in India, emphasizing the theoretical foundations, practical applications and contextual challenges, taking the Kochi Metro Rail Project as an intensive case study

Objectives

- Examine the conceptual and theoretical grounds of risk management in infrastructure megaprojects.
- Determine major risk categories in urban metro systems in developing countries, putting an emphasis on the Indian context.
- Survey existing risk management frameworks and their relevance to public–private, multi-stakeholder projects.

- Investigate the extent to which socio-political, financial and organizational factors shape risk outcomes in the Kochi Metro Rail Project.
- Recommend strategies, policy-level changes, and management practices that would enhance risk management in future metro and infrastructure projects in India.

Research Methodology

This study adopts a qualitative-dominant case study approach with content analysis. In relation to the proprietary content, secondary data resources were also used in this paper. The researcher reviewed 32 initial papers from the relevant academic databases due to the time constraints of the master's thesis. Out of the 17 pages filtered for papers specifically related to risk management in the infrastructure projects, 15 were finally chosen to give enough information for the empirical study, thus being considered relevant. These data sources were credible and verifiable project documents like the Detailed Project Report (DPR), KMRL annual reports, Environmental and Social Impact Assessments, and other official documents. These sources were selected for their authenticity and full coverage of the Kochi Metro Rail Project, including the aspects of technical, operational, financial, human resource and scheduling. The coding process required multiple readings of the documents to uncover risk events, numerical indicators, recurring patterns, and problems. Through this method, the researcher was able to obtain insights that were specifically aligned with the research goals.

Visual aids were used in the empirical component to show clearly: the risk categories distribution, the operational performance trends, and the different risk mitigation measures that have been applied by KMRL.

This methodology strategy was utilised to support the paper containing limited proprietary resource, and plenty secondary sources which both combined helped to analyze historical decisions, risks, and outcomes. Qualitative content analysis is applied, for instance, in policy reports, media articles, audit records, and stakeholder statements, to give a descriptive explanation of the non-quantifiable and contextual risks, which are often found in large-scale public projects. The basic project metrics of cost, timelines, land acquisition data, and ridership statistics are used to give further support to qualitative observations. The mixed approach serves to evaluate the effectiveness of risk mitigation strategies more broadly. The combination of methods is used with a deliberate intention because Kochi metro megaproject have both measurable aspects (cost, schedule) and non-measurable aspects (stakeholder resistance, governance challenges) and thus need mixed-approach analysis.

Structure of Thesis

The structure of the thesis is as follows. The first chapter introduces the theoretical foundations of risk management in large-scale infrastructure projects. The second chapter elaborates on existing frameworks and practices. The third chapter discusses metro rail projects and presents the context for the case study. The fourth chapter examines risk management practices and their application in the Kochi Metro Rail Project. The final chapters focus on complex risks, including human resource, organizational, and digitalization-related challenges, before concluding with findings, practical recommendations, and limitations.

This research adds to both science and practice by giving a thorough look at how risk management has been performing in the Indian metro rail. It also leaves insights about gaps and suggests ways to improve project outcomes. The study has a unique manner due to its case-based methodology integrated with a systematic evaluation framework, which can enhance risk management practices in other extensive infrastructure initiatives. Some of the limitations addressed- proprietary project data is limited, and the dependence on expert interviews, which could make the results less objective. Even with these limitations, the results are still useful for project managers, policymakers, and other people involved in big infrastructure projects,

1. Literature Review Methodology

To strengthen the theoretical basis, relevant literature related to the theme was reviewed. The major databases that were used include Scopus, Web of Science, Science Direct, and SpringerLink. Apart from these, Google Scholar was also referred to in order to access additional peer-reviewed studies. Some reports by institutions such as the World Bank, OECD, and UN-Habitat were looked into but were never really considered as theoretical works, more for enriching the background.

The keywords searched for *were risk management in large-scale infrastructure projects, resilience-based project management, risk governance metro rail projects, infrastructure uncertainty and complexity, and sustainability and risk management LSIPs*.

1. Boolean operators were applied to improve the search.
   Procedure - The review was done in three steps: first by title, then by abstract, and finally by full text.
   At the start, there were 236 articles. After title checking, 118 remained. After abstract checking, 62, and finally 56, after checking the full text. In addition, 10 classical works (for instance, Flyvbjerg, COSO, and ISO guidelines) were added to give theoretical depth. They are older than 5 years, but kept in balance with 25 percent of the total sources

1.1 RISK MANAGEMENT IN LARGE-SCALE INFRASTRUCTURE PROJECTS

Large infrastructure projects are the driving force of socioeconomic development, and these projects can be airports, metro systems, or power plants and more. These projects are build to satiate the following necessities consisting of ease of travel, job shortages, and improved urban living standards. However, in actuality, because of their enormous scale, complexity, and unpredictability, these projects carry a high risk. Hence, they differ from smaller projects because of this.

Large-scale Infrastructure Projects (hereinafter mentioned as LSIPs) are confronted with obstacles and are prolonged for years of completion. It has been known that certain LSIP often cross the duration of a particular political administration while having ties with numerous stakeholders and debts of investments ranging beyond billions. The obstacles that are frequent and that are recognised conspicuously were delays, cost overruns, and even public dissatisfaction. Thus, the prior reason for the implementation of risk management comes into play here. These days, it is regarded as an essential component of project governance and strategic decision-making, not merely a supplementary tool (Lovallo, Cristofaro, & Flyvbjerg, 2023)

Mega infrastructure projects play a major role in boosting a country's economy and improving people's quality of life. At the same time, these projects often face issues of cost, project completion delays, and disagreements among stakeholders. While traditional project management methods such as PRINCE2, PMBOK, and Agile offer useful frameworks, they are not always suitable for megaprojects because of the unique difficulties involved.

In the global setting, developing and developed countries share different volumes in infrastructure investments. From their GDP's, the former one takes up to 2 to 3 percent while the latter takes around 5 to 7 percent. These investments had influenced major projects, such as in the case of China's High-Speed Rail project that supports regional integration (Chen et al., 2019). Still, megaprojects are highly risky: around 90percentage of them exceed their original budgets, with an average overrun of about 28 percent (Flyvbjerg, 2023). Some well-known cases, like the Berlin Brandenburg Airport, which went over budget by more than €5 billion and was delayed by 9 years, show why it is so important to develop a more systematic and flexible approach to managing these projects (Gohar, 2025).

Massive and complicated infrastructural projects are able to exert influence that lasts for decades across various domains such as the economy, the society, and sometimes even the nature. Their planning has to be contingent upon very accurate time frames, and the use of the agile methodology is not applicable for them all the time. Developers of software often resort to the agile paradigm, since it is all about immediate goals and the building-up of the product step by step. Sometimes, the method gets to be applied in the case of infrastructure, but it is not always the right situation as these projects involve much greater and long-lasting issues.

Those infrastructure projects that are successful are the ones that are well thought out and take into consideration all the social, financial, and technical aspects. High-speed trains in China are a magnificent example where proper planning along with powerful government support have made the difference as it has been completed 95% on time. Besides realizing the importance of the stakeholders such as government, private partners, and local communities, adding the factor of stakeholder involvement might even out result in fewer delays (Chen et al., 2019). Another aspect of the project that needs continued attention is managing uncertainties such as political, financial, and technical risks. One more instance is the Crossrail project in London, which was able to reduce cost overrun by 15% through effective risk management.

Governance also is a key factor in determining success. The factors of clear accountability, transparency, and effective decision-making can all contribute to the successful completion of a project. The Sydney Opera House demonstrated this by utilizing a novel public-private partnership, which enabled it to stick to its schedule despite the early difficulties. The Triple Constraint Model and Stakeholder Theory are concepts that not only explain the practicality of these methods but also provide invaluable input for guaranteeing the success of massive projects.

1.1.1 Theoretical Foundations: Risk, Uncertainty, and Frameworks

The most successful infrastructure projects are those that are properly planned by considering different factors like social, financial, and technical aspects. China's High-Speed Rail is a very good example of how proper planning and strong government support can make a real difference, as it was able to finish 95 percent of the project within the scheduled time. It is also very significant to involve stakeholders such as government agencies, private partners, and local communities, as the projects with greater stakeholder participation generally face fewer delays (Chen et al., 2019). Managing uncertainties such as political, financial, and technical risks throughout the project is another key factor that should be taken into account. A good example can be given of The Crossrail project in London which was able to reduce cost overruns by 15 percent by efficiently managing these risks. Good governance is another way of saying the same thing, which could be understood that accountability, transparency, and effective decision-making can lead to the success of a project. The Sydney Opera House demonstrated this by using a novel public-private partnership that allowed it to be completed on time despite having difficulties in the beginning. The Triple Constraint Model and Stakeholder Theory indicate why these methods succeed and support large-scale project success by providing the necessary guidance.

Our decisions, it is never strictly understood what the results will be like, but usually, we can at least roughly forecast the degree of certainty that will accompany the uncertainty, ambiguity, and risk involved. The level of risk associated with a decision is situation-dependent, and experience teaches that recognizing and managing these factors is frequently the reason for success. Research also indicates that risk and uncertainty are sometimes confused with each other, which can lead to erroneous decision-making (Bonjean Stanton & Roelich, 2021).

Risk is defined by the presence of various possible outcomes, but the chances of these outcomes are either known or can be derived. In contrast, uncertainty is characterized by the lack of knowledge or inability to derive the chances (Liu, An, Kim, & Liu, 2022). Uncertainty can be absolute, where nothing is known, or it can be relative, where at least some assumptions are made. Connected with this are the notions of risk aversion (the preference for predictability), uncertainty or ambiguity aversion (the choice of known chances over unknown ones), uncertainty avoidance (the different ways cultures deal with unpredictability), and loss aversion (the tendency to more strongly fear losses than to value equivalent gains). Ellsberg's Paradox is one such famous case that demonstrates people's usual preference for known probabilities over unknown ones, even though the latter might yield better rewards.

Risks can originate from various sources like economic (market or credit risks), political (policy changes, terrorism, or cybercrime), social (cultural differences or consumer trends), and international (competition among countries). Having knowledge of these concepts enables managers and decision-makers to better handle risk and uncertainty in financial and business situations (Alhabeeb, 2025).

Although it is not possible to absolutely foretell the result of any decision, it is very much possible to assess different levels of risks and uncertainty. The risk factor varies with the case under consideration and history has shown that in many instances, success was determined by how well these elements were acknowledged and controlled. In the realm of decision making, one of the frequent problems is the mixing up of risk and uncertainty. Risk is understood as a situation in which the odds of the various outcomes are known or at least can be estimated. On the contrary, Uncertainty is generally characterized as and applies to situations where the odds are completely unknown or cannot be calculated at all. Uncertainty may be total, implying that no information is given or it may be partial when some assumptions and estimates are still possible. likewise, there are some concepts associated with these two ideas such as risk aversion, which is the preference for safety; uncertainty or ambiguity aversion, which is the preference for known probabilities; uncertainty avoidance, which shows how different cultures handle unpredictability; and loss aversion, where people are more afraid of losing than they are willing to accept receiving equivalent gains. Ellsberg's Paradox exemplifies this by demonstrating how people frequently take known risks even when uncertain alternatives might yield higher rewards.

Organizations depend on structured methods to systematically deal with risks. According to Kumar (2021), the COSO 2004 framework puts forward ERM as the way to synchronize risk appetite with the business strategy, to refine risk responses, to prevent unexpected losses, and to manage one risk throughout the whole company. COSO categorizes objectives into four groups: strategy, operations, reporting, and compliance, and it outlines eight elements of ERM, namely internal environment, objective setting, risk assessment, and monitoring. Though COSO 2004 offered a detailed method, Al-Dabbagh (2020) points out that the COVID-19 pandemic exposed its drawbacks since companies needed mechanisms for swift and proactive decision making, and thus, can lead to faster and more proactive decision-making mechanisms were required by organizations. However, the connection between strategy and performance was further bolstered by the COSO 2017 update which first introduced the five major pillars: the first one is governance and culture, the second one is strategy in addition with objective setting, third is performance, fourth is review and revision, and fifth is a compilation of information, communication, and reporting. Further to these pillars, 20 principles were developed that guide organizations in successfully integrating risk management into their corporate strategies (Efe, 2023). ISO 31000 is another commonly accepted framework that transcends distance sectors from its very first release in 2009, which featured three main pillars: principles, framework, and process. The principles stress the importance of supplying value, risk-taking as a component of decision-making, processing uncertainty, having the best available information as a basis, being open and engaging, rising to the occasion, and concentrating on continuous improvement. The framework portrays the concepts of trust in leadership, right design, execution, supervision, and continual assessment (Efe, 2023).

ISO 31000 was revised in 2018 to give more attention to value creation and protection, a strong leadership approach, and deeper embedding of risk management in the organization's processes. The framework was also enhanced, and the areas of context, accountability, resource allocation, and communication were boldly targeted. Process-wise, there was no big change but some parts, like reporting and documentation, were updated (Efe, 2023). Depending purely on their peculiar goals, interests, and the specific needs of their industries, organisations might choose between COSO, ISO or even use both. This gradually makes it clear that risk management has transitioned from being a non-core function to becoming a critical aspect of governance, strategy, and long-term success.

1.1.1.1 Project complexities

A Project management theory that demonstrates the influence of project complexity on a project's aim, organizational structure, team experience, and management processes is termed complexity theory. Complexity is defined solely as a factor that affects project coordination, planning, and control, makes it harder to specify primary goals, affects team selection, and influences key project outcomes such as cost, time, quality, and safety. As the complexity of projects increases, traditional practices of project management lose effectiveness, thus increasing the risk of failure. It is therefore imperative for project managers to understand and deal with complexity to ensure that they can make appropriate decisions, cope with ambiguity, react to emergencies, and limit the corrosive effects of complex and dynamic project environments. (Ghaleb et al., 2022)

Resilience-based frameworks go beyond risk management and focus on prevention and mitigation. LSIPs involve an array of stakeholders in this structure. These will usually be government agencies, private financiers, local communities, and regulators. Hence, many interests clash, expectations clash, and power clashes. Coordination and consensus-building hence, become difficult. Research underlines managing stakeholder relations as a core element of project success, while conflicting interests lead to project delays and costs. (Dwivedi, 2021) The technical side of LSIPs requires advanced engineering, new technologies, and multi-system integration. When referring to technical complexity as a crucial characteristic of major infrastructural projects, they point out how the convoluted nature of design and construction processes might give rise to unforeseen challenges (Eriksson, Pesämaa, & Larsson, 2023). LSIPs generally cover long periods; thus, economic conditions, politics, and societal demands are subject to change. Rese Research presents research that discusses ways long project durations might cause projects to fall out of alignment with present policy or market conditions to the detriment of their outcomes. Governance also referred as leadership changes, which is often a frequent occurrence depending on time, usually plays a part in project continuity and decision-making mechanisms. Similarly, several factors that are external influence LSIPs and their pressure several external forces exert their pressure develops overtime layers of complexity, and these factors that affects the economy, the environment and the politics by leading to crisis in economy, unrest in politics and challenges in the environment (Dirks & Schmidt, 2024). In recent years, the major pandemic - COVID-19, was one global health crisis that disrupted supply chains, labor availability, and regulatory environment-occasioning as opportunity for delayed execution and cost overruns. Accordingly, climate change implications call for adaptive design and resilience-based planning that, in turn, aggravate project implementation (Rifai et al., 2024).

Risk-based decision-making is a prescriptive approach focusing on setting strict thresholds beyond which certain actions must be taken. It assumes that a given threat can be quantified and that decisions can be made on the basis of comparing these quantifications against pre-established criteria. This method provides clear and simple steps to follow but may turn out to miss adequately accounting for the changing and complex nature of LSIPs that exhibit risks being often interdependent and evolving over time (Caburao, 2025). Risk-informed decision-making, on the other hand, considers a wider range of various factors beyond just the risk assessment. In a more traditional sense, an LSIP intends to embrace all social, political, economic, and environmental considerations entering into the decision-making process. This holistic way of thinking is in acknowledgment of the many complexities and interconnected elements within LSIPs; from this perspective, decisions would be more adaptive and context-specific (Vasconcelos, Barros, Soares, & Costa, 2023).

The COVID-19 pandemic is a relevant example of risk-risk trade-offs. The lawful measures put in place to reduce the health risks of COVID-19 introduced a slew of new risk factors, such as those concerning an economic downturn and cyber threats. As remote working spiked during lockdowns, cyberattacks increased as well, with phishing and malware being key incidents that cybercriminals exploited to compromise systems while organizations scrambled to adjust to the new operational realities. From this set-up, a risk-informed decision-making approach would have been appropriate in order to weigh the interplay of the various risks involved so as to arrive at balanced decisions." (Mondino, Scolobig, Di Baldassarre, & Stoffel, 2023)

For LSIPs characterized by their size, duration, and diversity of interests, an informed approach to risk is pertinent. These projects are subject to varying factors, from regulatory changes to innovations in technology and societal expectations. The idea that risk-informed decisions help LSIP managers navigate some of the complexities of these projects is to ensure decisions are made on risk-based assessments as well as on a larger context that defines the project.

Traditional project management approaches rely heavily on registers of risk as the main instrument for documenting and tracking risks (Buganová & Šimíčková, 2019). Although risk registers are good for keeping track of threats to projects, in the case of greater complexity and dynamism in the project environment, then these tend to be linear, static, and rapidly become obsolete (Akshay, 2023). This is since, in big projects, the risks are not fixed; they modify themselves according to political, economic, technologic, and environmental circumstances. The problem with this static risk register is that it gives a false sense of security and limits the ability of project managers to respond on a proactive basis to arising challenges (PMI, 2021). In their effort to overcome the problem of static risk registers, researchers and practitioners have increasingly supported adaptive and resilience-oriented approaches to risk management. This underlines the need for dynamic updating of risk assessments rather than treating risk simply as a one-off, predefined event. For example, ISO 31000 as well as the International Risk Governance Council (IRGC) frameworks emphasize continuous monitoring and review loops so that risks are reassessed as conditions change. This process makes an organization more agile and better prepared to face uncertainty.

Integration of digital tools and advanced technologies has also changed the character of risk management. Tools such as AI, BIM, and predictive analytics support project managers integrate risk assessment with real-time data so that risk assessments are more reactive and evidence-based. Moving from static registers to adaptive frameworks supported by technology allows projects to better anticipate emerging risks, compute vulnerabilities, and factor in overall resilience amidst uncertainty. Resilience-based frameworks go beyond the focus of risk management toward prevention and mitigation. Instead of attempting to eliminate all risks, these frameworks emphasize systems adaptation, the capacity to absorb shocks, and recover efficiently in the case of disruption (Buganová & Šimíčková, 2019). It is well recognized that uncertainties arise in LSIPs owing to technical, political, economic, and environmental factors from time to time. Thus, resilience is a key thought for infrastructure systems which are complex, interlinked, and difficult to predict (Nahid et al., 2024). Zhang et al. (2023) go further, saying that bringing in resilience into project management does risk mitigation but also the long-term sustainability of infrastructure outcomes.

Linking resilience-based frameworks to sustainability goals ensures the continued relevance of these concepts in contemporary or current project management (Nahid et al., 2024). Modern LSIPs are supposed to bring the agenda of climate resilience, social inclusivity, and sustainable development, which is in fact, specified in the UN Sustainable Development Goals (SDGs). For example, to withstand climate shocks like floods, extreme heat, and sea-level rise, while equally serving diverse social groups equitably. In this way, resilience becomes a linking concept, bridging the domains of risk management and sustainability.

Resilience-based approaches offer several benefits, especially to LSI Projects, principally because three important qualities are incorporated in resilience approaches. The first is the strategic aspect that ensures the management of risks becomes embedded within governance structures rather than being just a technical consideration. The adaptive element necessitates updates to risk assessments dynamically, through real-time data, predictive analytics, and monitoring systems. The in-the-strict sense resilient side allows recovery and sustained functioning of infrastructure following a disruption. This is quite a radical shift away from, on one hand, reliance upon being reactive to outward checklists and, on the other, stagnant risk registers to an embrace of going-proactive towards a governance tool set geared for long-term success of projects. This conceptual basis is very much essential for study pertaining to metro projects such as Kochi Metro and the multilevel risks involved—including technical, financial, political, environmental. Under a resilience-based approach, such projects are viewed not just in terms of their ability to avoid risk but also in their ability to adapt, recover, and maintain sustainability in urban development.

1.1.2 Categories of Risks in Metro Rail Projects

Metro rail projects are among the most difficult variations of urban infrastructure developments. Metro systems are unlike the usual building projects, given that they cost many millions of dollars and involve high technological sophistication, and they are set in crowded urban environments. Design, financing, and operation involve varied stakeholders ranging from the government, private investors, and the public, thereby increasing uncertainty and risk potential. These risks span cost overruns, technical failures, social resistance, and regulatory roadblocks, each having a great bearing on the end performance and sustainability of a project.

Based on the established regulation of project management processes, risks are to be identified and categorized before the initiation of mitigation of the issues. To support this statement, the PMBOK Guide states that for the proper governance of a project the initial identification and assessment of the risks has to be given the main priority so as to deal with these issues in a systematic manner (Project Management Institute [PMI], 2021). Therefore, it is the same in the case for the metro projects and the reason for understanding the risks and their variations helps in their progress.

1.1.2.1. Financial Risks

The financial risks in metro rail projects usually originate from money and economy-related issues, which can affect how the project is developed, the costing, and whether it is financially stable in the future. These kinds of risks are mostly seen in very large infrastructure projects because huge investments are required, completion time is verylong, and funding sources are often too complex (Sinto & Saranya, 2019). Main examples of financial risks are depending too much on debt or PPP models, sudden price rising of construction materials due to inflation, foreign exchange fluctuations when equipment is imported, and also late receiving of government loans or grants (Musarat, Alaloul, and Liew, 2021). For example, in the case of the Delhi Metro, there were delays in getting funding from government agencies, and then the construction was affected. As a result of this, changes in resources had to be made (Jadhav, Gollu, Shivaswaroop, & Ghosh, 2022). These kinds of financial problems are not only delaying the schedules but also making less confidence for the public, contractors, and investors.

herefore, proper budgeting and careful financial planning should be done if these issues are to be avoided.

1.1.2.2 Technical Risks

Technical risks are usually related to the design, engineering, integration of technology, and the safety of operations in metro rail projects. These risks are becoming more substantial because metro infrastructure is very complex, as it involves tunnels, elevatedtracks, signaling, rolling stock, and also the connection with existing city utilities (Zhang,2024). Technical risks are generally categorized in the following, if the design has mishaps, even related to its engineering dynamics or the quality of the construction technology is compromised, or if any troubles occur in signaling, power, and smooth communication (Procore Technologies, 2024). When higher technology such as automation and driverless trains is used, then unexpected engineering challenges are being faced, which needs more time, energy and cost. Also, when tunneling is being done in crowded areas, soil instability or disturbance to underground utilities can be happening. These technical problems are causing delay in construction, cost overruns, and sometimes safety standards are not followed. For avoiding such issues, project developers are required to do proper design validation, strong quality checks, and monitoring continuously during the project (Kulkarni et al., 2022)

1.1.2.3 Environmental & Social Risks

As there is danger for the environment that must be saved, and also some local communities are involved, metro rail projects are subject to many external and social risks. Such risks are generally taken in connection with land acquisition disputes, resettlement of displaced families, disruption to ecosystems, and nonfollowing of environmental regulations (Kumar, 2022). Not only is land clearing required for a metro project, but also the diversion of utilities. In some cases, natural landscapes are changed, which creates opposition from the public, legal, and regulatory problems.

Usually, delays are created when local communities resist displacement or when environmental assessments reveal major ecological problems like wetland destruction or urban flooding intensification. If stakeholders are not properly engaged, social unrest or legal cases may soon arise, thereby causing cost escalation as well as delay to projects. To eliminate such issues, environmental and social impact assessments should be carried out. Stakeholders should be openly engaged. The construction of any metro should be sustainable to meet any legal and social expectations.

1.1.2.4. Political and Regulatory Risks

Political and regulatory risks in metro rail projects arise due to the change in government policies, political instability, corruption, or conflict among the regulatory agencies (Demirci, Okudan, Demirdöğen, & Işik, 2025). In the case of political risks, some aspects relate to policy changes, pauses in clearances and sudden government administrative changes might hinder the progress of a project. As for an example, if there are new land acquisition laws, safety standards, or town planning regulations, there may be forced redesigns and requirements to comply with the new regulations, which can be the reason for delays. Likewise, misconduct like bribery or red tape would cause anything from subpar permission processes to late issuance of funds, thereby causing financial and operational pressure. These risks can be overcome by maintaining cordial relations with the government, keeping vigil on regulatory changes, and keeping the communication transparent with all stakeholders to accommodate any changes these risks may bring about.

1.1.2.5. The Operational Risk

Operational risks are associated with the daily activities of running, maintaining, and managing the metro system. Such risks might include maintenance failures, shortage of skilled labour, inadequate training, accidents, unforeseen changes in passenger demand, strikes, or natural disasters (PMI, 2021). For instance, if routine maintenance is delayed and signal systems are breaking down, services may be affected, and people become dissatisfied with additional expenditure. Similarly, it also causes an eventual decrease in operational efficiency due to a shortage of skilled staff or labor disputes. Henceforth, to avert such risks, preventive maintenance schedules should be employed, staff training should be conducted on a periodic basis, and modern monitoring along with contingency plans should be put in place for the smooth operation of services.

1.1.3. Global Best Practices in Risk Management

Large-scale infrastructure projects are undertaken for the purpose of construction and improvement of a metro transit system, airports, and high-speed rail, which are surely considered among the most expensive and technically arduous in present-day economies.

These high-profile projects are faced with an immense number of risks requiring many years for execution, and these risks are mostly connected. The repercussions of these risks often lead to damage to on-time delivery and may even affect the long-term sustainability of the project. Since the execution clearly depends heavily on political and financial commitments. As these are a matter of national competitiveness and also set directions for urban development, not managing their risk has the potential to lead to huge social, economic, and political problems. In the past, risk management for LSIPs consisted of maintaining static registers and dealing with problems as and when they appeared. Over time, people began realizing that risks are dynamic and complex, which favored a more proactive and adaptive approach. Hence, risk management now encompasses not only the identification and control of threats but also issues related to governance, employment of technology, innovative contracts, and resilience-building into the system. Therefore, this section is organized into a review of the four main categories of international best practices for managing risks in LSIPs. They are governance frameworks, technological integration, contractual approaches, and resilience-based approaches. In combination, they provide an account of how global experiences may prove useful in enhancing metro rail and other infrastructure projects in updates, depending on their respective situations.

1.1.3.1 Governance Frameworks

In project management, governance is understood as the structures, processes, and rules defining who has decision-making power, how accountability is ensured, and the means by which project objectives are aligned with stakeholder expectations (Turner, 2020). The most effective governance is the set of institutional arrangements under which LSIPs are directed and controlled such that the management of risks is transparent and accountable (Derakhshan, Turner & Mancini, 2019). One of the governance functions that have greatest importance in LSIPs is the early alignment of stakeholders. Hence, the very first steps in the project include assuring the presence of government agencies, financiers, contractors, and even local communities. If they are brought in at the beginning, the possibility of conflicts will be avoided, the mobilization of resources will be supported, and a joint ownership of the project outcomes will be created. Moreover, clear accountability systems that are established on the clear definition of roles and in transparent reporting as well as oversight mechanisms will prevent disputes and delays since every party knows what is expected of them, and it is being monitored (Di Maddaloni et al., 2025). Uncommon cases are shining examples of governance impacting project performance. For example, the Crossrail Project in the UK showed that early coordination and a strong oversight structure dealt with technical and financial complexities

(Gohar, 2025). Similarly, the Hong Kong MTR is often referred to as the case study wherein governance structures and ongoing consultations with stakeholders contributed to its strong reputation of efficiency and dependability (To, Lee, Billy, 2020). Therefore, with strong governance in place, conflicts and delays become fewer, whereas projects are better viewed as legitimate and transparent. A project manager integrates stakeholder interests into a governance structure that holds those interests accountable for providing credibility and sustainability to projects that are normally complex and politically sensitive.

1.1.3.2. Technological Integration

Risk management in LSIPs has undergone vast transformations in the era of digital tools. BIM is used for giving live visualization of the complex project parts, whereas AI and predictive analytics are used to foresee cost overruns, delays, and safety incidents (Rane, 2023). These tools were thus aiding in doing risk assessment more dynamically, instead of relying merely on static risk registers. Also, chains of technical risks were anticipated using BIM and digital twin technologies during the construction of the Grand Paris Express and with mitigation actions being taken before the problems grew bigger (Zhang, 2025). Because of such technologies, risk management has become more iterative, data-driven, and adaptive to new uncertainties that are always emerging during such long projects.

1.1.3.3. Contractual Approaches

These keep the risk-sharing and risk-transfer mechanisms between parties in the LSIPs. Usually adopted are the PPP models (Jiang et al., 2025), since under such an arrangement, the financial risk as well as operational risks are shared between the government, private sector, and occasionally the lenders as well. By way of illustration, Delhi Metro adopted the hybrid PPP model, under which some of the financial risks were borne by the international funding agencies. And therefore, the financial burden of the government was reduced, and the project could be undertaken without hurdles (Sitharamaraju et al., 2020). These arrangements likewise sustain financial viability and encourage cooperation, but such contracts must always be carefully negotiated to avoid unfair risk transfer that could otherwise lead to problems and even obstruct the attainment of the principal project objectives.

1.1.3.4. Resilience-Based Practices

Resilience-based practices focus on prevention but also on adaptation, recovery, and sustainability of operations in the long run (Nielsen & Faber, 2021). By adding resilience, projects become associated with wider sustainability targets such as adaptation to climate change, disaster preparedness, and social inclusion. For instance, metro systems in places exposed to climate change have designed infrastructures to take care of extreme heat or be safe from inundation, thus averting disruptions (Ojo, 2024). Resilience, when incorporated into design and project management, helps the projects to reduce vulnerabilities to unforeseen events such as pandemics or climate shocks, securing infrastructure investments in the long term and ensuring their continued usefulness and reliability.

1.1.4 Risk Management in Indian Metro Rail Projects

Urban rail systems in India are often referred to as the key players belonging to large-scale capacity-line infrastructure in this country, and for reasons of assessing risk perspective for LSIPs. Metro projects involve a whole generation of risks coming from scale, capital, politics, and society. Within highly dynamic urban environments characterized by fast-growing populations, dense settlement patterns, and complex regulatory tasks, these projects are absorbing ever more layers of risk. Risk management operates like the central nerve deciding on efficiency, timely completion, and the ability to address economic and social needs. Metro projects in India face peculiar problems such as land acquisition issues, political interference, funding gaps, and a host of technical problems. For this reason, they are often taken as prime examples to investigate how governance structures, risk mitigation steps, and sustainability practices interrelate under an uncertain environment. In this section, the three metro projects of Delhi, Bangalore, and Kochi are put side by side, considering governance, risk management, and sustainability.

1.1.4.1. Case 1: Delhi Metro

Delhi Metro has often been considered as one of the best among the metros in India majorily due to factor of governance which had a strong structure, popularly known as the Sreedharan model. Accountability was clear, stakeholders were involved at an early stage, and most importantly, international cooperation was sought. Risks were mitigated through arrangements like PPPs, international bidding, and international technical expertise. So once confidence was developed among the stakeholders, funds were better managed, and comparatively little trouble was faced in land acquisition (Adil & Reza, 2020). This has largely been one of the case studies for other Indian metros to imitate.

1.1.4.2. Case 2: Bangalore Metro

Weak coordination among agencies, problems with environmental clearance, and technical difficulties led to delays in the Bangalore Metro. Risk management wasn't effectively implemented because stakeholder alignment was missing at the outset, and contract enforcement was lax. These issues point out the importance of certain necessities including improvement in the governance structures, familiarization of digital tools, and more stringent PPP frameworks to reduce delays and creditors & risks (Mamillapalli & Pusarla, 2023).

1.1.4.3. Case 3: Kochi Metro

Kochi Metro is included as one of the cases as it has been chosen for this research study to be analyzed in depth in the coming chapter. In a gist, Kochi Metro is name synonymous with innovation and sustainability. Kochi Metro invested in solar power, green stations, and more energy-efficient systems. Furthermore, it pronounced itself in social inclusion by hiring women and transgender persons, supporting local communities along the route. Resilience, active stakeholder involvement, and embedding sustainability in planning and implementation all shaped risk management here (Aswathi & Wilson, 2020)

1.1.4.4. Post-2019 Developments

Since 2019, metro projects in India have been designed with resilience and integrated risk considerations in mind, especially after the onset of new challenges brought about by the pandemic. Unique instruments of raising funds, such as green bonds and ESG-linked loans, are also in vogue. The communities are being engaged more through participatory and transparent methods (Balasubramani, Mahalingam, Scott, 2020).

In all, Delhi Metro stands for good governance, Bangalore Metro is the result of coordination and environmental problems, whereas Kochi Metro emerges as a symbol of sustainability and inclusion. Indian metros are slow in pursuing integrative and resilience based risk management. Occurrences like failures of coordination, political interference, and financial gaps continue to exist. These observations set the stage for applying good international best practices in future projects.

1.1.5 Human Resource and Organizational Risks in Metro Rail Projects

Large metro projects are highly complex undertakings, not only needing technical capacity a nd huge funds but also depending heavily on people and organizations on a long-term basis. Though financial or technical risks are usually discussed in literature, many paper s demonstrate that human and organizational risks have a driving influence on project succe ss. Herein, some case examples are observed to show how these risks manifest and how th ey are mitigated.

1.1.5.1 Workforce Risks

The risks that are occurring or are relevant in times of labour are considered workforce risks and these consist of the risks that are occurring or are relevant in times of labour are considered workforce risks and these consist of skills, inadequate training, or perhaps even high turnover. In metro projects, tunneling, signalng, and depot operations require a very special combination of knowledge that might not always be available.

For instance, a risk study on Lahore OrangeLine Metro discovered human errors to be even more frequent than equipment failures in the depot operations. Maintenance or decision-making errors were numerous and grave. Zhang et al. (2022) formulated an early warning system in Chengdu Metro Line 11, where, through this system, they revealed that "man" was one of the main risk dimensions; but not to overlook the fact that the model's accuracy largely depended on the collection of data regarding staff training and behaviour. Meanwhile, Li, Guo, & Du (2024) opine that low ventilation and dim lighting can affect the health of the workers while they studied the underground depots of Guangzhou and Chengdu.
These cases attest to the reality that workforce risk directly causes delays, accidents, and co st overruns. This is, therefore, why workforce planning (skills, training, environment) should b e regarded on par with technical or financial planning.

1.1.5.2 Organizational and Management Risks

Risks encountered by organizations appear whenever leadership, reporting, and coor dination have not been well organized. Now projects encounter duplicate efforts, lost oversig ht, or hold-ups.

Text mining research showed that many accidents in Chinese subway shield construc tion had weak safety management and enforcement of rules (MDPI). They tracked a path that starts off from the lack of self training to low awareness and then it proceeds to low awareness thereby violation of rules which inevitably ends up in multiple accidents. In a different case, the study of evacuation modeling found that good procedure management and staff training mattered a lot in the outcomes (SAGE Journals).
The staff lack in supervision and the weakness of inspection as derivations works to propagat e risks in constructions (Qin & Zheng, 2024).

So all these studies demonstratedthat us that without strong allocation of responsibiliti es accompanied by a strong inspection regime, the incidents stand a wonderful chance of occurrence.

1.1.5.3 Safety and Human Error Risks

Large metro projects are highly complex undertakings, not only needing technical capacity and huge funds but also depending heavily on people and organizations for a long-term basis. Though financial or technical risks are usually discussed in the literature, many papers demonstrate that human and organizational risks have a driving influence on project success. Herein, some case examples are observed to show how these risks manifest and how these are mitigated. Workforce risks refer to things like shortage of skills, inadequate training, or perhaps even high turnover. In metro projects, tunneling, signaling, and depot operations require a very special combination of knowledge that might not always be available.

For instance, a risk study on Lahore Orange-Line Metro discovered human errors to be even more frequent than equipment failures in the depot operations. Maintenance or decision-making errors were numerous and grave. Zhang et al. (2022) formulated an early warning system in Chengdu Metro Line 11, where, through this system, "man" is one of the main risk dimensions; the model's accuracy largely depended on the collection of data regarding staff training and behaviour. Meanwhile, Li, Guo, and Du (2024) looked at underground depots in Guangzhou and Chengdu and found that bad working environments such as low ventilation and dim lighting made errors and health concerns more prevalent.

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1.1.5.4 Stakeholder and Team Dynamics

A Metro project is a collective effort involving a wide range of actors-the government, contractors, consultants, regulators, and communities. In the absence of trust and coordination, the usual delays and disputes arise. For instance, in the Chinese subway shield projects, accidents tended to arise when contractors and regulators failed to coordinate on safety rules . According to Li, Guo, and Du (2024), in Guangzhou and Chengdu, an undesirable depot environment caused increased stress among team members, thereby inhibiting communication. Dispatcher team study results showed that emergency errors were more often associated with role ambiguity and lack of rehearsals. Therefore, stakeholder and team dynamics are in no way peripheral issues with regard to project success.

1.1.5.5 Integration with Risk and Resilience Frameworks

Lately, risks involving humans and organizations are being put into resilience frameworks. Arup Rail Resilience Framework (2024) elaborates on how resilience incorporates leadership, culture, social context, not only assets. Further, digitalisation presents opportunities yet makes vulnerabilities--such as Japan's earthquake early warning system, which functions because of organizational protocols, not mere technology. (Velazquez, Pescaroli, Cremen, & Galasso, 2020)Zhang et al (2022) in Chengdu's warning model combine the human and machine factors as well. So the evidence shows that resilience frameworks gain strength by the explicit insertion of human and organizational factors.

1.1.6 Technological and Digitalization Risks in Metro Rail Projects

On the modern times advanced technologies bring out efficiency but also vulnerabilities and these technologies can be identified as automation, signaling, real-time monitoring, digital project management tool and smart ticketing systems. Literature has highlighted that technological risks such as system failures, operational breakdown or even security breaches can disrupt the project delivery and also long-term operation. This section will be adding into the existing framework by looking at the risks that come with digital transformation in metro rail projects.

1.6.1 Dependence on Advanced Technology

Metro projects are increasingly reliant on automation, signaling and BIM, with digital tools being added to the toolkit as they develop. These raise the issue of efficiency versus vulnerability. Love et al (2022) gave emphasis that extreme reliance on these systems inevitably creates a “single points of failure.” A signaling failure can bring the entire system to a stop. BIM has since caused some issues when poor integration resulted in costly redesigns.

1.1.6.2 Cybersecurity and Data Risks

Being digitized, metros produce huge quantities of sensitive data. Hosseini et al (2019) testify that this opens them to cyber-attacks. Some metro networks in Asia were hacked, disrupting ticketing and passenger information. This shows that cybersecurity should be taken seriously as a part of risk management, not relegated to an afterthought.

1.1.6.3 Multi-Technology Systems Integration Risks

Metro systems are made up of different technologies like rolling stock, electrification, and fare collection that are operating together. However, when there is poor coordination among these different technologies, it can lead to delays and cost overruns (Geng et al., 2024). For instance, the rolling stock in the Delhi Metro project signaling was not synchronized thereby the risk of delays was increased. So, this has made it very clear that strong coordination and thorough testing are the things that are needed in the project.

1.1.6.4 Obsolescence and Lifecycle Risks

Another big issue is the rapid technological obsolescence. Flyvbjerg et al. (2023) talk about this in terms of the “technology lock-in” where the project is made to use the old system only. This leads to a situation where the costs are not easy to see and the efficiency is low. Therefore, metro projects should treat the lifecycle risk planning as part of their first step towards preventing such problems.

1.1.6.5 Mitigation through Digital Risk Management

ISO/IEC 27005 and other similar frameworks assist in the structuring and controlling of digital risks (Leidman, 2025). Predictive analytics and AI are some of the tools that can give early warnings thus preventing disruptions. For instance, the use of digital twins can mimic the possible risks and even recommend ways to mitigate them (Mikołajewska et al., 2025; Joni & Graepel, 2024). And so, the digital tools can not only increase project resilience but also make the projects evolve along with the fast-changing technology.

On the other hand, these technologies bring up the question of efficiency versus vulnerability. According to Love et al. (2022), the major disadvantage of large-scale adoption of digital systems is that they create “single points of failure.” A situation where a signaling failure could paralyze the whole metro is a good example. Another case is the integration of BIM, which has caused redesigns in some projects and consequently, incurred costs.

2.1. Research Methodology

2.1.1 Research Model

The study examines the qualitative research meant through which risk management practices of Kochi Metro Rail Project are explored by document-based content analysis. The researcher has requested, through a formal email to Kochi Metro Rail Limited, permission to conduct the interview from the authorities who were responsible for the Metro Projects. Unfortunately, they denied permission to conduct the interview because of the lack of presence of researcher in India. Since the researcher was in a foreign Country they gave permission to conduct the thesis by using the information that was publicly available (Cheong, Lyons, Houghton, & Majumdar, 2023). Therefore, utilized the available relevant Metro Rail Project resources that provided numerical and qualitative data, which were adequate for this study. The paper was actually a single case study approach to analysis, which gives a detailed insight into the risk events in the world, mitigation actions taken, and operational end results (Barghi & Shadrokh Sikari, 2020). The reason for the selection of this design was that it was useful for the systematic extraction, coding, and interpretation of very detailed information from the documents of the project, like Detailed Project Reports (DPRs), KMRL annual reports, audit reports from the Comptroller and Auditor General (CAG), project progress updates, and operational performance data. The qualitative content analysis was firmly based on the existing theories, including PMBOK, ISO 31000, and PRINCE2 risk standards, and ALARP and Enterprise Risk Management (Feitosa, 2025) principles as well, which made it possible to assess risks in a structured way by dividing them into technical, financial, human resource, safety, documentation, and operational.

The risk management interventions have been mainly evaluated by extracting the patterns, trends, and quantitative indicators like budget deviations, delays, employee skill development hours, and performance indicators such as punctuality and headway. While existing literature has been primarily concerned with isolated technical or financial risks in metro projects (Wolters Kluwer, 2022), often neglecting the integration of underground, human, operational, financial, and documentation-related risks, this study holds that a holistic and structured risk management approach covering all major risk categories is necessary for achieving operational excellence and timely project delivery. The basic idea was that by integrating risk management over the various domains of subsurface, workforce, management of finance, safety, and operations, the decision-making, resource allocation, and coordination of the multilingual teams will be better and the project's overall performance would be improved. The reason why the Kochi Metro Rail Project was chosen to be investigated is the importance to the country of India, the clear reporting throughout the project, the existence of extensive official documentation, which gives access to theoretical and practical data. Moreover, the study makes it possible to draw on different sources of secondary data, thus performing triangulation of sources, which increases the trustworthiness and applicability of the findings and at the same time allows for an assessment of risk management in a real-world infrastructure scenario.

2.1.1.1 Research Questions

1. How can risk management strategies be evaluated and improved to increase the efficiency, reliability, and success rate of large-scale infrastructure projects such as the Kochi metro rail project?
2. How effective are current risk management frameworks, such as ISO 31000 and PMBOK, in mitigating the risks faced during the Kochi Metro Rail Project?

2.1.1.2. Research Aim

The research aim is mainly focused on evaluating the risk management practices in the Kochi Metro Rail Project through qualitative and secondary data analysis, and also to generate recommendations for improving the risk governance in the coming large-scale infrastructure projects in India.

2.1.1.3. Research Objectives

- To investigate the frameworks of risk management that were used in the Kochi Metro Rail project and the theories that support the project.
- To determine and categorize the primary technical, financial, scheduling, operational, safety, security, documentation, and IT risks faced during the Kochi Metro Rail Project.
- To perform an analysis of the project data and qualitative sources to assess the success of the risk mitigation strategies applied in the project.
- To create some specific suggestions for improving risk management practices in future infrastructure projects based on insights from the Kochi Metro case.

2.1.1.4. Research Sample

The selection for this study mainly relies on the most reliable and publicly available accessible documents that are related to the Kochi Metro Rail Project, mainly the first phase, and extensions. The documents consist of Detailed Project Reports (DPRs), KMRL's annual reports, government sanction and cabinet approval documents, audit reports, Asean Development Bank reports and media sources. While concentrating on these sources, I make sure that the study maintains its credibility by mainly relying only on verified secondary sources. At the same time, a thorough risk assessment was made as much as possible.

The first step involved in analysing the DPR for Phase 1 from Aluva to Petta and the extension to Thripunithura Phase 1B in order to analyse the project budget figures, financial arrangements , land acquisition strategies, and technical provisions. Initially, the DPR indicated a sanctioned cost was ₹ 5,181.79 crore not only that it also mentioned the revised cost was ₹ 5,687.79 crore. It I mainly due to the underestimated interest occurred during construction work and also because of the additional project costs. Both of these became the reason for the financial baseline for the risk-escalation analysis.

In addition, while examining the KMRL’s annual reports of several years, especially around 2020–24 are included in the sample, which helps me to acquire more detailed financial statements, operational data, and management comments. These reports clearly indicate the details for the financial year 2023–24, which were relevant for my paper, like the operating expenses amounted to ₹ 205.60 crore. And also, the total operating revenue was ₹ 168.23 crore, which is actually the sum of fare and non-fare, which resulted in a huge mismatch. In the report Finance charges of ₹ 294.22 crore were reported as well. The financial risk burden was quantified using these figures.

Thirdly, the review of the audit and the oversight documents that include reports by the Comptroller and Auditor General and Kerala’s Public Accounts Committee was carried out. As per the report, the common delays mainly occurred due to various factors like land acquisition, design etc. Even though the scheduling delays at the performance-audit level were not publicly available in CAG or PAC reports, the financial audit worked recognized KMRL’s accounting disclosures and showed the lack of external verification of schedule risks in the case of KMRL.

Fourth, the government-sanctioned documents and cabinet notes, like those of the Ministry of Housing and Urban Affairs, were also used. From these reports, the Union

Cabinet has approved Phase 2 at a cost of ₹ 1,957 crore. Apart from that the KMRL's website also contains a project profile which is essential to specify technical details, including the design speed of the train, that was approximately 90 km/h, the train capacity was about 975 crush-load passengers, and the details of the infrastructure parameters.

Fifth, I also relied one set of sample sources that consists of media. Also, go through the articles from the popular newspapers like The Times of India, The New Indian Express, The Manorama, and others, giving real-world data on ridership, revenue, and recovery trends during the COVID-19 lockdown.

2.1.1.5 Research Procedure

For this study, the research methodology was well-structured and also has multi-staged phase, which involved using different techniques such as reviewing documents, focusing on performing qualitative analysis of the content, and conducting limited quantitative interpretation. However, the researcher had to meet a duration limit of the master's thesis paper, which was comparatively small. Hence, the researcher was only able to do a study on 15 papers collected from the database available, more than 32. While collecting the information from these 32 papers, the researcher filtered for papers related to the theme of risk management, and of these, 17 papers were more suitable for the study. At the end, the researcher had to work with only 15 papers due to the previously mentioned time limit. However, the researcher was able to acquire and collect sufficient information for conducting the empirical study. The process began with the systematic gathering of various data from different sources, with the primary source of focus on the authoritative and verifiable documents. These documents include the Detailed Project Report (D, KMRL annual reports, and so on. In addition, these sources were chosen because they would provide not only the authentic information but also give comprehensive insights into the various dimensions of the Kochi Metro Rail Project, such as technical, operational, financial, human resource, and scheduling.

The information was then sorted, organized, and stored in an MS Word file for the purpose of systematic review, and qualitative content analysis was also carried out. The study was limited to that information which was considered relevant and useful only. Moreover, all the documents were coded manually according to predefined themes like technical risk, financial risk, human resource risk, safety risk, documentation and scheduling-related risk. The process of coding included the reading of the documents repeatedly to recognize information related to risk events, numerical indicators, patterns, and issues that kept recurring. Then, findings were cross-checked across multiple independent sources for accuracy, which made it possible for every numerical and factual detail to be verified using at least two independent and credible sources, thereby it helped in improving the credibility of the findings. After the qualitative coding process, the numerical data taken from the documents were systematically arranged and transformed into visual formats like tables, figures, and bar charts. The Figures that were validated and could be verified were the only ones to be used, thus guaranteeing academic rigor and correctness. These visual aids were incorporated in the empirical component of the research because it were presenting very clearly the distribution of risk and made it easy to understand the categories, the trends in operational performance, and the different risk mitigation measures that KMRL had applied to a certain extent. In general, the whole research process followed the same steps for collecting data in a systematic way, giving the interpretation of the data very reliable and drawing the evidence-based conclusions that were completely identical to the four research objectives of the study.

2.1.1.6. Research Problem

Theoretical and empirical studies have not dealt with the application and effectiveness of risk management techniques in urban-based Kerala. A lack of intensive project wise assessments limits the evaluation of existing practices and the formulation of better risk governance models for future infrastructure projects in India.

2.1.1.7. Research Timeline

The empirical study was conducted throughout the months of September to the last weeks of November. Initially, one month was spent on the collection, classification, and organization of secondary materials necessary for the study. Later on, it proceeded to a thorough reading and understanding of the materials to emphasize the risk-related factors. The analyzed data were transcribed into software such as Word and Excel. Coming to the last weeks of November, the data stored were utilized to be presented in this thesis paper.

2.1.1.8. Ethical Considerations

This research follows the ethical codes of the academia, and thus it is very transparent, objective, and responsible in its information use. A formal request for permission was made to Kochi Metro Rail Limited (KMRL); they allowed access only to online documents available to the public and did not allow interviews with the staff or stakeholders. Accordingly, the research is based solely on secondary data.

The sources of the data were all public, government-issued, or institutionally published documents, thus, ensuring ethical data collection without breaching confidentiality or restricted access policies. The documents were objectively reviewed with no manipulation or selective reporting to prevent bias and maintain academic integrity. All numerical data were verified by cross-checking with multiple reputable sources to guarantee accuracy. Proper citations and acknowledgments were given throughout the study to respect and protect intellectual property rights.

3.1 Research Results

3.1.1 Theoretical Risk-Management Foundations

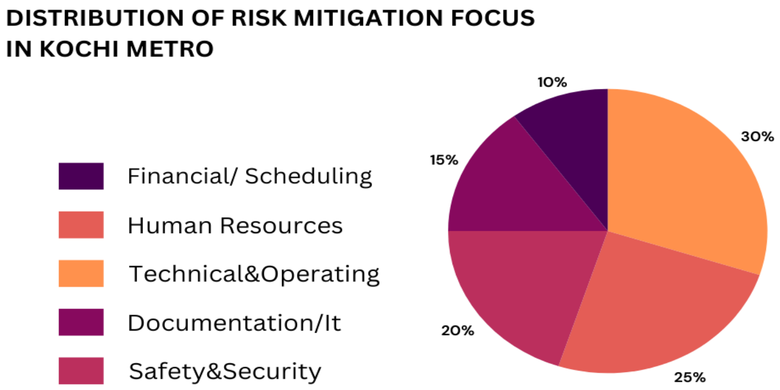
Kochi Metro's risk management method is underpinned by three theoretical horizons that are interrelated, these being Total Productive Maintenance (TPM), ALARP (As Low As Reasonably Practicable) and Enterprise Risk Management (ERM) (Heliyon, 2023). Of these, TPM is the most deeply rooted in KMRL's operation and maintenance plan. At the same time, preventive maintenance, predictive diagnostics, and condition-based maintenance significantly lessen the occurrence of the technical failures. An instance is the three switches that were refurbished as they were causing outages due to capacitor aging and voltage-regulator defects. The switch that was refurbished delivered six months of uninterrupted operation and no faults were reported. The application of automatic lubrication systems on the curves with a sub-190-meter radius and the deployment of drone-based inspection for waterlogged or structurally sensitive viaducts are other examples of condition-based TPM interventions.

KMRL's safety evaluation process clearly shows that the ALARP principle is applied in this project. The factors like policing, disaster-response, fire, and health services were involved in multi-agency emergency simulations conducted at Thripunithura station. The decisions regarding the protocol design and resource allocation were made by considering the severity of probable hazards and the extra cost of risk control measures. And also, the KMRL is not reducing risks indiscriminately but rather appears to have reached the place where the cost of further mitigation exceeds the benefit of increased safety.

KMRL in the light of a governance approach and implements ERM from the management point of view by designs and implementing systematic methods to identify risk in the areas of technical, financial, operational, HR, and scheduling. Continuous risk monitoring through annual safety audits is practiced and these audits encompass the depot, Operations Control Center (OCC), and all 25 stations. The company plans to be cautious in a calculated manner that is financial risks, for instance, are managed with a mixed funding model and operational risks through regular maintenance and personnel training. In combination, these frameworks offer the conceptual basis for the imminent risk management analysis.

Figure 1

Risk Mitigation Focus based on intervention frequency/impact



Source: Sattva, 2025

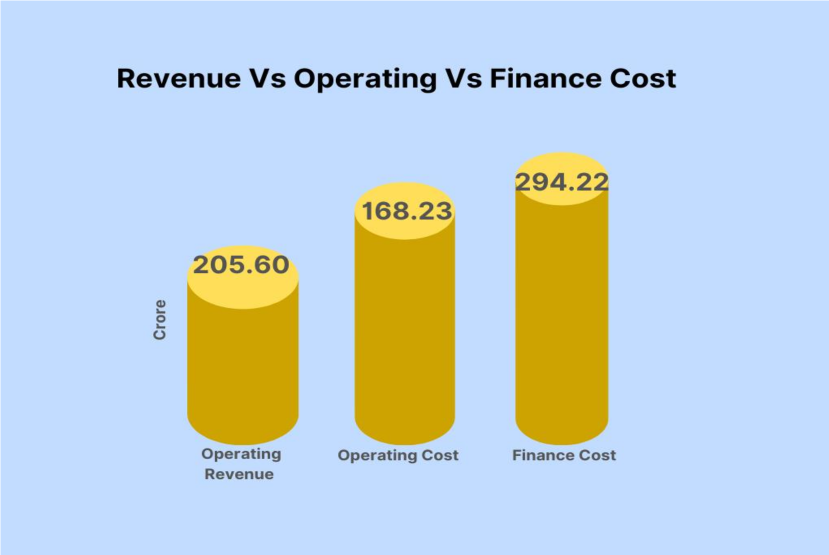
3.1.2. Identification of Major Risk Categories

3.1.2.1. Financial Risk

The financial risk is one of the major hurdles for the KMRL and it is indisputable. Besides, the total cost estimated for Phase 1 actually costed from Aluva to Petta was ₹5,181.79 crore. This figure was partitioned into three segments. One is the Government of India's share of ₹1,002.23 crore (20.26%), the second is the Kerala Government's share of ₹2,009.56 crore (35.83%), and finally the JICA loan of ₹2,170.00 crore (43.88%). Despite this solid funding sources the cost, however it is escalated in a noticeable manner. KMRL's records reveal that the cost increased to ₹5,687.79 crore as per the Detailed Project Report (DPR). Consequently, the project turned out to be approximately ₹506 crore more expensive than what was originally approved (DMRC, 2021; Kochi Metro Rail Limited, 2024).

Figure 2

Comparing Operating Revenue, Operating Cost, and Finance Cost



Source: Sattva, 2025

3.1.2.2. Scheduling Risk

In the case of Kochi Metro, scheduling risk is mainly caused by land acquisition, administrative approvals, and materials supply constraints at the very deep levels. As per the documentation the Phase 1 required land approximately equal to 31.92 hectares, where the whole issue resulted in very complex compensation negotiations, legal battles, and processes for relocating (MoHUA, 2022; DMRC, 2021). The contractors have openly told that the design plans were submitted very late and in some cases the detailed design drawings were provided in the 24th month of construction instead of the 6-month period originally planned. This clearly indicates a huge design-approval bottleneck (DMRC, 2021; KMRL Annual Report, 2024). The Phase 1A/1B DPR has also pointed out "regulatory and legal complexity in land acquisition, particularly after the updated land acquisition policies were implemented, as the main reason for schedule delay and cost increase. Even though the DPR does not give explicit delay data month-wise, the revised cost (₹5,687.79 crore) interprets such delays as a financial burden.

On top of that, supply chain constraints make the scheduling risk even more worse. Several project analysis reports have suggested that KMRL had continuous problems in getting aggregates, metals, and construction-grade materials. Such delays would eventually slow down the civil works significantly, which are the most affected ones in the urban areas due to high-demand situations (Sattva, 2025; Prabhakaran et al., 2023).

The public's comments indicate that the shortages of materials were not isolated incidents, but rather a series of problems that occurred in throughout the construction period and possibly made the schedule even more unpredictable (Krishnan et al., 2024)

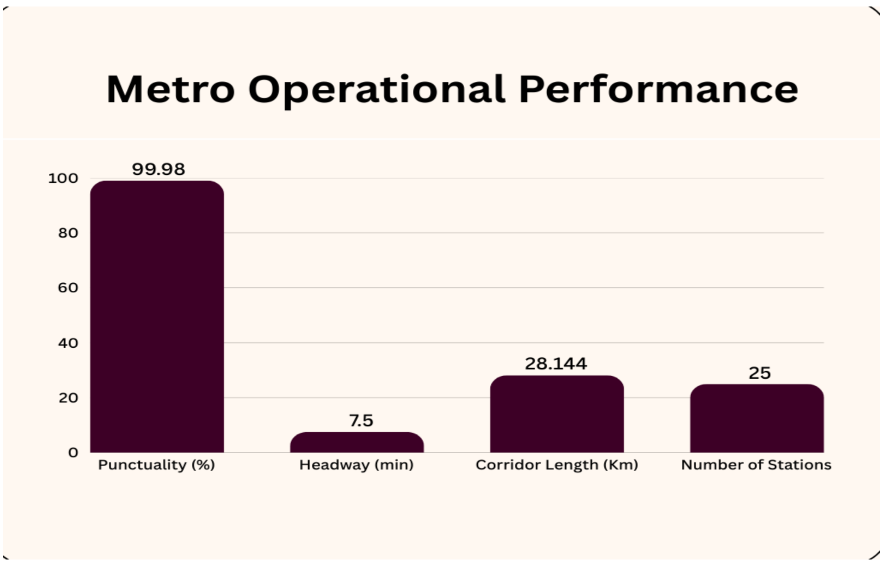
All these factors together have put KMRL's project timeline under strain. Original DPR timelines indicated phased completion. However, subsequent real-world progress was lagging behind. Although public documentation does not always provide a fully audited month-by-month delay log, the qualitative evidence is also strong enough to indicate that the scheduling risk should be regarded as a major factor in cost escalation and the project uncertainty. (Sattva, 2025; Kochi Metro Rail Limited, 2024).

3.1.2.3. Operational / Technical Risk

The operational risk comprises of machine breakdowns, including those of the infrastructure, and maintenance-process risks. In general, KMRL's introduction of TPM has a significant impact on such risks, including the refurbishing of switches that are malfunctioning, constant monitoring of the condition of the tracks using drones, and applying lubrication to high-friction areas are all methods used to control risks pre-emptively. The in-house built On-Board ATC Simulator is another very useful tool for KMRL as it allows them to create train control scenarios and test system behavior off-line, thereby cutting down the risk that comes with real-world deployment (Krishnan et al., 2024).The key performance metrics are listed below.

Figure 3

Operational Performance



Source: Sattva 2025

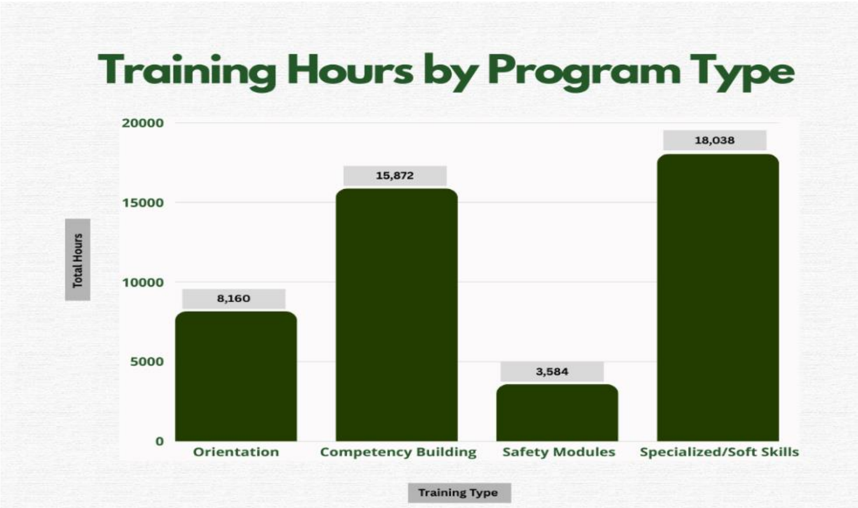
Nevertheless, there is still a risk. Even if the infrastructure is in pristine condition, external pressures may cause it to degrade, hence KMRL has to be on the lookout for any sign of wear and tear on their components. The case of refurbished switches is a good example. Even though they have passed the six-month test, their longevity still depends on constant monitoring and timely replacement planning (Aswathi & Wilson, 2020). In addition, during the rainfall season, in the areas where water floods in frequently, elevated viaducts and station structures are particularly falls victim to environmental and structural risk (Dhurai, Chandran, & Shaheem, 2023).

3.1.2.4. Human Resource Risk

The risk associated with human capital is very high. KMRL has to not only employ workers with the required technical skills but also those who are able to communicate fluently in two or three languages. The main emphasis on employee training which saw the organization conduct 216 batches in one year, comprising 1,792 employees and totalling 45,654 hours, is indicative of the company's management of this risk in a proactive manner. The training sessions offered were for orientation, safety, competency, and soft skills demonstrating the choice of a comprehensive approach. Below are the different types of employee training conducted along with the total hours spent on each. (Sattva, 2025; Kochi Metro Rail Limited, 2024)

Figure 4

Training Hours by Program Type



Source: Sattva 2025

However, at the same time, this extent of training also portrays the intensity of the hidden risk: the probability of operational failure, communication breakdown, and safety incident is sharply increased without the training. Besides, the use of migrant labor increases the risk factor, as it creates more challenges in terms of coordination, retention, and social integration for the consistent performance of the workforce, especially in cases of maintenance work or emergency response.

3.1.2.5. Revenue Risk

The KMRL revenue risk encompasses more than just dependence on fare-box. Before the COVID-19 pandemic, the number of riders was the highest at 123,975 passengers every day. The fare revenue was still not enough to support the entire operating and financing costs, taking into account the large capital investment. The pandemic made this vulnerability glaringly obvious. The KMRL suffered a total loss of fare revenue, and the ₹2.41 crores per month of non-fare revenues could not even cover the fixed monthly costs of ₹6.96 crores. This inherent weakness in the structure implies that any future event, whether it be a disruption in operations, a fall in ridership, or an economic recession, will very likely be a financial sustainability risk. KMRL might still face revenue shortfall risk in the event of very efficient operations unless the streams of non-fare income are very much strengthened (through leasing, transit-oriented development, naming rights, etc.) (Asian Development Bank, 2021; Sattva, 2025).

3.1.2.6. Safety and Security Risks

According to Singh (2020) Kochi metro faces threats that is concerned with safety and security, and these issues mainly originated through uncertainties such as operational interruptions, emergencies, and organized security threats which might endanger the safety of the passengers and the continuity of the system. When such a case presents itself, the need for a multi-agency emergency-response framework deems favor. For instance, in Kochi metro, as it is functioning in a densely populated urban area where different security breaches, equipment failures or hazardous incidents could quickly escalate (MENON, 2023; MoHUA, 2022). These mentioned risks were confronted by carrying out a large-scale security mock drill at Thripunithura Station, which involved the participation of multiple agencies, including Police, Traffic Police, SISF, SSB, TCS, Quick Response Team, BDDS with the Dog Squad, Fire and Rescue Services, DDMA, District Medical Team, and Anti-Terror Squad. The extensive participation of different agencies in the drill demonstrates the scale of possible emergencies that the system has to be prepared for in advance. Even though the punctuality has been unbelievably high at 99.98%, and the train operations are being carried out at an optimized headway of 7 minutes and 30 seconds across the 28.144 km corridor with 25 stations. An important discovery arose out of these practices, stated that even after continuous monitoring, there were some risks associated with service reliability, crowd management, and the system lingered. Annual safety audits conducted across all operational departments have led to focused improvements, however, the system is inherently vulnerable to safety and security threats which could interrupt the operations if not managed constantly (Kochi Metro Rail Limited, 2024; Sattva, 2025).

3.1.2.7. Documentation and IT Risks

The Kochi Metro has been criticised for varying risks related to delays in the schedule, especially concerning the approval of the design, and inefficient scope changes. These issues originally arose due to the inconsistency of data, critical technical information loss, poor cybersecurity, and the slow pace of information exchange among the (Dhurai et al., 2023).; MoHUA, 2022). To confront these issues, KMRL implemented its Centralized Digital Inventory Management System not just for the Utilities and Track departments but for the whole West and East divisions, thus the risk of having outdated or missing construction and maintenance records being matured is reduced (KMRL Annual Report, 2024). The use of the K-VAULT digital file-sharing platform not only slows down the risks that are connected with unauthorized access, file duplication, and inconsistent version control but also helps to clarify the relationship between the departments and to improve communication between them (Sajeevan et al., 2023). Regarding security concerning the IT, KMRL took quick initiatives and has also installed Adiscon LogAnalyser that can collect the logs coming from the firewalls, the RADIUS servers, the DHCP systems, and other network services that are vital to the operation, thereby reducing the likelihood of cyber intrusions, network misconfigurations, and operational disruptions going undetected (Singh, 2020). Despite these improvements, the underlying issues linger, including documentation gaps and delays in finalizing design drawings, obtaining permits, and executing scope revisions, which puts forward the fact that digital tools are inefficient in clearing out inadequacies across the organisations. (Sattva, 2025; Aswathi & Wilson, 2020).

3.1.3. Expansion and Future Phase Risk

Phase 1 showcased several risks that were needed prior to and immediate action; however, it doesn't halt there, which is the reason for the introduction of phase 2. The second phase (JLN Stadium to Infopark) is approved with an estimated cost of ₹1,957 crore, according to the official statements in the media. However, the first signs indicate that the same risk patterns as before are emerging the land acquisition delays, regulatory challenges, and the risk of further increases in cost (DMRC, 2021). For example, it was mentioned that in the areas where land was being acquired, the notifications of acquisition have already been prolonged by six months, which means that the risk of delay in the schedule is being carried over into the next major expansion phase (MoHUA, 2022; Kochi Metro Rail Limited, 2024). Considering the experiences from Phase 1, with an increase in costs of more than ₹500 crore and scheduling problems, the risk for the next phases may multiply unless risk management practices are reinforced, the institutional capacity is scaled up, and transparency is improved (Sattva, 2025; Kochi Metro Rail Limited, 2024).

3.1.4. Effectiveness of Risk Mitigation Strategies

The KMRL risk mitigation framework is seems to be only the partially effective, but it has not eliminated vulnerabilities that are residual in nature. From the financial perspective, the blended funding strategy that combines the government equity and concessional JICA debt has been an excellent support, allowing no interruption to the project execution even in the face of significant cost escalation. On the other hand, high debt service and the interest costs of ₹294.22 crore in one year have been and still are the main contributors to KMRL's loss of net profitability, thus making it difficult for KMRL to turn operational gains into long-term financial strength.

On the operational side, the blending of the maintenance techniques based on Total Productive Maintenance, and predictive simulation (Automated Train Control) has been decreased the risk of failure, while investment in human resources has been building up the capacity (Aswathi & Wilson, 2020; Krishnan et al., 2024). The performance over six months of the refurbished switches indicates the technical resilience, while thorough training ensures both safe and effective operations (Dhurai, Chandran, & Shaheem, 2023). Nevertheless, the risk of scheduling due to delays in land acquisition and shortage of materials continues to be a significant factor, suggesting that technical and HR measures, although very strong, can hardly keep the project safe from external policy and the regulatory challenges (Thomas & Sangeeth, 2022).

Revenue diversification, although it is being pursued, is still too weak to cope with the financial risk completely. The ₹4.55 crore/month loss during the pandemic proves the reliance on the fare and the limited non-fare streams. For risk mitigation to be successful and continuous, KMRL will have to fasten its on non-fare revenue strategy considerably, making full use of the real estate, station commercialization, and integrated mobility (Asian Development Bank, 2021; Sattva, 2025). The risk that has been taken into Phase 2 shows that risk management needs to change. Although it has been the case that the past practices have led to the mitigation of many risks, and the expansion opens up new challenges, especially in terms of land acquisition and obtaining regulatory approvals. Which literally need more proactive and transparent governance of risks. (DPR – Kochi Metro Phase 2, 2021).

3.1.5. Summary of Key Findings

The research succeeded in evaluating the risk management of the Kochi Metro Rail Project by qualitative review and secondary data, thus revealing the project successfully faced technical, financial, social, and environmental as well as organizational challenges. The results indicated that Kochi Metro had a composite plan based on ISO 31000, the PMBOK risk process, and the already existing governance practices of the Delhi Metro. This plan has facilitated those formal risk-identification workshops, continuous risk reviews, inter-agency coordination, and systems thinking which were shaped by multi-stakeholder oversight and contingency planning. The study spelled out clearly the main risks like technical problems related to land acquisition delays, utility shifting along congested corridors, and engineering limitations in crowded neighborhoods; (MoHUA, 2022; Thomas & Sangeeth, 2022). Moreover financial struggles caused by increasing construction costs, variable material prices, and reliance on state and central government funding like social conflicts resulting from resettlement, community antagonism in places like Ernakulam and Aluva and political delays; environmental threats due to monsoon disruptions, flooding in low-lying work areas, and slow environmental clearances (Krishnan, Raj, Valsan, & Muthulakshmi, 2024). Additionally, organizational issues arising from the inconsistency in contractor performance, communication lapses between KMRL, DMRC, and local agencies, and the difficulty of coordinating numerous work packages.

Moreover, the study indicated that the risk management style of Kochi Metro was not only a single but a multifaceted approach supported by existing theory. It also made use of tools that are connected to enterprise risk management (ERM), total quality management (TQM), and capital asset planning models (CAPM). High operational performance standards were kept through disciplinary maintenance, simulator training, and frequent testing as well. The project, despite its advantages, still encountered significant risks. The budget overruns alone went up by over ₹506 crore, the financial costs added to a total of ₹294.22 crore and the COVID-19 caused revenue losses of about ₹4.55 crore a month on average (KMRL, 2024). Scheduling-related risks because of land acquisition issues and delays in the transfer of sanctioned designs also plagued the project. The extent of external monitoring on timeline-related risks is not much as the Public Accounts Committee and the Comptroller and Auditor General have not made any performance audits public. The assessment indicates that although measures to reduce vulnerability, such as phased construction, real-time monitoring systems, community engagement, and scheduling flexibility around monsoon seasons have all played a part in bringing down the disruptions, there are still some gaps (Sajeevan et al., 2023; Aswathi & Wilson, 2020). The report recommends that Kochi Metro should be provided with stronger financial reserves, faster design approval paths, and more audit transparency. These changes could make the project more resilient against future risks and, at the same time, could set a new standard for the infrastructure projects in India, through better risk management.

3.2 Discussion

The discussion section takes a look at the empirical results of the Kochi Metro Rail Project from the perspective of the above-discussed theoretical risk management frameworks, PMBOK, ISO 31000, PRINCE2 Risk Theme, and infrastructure-specific risk models. It attempts to determine not only the degree of conformity between Kochi Metro practices and the global standards already established but also the areas of divergence and the consequences that such a situation would have on the large-scale public infrastructure projects in India. The talk further goes into the integration of various risk types, including technical, financial, human-resource, safety, operational, and documentation, contributing to project performance as a major factor, while at the same time, it reveals the organisational weaknesses that continue to render the entity vulnerable to future risks.

One of the main results of the empirical investigation is a very strong risk management culture in operations at Kochi Metro, especially when the construction of Phase 1 was over, and the place was open to the public and was operating. This development is in the area of Total Productive Maintenance (TPM) and the use of preventive and predictive maintenance. Also, these are the project techniques, including drone-based inspections and the integration of signalling and rolling-stock risk controls that are in line with PMBOK's monitoring and controlling process (Aswathi & Wilson, 2020; Dhurai et al., 2023). These measures indicate an agreement with ISO 31000's approach, which focuses on the establishment of a proactive risk infrastructure where the early-warning systems are included in the daily operations. The rotating refurbishment of one of the three automatic switches, which by now have been in service for the last six months without any interruption, is a good example of the organizations capabilities to detect deterioration of risk in the asset, perform root cause analysis, take corrective actions, and monitor the long-term stability just as in the case of the risk treatment cycle defined in ISO 31000 (Sattva, 2025, Kochi Metro Rail Limited, 2024).

On the contrary, the investigation has carried out through a different pattern in the aspects of financial, scheduling, and external governance risks. While referring the PMBOK it is clearly laid down the structured procedures for cost estimation, development of a cost baseline, reserve analysis, measuring of earned value, and cost-risk. The findings reveal that Kochi Metro and Phase 1 largely neglected these procedures, particularly at the budgeting stage. The project was initially sanctioned at ₹ 5,181.79 crores but later went up to ₹ 5,687.79 crores, mainly because of the interest during the construction period being incorrectly estimated (DMRC, 2021; Kochi Metro Rail Limited, 2021; Asian Development Bank, 2021). On the other hand, the ISO 31000 suggests a very active risk management approach where the company always reviews its assumptions via risk identification and review. Nevertheless, it appears that the cost estimates in the DPR are stuck in time, with no thorough sensitivity analysis or scenario testing done. This difference reveals a very common risk management failure that is frequently encountered in the Indian infrastructure projects, particularly the inability to incorporate risk quantification into early-stage financial planning (MoHUA, 2022; Menon, 2023).

Moreover, the other risks accompanying scheduling that resulted from land acquisition, design approvals, and material shortages suggested that changes in the methods of PRINCE2 and PMBOK were mostly perceived as introducing issues through nonmanagement and nonengagement of stakeholders and lack to surely escalate matters. Grounded on the PRINCE2 approach, the early definition of tolerances in the marketing of the project and, subsequently, the realization of the tolerances based on the PRINCE2 approach. However, the situation where some said that 24 months would be needed for the finalization of design hand overs indicates the problems that come with the application of contractual discipline. The Development Project Report (DPR) offers a detailed account of the challenges concerning land acquisition, stating that 31.92 hectares is the requirement of Phase 1 only, yet there are no records to substantiate that a risk management committee existed or that there was a process for elevating issues during the acquisition bottlenecks (MoHUA, 2022; Menon, 2023). The integration of the ISO 31000 and the principle of stakeholder communication appears to be poorly implemented, hence it may have been underrated or not correctly modeled at all the risk factors of community resistance, compensation disputes, and regulatory delays.

One of the remarkable revelations from the research is the intricate nature of human-resource risks, more so in a multilingual operational setting. The impressive figures of Kochi Metro’s training accomplishment, 45,654 training hours spread over 216 batches and including 1,792 employees, demonstrate the close connection with the competency development definition as per PMBOK and the PRINCE2 emphasis on project assurance through trained personnel (Sattva, 2025). However, the communication problems between the local and the migrant workers still persists. indicating that there are still weaknesses in the organisation’s HR structure. Although technical and safety training are given extensive coverage, cross-cultural and communication training is not that well established and is less institutionalized (Sajeevan et al., 2023; Aswathi & Wilson, 2020). ISO 31000 states that risk culture is a very important organizational resilience component, but the empirical data reveal that this cultural embedding is still incomplete, particularly in operational departments where migrant labour and contractual workers are involved.

Kochi Metro's financial sustainability needs to be seen very critically as well. Annual reports affirm that the operating revenue cost ₹ 168.23 crore in the financial year 2023–24 was lower than the operating expenditure cost ₹ 205.60 crore, while finance charges amounted to ₹ 294.22 crore (Sattva, 2025). Although this financial mismatch is typical of metro systems around the world, it becomes a bigger risk under the tax-heavy funding model of India. PMBOK states that the presence of financial dependencies that have not been properly managed and the continuous debt liabilities constitute the very long-term strategic risks that should be closely watched throughout the whole project life cycle (Sattva, 2025). The dependence on non-fare revenue of ₹ 2.41 crore monthly during the lockdown shows innovation, but at the same time, it reveals fragility if the economy changes. ISO 31000 points out the need for the diversification of mitigation strategies, however, Kochi Metro’s revenue model has not yet matured fully to fare and advertising income with station retail and real estate that are still underdeveloped in comparison with global standards like Hong Kong’s MTR or Singapore’s MRT (Krishnan et al., 2024; Dhurai et al., 2023; Sajeevan et al., 2023).

The paper points to a shortfall in record-keeping and cooperation between different agencies. Both PMBOK and PRINCE2 highlight the importance of project documentation, such as the change records, version history, and communication protocols. Kochi Metro has a well-organized safety and maintenance documentation; however, the findings indicate a lack of uniformity in design- documentation workflows, contractor submissions, and regulatory approvals during Phase 1 construction. This is especially critical because documentation gaps are one of the main causes of scheduling delays and rework. Therefore, the project risks are interconnected, a concept that has been clearly emphasized in modern integrated infrastructure risk models (DMRC, 2021).

The main theoretical implication of this work is that risk in infrastructure projects is not confined to individual categories but behaves as a dynamic system whereby failures in one area spread outwards. Financial risk gets amplified through scheduling delays, scheduling delays get intensified through weak documentation, HR risks get magnified through unclear communication protocols, and operational risks go up through inconsistent training. This is in line with the systemic risk view of the risk theory, which criticizes the fragmented, silo-based risk handling approaches that are still present in many developing-country projects (Sajeevan et al. 2023).

3.3. Research Limitations

The findings of this research were extensive and are however profoundly limited by a few crucial limitations that have an impact on the research scope and depth. The most significant limitation was the use of secondary data sources like Detailed Project Reports (DPRs), annual reports of KMRL, audits by CAG, and other documents available to the public. Although these sources furnish a significant amount of information about financial activities, operations, and project milestones, they do not present the detailed datasets required for precise quantitative risk analysis at the component-level or month-wise. For instance, while the overall cost escalations and financial figures for the year are disclosed, the detailed information regarding delays, cost overruns, or risk events at the station or segment level is not available to the public.

Another hindrance is the lack of primary data. The researcher had approached KMRL with a request to interview project teams and technical experts, but permission was only granted for access to public documents. It resulted in the researcher being unable to get the valuable firsthand insights into the internal decision-making, risk mitigation, and undocumented challenges. Thus, the absence of expert input diminishes the quality of qualitative analysis and also limits the degree to which secondary data can be validated.

Methodologically, the study is also constrained. Although qualitative content analysis is also helpful in recognizing patterns and practices, it is not suitable for advanced statistical modeling, as longitudinal operational datasets are missing. Indicators such as peak ridership or non-fare revenue provide some context, but they cannot be utilized to define causal relations or quantify the exact influence of individual risk factors.

In addition, the verification of the risk related data independently from the management is very limited. Reports from the CAG and the PAC provide oversight on a large scale but do not present detailed audit findings, which are crucial to determining the operational, HR, or technical failure risks associated with the project. This situation leads to a constraint in cross-checking the correctness of all the risk events that have been reported in secondary sources.

Moreover, external and uncontrollable factors including pandemic disruptions, inflation, and variations in supply chains create uncertainties that the available data cannot be completely assess. For instance, the financial impact of COVID-19 on the patronage and revenue has been also documented, but the long-term implications for the next phases of Kochi Metro still remain uncertain.

To conclude, interpreting the results must take into account limitations due to reliance on the secondary data, absence of interview-based primary insights, lack of quantitative detail, and no external auditing of detailed reports. Stakeholder interviews, internal operational datasets, and longitudinal tracking of risk events would be the sources of a more detailed understanding of risk management effectiveness in large-scale infrastructure projects through future studies.

Conclusion

The Kochi Metro Rail Project, including phase 1 (Aluva-Petta) and phase 1B, is an excellent case study of risk management evaluation in large-scale infrastructure projects. The research applied a content based qualitative analysis method to drastically examine the interaction of the risk identification, assessment, and mitigation strategies in the financial, operational, scheduling, human resource, and revenue domains through comparing and integrating the information of KMRL& Project Reports (DPRs), annual reports covering the project in media, and secondary studies.

KMRL's operational risk management is aligned with global frameworks, such as Total Productive Maintenance (TPM), ALARP, and Enterprise Risk Management (ERM), and this is reflected in the measures undertaken at the operational level. Among these strategies, the refurbishing of three critical switches, automated lubrication systems, and drone inspections, among others, were all noted to be effective interventions that enabled the company to operate for six months without interruption. Training of 1,792 employees in batches of 216 for a total of 45,654 hours proved to be an excellent support in the human resource area, as these workers became ready and less prone to error while they spoke multiple languages, thus further contributing to the reliability of operations.

Nonetheless, the remaining risks show the need for enhancements in some areas. The total budget for Phase 1 was originally set at ₹5,181.79 crore but had to be increased to ₹5,687.79 crore because of the incorrect computation of interest during construction and improper utilization of risk modeling techniques. The financials for FY 2023-24 point to a net loss of ₹433.49 crore, finance costs of ₹294.22 crore, and a revenue from operations of ₹168.23 crore which is still lower than the expense of ₹205.60 crore incurred during operations. Revenue risks became apparent during the pandemic when the suspension of fare collection led to a loss of ₹4.55 crore every month despite the company earning ₹2.41 crore per month from non-fare sources.

The delays in land acquisitions (31.92 hectares needed for Phase 1) and design approvals in general were the main reasons for the project to fall behind schedule. Some contracts were submitted after 24 months instead of the planned 6 months. Besides, the delays were exacerbated by the supply chain and regulatory problems, and the need for a sophisticated scheduling risk governance approach was highlighted. Technically, operational risks were overcome, but factors such as the waterlogging of monsoon in the elevated viaduct areas still pose a threat to the operations.

The second phase from the JLN Stadium to Infopark, estimated cost at ₹1,957 crore and will bring in new uncertainties such as the already indicated land acquisition delays of 6 months and potential cost increases, which bring forth the very need of applying the lessons learned from phase one. The second phase is the the Pink Line' from JLN Stadium to Infopark via Kakkanad, has been rescheduled to commence full operations by December 30, 2026. The first phase, which will include 5 stations, is likely to be opened by June 30, 2026. The project's cost has been approved at ₹ 1,957.05 crore as per the DPR.

Recommendations

Recommendations for the project are based on the analysis and findings to fortify risk management and operational efficiency in Kochi Metro and analogous infrastructure projects:

To begin with, it is vital to commission performance audits by independent entities at the project level. The audits that are to be undertaken with complete transparency and made public will measure the risks of schedule delays, cost escalations, and land acquisition in an objective manner that will be able to vouch for the internal risk management efforts. KMRL would thus be able to set a standard for measuring risk management and find out which areas to improve on through this method.

The second point to consider is financial resilience, which needs to be fortified. A continuous fund dedicated to contingency, refinancing options being explored, interest cost reduction, etc, are some of the ways that need to be taken to shield debt service risk. Thus, these measures will provide the organization with a reservoir to withstand revenue shocks, like that of COVID-19, and lessen the fiscal pressure of the next phases.

Thirdly, the land acquisition and regulatory risk approaches should be assertively institutionalized. A specialized unit in charge of mediating with the state, local people, and lawyers would be able to shorten the negotiation time and thus save on costs. The use of forecasting land acquisition models alongside real-time monitoring will give the organization the ability to track the risk dynamically.

Fourthly, the efficiency of the design approval process has to be enhanced. The appointments of design consultants must stipulate very strict deadlines and also attach penalties that are linked to performance in order to stop the processing of detailed design submissions from being delayed. It will be easier to get approvals and the risk of scheduling will be less if all stakeholders are involved in the design-review workshops that are held regularly.

Fifthly, the strategy for revenue diversification should be fast-tracked. KMRL can create new non-fare revenue streams by developing the surrounding areas of the station commercially, partnering with real estate in the vicinity of the transit stations, online advertising, and offering full mobility services like parking, ride-sharing, and feeder services. By fortifying these resources, the company aims to lower its dependence on the revenue generated from the fare-box which will consequently lower its exposure to any operational or external shocks.

Sixthly, then, risk management will have to shift its gears for Phase 2 and beyond. The experience of the first phase, especially in terms of increased costs, delayed schedules, and the creation of operational bottlenecks, will be the basis for the new phase's risk-monitoring framework that will be established. First, the very critical and early interventions that will include regulatory approvals tracking, cost escalation modeling, and resource allocation optimization, will make the project more resilient.

At last, transparency and reporting need to be improved. It is suggested that the annual report should have a special “Risk Disclosure” section with measurable metrics like cost escalations, land acquisition, design approvals delays, workforce training effectiveness, and mitigation measures implemented. This openness creates a relationship of accountability and trust, supports institutional learning, and provides better decision-making for both KMRL and external stakeholders.

In conclusion, KMRL’s risk management system is operationally effective but shows weaknesses in the areas of financial resilience, scheduling efficiency, revenue diversification, and documentation standardization. Closing these gaps is vital for the increasing the effectiveness, reliability, and eventually the success of metro projects and other large-scale infrastructure initiatives in India.

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ANNEX 1

Email Request for Permission to Conduct Interviews with Kochi Metro Rail Project Authorities

866.Sreelakshmi S <sreelakshmi13022002@gmail.com> Thu, 31 Jul 2025, 12:33

to gopikrishnan.tr, jesly.j, ratheesh.s

Respected sir,/authority

I hope this message finds you well.

My name is **Sreelakshmi Sasikumar**, and I am currently pursuing my Master's degree in **International Project Management at Vilnius University in Lithuania**. As part of my academic requirements, I am conducting research for my master's thesis on the topic:
"Risk Management in Large-Scale Infrastructure Projects: A Case Study of the Kochi Metro Project in Kerala."

The objective of my study is to explore the risk management strategies employed in the planning and execution of the Kochi Metro project, including how various project risks were identified, assessed, mitigated, and monitored. I believe this research will contribute valuable insights into managing complex infrastructure projects, particularly in developing urban settings.

I am kindly seeking your permission to use the Kochi Metro Project as a case study for my thesis. If granted, I would also appreciate access to any publicly available documents, reports, or, if possible, the opportunity to speak with relevant personnel for academic purposes.

Please be assured that **all information collected will be used solely for academic research**, and **the identity of any participating individuals or authority personnel will be kept strictly confidential**. No names or personal identifiers will be disclosed in the thesis, and full anonymity will be maintained in accordance with ethical research standards.

This study is supervised by **Professor Birutė Miškinienė, Managing Director of Vilnius University Business School**. I am also attaching the official agreement from the university confirming her supervision and other necessary documents for your reference.

I would sincerely appreciate it if you could kindly grant me your permission to proceed with this thesis research.

Thank you very much for considering my request. I look forward to your positive response.

Warm regards,
Sreelakshmi Sasikumar
Master's Student – International Project Management
Vilnius University, Lithuania
Email: sreelakshmi13022002@gmail.com
Phone: +370 68134992

ANNEX 2

Communication from Authorities Requesting Official Documentation from the study coordinator for Permission :

VILNIAUS UNIVERSITETAS
VILNIUS UNIVERSITY

TO WHOM IT MAY CONCERN

July 29, 2025 No. 20150

CERTIFICATE

We certify that Sreelakshmi Sasikumar (date of birth: 13/02/2002) is a student at Vilnius University:

Faculty:	Business School;
level of studies:	Master studies;
mode of studies:	Full-time;
degree programme:	International Project Management (state code 6211LX028);
year of studies:	1;
programme duration:	1,5 years.

Estimated date of graduation is January 26, 2026.

We certify that Sreelakshmi Sasikumar is currently working on her Master's thesis under the supervision of PhD. Birutė Miškinienė.The title of her thesis is:
"Risk Management in Large-Scale Infrastructure Projects: A Case Study of the Kochi Metro Project in Kerala."

This document is automatically generated and does not require the Vilnius University officer's signature and (or) the stamp in order to be considered valid. Document authentication links are provided at the end of the document.

Printed by
Study coordinator

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of Legal Entities
211950810

ANNEX 3

Response from Kochi Metro Rail Authorities

Ma'am/ Sir

Greetings of the day!

Kochi Metro Rail Ltd being a PSU takes Internship requests seriously and facilitates the same.

It has now been brought to our notice that the student (BA Economics graduate & now pursuing Masters in Business Management) has no intention of reporting to KMRL for Internship/ Project/ Thesis work.

Accordingly, it is informed that we regret, and we cannot permit request for Project / Thesis Work in the absencia.

Student is free to carry out her own reprt from information available in the Internet online/ open source data for her project work and for which KMRL will neither hold any responsibility nor approval.

This is for your kind information please.

Warm Regards

Gopikrishnan T R
Manager (Admin & Estate)
Kochi Metro Rail Limited | www.kochimetro.org
A Joint Venture company of Govt. of India & Govt. of Kerala
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To: "T R Gopikrishnan" <gopikrishnan.tr@kmrl.co.in>, "Jesly Jayan" <jesly.j@kmrl.co.in>, "Ratheesh S" <ratheesh.s@kmrl.co.in>