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Key Lead Indicators

An explorative research on improving the performance of large inner-city rail infrastructure projects across Europe

Yash Bhattad

M.Sc. Thesis | Construction Management and Engineering

M.Sc. Thesis

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By

Yash Bhattad

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Author

Name:	Yash Bhattad
Mail:	yb15151@gmail.com
Student no.:	4739957

Graduation Committee

Chair:	Prof. dr. ir. M.J.C.M Hertogh	TU Delft
First supervisor:	Dr. ir. M. G. C. Bosch-Rekveldt	TU Delft
Second supervisor:	Dr. M. Leijten	TU Delft
External supervisor:	Ir. S. Brouwer	AT Osborne
External Supervisor:	Ir. M. Roelofsen	AT Osborne

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Preface

*This is the **Master thesis** report as a part of the M.Sc. program in **Construction Management and Engineering** at the Civil Engineering Faculty of **TU Delft**, **The Netherlands**. The thesis has been carried out in collaboration with **AT Osborne**, a renowned management consultancy firm in the Netherlands. The fundamental objective of the research is to develop the theory on performance of large infrastructure projects across Europe by identifying and analysing the lead indicators present in the projects. The thesis has been completed in a span of approximately eight months, starting on the 24th of January 2019.*

*This thesis has productively gained from the contributions and involvement of various individuals throughout the process. First and foremost, I would like to thank **Ir. Sandra Brouwer** and **Ir. Mark Roelofsen** for providing support and eagerly supervising the research at **AT Osborne**. It has been an absolute pleasure working with you and the company. I would further like to thank **Dr. Marian Bosch-Rekveldt** for her patient and remarkable academic inputs to the research structure and content of the report and being accessible throughout. I would like to thank **Prof. Dr. Marcel Hertogh** and **Dr. Martijn Leijten** for their expert insights which gave a profound direction to the research and polished it further.*

*Last but not the least, I would like to thank **Mr. Riggert Anderson**, **Mr. Stefan Persson, Mr. Gerard Scheffrahn**, **Mr. Pelle de Wit**, **Mr. Sigi Herzog** and **Mr. Karl-Johann Hartig** who politely and patiently devoted their time in providing key insights related to various projects studied in this research. Further, I would thank **Mr. Rudolf Rijkens** and **Mr. Alex Miggelenbrink**, the experts from AT Osborne, who comprehensively provided their contribution in developing the results of this research.*

Finally, and above all, I want to thank my parents and grandparents who have been a constant source of motivation and energy throughout the master's program. Without their support and hard work, this master's program would not have been possible. In the end, I am also thankful to my brother, my sister-in-law, my fiancée Deeksha, my cousins especially Pranjal, Anuraag, and Akansha and all my dear friends especially Atul, Akshay, Abhishek, Khyathi, Nikhil, Jyotsni, Harsh, Pratul, Ragav, and Asmeeta for providing ever needed support during the entire master's program.

Wish you a pleasant read!

Yash Bhattad

Delft

Executive Summary

Introduction

Large Infrastructure Projects (LIPs) are well-known for their huge project duration and budget; large number of stakeholders and complexities involved. They are not easy to manage and some of them have an unpleasant history in relation to poor performance, specifically the ones among the transport infrastructure projects. Since decades, valuable measures to monitor and estimate performance outcomes are produced based on the criteria of success or failure. Most of these measures, however, are 'Lagging Indicators' that provide only the post-project performance information, primarily associated to issues of cost, time and quality, which only signifies a base for learning, but cannot be influenced.

Opposing to the Lagging indicators are the 'Lead Indicators' which predict deviation in the performance at an early stage. These indicators forecast the risks, alert the project and offer an opportunity to influence the performance before it is majorly deviated; hence, increasing the chances of project success. Yet, very limited research is available on lead indicators, especially in large transport infrastructure projects. Therefore, this research explores the Lead Indicators to influence the project performance.

The scope of the research includes identifying and analysing the most significant or 'Key' Lead Indicators (KLIs) because a project can encompass several lead indicators, out of which only few might be substantial. KLIs are researched in large inner-city rail infrastructure projects. The emphasis is on projects within Europe and not beyond due to the ease of access to the resources and information concerning the projects. The research is conducted from a public body's (client) perspective.

Research Design

The following research question is drawn:

How can Key Lead Indicators be used to improve project performance of inner-city rail infrastructure projects across Europe?

The research approach consists of three phases. Phase I consists of Literature study research to discover, collect the impressions of KLIs and strengthen the foundation of the research theoretically.

Phase II consists of Case study research to explore the KLIs from various inner-city rail projects and build the research practically. This phase is further divided into three stages. The first stage is 'Case Study Outline', which consists of a case selection criteria, corresponding to which the projects are selected. Also, an interview protocol is set, and interview questions are outlined to collect the data in the following stage. Following stage is 'Data Collection' where project documents are reviewed and interviews with project managers/coordinators are conducted. Relevant data is collected, which leads to the findings of KLIs. The last stage is 'Data Analysis and Validation' where the collected KLIs from all the cases are combined and validated by checking the consistency in responses from the interviewees of each project. The validated KLIs form the final research framework. This framework is analysed further through expert's consultation, where experts input ways to deal with the identified KLIs in practice.

Phase III is the End of the research in which the results are discussed along with its limitations. The research is concluded and recommendations for practice and further research are developed. This research is conducted with AT Osborne, a management consultancy firm in the Netherlands specialised in advising and managing complex infrastructure projects.

Results

Through literature study, the terminology of Key Lead Indicators is defined as "*The most significant forward-looking measures that evaluate and provide a basis to act on the project performance objectives in a manner that offers indication about potential risks that are likely to affect the project outcomes*". It is noted that scant amount of literature is available on the concept of Lead indicators. Most of the literature obtained are focussed on the concept of Early Warning signs. The definitions for both these concepts and their terminology are found to be similar, hence both of them are determined to be synonyms. An 'indicator' means it expresses both the aspects of a project, positive and negative. The KLIs retrieved from the literature, however, only replicated the occurrence of negative aspects. To surmount this situation, the identified KLIs are defined in such a way that they are neutral, hence replicating both the positive and negative aspect of a project. The theoretical framework is established as presented in the table I and KLIs identified from the literature are: *Design Change; Communication; Decision Making; Level of Experience; Trust; conflicts; Criticism; Mood; Attitude; Commitment and KLIs from External Category*. These KLIs are grouped into six categories from the literature as observed in table I. The external category consists of KLIs that can be hardly influenced, although they are considered relevant for further research.

Category	KLI	Definition
Change	Design Change	Number of Changes in Clients Requirements
Communication	Communication	The precision of delivering the messages completely (or) degree of communication between all stakeholders
Client Related	Decision making	The speed with which the decisions are taken especially from clients side. (Fast/slow/no decision)
Management	Level of Experience	The level of experience of Project Personnel (High/Low)
Behaviour	Mood; Attitude; Commitment; Conflicts; Trust; Criticism	Nature of behaviour of individual stakeholders of client/contractor/supplier (Abnormal/Normal)
External	Price fluctuations	Fluctuations in the market prices of the commodities, goods and labour.
	Economic conditions	Changes in exchange rate, inflation rate, interest rate etc.
	Weather conditions	Effect of different weather conditions on the project
	Changes in Laws and Regulations	Changes in laws and regulations by the government in between the project.

Table I; Theoretical Framework

Next, case studies were conducted to obtain the KLIs from practice. To select the projects, the criteria was as follows: First, all projects should be large inner-city rail Infrastructure projects (>1bn USD); second, all projects should be selected across different European countries; third, all the projects should be publicly initiated. Fourth, the projects should be characterised as complex because it can provide opportunity for more uncertainties, opening the door to identify a greater number of KLIs. Lastly, a combination of both finished and unfinished projects should be selected. Corresponding to this criteria, three projects are selected: Stockholm Metro Project (CI), North South Line Project of Amsterdam (CII) and Vienna Main Station Project (CIII). To collect the data from these projects, a two-fold approach is used: through project documents and interviews with project employees. Respective documents like lessons learnt, assessments report etc. are collected which provide mainly the background information of the projects. Two major events (one positive and one negative) from each case were focussed on. The term 'event' refers to occurrence of any specific outcome/activity associated with the final project deliverables. For the interviews, two project managers/coordinators per case were invited and significant data was collected through a set of interview questions. These set of questions were framed in a semi-structured and explorative manner, divided into three parts: First, introduction to the concept of KLIs is briefed to respondents. Second, open questions are framed to explore the root causes (KLIs) of these events. Last, KLIs from the theoretical framework are evaluated.

It was found that almost all the events had more than one KLI. *Lack of Experience* is observed as the KLI behind the negative events of CI and CII. Similarly, *Close Stakeholder Engagement* was observed across all the cases which led to the positive events. A chain of intermediate causes were identified which were led by the KLI, which then resulted in the occurrence of the event. These intermediate causes aren't the most significant ones and hence they are believed to be just the Lead Indicators (LIs) and not the 'Key' Lead Indicators for the event. For instance, '*Communication'*, '*Design Change'*, '*Trust'*, '*Motivation'*, '*Optimism Bias'* are frequently observed as LIs in the projects. Moreover, *Communication* and *Design Change* were also identified as KLIs in both, the cases and the theoretical framework.

The KLIs from practice were linked to the theoretical framework. All the KLIs of theoretical framework except *Mood*, *Conflict*, *Trust* and *Criticism* of the *Behaviour* category were observed in practice. Across the cases, *Lack of Experience* is strongly observed as a KLI which mainly led to *Design Changes*. New KLIs were also identified in practice: all of them were identified as indicators of the positive events, indicating the lack of theoretical research of KLIs focussing on positive aspects of the project. The external KLIs were observed frequently and were found to vary in each project. To sum up, 21 KLIs were discovered, 10 of which were identified in both theory and practice and the remaining were newly detected in practice. These KLIs form the research results as presented in table II.

Category	**KLI identified in both theory and practice**		**Category**	**KLI identified in practice**	
Change	1.	Design Change	**(External) Stakeholder Related**	11.	Transparency in role division
Communication	2.	Communication		12.	Stakeholder Benefits
Client Related	3.	Decision making		13.	Stakeholder Engagement
Management	4.	Level of Experience		14.	Goal Alignment
(Internal) Stakeholder Behaviour	5.	Attitude	**Work Culture**	15.	Project Environment
	6.	Commitment			
External	7.	Price fluctuations	**External**	16.	Political Decisions
	8.	Economic conditions		17.	Decision Making from External parties
	9.	Weather conditions		18.	Unknown Knowns
	10.	Changes in Laws and Regulations		19.	Financial Condition of Contractors/Subcontractors
				20.	Assumptions of Clients towards Contractors
				21.	Political Stability

Table II; Framework of KLIs

These KLIs are grouped into 8 categories. The left part of table II comprises of 6 categories and their KLIs are found both in theory and practice. All of them are previously defined in the theoretical framework. These are the most important KLIs according to the findings. The right part of table II represents the 2 new categories of KLIs which are identified only in practice. The category of '*(External) Stakeholder related'* comprises KLIs which are only related to the external stakeholders in the project. Amongst this category, KLI of *transparency in role division* is defined as the level of clarity to the stakeholders about their role and responsibilities. *Stakeholder Benefits* is the number of stakeholders benefiting from the project. *Stakeholder Engagement* is defined as the level of involvement and support from the stakeholders. *Goal Alignment* is the number of stakeholders having the same mentality of achieving the common goal of the project. Another category in this table is the '*Work Culture'* which comprises KLI of *Project Environment* which is specified as the level of leniency, freedom and mental safety in the project culture. The External category common on both sides of the table consists several KLIs that are relatively less important due to their 'hard to be influenced' character.

Once the KLIs are identified, steps to measure and influence them were accomplished. A meeting with four experts from AT Osborne was conducted and the main aim of this expert consultation meeting was to further develop the results of the framework. Experts brainstormed ideas to achieve this aim, and ways to measure and influence each KLI were suggested. The results of the expert meeting are additionally supported by personal reflection, literature and data collected from the cases.

Steps to measure and influence some of the most important KLIs are described here. *Level of Experience* can be measured by reviewing the profile of the employees and their past expertise. It can be influenced by recruiting people through a thorough process in the vision of both recruitment team and the project team. *Level of Experience* is found to trigger *Design changes*, which acts as a measure for design changes. To avoid *design changes*, it is important to have a complete and fixed scope before starting with the design phase, which can avoid unnecessary and major changes and provide room for minor changes. Design changes are although inevitable. Hence, they should be seen more as an opportunity to improve the design and satisfy the client rather an influence on cost and schedule. *Communication* can be measured by the number of interactions between the stakeholder groups and can be influenced by having strong communication plan and having an experienced communication director in the top management. *Commitment* and *Attitude* of internal stakeholders are hard to be measured and influenced. However, using scrum tool to check ones progress can reflect the level of commitment. An employee's body language and way of interaction can act as a step to measure attitude.

Conclusion and Recommendations

The KLIs from both theory and practice are found including the ways to measure and influence them. This resulted in answering the main research question:

How can Key Lead Indicators be used to improve project performance of inner-city rail infrastructure projects across Europe?

Table II provides the Key Lead Indicators identified in the selected inner-city rail infrastructure projects across Europe. These KLIs themselves cannot guarantee improved project performance unless the steps to measure and influence them are effectively applied. Hence, these identified KLIs should be first measured in the project according to the proposed ways. When the KLIs are measured, it warns by indicating the probable positive/negative affect on the project. To influence on this probable affect, proposed steps to influence the KLIs should be implemented immediately. To sum up, by measuring these KLIs, the project can foresee the risks and later by influencing them, the project can control these risks even before it fires. Hence, this way the performance of the project can be controlled at an early stage which results in relatively improved performance.

It is recommended for practitioners to:

- Implement a thorough recruitment process and ensure best value is provided to both the employee and the employer.
- Embrace, communicate and celebrate positive aspects in the project rather than only focussing on negative aspects.
- Prioritize the clients requirements more than staying in budget and schedule.
- Empower the stakeholders in the project by promoting open communication, providing equal benefits and possibility for shared financial bonus.
- Focus more on improving personal relationships by enhancing positive work environment.

Recommendations for future research include:

- Researching on KLIs for positive events.
- Researching the correlation between the identified KLIs.

- Researching on more concrete steps to measure KLIs.
- Researching in quantitative manner.
- Researching KLIs based on different phases of the project.
- Researching the implications after the recommendations are applied in practice.
- Researching influence on project objectives when the identified KLIs aren't acted upon.
- Researching with different types of projects apart from inner-city rail across a greater number of countries in Europe.

Implications and Limitations

The findings of the research contributed to the suggestions from previous researchers to discover more proactive measures than reactive. The research made its first attempts to study on concept of 'Key' lead indicators. The finding of the research on KLIs leading to positive events in a project adds value to the existing literature. Also, KLIs add value to the management of project performance and performance metrics. Anyhow, due to the short span of research a few limitations were faced. These limitations consist:

- Research doesn't show the influence that KLIs can have on project outcomes.
- Only three cases were studied across three countries in Europe limiting the research's generalizability.
- Steps to measure and influence the KLIs can be biased by the experience of AT Osborne experts.
- The interviews and their results are arranged only from client's perspective.
- Research only focussed on inner city rail infrastructure projects.

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List of Abbreviations

KLI – Key Lead Indicator

EWS – Early Warning Signs

LIP - Large Infrastructure Project

LI - Lead Indicator

LPI – Lead Performance Indicator

EPC – Engineering Procurement Contracting

PPP – Public Private Partnership

IPAT – Infrastructure Project Assessment Tool

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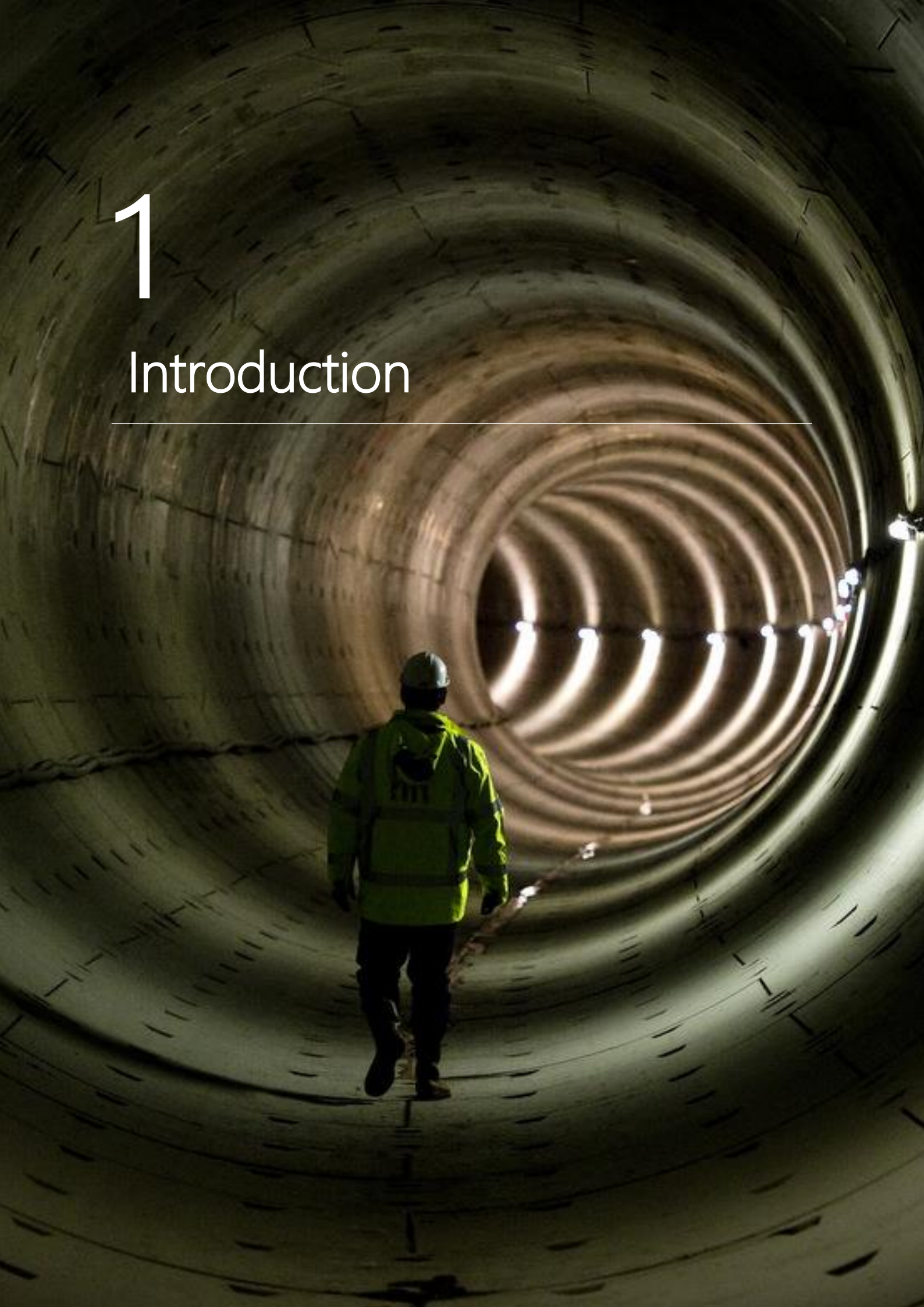
1 Introduction



This chapter provides introduction to this research. Firstly, section 1.1 introduces the background of the research regarding performance indicators. In section 1.2 a brief context of the research is described. Section 1.3 is dedicated to briefly distinguish the performance metrics of Lead and Lag indicators. Section 1.4 highlights the relevance of railway infrastructure projects among all types of transport infrastructure projects. In section 1.5 the problem statement of the research is described. Section 1.6 presents the research gap that needs to be fulfilled. Section 1.7 and 1.8 elaborates on the scientific and practical relevance of the research respectively. Lastly, Section 1.9 elaborates on the structure of the report chapter wise.

1.1. Background on Performance Indicators

Many past researches over four decades have revealed, that the low level of productivity in the construction industry hasn't improved with time when compared to other sectors. Productivity, in simple terms, can be defined as the ratio of output (Result) to input (Planned). If this ratio is higher, then the productivity is higher (Park, H. S., Thomas, S. R., & Tucker, R. L;, 2005). One main aspect for this low productivity in the industry is generally attributed to uniqueness of each project (Kenley & Harfield, 2015). Each project has a different outcome, and when these outcomes are put together, they decide the total productivity of the construction industry. It is evident from both theory and practice that most of the construction projects do not perform up to the mark which was set before the project realization (Caletka, 2014). Logically, this low performance of the projects contributes to the low productivity in the construction sector. But why do these projects don't perform well? Can't the problems behind this be identified and influenced even before they arise?

Since 20th century, the use of performance indicators had been in process for the purpose of performance measurement. Unfortunately, these performance indicators traditionally have relied only financial measures alone (Kagioglou, Cooper, & Aouad, 2001). These traditional performance measures are lagging indicators, which provide consequences of activities and events (Williams, 2012). For example, "Cost variance" and "Earned value analysis" technique have been used to measure performance of projects since decades. Managers are frequently unsatisfied with these traditional measures, when measuring project performance, and have voiced concern that these traditional measures could misinterpret the performance the projects (Choi, 2007). Practice and theories tend to understand and utilize more of lag measures with little emphasis on lead measures (Anderson & McAdam, 2004). The lag measures can identify the project's past performance – which are easily measurable - but not what contributed to achieve that performance, measures which are also useful. A simplistic example to illustrate this point can be drawn from the field of sports, for instance Soccer, where knowing the result of a match provides an indication of how the team performed but it suggests little on future improvements, identify mistakes and incorrect methods, assess individual performance or identify weaknesses.

1.2. Context of the Research

Megaprojects are known for their noteworthy characteristics like everlasting project time period, huge organizational complexity, long-lasting impact on the economy, environment and society, and a large investment commitment (Locatelli, Invernizzi, & Brookes, 2017). Although there is no single definition of megaprojects. For instance, from an investment point of view, the projects which have high degree of innovation & complexity involved and cross a benchmark of 1 billion USD budget, are considered megaprojects (Merrow, 2011). Analytically these mega-projects are of four types*: Infrastructure (e.g. rail, roads, ports, urban waters etc), Extraction (e.g. oil & gas), Production (e.g. industries, processing and manufacturing plants) and Consumption (e.g. malls, theme parks etc.)*. Out of all the four, history of Infrastructure projects is miserable due to its poor delivery in terms of both schedule and cost performance. (Locatelli, Invernizzi, & Brookes, 2017). This might be due to their added complexity for instance huge number of stakeholders involved, use of complex technologies etc (Hertogh, Baker, Staal-Ong, & Westerveld, 2008). Apparently, among the different types of infrastructure projects, large transport infrastructures projects are amongst the most controversial and they fall in the category of megaprojects since they attain the stated characteristics and often exceed the mark of 1 billion USD (Flyvbjerg B. , 2014). They are frequently over budget, delivered late and fail to deliver promised benefits (Flyvbjerg, Skamris, & Buhl, 2004) (Cantarelli, 2011).

However, a project failing or project success, does not occur instantly. Many consecutive events take place which ultimately results in its failure/success. The project problems like cost overruns and major delays are not suddenly discovered, instead they follow an incremental accumulation of problems (Wijtenburg, 2018). Similarly, any intermediate project success is quite rarely discovered because it's a tendency of the project to focus more on avoiding problems rather than celebrating success. These

successes also are led by a flow of interconnected positive responses/solutions. For present large and dynamic transportation projects, its crucial to identify at earliest the problems or opportunities which might mislead/enhance the project respectively. There are indicators which are present but are hardly identified and used relatively less than traditional indicators. They indicate at an early stage that the project might possibly deviate from what is expected. These indicators are known as 'Lead Indicators'.

1.3. 'Lagging' Indicators vs 'Leading' Indicators

Project performance measurement plays an important role in providing information about status of project progress/regress (Zheng, 2017). In recent decades, research attempts have produced many valuable measures to monitor the project progress (Jaafari, 2007) and to estimate project performance outcomes based on the criteria of success or failure (Cao, Qing; Hoffman, James J.; 2011; Atkinson, 1999). Nevertheless, most of this measurement builds on an approach that provides the ex-post performance information through the lagging indicators focusing on the iron triangle - cost, time and quality. Some researchers also extended their research beyond the traditional "iron triangle" by including other drivers likes customer satisfaction (Atkinson, 1999) and safety, but the reality of adopting lagging indicators has not changed. The drawback of lagging indicators is that they are backward focussed i.e. they measure performance on data already captured (Zheng, 2017). The lagging indicators help analysing whether the goals are achieved, but they do not provide project team earlier warning signs of project risks to thus improve the performance or results of projects through taking preventive actions (Zheng, 2017). These indicators are easy to measure and accurate, but hard to improve or influence.

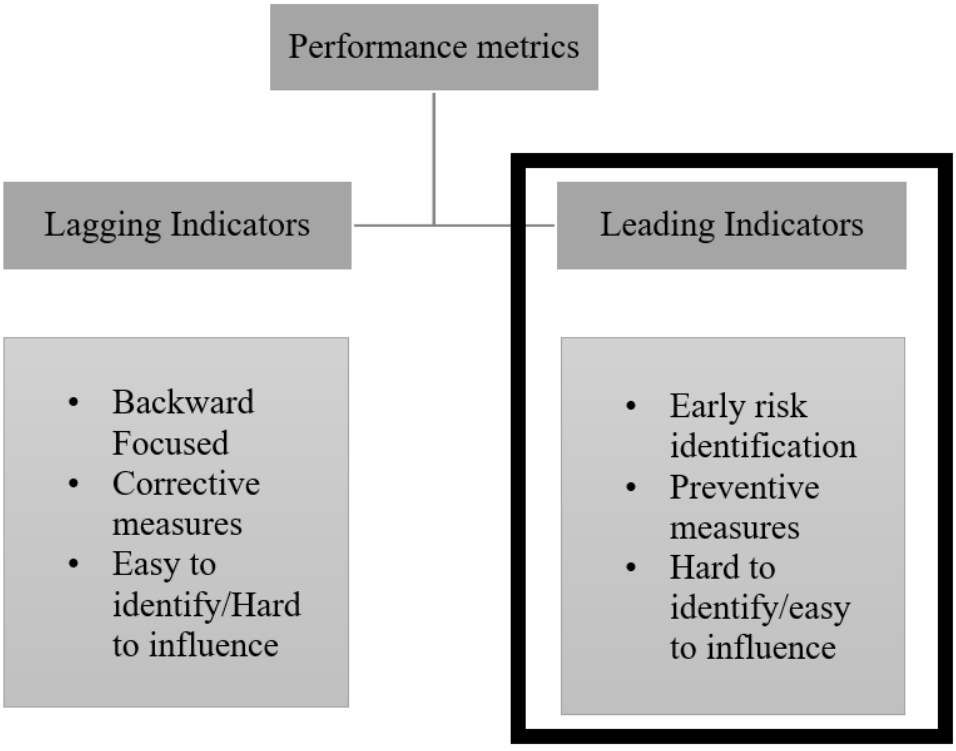


Figure 1; Lagging vs Leading Indicators

Due to the limits of the lagging indicators, few studies have focused on the identification and development of leading indicators. These leading indicators are unlike the lagging indicators. They can provide early warning signs and helps to identify potential risks, enabling project team gain additional insight into their project health status, and thus act before project performance is heavily altered (Zheng, 2017). However, these lead indicators are always quite difficult to measure compared to the lag indicators. They are predictive and can increase the chances of success if used effectively i.e., when

they are predicted, they provide information that allows to make better decisions before the outcome is clear (Erkins, n.d.). Figure 1 picturizes the differences between Leading and Lagging indicators.

1.4. Research Interest in Large Railway Infrastructure Projects

Since a decade, Europe is majorly focussing to develop excellent transport network in and across its countries. Apart from that, the need for such development in mobility is vastly growing. Therefore, Europe Commission (EC) has set up an ambitious programme of nearly 30 transport network Large Infrastructure Projects (LIPs) (Hertogh, Baker, Staal-Ong, & Westerveld, 2008). These Large Infrastructure Projects (LIPs) needs an effective execution to complete the trans-European network. The initiators and clients of LIPs in Europe are governmental organizations, and government is a Project Oriented Organization (Arvidsson, 2009).

Apparently, realising such LIPs is difficult as it is understood previously that these projects recurrently face substantial cost overruns and time delays. For instance, a cost study of 258 transport infrastructure projects covered across twenty nations on five continents estimates their cost overruns based on different modalities of infrastructure. For rail, average cost overrun accounts to 44.7%, for bridges and tunnels it is 33.8%, and for roads 20.4% (Flyvbjerg, B.; Holm, M. S.; Buhl, S., 2002). The variance in cost overrun among three types of modality is statistically significant, which indicates that rail projects tend to underperform the most or at least have a higher risk of uncertainty in terms of completion within target budget, among all the stated modes of transport infrastructure projects. Therefore, considering the study of Large Railway Infrastructure projects across Europe is interesting and seems valuable for this research.

1.5. Problem Statement

It is described that when evaluating the success/failure of any construction project '*a common approach is to evaluate performance on the extent to which client objectives like cost, time and quality were achieved*' (Kagioglou, Cooper, & Aouad, 2001). Undeniably, they are perceived as the 'three traditional indicators of performance' used in the UK construction sector. Although these measures offer a sign as to the success or failure of a project, they do not, in isolation, deliver a sensible view in project's performance. Due to their significant complex nature and their relevance previously mentioned, this research focusses on only Large railway Infrastructure Projects. Hence the main problem is: Although these performance measurement methods are applied in these railway infrastructural projects, which are usually the lagging ways to measure performance, most of the projects tend to fail. According to this, the problem statement sums to:

"There is a lack of research and focus on lead indicators, compared to lagging indicators."

1.6. Research Gap

The two research gaps identified are:

First, most of the research on lead indicators from literature study just focusses on specific areas like Safety lead indicators and on projects apart from the construction industry. None of the found literature provides answers so far on different Lead Indicators in Large Railway Infrastructure Projects.

Second, in order to improve the performance using the identified lead indicators, it seems crucial to build-on the research by finding steps to effectively use the Lead Indicators in future Large Railway Infrastructure Projects. Since the research on Lead Indicators is itself lacking, it is logical that research on directives to utilize them in the future railway projects must be undeveloped.

1.7. Scientific Relevance

According to Haji-Kazemi, there is a need to manage project performance in a proactive way rather than reactive. Present performance measurement systems used within organizations focus on the past, as opposed to the future. Hence, they lack the flexibility to transform (Feurer & Chaharbaghi, 1995). Stone and Banks (1997) points out that in the last two decades the project environment is highly dynamic which suggests that the conventional measures do not present a complete picture of project performance. Therefore, the organizations need to concentrate more on developing leading indicators, opposed to lagging indicators. These recommendations are the roots of this research.

1.8. Practical Relevance

To emphasis on management and organisation of such LIP's, the European Commission introduced a research programme called the NETLIPSE. It stands for 'NETwork for the dissemination of knowledge on the management and organisation of Large Infrastructure ProjectS in Europe'. The main objective of the NETLIPSE project is "*to engage a continuous and communicating network of LIP's across Europe for spreading knowledge and experience focussing explicitly on the management and organisational aspects of these projects"* (Hertogh, Baker, Staal-Ong, & Westerveld, 2008). The NETLIPSE project covers mainly 15 LIP's across Europe and to fulfil this objective, the quality of these LIP's has been accessed and best practices were recognized which can be helpful for other LIP's.

The insights from NETLIPSE research reveals that the LIP's are well organised on the 'Hard factors' when compared to the 'Soft factors'. The Lagging indicators are a form of Hard factors here as they are traditionally used to measure the performance and are quantifying the performance results after the occurrence of uncertainties. On the other hand, the Leading indicators are relatively intangible in nature which are hard to be measured. Therefore, they play a role of soft factors. Section 1.2. similarly insists that there is a need for LIP's to focus on performance measurement by also using lead indicators in order to predict problems and opportunities early in the project. Hence, this research is established to emphasis practically on lead indicators in large rail infrastructure projects.

1.9. Structure of the Report

This research is structured as shown in the diagram below (Figure 2). After this introduction, Chapter 2 continues with the Research Design. The sub questions of this research are answered in chapters 3, 4 and 5. Chapter 3 contains the literature review and their results. Chapter 4 elaborates on case study on three different construction projects. Chapter 5 discusses suggestions on usage of Lead Indicators to improve the project performance. Chapter 6 contains discussion and limitations of the research. Finally, Chapter 7 ends with conclusions, answers to the research questions and recommendations for practice and further research.

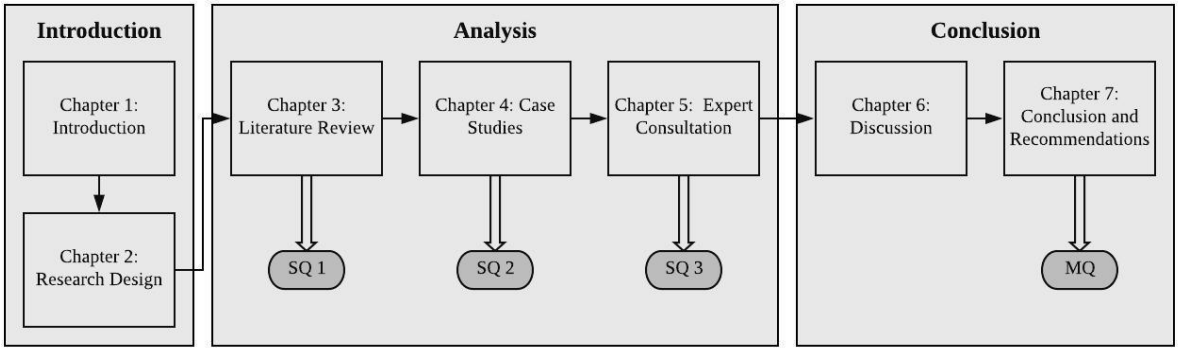


Figure 2; Structure of the Report

2 Research Design

This chapter is devoted to describing the objective, research questions and how this research is conducted i.e., the research methodology. In section 2.1, objective of this research is stated. Section 2.2 describes the scope to be covered in the research giving a complete essence about the research. Section 2.3 presents the main research question and the sub questions and why they are framed in such manner. In section 2.4, the applied methodology is introduced and explained.

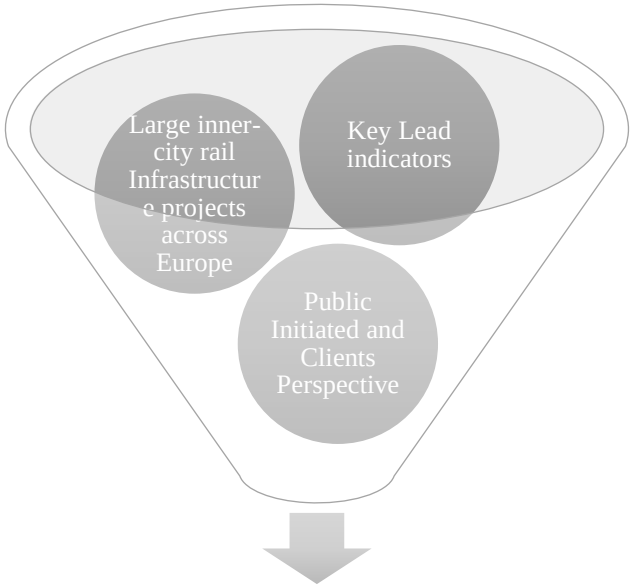
2.1. Research Objective

The research's objective is framed accordingly to fill the research gap and it is stated below:

'To further develop the theory on performance of railway infrastructure projects by critically identifying and analysing the Lead Indicators which influence the project objectives of chosen large rail infrastructure projects.'

2.2. Scope of the research

Figure 3 represents the scope model and is described in detail below.



Identifying and analysing the Key Lead indicators (from Clients-perspective) affecting the project objectives in large inner-city rail infrastructure projects, chosen among different countries around Europe.

Figure 3; Scope of the Research

2.2.1. Key Lead Indicators

The main subject of this research is on Lead indicators. The term 'Lead Indicators' includes all the Lead Indicators which may or may not be much significant. Hence, this research only aims to focus on Key Lead Indicators.

2.2.2. Large inner-city Rail Infrastructure projects

The railway projects can be of different types: inner-city, inter-city or cross border. 'Large' represents megaprojects that are considerable in size (> 1 Billion USD) and complex in nature. It interests the researcher to focus only on inner-city rail type of infrastructure projects (light rail, metro, tram or station development) for the following reasons (De Bruijn & Veeneman, 2009):

- Europe is focussed and has planned several light rail projects across various countries which still to be realised. Thus, this research can be valuable for the upcoming projects.
- Wide range of stakeholders are involved with different perspectives which increases complexity.
- Technical diversity is involved with numerous technical requirements and conditions.
- Wide range of geographical constraints while planning increasing the complexity.

2.2.3. Projects across Europe

Research in different countries across Europe might produce results from a broader perspective rather limiting it to only one country. Nevertheless, it is difficult to achieve access to the information and sources of network related to the projects realized in countries beyond Europe, hence, the research is only performed on projects within Europe.

2.2.4. Public Initiated Projects and Clients perspective

Only Public initiated projects are considered since most of the large infrastructure projects are initiated by public body. The 'public body' who is the client in these projects has a central role for the initiating and funding the project. Hence, this research is conducted from a Client's perspective.

2.3. Research Question

In order to achieve this research objective given the scope of the research, the main research question is:

"How can Key Lead Indicators be used to improve project performance of inner-city rail infrastructure projects across Europe?"

The first step is to investigate the Key Lead Indicators as performance measures from existing theory on its concept. To identify the KLIs from the theory, the following sub question is framed:

1) *What are the Key Lead Indicators that can be identified from literature?*

Next, to identify the KLIs in actual inner-city rail infrastructure projects, which builds the research practically, the following sub question is framed:

2) *What are the Key Lead Indicators that can be identified from practice among chosen projects?*

Once the significant lead indicators are investigated, on basis of this information, suggestions need to be provided on how to use these indicators. 'Use' of each KLI includes two aspects. First, 'Measuring' the extent to which it is present in the project before, second, 'Influencing' it to achieve the required level of its existence. These two aspects are required subsequently in order to be able to apply it in practice to improve performance of inner-city railway infrastructure projects. Hence, this sub question is framed accordingly to understand how these KLIs can be helpful. Therefore, the final sub-question is framed as follows:

3) *How can the identified Key Lead Indicators be measured and influenced in the future railway projects?*

2.4. Research Methodology

The Research Methodology is decided mainly based on how the research question is framed. The research questions can start usually with one of the five words: *What, Why, How, When* and *Where*. The question of this research starts with a '*How*'. Generally, a case study research method when used is more likely to provide the solutions for research questions starting with 'How' and 'Why' (Yin, 2014). Therefore, the chosen research strategy is Case Study Research. Figure 4 represents the methodology in a flow diagram. This strategy is divided in three consecutive phases: *Literature Study Research, Case Study Research* and *End of Research*. These three phases are explained in detail below.

2.4.1. Literature Study Research

The Literature Study Research is the first phase of the research. It strengthens the understanding of roots of the research and its findings theoretically. This phase consists of 2 parts: *Research definition* and *Literature study.*

After defining the research by describing the problem, objective and the research questions, the Literature Study phase continues with a thorough review of literature. Before starting with the case studies, it's important to have a theoretical background about the research. Until now, the subject of key lead indicators has been introduced briefly. Literature review on management of cost, scope, time and quality can provide the researcher an overview of KLIs and might deliver a set of lead indicators which have been scientifically and theoretically proven by different researchers in the past. This literature study ends by providing the set of KLIs which form the theoretical framework. This solves the first sub question (SQ1) of the research.

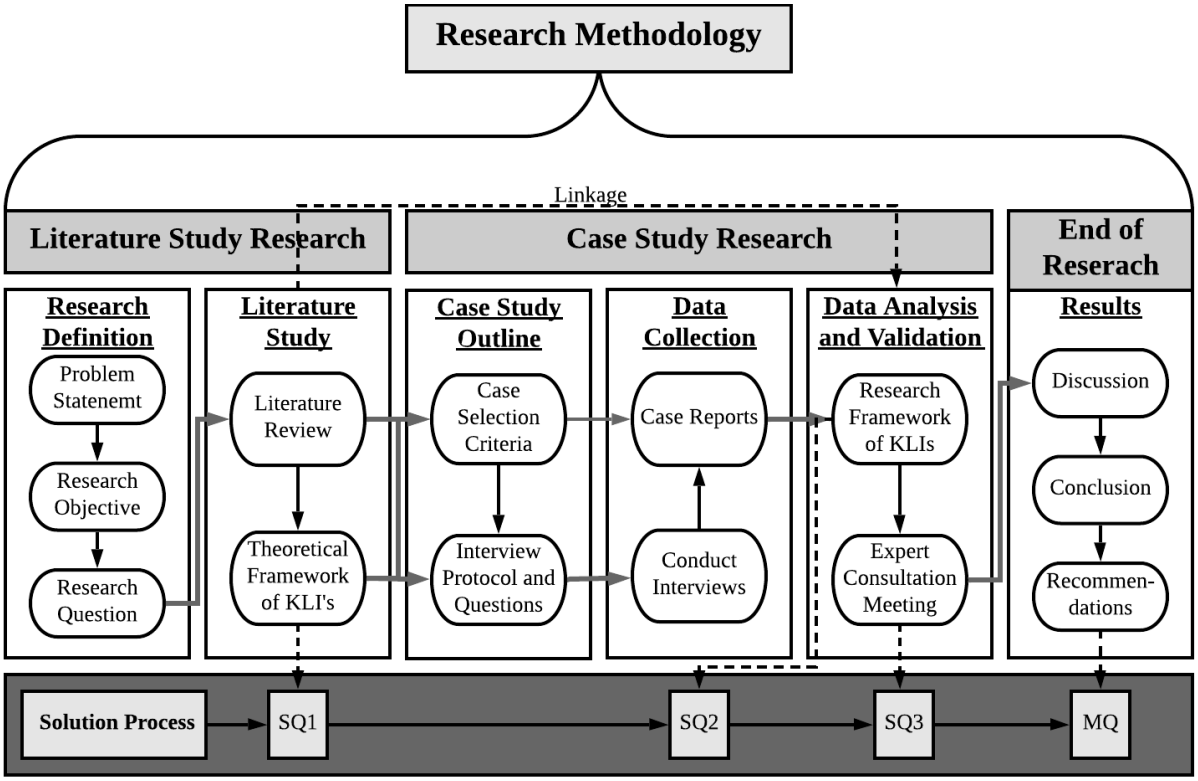


Figure 4: Research Methodology (Yin, 2014)

2.4.2. Case Study Research

This is the second phase of the research which is continued after the Literature Study Research. In this phase the cases are studied and KLIs from these cases are collected and analysed. This phase consists of 3 stages: *Case study Outline*, *Data Collection* and *Data Analysis & Validation*.

***Case study Outline*:** In this stage, a case selection criteria is developed based on the scope of the research and three cases (projects) are selected, each from different country. Since the research is across Europe, the countries and their respective project managers are chosen within the limits of reach of international network of the graduation company, AT Osborne. Connections are developed with the project managers/coordinators who have experience and have worked in the respective projects, to interview them later. Interview protocol and questions are established to collect the KLIs, from the perspective and experience of the interviewees, which were observed in respective cases.

Data Collection: The project reports and their lessons learnt literature (if available) are studied which can give a clear information about the project and relevant details about the case which can lead the researcher to identification of the KLIs. Next, due to the limited availability of connections internationally, only two project managers/coordinators from each cases are interviewed and their takeaways from the respective projects with respect to the interview questions are gathered. Major data is gathered from the interviews since it's based on the actual experience of the interviewees which is

valuable. The interviews are scripted and sent for re-verification of its consistency with the respective interviewee. Finally, the verified data is used, and it provides a list of KLIs from each case. This data is taken further for the analysis.

Data Analysis & Validation: A cross-case analysis is taken up to analyse the collected data. First, as it is an explorative research, the identified KLIs from each case are combined together and their frequency of repetition across all the cases is analysed. The combined KLIs are validated by verifying each KLI if it is cited by both the interviewees of each case. If not, it is attempted to verify by the examining the case documents and proving its existence. If none of the two aspects are fulfilled, then the KLI doesn't have enough support to be validated and is simply exempted from further research. The main goal of the analysis is to compared existing theory on KLIs with current practice, i.e., from chosen cases, and to obtain the most important KLIs. Also, the newly identified KLIs from practice adds value to this research. All these validated KLIs are then defined according to the observation's from cases/theory. A Framework of Analysis of KLIs is developed. This results by solving the second sub question (SQ2).

An expert panel meeting is setup with four experts of AT Osborne where the results of the cross-case analysis are presented and are generically validated. Their remarks are noted. The main aim of this meeting is to analyse each KLI by seeking suggestions on steps to measure and influence it. Personal reflection and data from cases is additionally used to analyse each KLI. These suggestions form the answer for the last sub question (SQ3).

2.4.3. End of Research

This is the final phase of the research. All the obtained results are discussed, and the limitations of the research are presented. Further, the research is concluded by answering all the sub question which directly leads to answering the Main question (MQ). Finally, recommendations for practice and for further research are suggested.

3

Literature Review

This chapter contains a literature study about Key Lead Indicators (KLIs). The aim of this chapter is to identify the KLIs from the literature.

The first sub question that is answered in this chapter is:

What are the Key Lead Indicators that can be identified from literature?

In order to answer this question, two aspects are necessary to discover: (1) The definition of a KLI, and (2) The identified KLIs to measure the performance of the variables namely cost, time, scope and quality.

This chapter is divided in three sections. In section 3.1, the concept of KLI is introduced and defined for this research. Section 3.2 elaborates on the identification of KLIs. It also provides the theoretical framework of KLIs. Section 3.3, concludes the findings of literature study.

The key words used to sort out the literature were ‘Lead Indicators’, ‘Performance Drivers’, ‘Early Warning Signs’, ‘Performance Indicators’, ‘Forward looking Measures’, ‘Weak Signals’, ‘Soft performance indicators’. All the literature was gathered using Google scholar, TU Delft repository, Word cat (TU Delft) and Research Gate.

3.1 Key Lead Indicators

In this section, the concept of Key Lead Indicators is introduced. Various definitions of Lead Indicators are discussed from literature, and definition of KLI for this research is determined.

3.1.1. Definition of KLI

The term "lead indicators" have similarly been described by various terms and definitions by many organizations, institutions and researchers. The terms comprise of 'Weak signals', 'Early indicators', 'Early Warning', 'Presignals', 'Symptom' etc (Nikander, 2001). Ansoff used the term 'weak signals', with the following description: '…imprecise early indicators about impending impactful events…all that is known is that some threats and opportunities will undoubtedly arise, but their shape and nature and source are not yet known' (Ansoff & Mcdonell, 1990; Williams, 2012). Similarly, the Construction Industry Institute (CII), based in University of Texas at Austin, defined Leading indicators as "Fundamental project characteristics and/or events that reflect or predict project health. When revealed in a timely manner, these indicators allow for proactive management to influence project outcomes" (Zheng, 2017; Choi, 2007). Likely, the Systems Engineering Leading Indicators Guide interpreted leading indicators as "measures for evaluating the effectiveness of the systems engineering activities on a program in a manner that provides information about impacts that are likely to affect the system or program performance objectives" (Zheng, 2017).

Few researches marked the importance of evaluation for the purpose of organizational improvement. One such researcher, Sarkis (2001) critiqued the benchmarking as a systematic process for evaluation of organizations. He explained the importance of Lead Benchmarking in projects and defined it as the "benchmarking which focuses on analysing forward looking, predictive and future performance comparisons" (Anderson & McAdam, 2004). From the project management journal, the research of Williams et al. (2012) reflected the lead indicators as Early Warning Signals (EWS). It cited that the basic idea of EWS is to focus on lead indicators. Additionally, it described EWS as an observation, signal, message or some form of communication that is or can be seen as expression, indication, proof or sign of existence of some future or incipient positive or negative issue (Williams, 2012).

The term 'Key' Lead Indicators, which is relevant to this research, is preferred to identify the most common and significant lead indicators. Understanding the various definitions of Lead Indicators, the best suitable definition of KLI for construction projects is proposed to be as follows:

> *"The most significant forward-looking measures that evaluate and provide a basis to act on the project performance objectives in a manner that offers indication about potential risks that are likely to affect the project outcomes."*

This definition is adopted in this research, since it is referred from the trusted system engineering's guide from the research of Zheng. This definition suggests KLI can predict both positive and negative impacts. Hence, this research focuses on KLIs predicting both the negative and positive events in projects. Outlook of both the events can provide KLIs which can improve the project performance.

3.2 Identification of KLIs

This section is about the identification of KLIs. Section 3.2.1 explains about different construction phases. Section 3.2.2 the gathered key lead indicators for the literature study will be generated in the last section.

3.2.1 Different Phases of Projects

Project phases are segments of a project where additional control is expected to effectively deal with the achieving of a key deliverable. The phase-division structure of a project allows it to be segmented into reasonable subsets for ease of management, planning, and control (PMI Standards Committee, 2008). Few literatures convey that Lead indicators can vary throughout the project. They differ between

stages of development (Williams, 2012). Williams et al. (2012) performed eight case studies of diverse projects (Public and Private) from Norway, UK and Australia. The results of these case studies provided with sets of Early warning signs in 3 different stages of the project – Project setup, Early stages & Project execution.

Similarly, a very recent literature of Habibi et al. (2018), which is repeatedly used in this research has studied over 200 peer-reviewed papers from different parts of the world and a vast range of leading performance indicators (LPIs) in each EPC phase was identified. It proposed that construction process (EPC Projects) can be examined in three main phases namely (1) Engineering phase (2) Procurement phase (3) Construction phase (Mahmoud-Jouini, 2004). Generally, the success of complex construction projects is strongly related to their lifecycle performance (Dao et al., 2016a). Therefore, Lead Indicators should be developed in phases and be utilized to measure construction success (Kermanshachi, 2016).

3.2.2. Identified Lead Indicators from the Literature

Habibi et al. (2018) conducted a comprehensive review of related performance papers to address the inconsistency issue of time/cost overrun indicators in construction projects. It focused on the phase-based review of performance indicators. It ranked and marked the frequencies of each identified indicator based on its importance. The indicators are reflected in each phase of EPC project respectively and are represented in the Table 1.

Habibi et al. (2018) found out that *design change* is a significant lead indicator affecting both cost and schedule performance in Engineering and Construction Phase. Similarly, it concluded that *resource shortages* and *price fluctuation* are quite frequent indicators causing delay/cost to overrun in Procurement phase. Also, since the indicators were grouped into different categories, the result conveys that the *External group* comprises of maximum indicators, followed by categories of *Management*, *consultant* & *client-related* in all EPC phases (Habibi, 2018).

Table 1; Lead Performance Indicators in EPC phases (Habibi, 2018)

Category	Indicators	Frequency	Ranking
Cost Performance indicators			
Engineering phase			
Change	Design change	7	1
Project Characteristics	Project size	4	2
Management	Poor communication between stakeholders	4	2
Procurement Phase			
External	Price fluctuations	14	1
External	Poor economic conditions (exchange rate, inflation rate, interest rate etc.)	9	2
Material	Shortage of Construction Material	9	2
Labour	Shortage of site labour	8	3
Construction phase			
Change	Design change	14	1
External	Severe weather conditions	11	2
External	Laws and Regulations	10	3
Consultant-related	Inaccuracies and deficiencies in cost estimates	10	3
Schedule Performance Indicators			
Engineering Phase			
Change	Design Change	13	1
Client-related	Slow Decision Making	8	2
Client-related	Delay in Approval stage	8	2
Management	Poor communication between stakeholders	5	3
Procurement Phase			
Material	Shortage of Construction Material	16	1
Equipment	Equipment Shortage (Machinery and its parts)	14	2
Labour	Shortage of site labour	13	3

Category	Indicators	Frequency	Ranking
	Construction phase		
Change	Design Change	28	1
Management	Poor site management and supervision	18	2
External	Severe weather conditions	17	3
Client-Related	Financial issues by client	17	3

Similarly, research of Williams et al. (2012) produced a research on early warning signs by performing case studies on a set of public and private projects. Several identification methods of EW signs were also reflected, among which two were found out to be very significant in projects: *Identification via Assessments* and *Gut-feeling*. These EW signs were divided into three project stages as mention earlier. Table 2 shows the concluded EW signs from the research. The identified EW signs were not divided separately as cost/schedule performance indicators as observed in Habibi et al. (2018).

Table 2; EW signs (Williams, 2012)

	Project setup	In early stages	Project execution
Assessments	• Sponsor(s) with unclear role • Lack of an implemented governance framework • Poor project definition • Lack of clarity in rationale, goals, and benefits • Poorly developed business plan • Poor definition of scale and what resources are needed • Unclear what assumptions are valid about the project • Lack of relevance of the proposed solution compared with the needs • The need for development of new technology • Main risks not identified	• Lack of a good business case • Deterioration of relations between the participants • Lack of a common definition of roles and responsibility • The project team overrelying on the consultant/contractor's people to "fix it" • Numbers/information missing in documents • Assessments not performed • Documentation not completed • Inappropriate quality of information and documentation produced • Missing competence in the project team • Guidelines for early phase assessments and "behavior" not followed • Disputed major decisions and complications arising from these • Main risks not identified	• People in "acting positions" with no authority to recommend action • Lack of documentation • An excess of "no cost/no time" effects leading to optimism bias • Contractor unfamiliar with domain responsibility • High level of subcontractors' claims and extension of time claims • Plans and reports too late and/or not clear • Contract obligations not fulfilled • Milestones/activity definitions unclear or missing • Missing competence in the project team • Remaining risks not identified
Gut feeling	• Sponsor(s) having unclear expectations • Vague or unclear reasons for undertaking the project (unclear thinking) • Needs considered not real • Inconsistent arguments about agendas • Uneasy comments and body language • The way questions are asked and how answers are given • Specific conditions exist that will make cultural aspects important	• Leadership issues • The way answers are given to critical questions, when the answers are vague • Strained atmosphere • Lack of a culture of openness and good communication between the actors • Confusing or wavering changes in position over time • Uneasy comments and body language • Stating uncertainty, unwillingness to conclude • Parties unwilling to share relevant information • Parties voicing reservations and politically hedging their positions	• Leadership issues • Lack of commitment to make decisions • Frequently changing decisions • Continually unfulfilled promises • Vague answers to critical questions • When people work too much or too little • Uneasy comments and body language • Not showing trust in the project organization

Nikander (2001) performed an in-depth study on Early Warnings in construction project. It provided a hypothetiocal relation of dependencies between early warnings, problems, causes and their responses picturised in Figure 5 below.

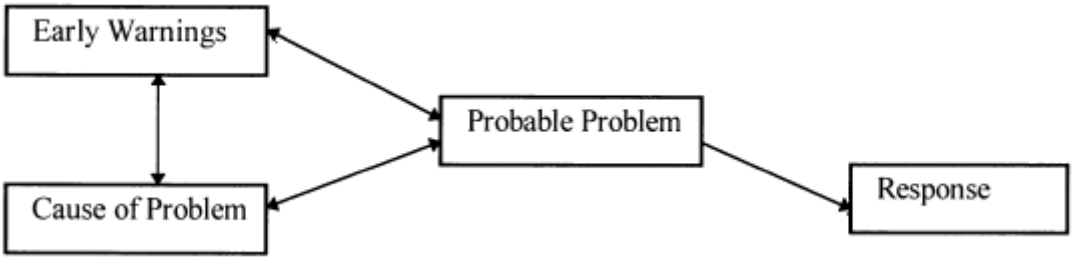


Figure 5; Dependencies between early warnings, problems and causes (Nikander, 2001)

The study first interviewed 17 project professionals and later performed research on four projects where it interviewed many parties that participated in those respective projects. The study identified 68 early warnings which were clustered into 11 main groups. Additionally, it identified the major project problems and again grouped them into four cateogaries. Table 3 represents most frequent combinations of the Early warning main groups and Project problem main groups. Similarly, Table 4 presents the frequent combination of these problems and their most probable causes.

Table 3; Early Warning Main groups - Project problem main groups (Nikander, 2001)

Early warnings, main group	Project problems, main group (%)			
	Schedule problems	Delivery problems	Planning problems	Management style problems
Personnel, project group	2.31	3.09	4.02	6.38
Project parties	1.84	1.72	2.43	2.76
Documents	2.58	2.08	1.03	1.32
Working within the project	2.29	0.91	3.40	1.46
Project planning	0.94	3.10	1.55	0.76
Communication	0.44	1.14	0.58	2.23
Differences and deficiencies in project culture	0.17	1.19	1.29	2.64
Project control and reporting	2.76	1.36	0.81	0.54
Project manager, management	0.10	0.77	1.03	0.91

Table 4; Project Problems - Causes of problems (Nikander, 2001)

Project problems, main group	Causes of problems (%)						
	Management	Project culture differences	Many reasons	Organization	Personnel skills	Resource shortage	Attitude
Time, Schedule problems	1.68	3.25	4.75	1.06	1.09	1.43	0.88
Performance, Delivery problems	1.88	4.15	2.02	0.96	1.97	1.63	0.93
Problems in management, total	3.23	4.61	3.25	1.85	1.10	1.53	2.20
Planning, tech	2.76	6.59	1.35	2.35	0.57	2.67	1.29

AT Osborne derived their own list of EW signs, following from sessions with experienced project managers (AT Osborne, 2017). Subsequently, these signs were divided over different categories: Trust within the team, Workload, Opportunity and attention for reflection, Clearness of strategy, Relation with environment, Collaboration between colleagues, Feasibility of project goal, Support by environment, Safety to express opinion & Team ambiance. The categories by AT Osborne are mainly based on their character. Furthermore, AT Osborne focused solely on soft EW signs.

3.2.3. Analysis and Theoretical Framework of KLIs

The previous section outlined an overview of the Lead indicators and Early warning signs identified by various researchers. The available literature to identify the 'Lead indicators' is found to be scant. There is gap in terminology and interpretation around the concept of leading indicators. There is quite some literature available on Early Warning signs, however, a clear similarity between both the concepts is missing. Also, none of the literature specifies a clear distinction between the two of them. Thus, the literature on both the concepts were reviewed. Nikander (2002) defined an EWS as:

"*It is an observation, a sign, a message, or some other item that is or can be seen as an expression, an indication, a proof, or a sign of the existence of some future or incipient positive or negative issue. It is a sign, omen, or indication of future developments.'*

When compared this definition with the definition of a KLI previously defined, there is a major overlap. It is even found that the concept of EWS is also to emphasis more on lead indicators (Wijtenburg, 2018). Moreover, many Lead Indicators are in parallel with the identified Early Warning signs. Hence, for this research, it is understood that both the concept of Lead Indicators and EWS are similar i.e., the term 'EWS' is just a synonyms of 'Lead Indicator'. It is proposed that more research can be performed comparing concepts of Lead Indicators and Early Warning Signs which can robustly approve the correlation between them.

All the limited number of identified Lead indicators from the literature can be significant for the research further. However, not all of them focus on the clients-perspective which is the one of the main motivation of this research. Here, client-perspective refers to the indicators which have a certain degree of influence by the client on them. Moreover, from a client's-perspective these indicators are not only spread in a single phase of the project, rather they are evident to exist throughout different phases of the project. Therefore, this research will continue to discover the lead indicators throughout and not specific to a phase of the project. The following list of KLIs are the identified lead indicators from the literature which will be further investigated in this research (Table 5).

Table 5; KLIs from Literature study (Habibi, 2018)

Category	Indicators
Cost Performance indicators	
Change	Design change
Project Characteristics	Project size
Management	Poor communication between stakeholders
External	Price fluctuations
	Poor economic conditions (exchange rate, inflation rate, interest rate etc.)
	Severe weather conditions
	Laws and Regulations
Consultant-related	Inaccuracies and deficiencies in cost estimates
Schedule Performance Indicators	
Change	Design change
Client-related	Slow Decision Making
	Delay in Approval stage
	Financial issues by client
Management	Poor site management and supervision
	Poor communication between stakeholders
External	Severe weather conditions

The category of 'External' lead indicators is considered relevant for this research since it was found to be the most frequent set of Lead indicators in projects (Habibi, 2018). Though this category has almost no degree of control by the client, it's important to further discover if the External category of KLIs greatly influences the performance of a project. This can reveal the standing of external KLIs in large infrastructure project.

The literature study also discovered a relatively vast part of Early warning signs. The significant EWS are presented in Table 6. These EWS were are chosen from all the three literatures (Nikander, 2001) (Williams, 2012) (AT Osborne, 2017). The EWS were described and segregated based on the clients

perspective and its importance and frequency, which were quantified by percentages (Appendix A) in Nikander (2001).

Table 6; EWS from the Literature (Nikander, 2001) (AT Osborne, 2017) (Williams, 2012)

Category	***Early warning signs***
Personnel, Project group	Personal behaviour (Mood, attitude, conflicts, commitment etc.)
	Non-verbal information
Project planning	Preliminary planning
	Level of Contract drawn (in terms of professionalism, ambiguity)
Project control	Progress control
	General monitoring (Methods, speed and quality of work)
Working within the Project	Work initiation
	Lack of information
Communication	Miscommunication
	Tone of messages
	Conflicting information
	Insinuation
Expressed by parties	Typical to client (No decision/ Delayed decision, trust, support etc.)
	Advance billing
Documents	Reporting
	Schedules (Level, Quality, Receiving)
	Technical plans
Project culture	First impression to client
	Lack of experience
Other	Gut-feelings
	External
	No EWS obtained

The analysis of table 6 indicates that many cost and schedule KLIs overlap with each other. Moreover, the identified set of KLIs doesn't offer any explanation about it affecting only cost or only schedule objectives of a project. Hence, the KLIs shall not be segregated based on different project performance objectives (Cost and Schedule) and rather they will be just seen as 'KLIs' in a project.

As presumed, both KLI and EWS are similar in their concept, it is now important to sort out the indicators which completely/partially overlap with each other from both Table 5 and Table 6. Hereby, table 7 presents the comparison of identified KLIs and EWS from the literature (table 5 and table 6 respectively) which overlap with each other. The KLI and EWS in each row are overlapping with each other according to their definitions. The categories which consists these KLIs and EWS are also indicated in the table.

Design Change seems to be evident as KLI in both cost and schedule indicators. Also, *Preliminary planning* is an EWS which is related to the inadequacies in the project planning. *Poor communication between stakeholders* (KLI) and *Miscommunication* (EWS) are two overlapping indicators, which seems to be very significant in projects. Similarly, *Slow decision making* (KLI) and *No Decision* (EWS) overlap completely with each other. *Poor site management and Supervision* (KLI) is a management problem which can be related to the Lack of Experience (EWS) under the project culture category. Knowingly or Unknowingly, the Project Personnel or group behaviour (EWS) seems to play an important role because the behaviour a person or a group is a very human factor and any miscommunication, slow decision, lack of experience etc. might also arise due to it. This EWS is marked as the highest occurring and most relevant in table 24 (Appendix A). Hence, it is logical to

consider Personnel/Project group behaviour as a KLI. Apart from all the categories, the External category of KLI is also an evident and important EWS.

Table 7; Comparison and overlap of KLIs and EWS

KLIs (Habibi, 2018)		***EWS (Nikander, 2001) (AT Osborne, 2017) (Williams, 2012)***	
Category	*Key Lead Indicator*	*Category*	*Early warning signs*
Change	Design Change	**Project planning**	Preliminary planning
Communication	Poor communication between stakeholders	**Communication**	Miscommunication
Client Related	Slow Decision making	**Expressed by parties**	Typical to client (No decision/ Delayed decision)
Management	Poor site management and supervision	**Project culture**	Lack of experience
Behaviour	Mood, Attitude, Commitment, Conflicts Trust, Criticism	**Personnel, Project group**	Personal behaviour (Mood, attitude, conflicts, commitment etc.)
External	Price fluctuations Poor Economic conditions Severe Weather conditions Laws and Regulations	**Other**	External

However, if taken a closer look on these overlapping indicators, most of them tend to indicate the problems or failures in a project. For example, *Poor Communication, Slow/no decision making, Lack of experience, Abnormal Behaviour* etc. indicate the negative aspects in a project which might arise problems. Therefore, it is conceived that the referred literature on EWS and KLIs considered only the negative aspects of the project.

However, this research focusses on identifying KLIs which indicates not only the problems but also the achievements of the project. As a matter of fact, an indicator is a measure which indicates the state or level of its presence in the project, depending on which it might consequently lead a positive/negative event. This means indicators are neutral measures whose degree of presence in the project predicts the probable outcome to be positive or negative. Hence, the indicators should be considered neutral instead of biased towards negative or positive aspects of the project. This discrepancy can be solved by interpreting and changing the negatively focussed indicators of the theory to neutral. This is achieved in the theoretical framework presented in table 8. It replicates all the KLIs from the theory but in a neutral manner. All these indicators are the KLIs of theoretical framework and are defined. The categories of these KLIs are carried forward from the source of Habibi (2018). The sources from which these KLIs are collected are also mentioned.

Table 8;Theoretical Framework of KLIs

Category	KLI	Definition	Source
Change	Design Change	Number of Changes in clients requirements	(Habibi, 2018); (Nikander, 2001) (Williams, 2012)
Communication	Communication	The precision of delivering the messages completely (or) degree of communication between all stakeholders	(Habibi, 2018); (Nikander, 2001) (Williams, 2012) (AT Osborne, 2017)
Client Related	Decision making	The speed with which the decisions are taken especially from clients side. (Fast/slow/no decision)	(Habibi, 2018); (Nikander, 2001) (Williams, 2012)
Management	Level of Experience	The level of experience of Project Personnel (High/Low)	(Habibi, 2018); (Nikander, 2001) (Williams, 2012)
Behaviour	Mood	Nature of behaviour of client/contractor/supplier (Abnormal/Normal)	(Habibi, 2018); (Nikander, 2001) (Williams, 2012) (AT Osborne, 2017)
	Attitude		
	Commitment		
	Conflicts		
	Trust		
	Criticism		
External (Category of KLIs on which there is very less or no degree of control by the client)	Price fluctuations	Fluctuations in the market prices of the commodities, goods and labour.	(Habibi, 2018); (Nikander, 2001) (Williams, 2012)
	Economic conditions	Changes in exchange rate, inflation rate, interest rate etc.	
	Weather conditions	Effect of different weather conditions on the project	
	Changes in Laws and Regulations	Changes in laws and regulations by the government in between the project.	

3.3 Conclusion

This literature study has been conducted to provide understanding in the concept of Lead Indicators as described in the literature. The first sub question that is to solve from the literature review is:

What are the Key Lead Indicators that can be identified from literature?

Key lead indicators are forward-looking indicators in a project to detect the possible interventions in the project outcome. They are just the probable indications which when identified can be used to evaluate the future project performance objectives. Literature shows that there is a need of flexibility to transform the project performance. According to many sources, use of only non-traditional ways to evaluate performance doesn't anymore work well within the present project dynamics. Therefore, identification and use of Lead indicators in the project can have significant effect on its performance.

The set of Lead indicators can be identified in various phases of the project affecting various project objective areas like cost and schedule. But it is found that the Lead Indicators from a client's-perspective are evident to exist throughout different phases of the project. Hence, for this research, Lead Indicators will be studied throughout the project irrespective of specific phase(s). The Lead indicators from the literature are focussed predominantly on the cost and schedule performance. However, some of the cost and schedule indicators were overlapping with each other. Hence, the identified KLIs are not segregated based on different project objectives like cost or schedule indicators.

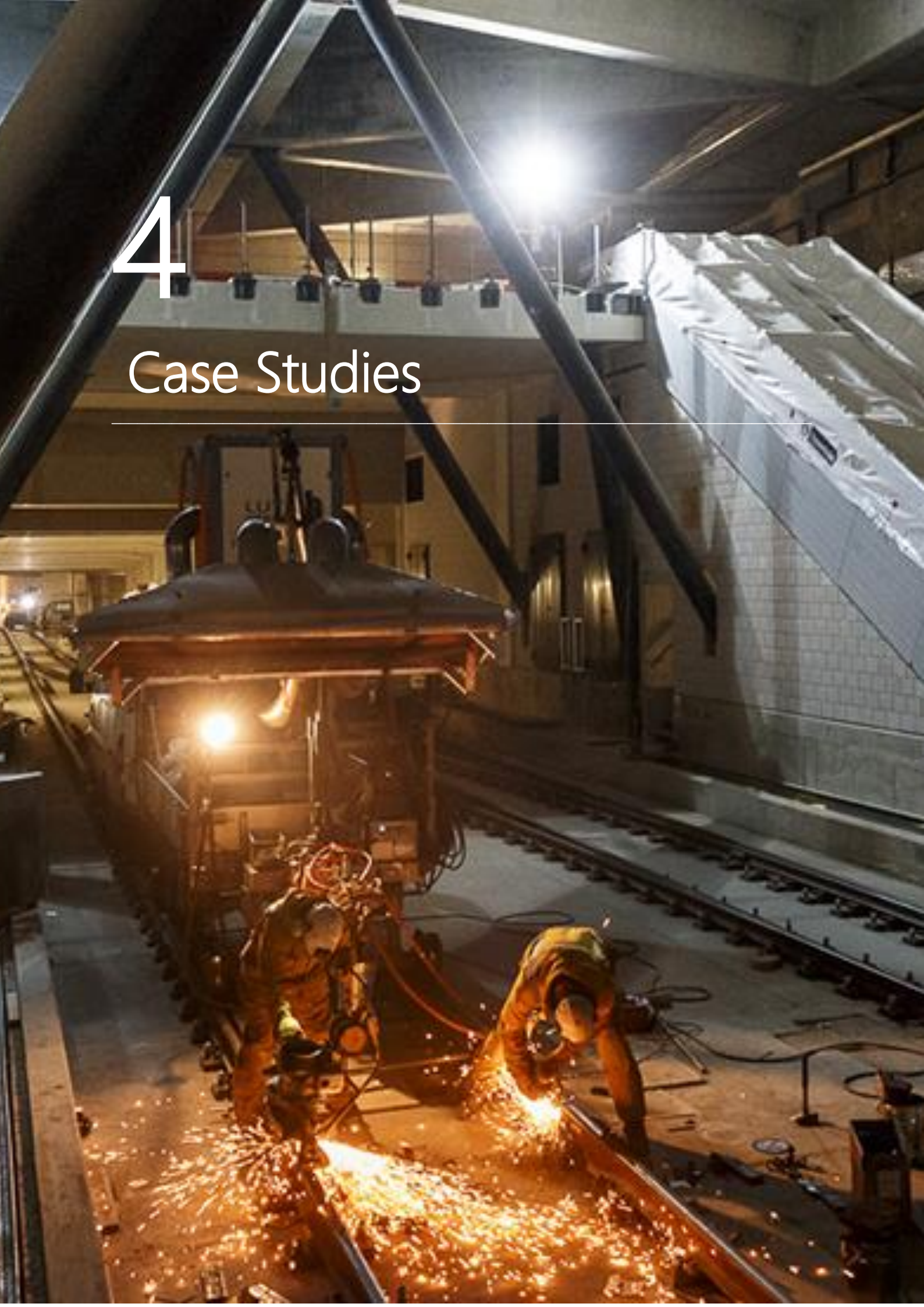
It is noted that negligible amount of literature is available on the concept of Lead indicators. Most of the literatures obtained are focussed on Early Warning signs. Although, through various literature, it is evident that both the concepts and definitions of EWS and Lead Indicators are similar, and hence both of them are believed to be the synonyms. The indicators identified from both the concepts were analysed and merged if they were overlapping with each other. Finally, the theoretical framework is established and the KLIs identified from literature are presented in the table 9.

Table 9; KLIs identified from Literature

Category	KLI	Definition
Change	Design Change	Number of Changes in Clients Requirements
Communication	Communication	The precision of delivering the messages completely (or) degree of communication between all stakeholders
Client Related	Decision making	The speed with which the decisions are taken especially from clients side. (Fast/slow/no decision)
Management	Level of Experience	The level of experience of Project Personnel (High/Low)
Behaviour	Mood; Attitude; Commitment; Conflicts; Trust; Criticism	Nature of behaviour of individual stakeholders of client/contractor/supplier (Abnormal/Normal)
External	Price fluctuations	Fluctuations in the market prices of the commodities, goods and labour.
	Economic conditions	Changes in exchange rate, inflation rate, interest rate etc.
	Weather conditions	Effect of different weather conditions on the project
	Changes in Laws and Regulations	Changes in laws and regulations by the government in between the project.

4

Case Studies



This chapter contains the results of a case study conducted on the selected inner-city rail infrastructure projects across Europe. The goal is to explore the cases and identify the KLIs in these projects. The second sub-question that is answered in this chapter is:

What are the key lead indicators that can be identified from practice among chosen projects?

This chapter is constructed as follows. Section 4.1 elaborates on the case study outline. It discusses case selection criteria, the selected cases, the data collection approach, the interview protocol and questions, the retrieved data and the structure for next sections. Section 4.2 is dedicated for case study and analysis of Stockholm metro expansion project. Section 4.3 describes the Case and Analysis of North South Line project, Amsterdam. Section 4.4 discusses the Case and Analysis of Vienna Main Station Project. Section 4.5 is the cross-case analysis of all the three cases discussed in its previous sections. Section 4.6 concludes the result of this chapter by answering the aforementioned sub question.

4.1 Case Study Outline

This section forms the first phase of the Case Study Research: *Case Study Outline*. The goal is to select the cases based on the criteria and formulate the interview question. Section 4.1.1. contains the case selection criteria which is framed in according to the scope of the research and the literature study. Section 4.1.2. represents the cases selected according to this criteria. Section 4.1.3. explains the data collection approach to extract information from the cases. Section 4.1.4. includes the interview protocol relevant for data collection for the case study research. Section 4.1.5. consists information regarding the sources from which the data will be collected. Section 4.1.6. describes briefly about the structure of sections of each case where the data is collected.

4.1.1. Selection Criteria of Cases

Projects are selected based on following criteria:

- *Large Inner-city rail infrastructure projects* (refer section 1.9.2.)
- *From different countries in EU* (refer section 1.9.3.)
- *Publicly initiated* (refer section 1.9.4.)
- *Characterised as complex:*

Complex projects for example involve many variety of stakeholders, technical complexities, enlarged and a dynamic scope. This will seemingly tend to rise the uncertainties in the project. More number of uncertainties/problems will have a greater number of causes which means they are backed by a greater number of Lead indicators (Fig. 5). Therefore, projects with a complex character are interesting to identify numerous lead indicators.

- *Combination of finished/unfinished projects:*

As discussed in previous chapter, Lead indicators occur during the entire course of a project. Projects that are already in operation provide the advantage to reflect on the whole project life. Besides, it is expected that project employees can reflect more objectively when they are no longer closely involved in a project. However, retrieving memory about symptoms of consequences in the early stages of the project where the client is majorly involved is rather difficult after project completion. Therefore, projects which are running in early phases are also considered. These projects provide the advantage that KLIs should be currently present. Therefore, both unfinished and finished projects are considered.

4.1.2. Selected Case Studies

Three cases are selected based on the selection criteria. The list of the projects with a brief description is mentioned in Table 10. Each case is selected from a different country in Europe and every case has its own complexity involved. All the selected cases are large inner-city rail projects with a budget greater than 1€ billion. CI is unfinished and CII & CIII are already completed. All these cases are public initiated projects.

Table 10; Selected Cases

	Project Name	Description	Budget (bn EUR)	Project Duration
CI	Stockholm Metro Expansion, Sweden	Expansion of city metro with 20km of new track and 11 new stations on four sections in the region	2.8	2014 – 2026 (planned)
CII	North-South line Amsterdam, the Netherlands	Complex project which involved construction of a metro line which was a drastic change to Amsterdam's public transportation network for better accessibility, capacity and quality	3.1	1999-2018

	Project Name	Description	Budget (bn EUR)	Project Duration
CIII	Vienna Main Station, Austria	Construction of a 20,000m² new station building, a new Austrian Federal Railways headquarters building, development of a 109ha surrounding area, with 5,000 residential apartments and 550,000m² of office space	4	2006-2015

4.1.3. Data Collection Approach

A vast focus will be on data collection from the cases to explore and relate to the findings of the Literature review. A two-step approach is used to investigate the KLIs from the selected cases. It is presented in Figure 6.

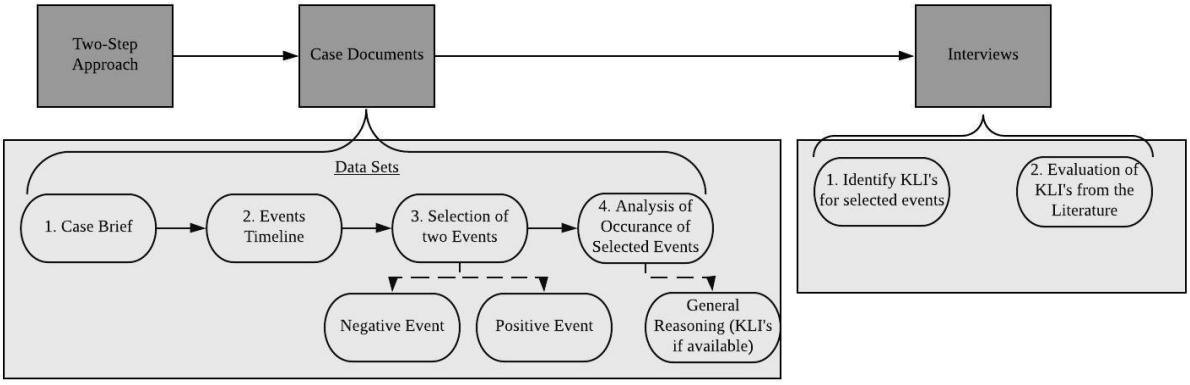


Figure 6; Data Collection Approach

First step is by studying the case documents. These projects run over a long period of time which indicates that there might have been many positive and negative events for each project. Here the term 'event' refers to occurrence of a particular activity/outcome associated with the actual delivery of the final deliverable to the client, within the project life cycle (Project Management Institute, 2004). Hence, there might exist numerous KLIs for all such events which would be impossible to efficiently identify them all in such small span of time available for the research. Therefore, the study of each case will be limited to only two of such events (one negative and one positive) rather that learning all events broadly throughout the case. A positive event is specifically chosen because KLIs are indicators which replicate positive and negative side of the project. So, considering such events are useful to know which KLIs can positively influence the performance of the projects. The lead indicators identified for the first time in the literature were only focussed towards the negative aspects of a project. Hence, to eliminate this misconception about KLIs, both type of events is considered. Thus, through the case documents, four main data sets extracted sequentially can be: Case Briefing, Events Timeline, Selection of Events and Reasoning behind the occurrence of each selected event (if available). If the fourth data set not available in the documents, interviews can help to identify KLIs for that event.

Identifying the reason behind occurrence of an event implies identifying the root cause of the event. The root causes are nothing but the first indicators or early warning signs. According to the definition of KLIs, KLIs are the most significant measures i.e. when they are identified and influenced, its impact on the project should be the most significant. Similarly, when the root cause of an event is infleuenced at an early stage, it can significantly influence the development of further chain of causes leading to the event thus significantly impacting the probable effect on project outcomes. Hence, these root causes can be seen as the KLIs of the events in the respective projects. If a chain of intermediate causes exists

led by the key cause, which then finally leads to the event, they are believed to be just the Lead Indicators and not a KLI, their occurrence is at a later stage when compared to the stage of occurrence of a KLI.

The second step is the interviews. After evaluating project documents, the negative and positive events are available. Firstly, interviewees will again be asked about these events and reasoning for occurrence of those events. They will be indirectly asked to point out the most influential or root cause (KLI) for those events. Secondly, the interviewees will be then asked their view on the KLIs of theoretical framework and how were they related to the case events. This way, both the KLIs from literature can be evaluated and the additional KLIs can also be identified.

4.1.4. Interview Protocol

Two interviews from each case project are conducted. The details of each interviewee can be found in table 25 (Appendix B). Each interview lasts up to 1.5 hours. The conversations are recorded, transcribed and submitted for confirmation/approval with the interviewees. Interviews of CI and CIII are conducted via Skype call since the interviewees are from different countries. A semi-structured and explorative character is used to frame the interview questions, represented in Appendix B. The interview is divided into three parts.

The first part of the interview serves as an introduction to the interviewee. Here it is confirmed to what extent interviewees are acquainted with the concept and terminology of KLI.

The second part of the interview fetch information about case-specific events. Questions will be asked related to the reasons behind chosen impactful events that have determined the project's course. Subsequently, the root cause(s) of the events are enquired, through which KLIs that led these events can be identified.

In the final part of the interview, the KLIs of theoretical framework are presented to the interviewees. They are asked to indicate the KLIs that played a role in the selected events. The influence of each of those KLIs on the project is discussed. Concluding the interview, it will be asked what in hindsight can improve by the usage of KLIs.

4.1.5. Retrieved Data

In analysing the different projects, six interviews are conducted. The project function and project organization to which each interviewee belongs is also described in the table 11. For the ease of reference, each interviewee is coded respectively. The information from these interviews is supplemented by different project documents referred in each case. They are similarly coded and presented in table 12.

Table 11; Interviewees of all cases

Case	Code	Interviewee Function	Organization	Interview Source
CI	*i1.1*	*Chief Executive Director*	*FUT*	(Anderson R. , 2019)
	i1.2	*Manager of Authority Processes; Director of Planning*	*FUT*	(Persson, 2019)
CII	*i2.1*	*Project Leader; Commissioning Manager*	*AT Osborne*	(Wit, 2019)
	i2.2	*Project Manager; Construction Director; Commissioning Manager*	*AT Osborne*	(Scheffran, 2019)
CIII	*i3.1*	*Project Coordinator*	*OBB*	(Herzog, 2019)
	i3.3	*Head of Railway department; Project Manager*	*OBB*	(Hartig K. J., 2019)

Table 12; Documents of respective cases

Case	Code	Document Name	Type	Source
CI	*d1.1*	*New Metro Stockholm: IPAT Assessment Document*	*Assessment report*	(Dijk, Baker, Rydberg, & Staal, 2015)
	d1.2	*New Metro Stockholm: IPAT Background Document*	*Assessment Report*	(Anderson R. , 2015)
CII	*d2.1*	*Onderzoek Noord/Zuidlijn*	*Information Document*	(Gementeraad Amsterdam, 2005)
	d2.2	*Deep excavations for Amsterdam Metro North-South line: An update and lessons learned*	*Research Paper*	(Tol, A. F. van; Kroff, M.;, 2012)
	d2.3	*Samenspel en tegenspraak: Tien lessen uit de Noord/Zuidlijn*	*Lessons Learnt Document*	(Kho & Desloover, 2013)
CIII	*d3.1*	*Vienna's "Project of the Century"*	*Information Document*	(Noether, NA)
	d3.2	*Stationen Zwei: die planung*	*Planning Document*	(Pauser, 2012)
	d3.3	*The Vienna Main Station: introduction to the project*	*Project Progress Presentation*	(Hartig K.-J. , 2019)

4.1.6. Structure of Further Sections

The further sections (4.2, 4.3, 4.4) in the report are specific to each case and their data is collected in these sections. These sections form the second stage of Case Study Design: *Data Collection.*

The approach of collecting the data described in the previous section remains same for all the cases. Thus, the structure of these case-specific sections also remains the same. To exempt from stating the same structure in all the three sections repeatedly, it is stated here itself. First, the case is introduced briefly (section 4.2.1, 4.3.1, 4.4.1). Next, facts and figures of the project are presented (4.2.2, 4.3.2, 4.4.2) to understand the project more clearly. Organizational structure (4.2.3, 4.3.3, 4.4.3) and timeline of events (4.2.4, 4.3.4, 4.4.4) explaining the period of occurrence of major events follow next. The events are selected (4.2.5, 4.3.5, 4.4.5) from the case documents or the interviewees for which the KLIs are to be enquired. Further, the information for each event is extracted and analysed (4.2.6, 4.3.6, 4.4.6) which is represented in the table and KLIs are identified. The colour code used in the table is: Red (KLI has no link to the theoretical framework); Green (KLI also identified in theoretical framework); Yellow (KLI of External Category). The colour coding is used to understand if the KLIs is newly identified or if it has also been observed in theoretical framework. Finally, KLIs found in each case are indicated (4.2.7, 4.3.7, 4.4.7).

4.2. Case I: Stockholm Metro Extension project

4.2.1. Case Introduction

Stockholm is one of the fastest growing urban areas in Europe and it is expected to grow by over 35,000 people a year. As Stockholm is growing at this rapid pace, the strain on public transport are also increasing. The Metro is the most commonly used transportation mode in Stockholm. As of now, the tracks of the metro are already being used at almost its maximum capacity in the rush hours. Hence, a necessary negotiation of an agreement on extension of metro lines and construction of more homes to meet the intense population growth of Stockholm was led in 2013 by the Swedish government (Dijk, Baker, Rydberg, & Staal, 2015).

In January 2014, the government, Stockholm County Council and the City of Stockholm, Municipality of Nacka, Järfälla Municipality and City of Solna mutually agreed on the "2013 Stockholm negotiations" on expansion of the Metro and increased housing construction. Stockholm County Council is responsible for the expansion. In the agreement:

1. The four municipalities agreed to build 78,000 new houses in the vicinity of the metro.

2. The Stockholm County Council was responsible for the expansion of the new Metro divided in four different separate sub-projects: to *Nacka* and the Blue line would be extended to *Gullmarsplan* and connected to the existing green *Hagsätra* line branch, to *Arenastaden*, to *Barkarby* and the construction of Depot and Rolling stock. The map of existing and planned extension of metro lines is presented in Figure 7.

Figure 7; Stockholm Metro Map (Anderson R. , 2015)

4.2.2. Project Facts and Figures

Table 13 presents few facts and figures of the metro extension.

Table 13; Key Facts and Figures of Stockholm metro project (Anderson R. , 2015)

Key Figures	Details
Project Type	Metro (Expansion project)
Project size	19km tracks, 10 stations
Project owner	Public
Project Financing	Swedish government, Stockholm County Council and the City of Stockholm, Municipality of Nacka, Järfälla Municipality and City of Solna
Planned Investment Cost	€2.6 bn
Date of Decision to build	January 2014
Start of Planning phase	2014
Planned Period of Construction phases	1. Barkarby: 2016-2021 2. Odenplan - Arenastaden: 2016-2022 3. Nacka/Gullmarsplan: 2018-2025 4. Depots: 2018-2022 5. Rolling Stock: 2022-2024
Planned start of Operations	Phased, with full completion in 2025.

4.2.3. Project Organization

The County Council Executive Board was assigned to be responsible for implementing the extension of the Metro. For this purpose, the County Council Executive Board set up a new administration – the Extended Metro Administration – tasked with implementing the county council's part of the agreement. The administration is known as FUT, the Swedish acronym for 'Extended Metro Administration' and it reports to the County Council Executive Board and to the Board. The board consists of representatives of all parties to the Stockholm agreement of 2013 and is responsible for matters of principle, overviewing the different projects. A joint Steering Group for the implementation of the extended metro has been appointed to support the work. The county council leads this Steering Group whose other members are municipal and government officers. (Anderson R. , 2015)

The FUT is organised to manage four projects: Metro to Nacka/Gullmarsplan, Metro to Arenastaden, Metro to Barkarby and Depot and Rolling stock. There are also five supporting and steering functions of an administrative and a technical kind. These are Finance and Administration, Communication, Engineering and Environment, Permission and land acquisition, and Procurement and legal matters. The four projects are led by project managers and the supporting functions by managers responsible for their operations and activities. The administration is led by a Head of Administration. The organisation of the FUT is shown in Figure 8. (Dijk, Baker, Rydberg, & Staal, 2015)

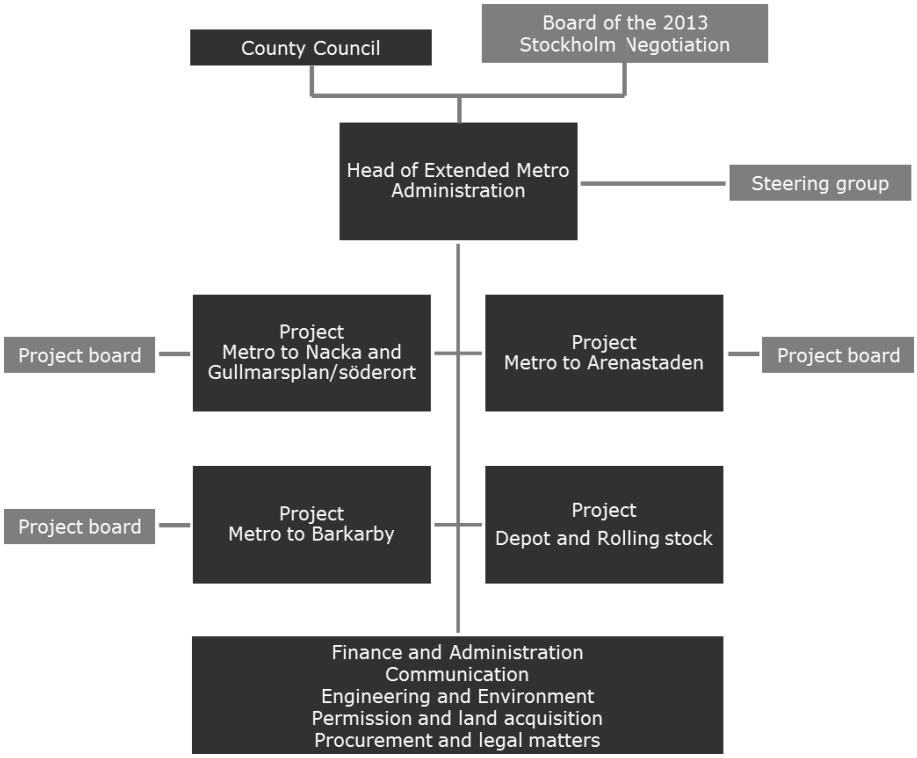


Figure 8; Project Organization (Anderson R. , 2015)

4.2.4. Events Timeline

Major events of the project that took place until now are presented in Figure 9.

Figure 9; Timeline of events - Stockholm Project

The idea of metro expansion was evident in 2012. On 11th November 2013, the government of Sweden presented the negotiations to the Stockholm city council and to the other municipalities which were a part of the Board. In January 2014, the agreement was signed by the board. Subsequently, on 18th of February 2014, the County council approved the main agreement and three sub-project agreements (of three metro line expansion).

The planning work began in 2014. The work included drawing up the technical basis required to draw up a railway plan, an environmental impact assessment and the legal examinations. In the preliminary planning work, a system document was also drawn up the aim of which was to establish the principles of the. This phase also included carrying out geotechnical studies to determine the technical prerequisites for construction. From 2016, all the consultation work began from different parties who were interested like public, municipalities etc. The permit application was submitted to the Land and Environmental Court with respect to the ground water discharge. In 2018, the preparatory works started at different lines. These works included for example wiring and preparation of work areas. The construction work at the *Barkarby* line started off in 2018 and it is planned to start this year on the other three sub-projects (Dijk, Baker, Rydberg, & Staal, 2015).

4.2.5. Selection of Events

Three events are selected from the project. First is the *Stakeholders Agreement* (Positive event); second is the *Delayed Start of Construction phase* (Negative event); Third is *the Increased Project Costs than Planned* (Negative). The 1st and 2nd events were enquired with (*i1.1*). The 1st and 3rd events were enquired with (*i1.2*). This inconsistency in selection of two different negative events is because (*i1.2*) wasn't willing to discuss about the 2nd event. All the three events are elaborated below.

1) Stakeholders Agreement (Positive)

A huge number of stakeholders are involved in the extended Metro project, both internal stakeholders in the work and control of the project and external stakeholders. These are: County Council Executive Board, the municipalities, Board of 2013 Stockholm negotiations, National Transport Administration, Traffic Administration at County Council, the Land and Environmental court, Swedish Transport Agency, County Administrative Board, Major cable owners, Church of Sweden, Concerned parties and public, Stakeholder organizations, Media and suppliers.

The planning period for such LIPs is the most important period where all the big decisions are made, all the alterations occur, and the stakeholders are managed. Getting all the stakeholders to a common consensus is very necessary and important for a project implementation. It is evident that the project has progressed to the later stages only after the mutual agreement of these stakeholders. This seems to be an achievement and a positive event.

2) Delayed Start of Construction Phase (Negative)

The construction phase of sub projects: Odenplan-Arenastaden and Akalla-Barkarby station were scheduled to start in 2016. The actual start of their construction took place only after start of 2019 and 2018 respectively. There is a delay of approximately 3 years and 2 years respectively in both the lines. This event didn't run according to the planning and hence is chosen as a negative event.

3) Increased Project Costs than Planned (Negative)

When the negotiation was signed in the beginning of 2014, the cost estimates were also agreed. Later, the planning process started, and the design phase started. The design phase is controlled by the FUT, but the design work is carried out by some consultancy firms. In late autumn of 2015, the fist design documents were released along with the big cost estimate of the whole project. It indicated that the cost estimate was around 3 bn SEK (~282mln Eur) higher than what was estimated in 2014, which is significantly high.

4.2.6. Identified and Analysis of KLIs

The root causes for each event were questioned and data was collected. The key causes for each event were identified and are listed down in Table 14.

Table 14; KLIs of Stockholm Metro Project

	KLIs	Description	Analysis	Source
Stakeholder Agreement				
1.	**Highly Commited Negotioaters and other stakeholders**	When project was discussed in detailed, there were discussions with the municipality about agreements/disagreements. For instance, design of stations can affect the municipality the most. It takes time if they disagree on something, but the chief negotiator was very committed and managed to bring them to an agreement. There was a big demand for better infrastructure for public transport and led	When a person is committed, he is well-informed and active which ultimately led to positive results. Hence, Commitment is one of the key causes which made the agreement possible in short time. This KLI can be linked to the KLI of commitment in the theoretical framework.	(i1.1), (i1.2)

	KLIs	Description	Analysis	Source
		to commitment from different parties too.		
2.	**Clear division of roles**	As mentioned earlier, there are many stakeholders involved in the project. For instance, there are municipalities who are responsible for the construction of housing and detailed planning of city environment. Then there is the FUT (administration) that is responsible for the construction of new metro. And there are many more parties with different roles. To manage and get all the different stakeholders to an agreement is a challenge.	Managing all the different stakeolders in such huge project is challenging and can be overcome when division of roles is clear. Clear role division among the stakeholders helped to solve this challenge. This is a newly identified KLI.	(i1.1), (i1.2)
3.	**Benefit to each stakeholder**	When stakeholders were aware about the population growth, they knew that there were connected problems and metro project was an opportunity which could benefit all. For instance, the municipality needed more housing to support the population growth and the connected problem was to serve the capacity by building new house.	It was found out that every stakeholder had benefit out of the project. When there is benefit for every stakeholder involved, it motivates every stakeholder be associated with the project and subsequently leads to stakeholders agreement. This is a newly identified KLI.	(i1.1), (i1.2)
4.	**Close Stakeholder Engagement**	Stakeholders often worked closely with each other. For instance, public was engaged in many meetings, which led to good collaboration amongst stakeholders. Also, while the feasibility study of metro route to Nacka was going on, there was a good cooperation between county council and municipality of Nacka. This was possible when the stakeholders were engaged closely in the project.	When stakeholders are closely engaged it evolves collaboration in the work culture. Collaboration induces more cohesiveness and communication which certainly led to the willingness of the politicians and municipality. The interaction between different stakeholders whose interaction was a success factor. This is a newly identified KLI.	(i1.1), (i1.2)
5.	**Political Stability**	The project is broad and the government itself urged the need for this project for the population rise in the city. Hence, the change in the political party as a result of the election in 2014 did not influence the project.	Political elections are external factors that can affect the project at the time of Negotiations. Fortunately, it didn't affect the project and hence is one of the external KLI which contributed to the success of this event.	(i1.1), (i1.2)
Delay in start of construction phase				
1.	**Design Change**	There are many stakeholders and they come with many requirements and changes. Also there was a complex planning in place: the FUT and Municipality had separate plans which shouldnt be contradictory to each other. This complex planning and number of stakeholders led to design changes.	Complex planning and a greater number of stakeholders comes with a greater number of requirements. These factors aren't the causes but can be seen just as the conditions of the project to be able to realize it, which resulted in design changes ultimately leading to this event. Hence, design change is one of the key causes and was already observed in the theoretical framework.	(i1.1)
2.	**Lack of Experience**	The subway was built for the first time after 35years due to which hew technologies and systems were involved. Adapting to new technologies took time. Also, Shorter time span allotted for	The city lacked an experience in metro construction due to which a very optimistic planning of 4 years was in place to finish the design phase which wasn't	(i1.1)

	KLIs	Description	Analysis	Source
		planning period. Only 4 years was available planning which generally takes 7 years.	achieved and led to the delay. The intermediate cause here is Optimism Bias. Also, since there were technologies in place which the organization weren't aware of, the process of decision making was also slow and contributed to the delay. This KLI was already observed in theoretical framework.	
3.	**Slow Decision from External parties**	External parties are the parties who are not involved in the project but are important to make certain decisions related to the project. The time taken by them to make those decisions was hard to be influenced by the management team.	If a decision is needed from an outside party uninvolved in the project it can take some time, and this led to delay in the start of construction phase. Since there is less degree of influence on it, it is regarded as an external KLI.	(i1.1)
Increased Project Costs				
1.	**Lack of Experience**	Experience was taken from previous projects for instance the Stockholm city link project. It led to wrong estimates. For instance, the estimated ventilation system could have been reduced; the area of the tunnel section could have been shrinked; the space required for technical installations could have been reduced by one level beneath the ticket hall. The framework regarding what to construct exactly wasn't complete before starting the design work which led to choosing of more expensive solutions. This led to a non-optimal design which incurred many changes later.	The lack of experience in the project team led to carrying out superficial surveys and starting the design phase before accomplishing the complete technical framework or predesign work. Hence, these intermidiate causes led to choosing of non-optimal solutions in the design thereby incurring design changes and additional costs. This KLI was already observed in theoretical framework.	(i1.2)
2.	**Unknown knowns**	There were few questions that would come up at a later stage which the management team couldn't have known before. Specifically, the unawareness of bad ground conditions (large clay areas) below the planned Arenastaden station location leading to increase in the costs. There reason behind this was: Even though the project team had performed ground surveys they couldn't predict the presence of clay beneath it.	'Maybe' the bad ground conditions could have been predicted with more in-depth surveys. However, the ground conditions can be unpredictable sometimes due to changes in weather conditions. Thus, less degree of influence could be achieved by the project team on this cause. Hence, it is regarded an External KLI.	(i1.2)

4.2.7. Findings of Stockholm Metro Project

In total nine KLIs were observed in this case. Five led to the positive event and four other led to negative events, out of which Lack of Experience is observed as a KLI for both the negative events. Other than the KLIs, there were intermediate causes or LIs were identified are specifically *Design change*; *Communication & optimism bias*. The identified KLIs are as follows:

KLIs
Stakeholder Agreement
Hightly Commited Stakeholder(s)
Clear division of roles
Benefit to each stakeholder
Close Stakeholder Engagement
Political Stability
Delay in start of construction phase
Design Change
Lack of Experience
Decision from External parties
Increased Project Costs
Unknown knowns (Bad ground conditions)
Lack of Experience

4.3. Case II: North South Line Project, Amsterdam

4.3.1. Case Introduction

On 21 August 1991 a recommendation was issued by the Municipal Council of Amsterdam (MCA), which formulated the starting points and premises of the Project: "realize the metro North/South Line through the city, partly under the existing buildings, within time and within budget, without excessive hindrance, in order that the city remains functioning". Finally, after long negotiations and discussions, on 27th November 1996 a definite decision by the MCA approved the building of the project. (Gementeraad Amsterdam, 2005).

The North/South line Project is a very complex project which involved considerable technical challenges in the context of its design, procurement and construction. The long period throughout which the Project has evolved compounds its inherent complexity which has had a significant influence upon the strategy under which the Project is currently being managed by the principle parties: The Project Bureau and the Advisory Organisation (Gementeraad Amsterdam, 2005).

The North-South Line in Amsterdam is 9.5 kilometres long metro project, out of which 6 kilometres is sub-surface. It involved construction of 7 new stations and significant modification to one existing. Out of the 8 stations, five stations are constructed underground. This metro line starts at street level in the North of Amsterdam and passes under the historical centre of the city in a twin shield tunnel (Tol, A. F. van; Kroff, M.;, 2012). South of the historic centre, the line re-emerges at street level between the RAI conference centre and the existing railway station Zuid/WTC. Figure 10 represents the map of this project.

Figure 10; Map of North-South Line Project, Amsterdam (Gemeentelijk Vervoerbedrijf)

4.3.2. Project Facts and Figures

Table 15 presents few facts and figures of the NSL Project.

Table 15; Key facts and Figures of NSL Project

Key Figures	Details
Project Type	New Metro Project
Project size	9.5km tracks, 8 stations
Project owner	Public
Project Financing	Minister of Public Transport
Total Investment Cost	€3.1 bn
Date of Decision to build	27th November 1996
Start date of Planning phase	18th May 1995
Start date of Construction phases	22nd April 2003
Start date of Operations	22nd July 2018

4.3.3. Project Organization

The following Figure 11 indicates the various relationships between the parties to the Project. dIVV represents the Department of Infrastructure, Traffic and Transport. IBA is the Engineering Bureau of Amsterdam.

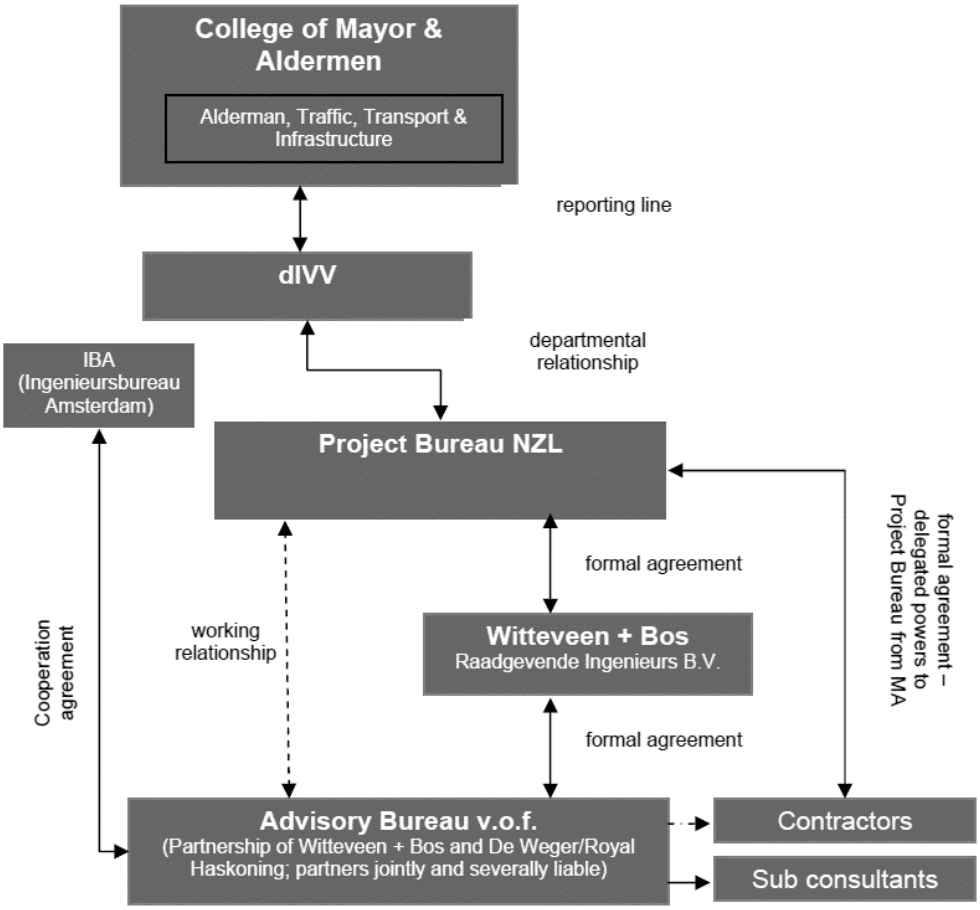


Figure 11; Project Organization of NSL Project (Gementeraad Amsterdam, 2005)

4.3.4. Events Timeline

Major events of the project that took place are presented in Figure 12.

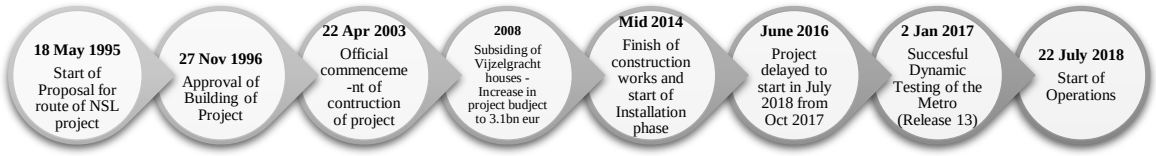


Figure 12; Events timeline of NSL Project

The MCA started with the proposal of the route of NSL in 1995. It submitted its proposal to the higher authorities for the approval. In November of 1996, the project got its first approval and planning of the project was started in full flow. Three rounds for tendering and procurement were arranged. Finally, on 22nd April 2003, the construction of the project officially commenced. A major project crisis occurred in the year 2008 when the houses near the station *Vijzelgracht* started to subside below the ground. This created a major public opposition to the project. In 2009, it was hence decided to delay the project by 5 more years from 2012 to 2017. After the event of *Vijzelgracht*, it was very crucial that such incident is not repeated. Therefore, from 2009 to 2014, lot of efforts were put to finish the civil works successfully.

The next phase was the installation phase which took a start in 2014. Although, in the end of 2013, the probability of finishing the project by October 2016 was calculated to be 1%. This was one of the challenge which gave an indication of project derailment. The concept of Release Management was implemented in 2015: The metro system consists of different technical installations like power supply, heating system, ventilation, escalators, fire protection, cooling systems, cctv's, intercom etc. and all of them needs to be integrated as one system. A roadmap was created where the process of integration was divided into different steps, each step was called as release event and in total there were 18 release events (numbered 1-18) until the completion of the project. With the success of each release event, motivation in the project personnel also increased. In June 2016, the delay in start of operations of the project from October 2017 to 22nd July 2018 was released publicly for the first time. Later, the Release 13 event was achieved successfully on 2nd January 2017. This event was the first test run of the metro through the station *Rokin.* It is also called "Dynamic Testing". Finally, on 22nd July 2018 the project started its operations and this event was also called as Release 18 which was the last release event.

4.3.5. Selection of Events

Two events are selected from the project. First is the *Successful Dynamic Testing* (Positive event); second is the *Delayed End of Construction phase* (Negative event); Both the events are described below.

1) Successful Dynamic testing - Release 13 (Positive)

Since there was a time crunch in the planning, the testing of the operation at one station was done in parallel to the construction of other stations i.e. the metro was tested already even before all the construction work was completed. This was done mainly due to limited time and to already learn from the findings of first testing that could be useful for adapting the testing on other stations. On 2nd of January 2017, this first testing took place. It was called "Dynamic Testing" event or "Release 13".

2) Delayed End of Construction Phase - Release 18 (Negative)

In June 2016, the planned end of construction phase or the planned start operations was delayed by 10months from October 2017 to 22 July 2018.

4.3.6. Identified KLIs

The key causes for each event were identified and are listed down in Table 16.

Table 16; Identified KLIs for NSL project

	KLIs	Description	Analysis	Source
	Successful Dynamic Testing			
1.	**Close Stakeholder Engagement**	In 2013, it was found that the interface between different systems weren't integrating with each other. This was due to separate contractors for separate systems. Involvement and support of all the stakeholders was required to solve this issue. Close cooperation and collaboration between the contractors and the operators and to a certain extent also the official authorities like the safety boards which created a mental commitment toward the work. The client also got involved with the contractor and worked together to develop new strategy to integrate all the systems again.	When stakeholders were closely involved, it evoked collaboration among the stakeholders. The involvement and collaboration of different authorities and especially the client closely with the contractors played a major part in the success of this event. This KLI is newly identified which wanst observed in the literature hence colured in red.	(i2.1), (i2.2)
2.	**Positive Work Environment**	There was a change in mindset of people over the period of 2015-2016. From a complaining and blaming mindset of the people working in the project, it changed to a mindset which thought about making progress and solving problems together. This change was due creation of positive environment around them. Monthly once, sessions were organized outside the regular workplace (For instance, a hotel outside Amsterdam, was booked) where it is more relaxed to stimulate collaboration between different parties. Discussions on how to implememt release manament and work towards the common goal took place in these sessions.	Previously, the project environment was critical and strict which prevented collaboration and having fun while working. With the seesions in place, Spending quality time together helped to improve personal relationships, trust, understanding mutual interests, which gradually led to the success of this event. Stimulating a positive work environment is a new KLI which is recognised from this case.	(i2.1), (i2.2)
3.	**Positive Attitude**	Release Management approach in the installations phase created some intermediate moments where everyone could celebrate as the project achieved certain level of success. For instance, in certain period of the project, the project team used to have something called "Cake Moment". It was celebrated every first Monday of the month where the team used to cut the cake and celebrate the success of past month. Every time different people in the organization used to bake the cake themselves and it was a treat for everyone.	Such small intermediate moments can create a "yes, we can do" mentality in the project organization and it brings positive attitude towards the project individually. This positive attitude keeps the individual motivated and hence better-quality decisions can be made. This led to the success of dynamic testing and Positive Attitude of people is regarded as a KLI here. Attitude is a KLI which has been observed already in the theoretical framework, hence, it is coded green.	(i2.1), (i2.2)
4.	**Common Goal of Stakeholders**	There was a common goal established between client, all the contractors and operators where everyone had a say on defining this goal. A shared team was	When the stakeholders have a same vision or goal, they all try strive to reach that goal. Similarly in this case, the	(i2.1), (i2.2)

	KLIs	Description	Analysis	Source
		made one year in advance to this event. This team was called as the release team. This team was responsible for achieving the common goal. The team included the best team member from each contractor, client and operator. It was made sure that the primary focus of each of the release team member was on reaching the common goal rather than interest of their company.	relaese team with different stakeholders shared the same goal by putting combined efforts to achieve this goal. Hence, Common goal is regarded as the key cause or KLI here which is newly identified in this research.	
5.	**Unknow Knowns**	Luckily, one of the contractor had a new CEO who had close past relations with the project director.	Close personal relations on a higher management level helps to have close communication and finalize things early. Since it was unexpected, it is regarded as an external KLI in the category of External KLIs.	(i2.1)
Delayed end of Construction Phase				
1.	**Lack of experience in operational phase**	The operator was not involved in the project until 2014 which indicates that there was a lack of experience in the operational aspects.	Due to lack of experience, changes were implemented in the all 6 different contracts after 2014. These changes consequently incurred changes in the design leading to increased costs and delays.	(i2.1), (i2.2)
2.	**Lack of Experience in installation phase**	The installation phase started in 2014, needed a completely different approach of working compared to the civil works. It involved many different techniques, different people since most of the people were working in the old approach as they used to in the execution phase.	There existed a lack of knowledge and experience in the installation phase, which took some time for the people to get adapted. This led to the delay.	(i2.1), (i2.2)
3.	**Bankrupytacy of subcontractors**	Bankruptcy of both the sub-contractors. Construction were stopped until new sub-contractors were found which caused a delay by 5-6months.	The bankruptacy of subcontractors contractors is an external KLI which couldn't have had much influence by the management team.	(i2.1)
4.	**False assumption of clients towards contractor**	There was a situation before the event where the contractor was complaining about necessity of clients close involvement. But the client believed it is not a genuine complaint and took them for granted. These false assumptions towards the contractors hampered the personal relations and created distrust.	When there is distrust between the stakeholders, automatically it led to irritation and arguments amongst the stakeholders, which further delayed the process. This is a less controllable situation since it's hard to influence someone's believe which led to unexpected results. Hence it was accounted as an External KLI.	(i2.2)

4.3.7. Findings of North South Line Project

In total nine KLIs were observed in this case. Five KLIs led to the positive event and four other led to negative events. Also, LIs of *Design change* and *Distrust* were found led by *lack of experience* and *false assumptions of client towards contractor* respectively. The identified KLIs are as follows:

KLIs
Successful Dynamic Testing
Close Stakeholder Engagement
Positive Work Environment
Positive Attitude
Common Goal of Stakeholders
Unknow Knowns
Delayed end of Construction Phase
Lack of experience in operational phase
Lack of Experience in installation phase
Bankrupytacy of subcontractors
False aasumptions of clients towards contractor

4.4. Case III: Vienna Main Station Project, Austria

4.4.1. Case Introduction

A remarkable project of the country-wide station modernization program, Vienna's new rail hub – the Hauptbahnhof (Vienna Central Train Station) – represents a key element of a capital-intensive expansion and reorganization of the rail transportation network in and surrounding Vienna (Figure 13). Replacing the city's South and East Train Station, it is accompanied by extensive infrastructure and urban development investments, including a new mixed-use neighbourhood called BahnhofCity (Railway Station City) on an adjacent rail yard that will house office space for around 20,000 employees, 5,000 apartments, as well as a broad array of commercial and recreational facilities (Figure 14). A PPP project was led by the federal infrastructure ministry, the City of Vienna, Austria's Federal Railways (ÖBB), as well as several private entities, the station was completed in 2015. In parallel with the new large-scale station, a high-speed rail connection is put into operation between Paris, Stuttgart, Munich, Vienna and Budapest (Noether, NA).

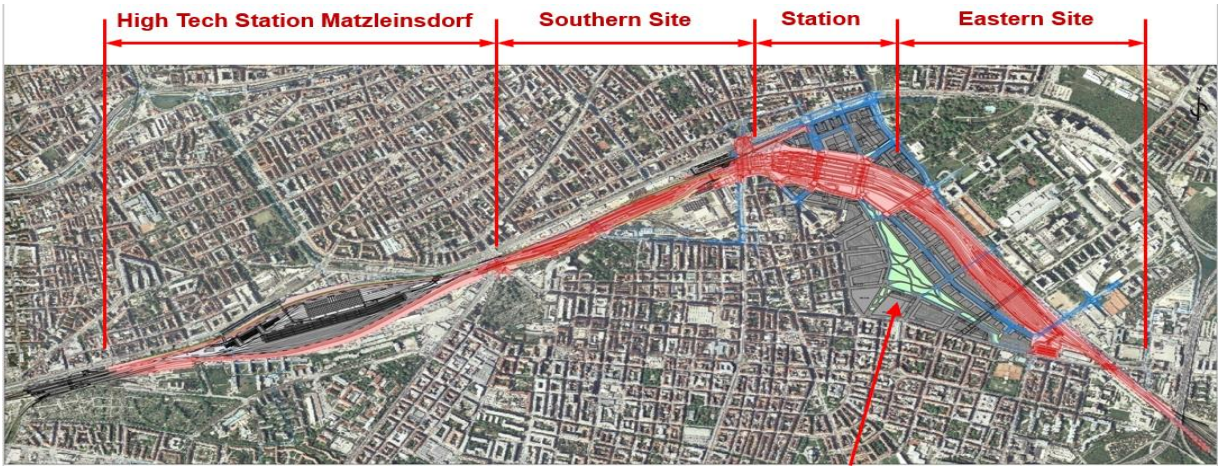


Figure 13; Vienna Central Station Project Site division

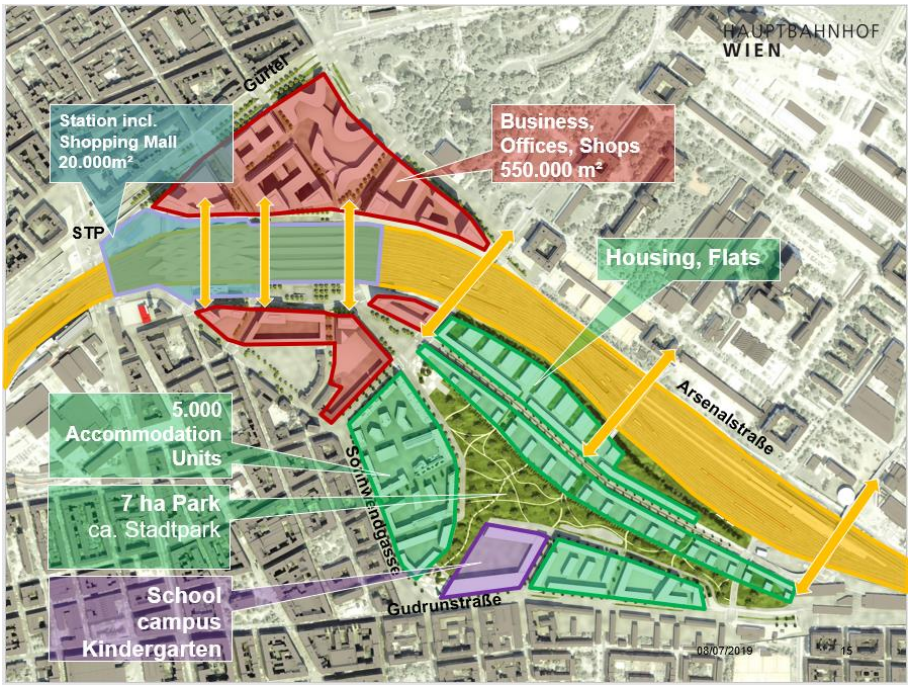


Figure 14; City Development Plan

4.4.2. Project Facts and Figures

Table 17 presents few facts and figures of the NSL Project.

Table 17; Facts and Figures of Vienna Main Station Project

Key Figures	Details
Project Type	Railway and City Development Project
Project size	59 ha
Project owner	City of Vienna, ÖBB (Austrian Federal Railways), Federal Government, private Consortiums.
Project Financing	City of Vienna
Total Investment Cost	€2 bn
Date of Decision to build	2003
Start date of Planning phase	2004
Start date of Construction phases	9th November 2009
Start date of Operations	14th December 2014

4.4.3. Project Organization

The organization of the project is presented as follows:

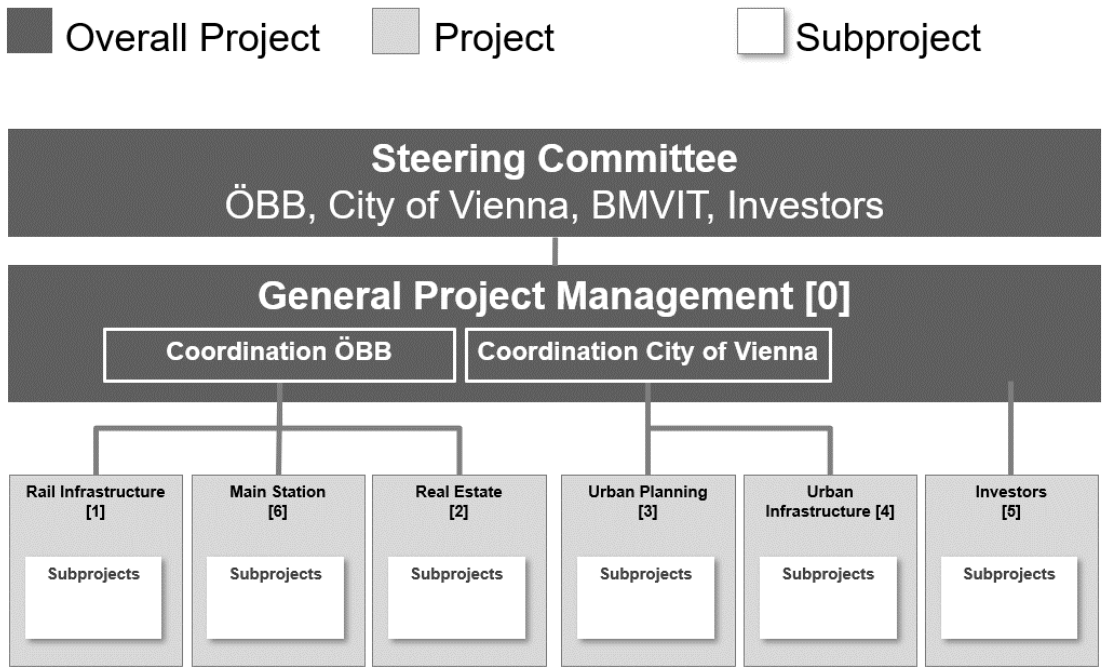


Figure 15; Project Organization of Vienna Main Station Project

4.4.4. Events Timeline

Major events of the project that took place are presented in Figure 16.

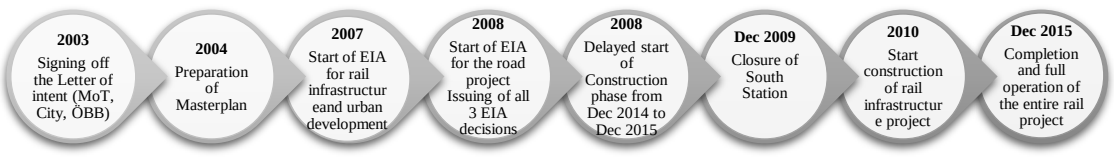


Figure 16; Timeline of Events of Vienna Main Station Project

It all began in 1989 with the fall of the Iron Curtain. All at once, Vienna was at the heart of Europe rather than being the easternmost city in Western Europe. Although considerations regarding the major project go back decades until 1872, the actual planning process began in 2002 with a feasibility study. In 2003 the City of Vienna and OBB then agreed on joint financing and an implementation period beginning in 2007. In 2003 the Republic of Austria, the City of Vienna and OBB signed a Letter of Intent (LOI): Vienna Station and Vienna Südbahnhof (South Station) District". The letter of intent stipulated that the "Vienna Station" project would be implemented jointly, and any real estate not required for operations would be used for urban development. The urban design competition resulted in the master plan adopted by the City Council in 2004 (Pauser, 2012).

The major "Vienna Main Station" project required three environmental impact assessments (EIAs) at once: for urban development, road construction and rail infrastructure. These were the first urban development-related environmental impact assessments based on the new EU directive in Austria – and therefore constituted new territories in every respect. The plans for the rail infrastructure project including the station were begun in 2005. The EIA for the rail infrastructure was submitted to the Austrian Federal Ministry for Transport, Innovation and Technology (BMVIT) in November 2007. The EIA for the urban development project was then submitted in December 2007; Finally, in April 2008 the EIA for the road construction project was submitted. In around ten months, all steps of the procedure, the public negotiations and the decisions by the authorities performing the assessments were completed, which was remarkable (Pauser, 2012).

In 2008, it was observed that the allotted planning period of 3.5 years was not enough which included also the requirement of new directive of performing three EIA's (i3.2). Generally, it takes at least 5 years for planning of such complex projects. Hence, the start of construction phase was delayed by 6months then. By 2010, the south station was closed, and the construction of rail infrastructure started. In December 2014, the operations of the new station were partially commenced and was totally operational in December 2015.

4.4.5. Selection of Events

Three events are selected from the project. First is the *Stakeholders Agreement* (Positive event); second is the *Construction of service station parallel to Authorization process and Environmental Impact Assessment without delay* (Positive event); Third is the *Delayed Start of Construction Phase* (Negative). Only 1st event was enquired with (*i3.1*) since the interview wasn't much aware of the 2nd and 3rd event. However, all the 3 events were enquired with (*i3.2)*. A 2nd positive event was selected since the (*i3.2*) didn't view the 1st event as a positive event rather just viewed it as a necessity for the project. All the three events are elaborated below.

1) Stakeholders Agreement (Positive)

This negotiation was the end of the discussion started in 1872 when it was first to build the Main station in Vienna. After so many discussions and events, the project negotiations were started in 2001. Hence, all the political parties in the federal government and Vienna city, including the opposition, were in the favour of the project. The starting point of the project was the letter of Intent. This LOI included:

- The main station should be built on the site of the former south and east railway line.
- As the two former station areas and maintenance sites will be shut down, that area should be used for the City development of Vienna.
- The City government of Vienna guarantees OBB that it will make zoning so that selling of the ground will be economically feasible.
- Every cent that is earned by the OBB by selling the land will be invested in the future project of Main station and nowhere else.
-

2) Construction of service station parallel to Authorization process and Environmental Impact Assessment without delay (Positive)

During the planning process, it became clear about different phases of construction of the project. When looked back to start from the point of opening of station in 2006, it was a discussion about what should be don't with the existing stations. If it is closed down, a lot of preparatory works had to be accomplished in between like changing the international bus station near to the new station, change of underground metro station as this was in the old station building, getting authorities from park authorities, railways, to build the entrances for the metro station etc. The most difficult task was building a new maintenance site with servicing and parking tracks, a huge maintenance hall etc. before closing of the old station within 23 months in parallel to the EIA and Authorization process. This was quite a task and we successfully achieved it.

3) Delayed Start of Construction Phase (Negative)

The month of December 2014 was chosen to finish the project because of general elections in Austria in that year. The politicians decided to the date of operations before this election. Although until 2008, the detailed planning between federal railways and different entities of Vienna government for supplies like water, electricity, telecommunication etc was not interconnected tight enough, when the starting flag for the project should have been shown. It was necessary to have a good interconnected planning, and this was communicated with other parties like the Board of Directors, the CEO and the politicians. And later, an additional year of construction period was granted, and the start of construction phase was delayed.

4.4.6. Identified KLIs

The key causes for each event were identified and are listed down in Table 18.

Table 18; Identified KLIs of Vienna Main Station Project

	KLIs	Description	Analysis	Source
	Stakeholder Agreement			
1.	**Benefit to each stakeholders**	All the parties had a benefit. The federal railways had an advantage by selling land, develop housing, save a lot of money by closing other terminals etc. The advantage for the city was there was 59 hectares of land that can be developed out of the project. The federal government had an advantage of making transportation hub for the city in all modes.	As disccussed previously that when there is benefit for every stakeholder involved, it motivates every stakeholder be associated with the project and subsequently leads to stakeholders agreement.	(i3.1), (i3.2)
2.	**Common Goal of the stakeholders**	It was clear to the politicians and public that there was a need for central station rather than having 7 different terminals. Hence there was a general agreement among the politicians and public. There was financial support from the governments, EU. Three environmental impact assessments were consucted to show the affect on environment due to this project. There was an open communication between public and the project. People who signed the agreement had good personal relations and could	Since a there was transperency in acceptance to achieve a goal among all the stakeholders, there was complele transperancy in communication them.	(i3.1), (i3.2)

	KLIs	Description	Analysis	Source
		talk openly without fear. They both wanted to implement this project as it was a chance for the future. They had the same perspective and picture.		
3.	**Political stability**	The project was an 100year old political discussion. There was a political will to go ahead with this project and thus, it was never at stake due to elections. It was always on control.	The government was stable and firm on its decision to execute the project since there was a striving need for it. Hence, political stability is an identified external KLI.	(i3.1), (i3.2)
Construction of service station parallel to Authorization process and Environmental Impact Assessment without delay				
1.	**Close Stakeholder Engagement**	In December 2009, the provisional Eastern Station and the station in Vienna Meidling was worked as terminal station for southern line. So, all these works were thoroughly planned in a short time. The operation team of the federal government took responsibility to solve all the operational problems between Vienna Meidling and the newly built service site since many trains were running in between. This was possible due to discussions and agreements between railways and the government. There was a "program setup" between different parts inside the railways like operational, servicing etc. led by the main station project manager. All worked quite easily and unanimously together.	Working unanimously together here is a key cause which led to thois event. When there is such close stakeholder engagement in the projects, certainly it leads to many discussions and finalizing on solutions together. This was achieved without any delay since all of them put their efforts together.	(i3.2)
2.	**Strong Communuication**	Regular meetings every month were organized to solve the specific problems which were observed.	Frequency of meetings determine the level of communication in the project. This KLI of "Communication" was already observed in the theoretical framework.	(i3.2)
3.	**Political stability**	There were more than one elections in the period of the project though it didn't influence the project at all.	This is already identified as an external KLI.	(i3.2)
Delayed Start of Construction Phase				
1.	**Optimistic Political decision**	The month of December 2014 was chosen to finish the project because of the general elections in Austria in that year. This was an optimistic political decision. Although in 2008, when the starting flag for the project should have been shown, the detailed planning between federal railways and different entities of Vienna government for supplies like water, electricity, telecommunication etc was not interconnected tight enough. It was necessary to have a good interconnected planning. Hence an additional year of construction period	The politicians might have seeked personal benefit by the publicity of their completed project before the upcoming elections. This was the reason why they chose to finish the project in 2014 itself even though it was quite ambitious and optimistic. Although, this could not be achieved due to the optimism Bias of the politicians. The plamnning was also weakly connected which led to the design changes, A politicaal decision	(i3.2)

	KLIs	Description	Analysis	Source
		was granted to make the changes in the design.	is an external KLI since it cant be influenced.	

4.4.7. Findings of Vienna Main Station project

Following from this case analysis, several findings are noted. In total eight KLIs were observed in this case. Six KLIs led to the positive events and two other led to negative events. The LIs of *Design change, optimism bias, communication* and *Motivation* are observed. They KLIs are as follows:

KLIs
Stakeholder Agreement
Benefit to each stakeholders
Common Goal of the stakeholders
Political Stability
Construction of service station parallel to Authorization process and Environmental Impact Assessment without delay
Close Stakeholder Engagement
Strong communication
Political stability
Delayed Start of Construction Phase
Political decision

4.5. Data Analysis and Validation

This section forms the third stage of Case Study Research and consists the cross-case analysis and validation of the KLIs. Section 4.5.1 represents the combined KLIs of all the cases and discusses the repetition of each KLI across the cases. Section 4.5.2 links the identified KLIs to the theoretical framework to obtain the analysis on newly identified KLIs and the one which are repeated from theory. Section 4.5.3 presents validation and final framework of all the KLIs from the analysis. The new KLIs are defined based on the case specific data and the KLIs which repeat are defined on the basis of theory itself. Finally, section 4.5.4 represents the findings from this cross-case analysis.

4.5.1. Combined KLIs of all cases

In this section, the KLIs from the all the three cases are combined (separated for Positive and Negative events). This is achieved along with marking their presence in each case. Table 19 attains the general overview of spread of all the identified KLIs across the chosen cases. The colour coding remains the same as observed in previous sections. "(E)" represents that the respective indicator is observed to be a KLI of External KLI.

The KLIs for positive and negative events across all the cases are respectively combined as most of the events were chosen are comparable to each other. For instance, events of *stakeholder agreement* (positive) & *Delay in start/end of construction phase* (negative) were chosen in (CI, CIII) & (CI, CII, CIII) respectively. As these events are comparable in all the cases, their KLIs can be combined. However, the research is crucially focussed to identify the KLIs instead of being event centric which focuses on the influence on project outcome. Thus, KLIs for the other chosen events *Successful Dynamic Testing* (positive, CII), *Increased Project Costs* (negative, CI) and *Construction of station without delay* (Positive, CIII) are also combined.

Table 19; KLIs from the case study

KLIs of Positive Events		Stockholm Metro Project (CI)	North South Line Project, Amsterdam (CII)	Vienna Main Station Project (CIII)
p1.	Hightly Commited stakeholder(s)	✓		
p2.	Positive Attitude		✓	
p3.	Clear division of roles	✓		
p4.	Benefit to each stakeholder	✓		✓
p5.	Close Stakeholder Engagement	✓	✓	✓
p6.	Common Goal of Stakeholders		✓	✓
p7.	Positive Work Environment		✓	
p8.	Strong communication			✓
p9.	Unknow Knowns (E)		✓	
p10.	Political Stability (E)	✓		✓
KLIs for Negative Events		Stockholm Metro Project (CI)	North South Line Project, Amsterdam (CII)	Vienna Main Station Project (CIII)
n1.	Design Change	✓		
n2.	Lack of Experience	✓	✓	
n3.	Decision from External parties (E)	✓		
n4.	Unknown knowns (E)	✓		
n5.	Bankrupytacy of subcontractors (E)		✓	
n6.	False aasumptions of clients towards contractor (E)		✓	
n7.	Optimistic Political decision (E)			✓

It is anticipated from table 19 that *Close Stakeholder Engagement* was observed in all the three cases. Stakeholders were involved very closely in all the three projects which contributed to the achievement of their respective positive events. In addition, CI and CIII observed all the stakeholders were benefiting in the project which one of the key cause for agreement of stakeholders at the time if negotiations. CII and CIII also shared a common KLIs. Their Stakeholders shared common goals to achieve their respective projects. Apart from these KLIs, *highly committed stakeholders, Positive Attitude, Positive work environment & strong communication* were found to contribute positively. It is to be noted that *communication* was strong observed as a KLI in CIII, but it also acted as an LI and was triggered by *close stakeholder engagement* and *positive work environment* of CI and CII respectively. External KLIs were also involved in the achievement of positive events. *Political stability* was one such KLI and *good personal relations on top management level* is another indicator part of the *Unknown Knowns* KLI.

Similarly, *Design change* and *Lack of Experience* were the KLIs which led to the negative event and were frequently observed across chosen projects. Moreover, *Design Change* more frequently acted as an LI led by the inexperience of the Management team and due to optimism bias. Thus, *Design Change* can be called as a KLI but more frequently these changes are triggered due to another LI or KLI. Apart from these two KLIs, several other External KLIs were observed which are presented in the table 19.

To sum up, the analysis fetched 16 KLIs: 9 (p1 to p8, p10) contributed to the positive events and 6 (n1 to n3, n5 to n7) to negative events. 1 KLI which is common for both type of events is *Unknown Knowns* (p9 & n4).

4.5.2. Relation of identified KLIs and Lead Indicators with the Theoretical framework

The KLIs have been identified from all the cases and combined in the previous section. Although, these KLIs are portrayed based on the events for which they were identified. Moreover, KLIs of both negative and positive events are listed separately. To recall again, the motive of this research is to identify indicators whose degree of presence in the project can itself predict it will affect the outcome negatively or positively. For this, as already discussed in chapter 3, the indicators should be neutral rather than considering as negative or positive. As the theoretical framework already exists with neutral KLIs, it's helpful to compare the identified KLIs with it to check weather KLIs are relatable, and later finalize all the KLIs in neutral manner. The comparison has been picturised in figure 17. In previous chapter, a colour coding for table of KLIs was prearranged and was explained briefly. This section will explain it more in detail.

Out of 16 identified KLIs in figure 17, five KLIs (p1, p2, p8, n1, n2) are identified in the case and in the theoretical framework. *Highly committed internal stakeholders* and *Positive attitude* are aspects if Human Behaviour and their definition from the analysis could be directly related to the KLIs of *Commitment* and *Attitude* from the theoretical framework in the behaviour category. *Strong communication* is an indicator which reflected the openness and transparency in communication amongst the stakeholders in Vienna Main Station project. The KLI of *communication* in the theoretical framework is defined as the level of communication in a project which includes openness and transparency. Hence, in this way it is linked to the theoretical framework. *Design change* was observed mainly from the clients side and was also dependent on the number of stakeholders in the project. *Lack of Experience* was clearly identified across the cases and hence it can be linked to the *Level of Experience*.

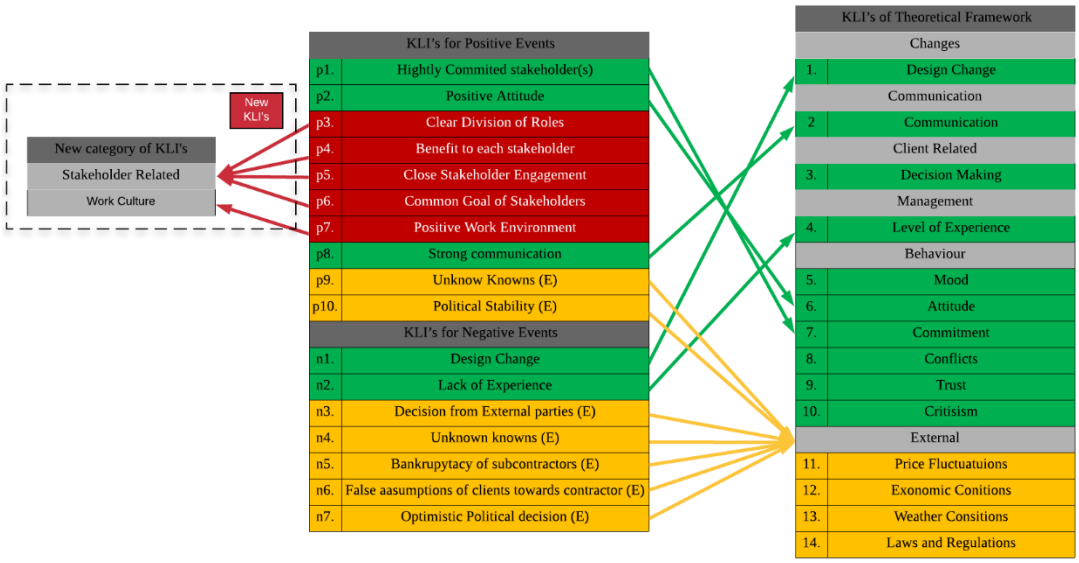


Figure 17; Comparison of identified KLIs & Theoretical Framework

Remaining 5 KLIs (p3 to p7) are newly identified KLIs from the case and importantly, all of them were the indicators of positive event. *Clear division of roles, Benefit to each stakeholder Close Stakeholder Engagement, & Common Goal of Stakeholders*: all four of them are stakeholder related KLIs. Hence, they are categorised as Stakeholder-Related KLIs. This can be observed on the left side of figure 17. *Positive Work Environment* is related to the culture of the project or the workplace. Similarly, it has been listed under the category of Work culture which is completely different and new. All these five KLIs are neutralized and defined according to case findings as: *Transparency in Role division, Stakeholder benefits, Stakeholder Engagement, Goal Alignment & project Environment* respectively.

Six KLIs (p10, n3 to n7) are newly identified KLIs in the case and all can be related to the External category of KLIs since they are specifically mentioned the case interviews. None of them were previously recognized in the theoretical framework.

- The KLI of *Unknown Knowns* includes many key causes, already observed in each case analysis, which are very specific to the respective project. It is a category in itself yet external. The causes like unexpected good personal relations, unawareness of bad ground conditions.
- Similarly, *Bankruptcy of subcontractors* as very less degree of influence by the management team. Hence, it falls into the external category. As it resembles a negative outcome, it is defined as a neutral indicator and called *Financial condition of contractors/subcontractors.*
- *Political stability* and *Optimistic Political decision* cannot be influenced and hence they are external and the optimistic political decision in Vienna main station project evoked optimism bias and led to delay in the project. Although, to make it a neutral indicator, it has been named and defined as *Political Decision,* which means the nature of the political decisions i.e., degree to which the decisions are taken for the benefit of everyone.
- *False assumptions of clients towards the contractors* led to a delay in construction phase. The image of the contractor in the client's perspective was wrong. When the client realised the situation, it was already late. Since it's hard to identify and influence someone's assumption, it is regarded as an external KLI. To neutralize the indicators, it is defined as *Assumptions of clients towards contractor* which means the degree of conventional mindset of client towards the contractor.
- *Decision from external parties* represents the speediness of decisions taken by the external parties. The influence on these parties is very less hence it's an external KLI.

Other than the linked and unlinked KLIs to theoretical framework, the KLIs of theoretical framework which weren't identified in the case are also important to note. *Decision making* is the speed with which decisions are made, although it wasn't observed for case specific events, it was evaluated by the interviewees that it was present in the project. The interviewees (i2.2, i3.2) mentioned that it was observed in the project although it wasn't identified as a key cause of the events. However, this indicator was identified to be an LI which was caused by the *Level of Experience* in CI. Hence, *decision making* is also considered as a KLI. Similarly, *Motivation, Trust* were identified as LIs in the case analysis. All of them were triggered by the KLI of *Stakeholder Benefits, Project Environment respectively*. Since these KLIs weren't observed in the theory, *Trust* and *Motivation* weren't considered as KLIs. Additionally, *optimism bias* is frequently observed to act as an LI. It is triggered by *Level of Experience* in the project organization. When the stakeholders were enquired about the external KLIs from the theoretical framework, all of them were identified in across the three cases. Although, they weren't observed specifically in each event. Hence, these were also considered to be a part of the framework which is elaborated in the next section.

4.5.3. Validated Framework of KLIs

The source of each KLI has been mentioned in the data collection chapters of each case. From that, the consistency of all the KLIs are checked. All the KLIs are valid which are repeatedly mentioned by both the interviewees. However, a few KLIs also exist which were extracted only from one interviewee. This is because of the discrepancy in the selection of events by each interviewee. Hence, they are still considered as KLIs and generically validated in the expert meeting. All the KLIs of external category are also validated even though few of them are extracted from a single interviewee because it is believed that recognizing external KLIs is hard, given there might be a number of external factors that can affect an event. These factors may be known to some manager and unknown/hard to be recognized by others. Hence, all the KLIs are valid and considered to form the final framework.

Table 20 provides an overview of all 21 validated KLIs with their respective definitions. The newly identified KLIs (1,2,3,4,10) and External KLIs (12,13,14,19,20,21) are defined based on the observations and analysis in the cases. The other KLIs are found to be directly related to the KLIs of theoretical framework. Hence, their definitions which were obtained previously remained the same. One exception is that, it is found that literature proposed a two-fold definition for KLI of *communication*. Although, through the case studies, only one definition for *Communication* is observed. It is: *Level of communication amongst the stakeholders* i.e., level of openness and transparency in communication.

These KLIs were further grouped into 8 main categories out of which six categories were already defined in the theory. Two newly added categories are *Stakeholder (External) Related* (1,2,3,4) and *Work Culture* (10). The *(External) Stakeholder related* category is defined to consist the KLIs which are related to the external stakeholders based on the observations from the case. External stakeholders are the stakeholders who represents certain entity or organization involved in the project. On the other hand, Internal stakeholders are the individuals who work in those entities and also are a part of the project. The category of *Work Culture* is about the organizational culture in the project. The KLIs of *Behaviour* are *attitude* and *commitments* are related only to the individuals i.e., the internal stakeholders in the project. Hence it is renamed as *(Internal) Stakeholder Behaviour*.

Table 20; Framework of KLIs from all cases

	Category	Identified KLIs	Definition
1	(External) Stakeholder Related	Stakeholder Engagement	Level of close involvement and support of all the stakeholders while working in the project. Which also means, how easily and unanimously they can work together.
2		Stakeholder Benefits	Number of stakeholder benefiting by the sanction of project. For instance: all are benefiting; or only a few; or none.
3		Transparency in Role division	Level of clearness of roles and responsibilities which are divided among the respective stakeholders.
4		Goal Alignment	Focus of stakeholders to work towards achieving solely the goal of the project i.e., the number of stakeholders participating in the project with the mentality aligning to achieve the goal of the project.
5	Management	Level of Experience	The level of experience and knowledge of Project Personnel or the project team regarding the different phases of a project.
6	(Internal) Stakeholder Behaviour	Commitment	Level of commitment of the stakeholders towards the project i.e., how active the stakeholder is in the project.
7		Attitude	Nature of attitude (Positive/Negative/Neutral) of the stakeholders towards the project i.e., the mentality and attitude of the stakeholders motivation in the project organization towards the project which also reflects their motivation.
8	Change	Design Change	Changes in design due to mainly the client and also other external Stakeholders (Changes in design due to a greater number of stakeholder)
9	Communication	Communication	Level of communication amongst the stakeholders of the project i.e., level of openness and transparency in communication.
10	Work culture	Project Environment	Nature of work environment (Positive/Negative) i.e., the level of leniency, freedom and mental safety to the stakeholders in the work environment; the level of smoothness in works which an environment can generate.
11	Client-Related	Decision Making	The speed with which the decisions are taken especially from clients side (Fast/slow/no decision)
12	External category (KLIs on which there is no or very less degree of control by the client)	Political Decisions	The nature of the political decisions i.e., if the decisions are taken solely for own benefit or for the benefit of everyone.
13		Decision making from external parties	The speed with which the decisions are taken by External parties are not the stakeholders of the project, but their decision is needed for the project.
14		Unknown Knowns	The identification of certain unexpected aspects which could have been know early but not know until identified. For instance, with respect to the case studies: Unawareness of Good personal relations at Higher management level between main stakeholders, unawareness bad ground conditions.
15		Weather Conditions	Effect of different weather conditions on the project
16		Price Fluctuations	Fluctuations in the market prices of the commodities, goods and labour.
17		Economic conditions	Changes in economic conditions which include the exchange rate, inflation rate, interest rate etc. when the project is ongoing.

	Category	Identified KLIs	Definition
18		Changes in Laws and Regulations	Changes in laws and regulations by the government in between the project.
19		Financial condition of Contractors/Subcontractors	Financial status of the contractors or subcontractors while the project is running.
20		Assumptions of clients towards contractor	The degree of conventional mindset of client towards the contractor.
21		Political Stability	Level of stability of the government in the country.

4.5.4. Findings of the Cross-Case Analysis

All the KLIs of table 20 are found from the case studies. Most of them could be linked directly to the categories of Theoretical framework and few of the indicators were newly identified. Although, few of the KLIs which were only a part of theoretical framework and were not identified in the case specific events, they were evaluated separately with the interviewers to know if it was observed in the project in general. Hence, they are also a part of this framework. Moreover, all the KLIs were presented to be neutral and not biased towards a positive or negative event. Now follows the main findings from this cross-case observation:

- The KLIs of *Design Change, Level of Experience, Communication, Commitment, Attitude* were identified both in the case studies and the theory. Hence, they are of high importance. Besides, *Design Change* and *Communication* are often found to be an LI more than a KLI. They are mainly triggered by *Level of Experience* and *Stakeholder Engagement* & *Project Environment* respectively.
- Similarly, *Decision Making* is found to act as an LI which is triggered due to *Level of Experience*. Although, it is a part of the framework of analysis since it is also replicated in theoretical framework. It is also observed in the projects but not specifically as a KLI for the selected events.
- Five KLIs are newly identified and they are observed only for the positive events. They are: *Stakeholder Engagement, Stakeholder Benefits, Goal Alignment, Transparency in role division and Project Environment. Stakeholder Engagement* and *Stakeholder Benefits* is frequently observed across the cases.
- The *External category* consist of many variety of KLIs out of which the ones identified in the events of the case studies didn't match with the KLIs of theory. Although, the KLIs of theory are evaluated and it is found that they are observed in the projects but just were not an indicator for the selected events. Hence, all the KLIs of case study and theory are combined to be a part of framework analysis. Relatively less focus is given to these external KLIs in the cross-case analysis since their character of 'hard to be influenced' makes them difficult to be even defined as a KLI. Although, it is good to at least know them and be prepared. Hence, they are included in the framework.
- Trust and Motivation among the internal stakeholders are identified as LIs in the case analysis. All of them were triggered by the KLI of *Stakeholder Engagement, Project Environment* and *Stakeholder Benefits*. Optimism Bias is a very frequently observed LI which is often found to be triggered by the KLI *Level of Experience*. However, they are not included in the framework since there is not enough proof to define it as a KLI.

4.6. Conclusion

This case study analysis has been conducted to identify the KLIs from practice. The second sub-question that is to solve from the case study analysis is:

What are the key lead indicators that can be identified from practice among chosen projects?

Stockholm Metro Project, North South Line Project of Amsterdam and Vienna Main Station Project were selected cases based on the selection criteria. The data was collected by two methods: Project Documents and Case interviews.

The project documents fetched the project information and events that have occurred. After attaining a brief idea about the project, the positive and negative events were selected about which was enquired in the interviews with different project managers and coordinators. The events selected such that they are similar and comparable across all cases. The events were selected only after the approval from the interviewees. The events selected such that they are similar and comparable across all cases. The interviews fetched the root causes or KLIs of the events particular to each case. All the case specific KLIs are drawn.

Being an explorative research, the KLIs of all the cases were combined. Cross case analysis is performed and relevance of each KLI is understood. These identified KLIs are matched with the theoretical framework to check if any KLI is repeated in the cases and find out the new KLIs. This led to validating the KLIs through looking at the consistency of the answers of the interviewees of each case and building of framework of 21 KLIs identified from practice.

All the KLIs from theoretical framework except the KLIs of Behaviour category (*Mood, Trust, Conflicts, Criticism*) were also observed in practice and are the most important. Apart from them, *Stakeholder Engagement, Stakeholder Benefits, Goal Alignment, Transparency in Role Division, Project Environment* are the newly identified KLIs from practice. Also new external KLIs were observed which mostly varied across different cases. *Political Stability* and *Unknown Knowns* are quite frequently observed external KLIs. The complete results of KLIs with definitions are provided in table 20. The KLIs of the practice are presented in the table below.

Category	KLIs		Category	KLIs	
Change	1.	Design Change	**(External) Stakeholder Related**	11.	Transparency in role division
Communication	2.	Communication		12.	Stakeholder Benefits
Client Related	3.	Decision making		13.	Stakeholder Engagement
Management	4.	Level of Experience		14.	Goal Alignment
(Internal) Stakeholder Behaviour	5.	Attitude	**Work Culture**	15.	Project Environment
	6.	Commitment			
External	7.	Price fluctuations	**External**	16.	Political Decisions
	8.	Economic conditions		17.	Decision Making from External parties
	9.	Weather conditions		18.	Unknown Knowns
	10.	Changes in Laws and Regulations		19.	Financial Condition of Contractors/Subcontractors
				20.	Assumptions of Clients towards Contractors
				21.	Political Stability

5 Expert Consultation

In this chapter, suggestions for developments are hunted based on the results of the case study. These suggestions are articulated in consultation with experts. This solves the 3rd and last sub-question of this research. The sub-question that is answered in this chapter is:

> *How can the identified Key Lead Indicators be measured and influenced in the future railway projects?*

This question is answered by conducting the following steps. On basis of the analysis of chapter four, a goal is setup to solve this sub-question. Following from these questions are formulated. In an expert meeting, concrete remedies are formulated to achieve these desired solutions to these questions.

This chapter is constructed as follows. Section 5.1 explains the approach and goal of the expert session. Section 5.2 discusses the questions for the expert session and the session setup. In section 5.3, solutions for improvement of the case study results are discussed. In section 5.4 conclusions are drawn.

5.1. Approach to further develop results of Analysis

The case study analysis has resulted in KLIs which are observed in rail infrastructure projects. The sub-question in this chapter is devoted to find out ways how these KLIs could be used in future projects.

The KLIs from the case study can be considered as the key indicators which are present in the large inner-city rail infrastructure construction projects in Europe. To further develop these KLIs it is first crucial for a project manager to take a step out and identify these KLIs being in busy project environment. At any point of time in the project, many concurrent activities keep a project manager busy which makes him difficult to recognize any such indicator. Once they are identified, their presence should be measured in the project. Measuring lead indicators is difficult as mentioned in the introduction. But once it is measured, ways to influence it can be developed which can help the project by minimising negative effects or enhancing the performance depending on how the KLI will influence the project respectively.

5.2. Expert Meeting Setup

These developments of the results are sought by consultation of four experts in an expert meeting. The details of the experts can be found in table 26 (Appendix C). This is done to guarantee tangible and industry braced enhancements. In order to facilitate this meeting, three questions are formulated. Hence, the three main questions are:

1) *How can a project manager identify these KLIs, being in a busy project environment?*
2) *How can each of these KLI be measured in future projects?*
3) *How can each of these KLI be influenced in future projects?*

The first question is common for all the KLIs since it's just to develop ways through which all the KLIs can be identified. Hence, during the session, the first question was asked and solution to it was brainstormed in groups. Next, in two small groups people were confronted with 2nd and 3rd question for each KLI every time. After brainstorm, possible solutions were discussed in this group, resulting in recommendations for each KLI. Requirements for this recommendation were: concrete and practically applicable. Subsequently, groups were rotated. In total, four experts participated in this session. The results of this session are presented in section 5.3.

5.3. Results of Expert Session

The following suggested recommendations are the result of an expert meeting, case study analysis and personal reflection. The first question is common for all the KLIs but the second and third ones are questioned for each KLI. Hence, the section 5.3.1. is dedicated to solving the first question. Section 5.3.2 will answer the second and third question for each KLI.

5.3.1. Identification of KLIs

How can a project manager identify these KLIs, being in a busy project environment?

In order to identify the KLIs in a busy environment, the project manager should in advance plan a reserve time in his/her schedule each month that could be spent for this task. He/she should always look one step ahead in the project so that he is aware what is coming next.

The expert meeting also suggested that frequent External Assessments like the IPAT assessment which is provided by the NETLIPSE organization should be conducted. It is found that the IPAT or 'Infrastructure Project Assessment Tool' is a tool widely used for infrastructure projects in Europe to generate ex-ante and ex-post evaluation, as well as used for monitoring and benchmarking purposes. The tool offers an indication to what extent a project organisation is ready to enter its next project phase and help to improve the project organisation (NETLIPSE, n.d.). Hence, this way the project is frequently monitored which can help identify Lead Indicators. Also, improving the project organization signifies

on influencing the soft and organizational factors once identified. These soft factors are a vital form of Lead indicators. Hence, this step of implementing IPAT assessment in LIPs can assist strongly in identification of lead indicators.

Further, the experts of AT Osborne suggest the usage of Project Barometer. It is a tool that provides a structured and easily accessible way to make the gut-feeling measurable within the project team. It should be understood that this tool is developed by AT Osborne itself and hence, this suggestion can be biased towards the improvement of their organization's business. These gut-feelings are however observed as lead indicators in the literature review of Nikander (2001) and are previous described from (AT Osborne, 2017). Hence, when project members reflect on these lead indicators, the tool scores those aspects higher or lower which results in identifying their existence in the organization earlier. This helps the project manager to know the teams own weaknesses and incompetence's. Hence, using a tool like project barometer can be a possible way to identify primarily the gut-feelings that are a form of lead indicators in the project.

5.3.2. Measuring and Influencing the KLIs

The entire set of ways to measure and influence them can be found in Appendix C (Table 27). This set consists of all the suggestions from the meeting and case interviews, out of which a few seemed to lack clarity and are unjustified. Such suggestions were simply filtered out. After filtering, table 21 below lists out all remaining and important steps to measure and influence the identified KLIs. For KLIs *Stakeholder Engagement, Goal Alignment, Project Environment, Attitude* and *Commitment* the expert sessions couldn't fetch any results. Hence, they are mainly analysed from the cases and personal contribution.

Table 21;Concrete ways to Measure and Influence KLIs

KLI	2. How can each of these KLI be measured in future projects?	3. How can each of these KLI be influenced in future projects?
Stakeholder Engagement	Measuring the actual involvement of each stakeholders can be tricky. Determining if a good stakeholder management plan is implemented, which promotes dialogue and keeps a track of timely involvement of stakeholders can measure the degree of their collaboration and involvement.	Use of Release management approach: Dividing the path of Design, Execution and Installation phases with small milestones leading to achieve the final goal of the project. After every milestone is achieved, its success should be communicated in the project and it should be celebrated with all the stakeholders. This enhances their motivation and develops positive attitude which keeps the stakeholders engaged to strive for the success of next milestone (i2.1, i2.2)
Stakeholder Benefits	If all stakeholders benefit, they must be happy. A consensus among a majority of the experienced employees was "happy people" is a precondition for a good project, and that discontentment represents the commencement of a negative development (Haji-Kazemi & Andersen, 2013). Hence, measuring the satisfaction/happiness levels of the client by using several tools and questionnaires available online should ultimately help.	The project should be taken forward only if every stakeholder is benefitting else it can raise conflicts in the project. If there is/are stakeholder who doesn't benefit much from the planned project, flexibility in the planning should be provided at early stages so that value can be added which can benefit both the project and the stakeholder on the cost of increased scope.
Transparency in Role Division	Frequently Checking the organizational chart, if there are clear roles and responsibilities, mandates about who can make the	Prefixed written agreements should be in place before starting off the project so that if there is any discrepancy or lack of clarity, the document can be referred and adapted.

KLI	2. How can each of these KLI be measured in future projects?	3. How can each of these KLI be influenced in future projects?
	decisions. Once this is checked, most important, evaluate if people obey this chart.	
Goal Alignment	This KLI seems to be similar to that of stakeholder benefits. If all the stakeholder is benefitting, they will strive to achieve than benefit while fulfilling the goal. Hence, Frequent interaction with all stakeholders to know their vision. If the vision is common, it indicates that all the stakeholders have a common goal.	The contractual arrangements should include provision for shared financial rewards/bonuses on achieving the milestones. Shared bonus system drives combined efforts amongst different parties hence keeping them motivated to achieve the goal of the project (i2.1)
Level of Experience	1.Thoroughness of the recruitment process is a direct measure for Level of Experience. 2. Checking the profile of employees involved in the project. This includes their experience by number of years in practice, educational background, past achievements in the field of their role.	1. The hiring team should involve the project team while recruiting, it can improve the level of experience of people that are being hired. 2. To be careful in the procurement phase by making sure that both the parties get the best price and value. 3. Hiring more experienced person for a limited time who can train the project managers from the clients side, who generally tend to lack experience in complex projects, but still are a part of it because since are appointed from the client. It will influence the number of avoidable failures in the project. 4. Hiring external personnel or outsourcing the work, i.e., if in case there are less experienced people in the team (i.2.2, i3.2)
Commitment	Use of scrum tool in the project organization reflecting every individual's task to be achieved/achieving/achieved in parallel to the allotted time frame for each task can help to see if the employee is actively achieving the tasks in the given time. This reflects the level of commitment in each individual. However, this doesn't guarantee if the person is really guaranteed. Commitment is really soft and integral part of a human. Being a soft factor, makes it hard to be measured.	It is rather difficult to influence this KLI since it is very soft and human aspect. As discussed previously, use of release management approach can enhance commitment of the individual stakeholders involved in the project.
Attitude	Personal attitude is reflected by body language, way of speaking in the project meetings.	It is believed that changing or influencing one's attitude is rather difficult than measuring it. If there is a lack of attitude towards the project, it reflects the lack of interest of a person. Personal interaction with the person to know the reason behind that attitude is the first step which can guide to take further steps to improve the attitude. If the further steps are not possible, it's good to replace the person which can be beneficial for both the project to evolve and the person's interest.
Design Change	1. It has been observed frequently that design change is an LI led by the KLI of Lack of Experience.	1. From the experience of different interviewees, it suggested hiring at least one highly experienced person for one or more

KLI	2. How can each of these KLI be measured in future projects?	3. How can each of these KLI be influenced in future projects?
	Hence, it's there is a lack of experience with different project phases, there are most probable chances of design changes. Hence, certifying the level of experience in the project is a probable measure. 2. Complexity of the planning phase and Number of stakeholders can be the measure, for instance: producing different designs for different stakeholders which can be complex, complexity of project itself is also a measure of design changes and if there are a greater number of stakeholders, it surely comes with more requirements and hence leading to design changes.	phases who can lead the team throughout that phase can be an influencing factor. 2. In a classical view of project management, changes are bad things. But, in complex projects changes are inevitable. One should always embrace the design change as an opportunity to reach the project goals since at the end of the day, it's more important that you deliver something which meets the clients need rather than staying within budget and delivering in time (i2.2). Hence, one must be realistic by learning these new things and find ways to alter or adapt to the changes coming throughout the project. 3.Completeness of the technical framework before starting design phase can influence the existence of probable major design changes in later phases of the project (i1.1)
Communication	1. Measuring the frequency of interaction between the stakeholder groups can provide the precision of communication in the project. 2. Measuring the percentage of consensus when decisions are being made can tell about how well the project information is being communicated to different individuals of the organization.	1. Making and following a time schedule of open meetings between different stakeholders to discuss: What is achieved, what are the problems, what is the way forward etc. which can help to keep the project organization clearly and completely informed (i3.2). 2. Implement a strong and strategic communication plan which is understood by every stakeholder. Such a plan should empower stakeholders to communicate every small deviation openly because when there is an open mind, people can anytime approach and be updated with the right project information. This will avoid misinterpretation with regards to the actions taken in the project. 3. Ensure experienced communication staff is hired, especially the director of communication, who should be a part of the top management (i1.1). 4. Update correct and necessary information on the project website. This can avoid lack of communication with the public. 5. Conduct meetings in-person with the nearby residents and public to discuss about the planning process. This creates transparency and enhances communication with end-users.
Project Environment	When stakeholders are complaining or blaming each other consistently, it depicts that there is somewhere a lack of trust or collaboration between them. Hence, constant observation off complaints or blames related to stakeholders says a lot about the project environment since the environment might not be supportive for their collaboration (i2.2). When it is observed that people can work with fun, it's an indication of positive side of this KLI.	1. Frequent sessions should be organized outside the regular workplace, where it is more relaxed to stimulate collaboration between different parties. This gives them time to spend quality time with each other. 2. Hiring a special team with a sole purpose of identifying and analysing the project work culture. Because, for instance observations of conflicts and blames might not be recognizable by a normal person who might be working towards achieving his own goals. This team should be involved in the meetings and across the coffee machines where there are more

KLI	2. How can each of these KLI be measured in future projects?	3. How can each of these KLI be influenced in future projects?
		chances to notice what the people think about the work culture.
Decision Making	1. Unclear mandates; Formal governance; Insufficient funds; Underperformance of contractors and provision incomplete information to clients are measures for slower decision making. 2. It is observed that slowness in decision making was an LI led by the KLI of Lack of Experience. Hence, the level of experience in the project organization is a probable measure to identify the speed of decision making.	1. Decisions that needs to be taken from client's side might sometimes take time. Hence, being in close contact with the client and if informed early about what kind of decisions to be taken, can speed up the process (i1.1). 2. Sometimes a no decision is also a wise decision (i2.1) in case to make a substantial decision or when there is a lack of information provided. Provision of complete and relevant information plays a major role to influence decision making. 3. The clients should be confronted with examples, stories, lessons learnt with respect to past projects) that can affect the project in monetary terms or in terms of schedule depending on the speed of decision making. This alerts the client about the necessity of Decision Making.
External KLIs	Since external KLIs cannot be influenced much, measuring them is also slightly difficult. Although importantly: 1. Contingency plans can be made to adapt the project to those political decision. 2. Keep a close check on the weather forecast and warnings. It also depends on the type of project which you are working on. For example, if it's an underground subway construction then the weather conditions wouldn't matter much. If it's a project in an open environment, then you should follow the weather conditions closely. 3.Since such large infrastructure projects are owned by the public bodies who are the clients of the project, governmental indicators about the market performance can be used to measure the economic conditions. 4. Studying the history of project portfolio of the contractor and their risk appetite can give an indication about their financial capability.	They are Hard to Influence. Hence, few points for KLIs which can be influenced: 1. For financial of contractors, do not accept contractors with a bad position in contracting process, if they have quoted a very less amount. Avoiding hiring of contractors with opportunistic behaviour. 2. Forecast on weather, market prices and economic conditions and plan in contingency. 3. Strict measures to carry out thorough ground surveys and other technical surveys to avoid problems related to the Unknown Known KLI.

5.4. Conclusion

This chapter developed the concept of KLIs from practice to be implemented in future projects. The third and last sub-question that is to be answered:

> *How can the identified Key Lead Indicators be measured and influenced in the future railway projects?*

To solve this, an expert panel was setup with four experts from AT Osborne. The objective of this expert meeting was two-fold. First, it's important to know how a project manager can take a step out and identify these indicators in a project where many concurrent activities are going on and keep him busy. Second, to know how each of these identified indicator be dealt with in future projects. Three questions were framed and the answers for all were brainstormed in two subgroups in the expert meeting. The answers also critically included interpretation of the researcher and the learnings from case studies.

The answer for the first question regarding identification of KLIs was recommendations to project managers: To plan reserve time each month for this task; To conduct external project assessments tools like IPAT; Use of tools like project barometer.

The second and third questions were answered for all KLIs individually, except for the KLIs of external category, which were answered by providing key steps for the category as a whole. This is because External category can be less influenced and measured. Both these questions were asked to find out ways to measure and influence the KLIs in future inner-city rail projects. Here are the main conclusions from the results of second and third questions:

- *Stakeholder Engagement* can be measured by checking if a good stakeholder plan followed for ensuring involvement of all the stakeholders; Use of Release management approach can influence it by motivating the stakeholders and improving their commitment to the project.
- *Stakeholder Benefits* and *Goal Alignment* can be measured by conducting surveys on the satisfaction of employees with the project and its environment. They can be influenced by providing the flexibility in planning which can also add value different project phases and providing shared financial benefits in the contracts respectively.
- *Level of experience* can be measured by checking the profile of employees working in the organization. It can be influenced by recruiting people with a partial authority to both the HR and Project team or hiring external personnel who can help in training the unexperienced.
- *Design change* is found to be triggered by *Level of experience* in the management team, hence it acts as a measure. However, changes in design should be seen more as an opportunity to improve rather than an influence on project cost and schedule.
- *Communication* should be measured by the number of interactions between the stakeholder groups and it can be influenced by creating an open and transparent project environment, having strong communication plan, or assigning the role of communication director in top management.
- *Commitment* and *Attitude* of the individual's seems hard to be measured and influenced, due to their soft and intangible nature. Scrum tool can be used to measure *Commitment* and *Attitude* can be measured by analysing the person's body language and way of interaction in meetings.
- *Project environment* can be easily measured from the number of complaints, blames that are heard from the project personnel. It can be influenced by organizing frequent relaxed sessions out of regular environment which can improve personal relations.
- *Decision making* can be measure by the level of experience of the project personnel. Generally, the decisions are delayed from the clients side, for which complete information should be provided and close contact with the client should be maintained.
- Most of the KLIs of External category KLIs could be measured but they are hard to be influence.

These steps It should be however noted that these suggestions are mainly discussed and provided with the experts from AT Osborne, who are a part of a management consultancy firm. Hence, these suggestions certainly have some bias towards the experiences of working at a consultancy firm. Also, few suggestions that have been proposed might carry own interest of the company to improve their future business. For instance, project barometer is a tool which is solely developed by AT Osborne. Hence, recommendation to use their product through this research can certainly help to improve the business of AT Osborne. Nevertheless, all the findings are interpreted to be valuable, being aware that they can carry certain bias as discussed.

6 Discussion

The previous chapters offered a detailed exploration into the subject of Key Lead Indicators and their measurability and influenceability. This chapter comprises of a discussion built on the researcher's reflection key findings, their implications and also the limitations of the research. Section 6.1 discusses the implications of findings of the research scientifically and practically. Section 6.2. discusses the limitations of the research.

6.1. Discussion on Findings

The objective of the research has been to identify and analyse the Lead Indicators in large railway infrastructure projects to enhance their performance. This was motivated by the initial finding that there is a limited knowledge available about Lead indicators, especially in transport infrastructure projects. The findings were derived through preliminary literature study on the subject, followed by explorative interviews with project managers of selected projects and sequentially through a panel meeting with the experts of AT Osborne. The results of the research demonstrate the additional value that lead indicators provide to the existing understanding of performance metrics in science and practice. This section discusses the implications of the findings scientifically and practically throughout the research process.

6.1.1. Scientific Implications

To identify the Lead Indicators, it is essential to explore and understand the subject efficiently, which was attained through a thorough literature study. The literature on the terminology and concept of Lead Indicators has been found to be almost non-existent. This provided a challenge in gathering insights specific to the concept. Through literature on similar concept of lead indicators, this research made first attempts to define and research about 'Key' Lead Indicators, mainly with support of Zheng (2017). No previous literature is found on the concept of KLIs i.e., most-significant forward-looking measures, which are first indicators that can reveal any deviation in project performance.

The research verified that the concept of Early warning signs and Lead Indicators are almost the same i.e., the phrase 'Early Warning Sign' is a synonym of the phrase 'Lead Indicator'. This is achieved by comparing the Lead performance indicators from Habibi (2018) and Early Warning Signs form the Nikander (2001), AT Osborne (2017) and Williams (2012). It was found that many of the KLIs (*Design changes, Poor communication, Poor site management and supervision, Slow decision Making* etc.) were overlapping with the EWS (*Preliminary Planning, Miscommunication, Lack of Experience, No/Delayed Decision* etc.) respectively. This finding is in line with the discovery of Williams (2012) and Wijtenburg (2018) which reflected EWS as Lead indicators.

The analysis of the literature study confirmed that the identified KLIs are focussed only on signalling negative incidents of a project. It is perceived that researching on an indicator implies researching on both positive and negative aspects of the project. Hence, the research interpreted these KLIs to be neutral and proceeded by choosing both positive and negative events to study the project's KLIs. This way, the research emphasised on the positive aspects and contributed to the existing literature of Habibi (2018) that gathered indicators which are only negatively affecting the project.

The research discovered that almost all the KLIs identified from theory repeats in the practice. *Design Changes, Level of Experience, Communication, Decision Making, Attitude, Commitment* and *External category of KLIs* were observed in theory, and they were also observed in practice. These KLIs are hence proved to be the most important. Also, external category comprises of maximum number of KLIs. These findings correspond to the conclusions of Habibi (2018) that *Design changes* are the most significant lead indicators and External category of KLIs are a frequent set in a project. However, Habibi segregates the lead indicators into different project phases which eases their management, planning and control. Due to explicit focus on clients-perspective, the research couldn't segregate the KLIs based on different phases of the project.

The research adds to the existing literature on lead indicators by discovering the new KLIs from practice: *Stakeholder Engagement, Stakeholder Benefits, Goal Alignment, Transparency in Role division and Project Environment.* All these newly identified KLIs were surprisingly discovered only for positive events. This implies a lack of existing research on the KLIs that can prevail, leading to positive incidents in a project.

The analysis also fetched some unexpected results. Few of the identified KLIs, were found to also act as an LI, which are not the most significant causes for the event. For instance, *Design change* and *Communication* were observed many times to be triggered by the KLIs of *Level of Experience* and *Stakeholder Engagement* respectively. Although, they both were also identified as KLIs at other instances in the case study. This has to say something about the character of the indicator. Thus, it is found that a correlation exits between different KLIs, which when researched further can demarcate the character of identified KLIs accurately. Habibi (2018) and also other reviewed literature didn't reveal about such correlations previously.

The part of the research findings that was obtained from the expert consultation meeting included views from only a limited number of experts. Moreover, the suggestions were based mainly on their and interviewees past experiences. Hence, the influence of the expert meeting on the research could have been stronger. Furthermore, the characteristic of a Lead indicator was discovered: they are hard to measure but easy to influence. Although several steps to measure the KLIs were identified, only a few of them are believed to be concrete measures. Whereas, the steps to influence were relatively solid and were easily recommended. Thus, the results of the expert meeting are stronger on the part of influencing the KLIs compared to the part of measuring the KLIs. The steps to measure the KLIs could have been sharper and hence, should be researched furthermore deeply.

This research focusses on the lead indicators and ways to measure and influence them. This is confidently an approach to focus on future rather than past, focus on proactiveness than reactiveness to measure and influence the project performance, as suggested by the results of Haji-Kazemi et al. (2013). Moreover, since there is a lack of focus on lead indicators, this research contributes to that research gap and adds value to the set of performance metrics in the theory of project performance as pointed out by Stone and Banks (1997). It contributes to the existing literature by providing recommendations to stimulate the use of KLIs. With these recommendations it expands the existing knowledge on measuring and influencing the KLIs.

6.1.2. Practical Implications

The research also has certain practical implications. The leading indicators are almost soft in nature compared to the lagging indicators. The LIP's are also systematized on these hard factors but lack focus on 'soft factors' (Hertogh, Baker, Staal-Ong, & Westerveld, 2008). The findings of this research demonstrate that KLIs are present in construction projects and should be used effectively. Due to their soft character, leading indicators are hardly identified in the construction industry. This research has successfully identified the KLIs in the existing rail infrastructure projects. It has even found that few KLIs like '*Lack of Experience*' and '*Stakeholder Engagement'* are frequently identified across these projects, even though the projects are realized in different countries. This implies that the KLIs identified can be directly learned by the managers of LIPs. Hence, this research contributes to the practical knowledge of the KLIs in the inner-city rail infrastructure projects and can improve the 'soft part' of performance metrics.

The research brings into light about various steps to measure and influence the KLIs in the project when they are identified. It is understood that measuring the indicators is on one hand a hard but is also vital. Only after they are measured, the steps to influence can be easily applied. Hence, through discussion with various experts in the field of infrastructure projects, the research provides concrete steps to measure and influence specifically for each KLIs. Given the poor statistics of performance of rail infrastructure projects, these steps of measuring and influencing KLIs shall provide the managers an additional room for manoeuvre to enhance the performance. These steps are however mainly based on the past experiences of practitioners; hence, their affect is not completely known until they are effectively applied in the future projects. Thus, in the next chapter, correspondingly key recommendations are provided for practitioners that should be implemented in future projects.

6.2. Limitations of the research

Similar to many research projects, this research is achieved in a timeline of little over six months. Hence, there are certain limitations in this research. The limitations are mentioned as follows:

1) The research was focussed on identifying the KLIs and ways to measure and influence them. But it doesn't show the influence on the project objectives. These affects should be researched and are suggested for further research.

2) This research is explorative, and it studied only three cases. Hence, this limits its generalizability. A suggestion for future research would be to perform a similar research with a greater number of cases.

3) The research was only focussed on inner city rail infrastructure projects. So, the results of the research cannot be used for other type of projects. Other type of projects should be included in the research for that purpose.

4) The research was conducted only across three different countries of Europe. Moreover, only one project was studied from each country. The results cannot be generalised for the whole Europe and hard to be generalized for a single country. More number of projects across a greater number of countries should be considered for that purpose.

5) Many KLIs were observed to be an indicator of only one event. Although, the percentage of contribution of each KLI which led to that event is unknown. This is due to the qualitative nature of research. A quantitative research can allow to estimate the percentage influence of each KLI on the event.

6) The suggestions on steps to measure and influence the KLIs were mainly derived from the expert meeting. Hence, they can hold certain bias towards the experience of experts of AT Osborne.

7) The interviews and their results are arranged from a client's perspective. Research findings can be further enhanced by including different perspectives i.e., to also interview contractors, consultants and suppliers.

8) The research was conducted for different countries. There might exist certain cross-cultural difference which has an effect on the project life cycle. However, it was not considered as a part of this research.

7 Conclusion and Recommendations

7.1. Conclusion – Answers for Research Questions

In order to conclude the research, the main research question should be answered. And to answer it, all the related sub questions should be answered. To be able to fill the current research gap, the following research main question has been formulated.

How can Key Lead Indicators be used to improve project performance of inner-city rail infrastructure projects across Europe?

The above main question can be answered by answering the following sub questions:

1) *What are the Key Lead Indicators that can be identified from literature?*
2) *What are the Key Lead Indicators that can be identified from practice among chosen projects?*
3) *How can the identified Key Lead Indicators be measured and influenced in the future railway projects?*

Hence, each of the sub question is answered below simultaneously.

1) What are the Key Lead Indicators that can be identified from literature?

Literature shows that there is a need to enhance the management of project performance. Key lead indicators (KLIs) are substantial predictive indicators in a project that detect the possible interventions in the project outcome. They are the probable indications which when identified can be used to evaluate and act on the future project performance. Hence, the indicators were identified from the literature. Finally, the theoretical framework was established and all the KLIs from literature, their categories, and their definitions are presented in Table 22 below:

Table 22; KLIs from Literature (SQ1)

Category	KLI	Definition
Change	Design Change	Number of Changes in Clients Requirements
Communication	Communication	The precision of delivering the messages completely (or) degree of communication between all stakeholders
Client Related	Decision making	The speed with which the decisions are taken especially from clients side. (Fast/slow/no decision)
Management	Level of Experience	The level of experience of Project Personnel (High/Low)
Behaviour	Mood; Attitude; Commitment; Conflicts; Trust; Criticism	Nature of behaviour of individual stakeholders of client/contractor/supplier (Abnormal/Normal)
External	Price fluctuations	Fluctuations in the market prices of the commodities, goods and labour.
	Economic conditions	Changes in exchange rate, inflation rate, interest rate etc.
	Weather conditions	Effect of different weather conditions on the project
	Changes in Laws and Regulations	Changes in laws and regulations by the government in between the project.

2) What are the Key Lead Indicators that can be identified from practice among chosen projects?

Three inner-city rail infrastructure projects were studied: Stockholm Metro Project, North South Line Amsterdam, Vienna Main Station Project. The results of the cross-case analysis showed that all the KLIs from theory were observed in practice expect Trust, Conflicts, Criticism and Mood. These KLIs are found to be the most important KLIs. New KLIs were also observed from practice and they are: *Stakeholder Engagement, Stakeholder Benefits, Goal alignment, Transparency in Role Division* and *Project Environment*. *Stakeholder Engagement* is defined as the level of involvement and support from the stakeholders. *Stakeholder Benefits* is the number of stakeholders benefiting from the project. *Goal Alignment* is the number of stakeholders having the same mentality of achieving the common goal of the project. *Transparency in role division* is the level of clarity to the stakeholders about their role and responsibilities. *Project Environment* is specified as the level of leniency, freedom and mental safety in

the project culture. Apart from this, numerous external KLIs were also observed. The final framework of KLIs in table 23 presents the 21 KLIs identified from practice. All the 21 KLIs were grouped in 8 categories.

Table 23; KLIs from Practice (SQ2)

Category	KLI identified in both theory and practice		Category	KLI identified in practice	
Change	1.	Design Change	**(External) Stakeholder Related**	11.	Transparency in role division
Communication	2.	Communication		12.	Stakeholder Benefits
Client Related	3.	Decision making		13.	Stakeholder Engagement
Management	4.	Level of Experience		14.	Goal Alignment
(Internal) Stakeholder Behaviour	5.	Attitude	**Work Culture**	15.	Project Environment
	6.	Commitment			
External	7.	Price fluctuations	**External**	16.	Political Decisions
	8.	Economic conditions		17.	Decision Making from External parties
	9.	Weather conditions		18.	Unknown Knowns
	10.	Changes in Laws and Regulations		19.	Financial Condition of Contractors/Subcontractors
				20.	Assumptions of Clients towards Contractors
				21.	Political Stability

3) How can the identified Key Lead Indicators be measured and influenced in the future railway projects?

The following are steps to measure and influence the identified KLIs:

1) To measure *Stakeholder Engagement*: Determine if good stakeholder plan is being followed; To influence: Release management approach should be applied in the projects.

2) To measure *Stakeholder Benefits* and *Goal Alignment*: Conduct surveys on the level of satisfaction of employees with the project and its environment. To influence them: Provide flexibility in planning to incorporate their requirements and provide shared financial benefits respectively.

3) To measure *Level of experience*: Scan through profile and expertise of employees. To influence: Recruit people under surveillance of HR and project team; Hire external personnel to help in training the unexperienced.

4) To measure *Design change*: Check the *Level of Expertise* in the project team which can trigger design changes. To influence: Fix the technical framework before starting design phase; It should also be seen more as an opportunity to meet clients requirements rather than an influence on project cost and schedule.

5) To measure *Communication:* Number of interactions between the stakeholder groups should be counted. To influence: Create an open and transparent project environment; Implement strong communication plan; Assign an experienced communication director in top management.

6) To measure *Commitment* and *Attitude:* Scrum tool can be used to measure *Commitment* and *Attitude* can be measured by analysing the person's body language and way of interaction in meetings.

7) To measure *Project environment:* Count number of complaints, blames that are heard from the project personnel. To influence: Organize frequent relaxed sessions out of regular environment

8) To measure *Decision making*: Level of experience of the project personnel can be a measure. To influence: Complete relevant information should be provided to the client; Close contact with the client should be maintained.

9) To measure main *KLIs of External category*: Presence of contingency plans to adapt to political decisions, close check on weather forecast, use of governmental indicators to check market performance, thorough check on financial stability of contractors. To influence: Do not accept contractors with poor financial position; Contingency plans for weather, market prices and economic conditions, thorough preliminary surveys before start of design/construction phase.

Main Question: How can Key Lead Indicators be used to improve project performance of inner-city rail infrastructure projects across Europe?

The utilization of the concept of Key Lead Indicator in practice is hardly identified in large infrastructure projects. Hence, after understanding the subject clearly, the Key Lead Indicators are discovered in the selected inner-city rail infrastructure projects across Europe, represented in table 23. Effective use of suggestions to measure and influence them, as discussed in the previous sub question, can help to improve project performance.

This can be achieved by first, measuring the KLIs according to proposed steps that provide indication if the project's performance can deviate negatively or positively. Once this is known, the steps to influence the KLIs should be executed accordingly. This way the risk of deviation is already known at an early stage and can be controlled. Thus, the probable deviation in the project's performance can be regulated accordingly resulting in relatively healthier performance.

In conclusion, this research presents a way to improve the performance of large inner-city railway projects. It contributes to the lacking literature on performance management and performance metrics by exploring the Key lead Indicators especially in the sector of large railway infrastructure projects.

7.2. Recommendations

This section is divided into two parts. First, section 7.2.1. is dedicated to the recommendations for practice. Section 7.2.2. provides recommendations for further research.

7.2.1. Recommendations for Practice

The following key recommendation arise from the understanding of whole research and are specified for the practitioners who should take up these steps in their projects in order to gain a chance to flexibly influence the performance of the project early.

1) **Implement a thorough recruitment process**:
   Having experienced project personnel is crucial. Involve an experienced project team member in the recruitment department which can improve the process of recruitment. Before recruiting it should be made sure that both the parties get the best price and value. This evokes the satisfaction of the employees which can improve their commitment towards the project.

2) **Achieving clients requirements should be given more importance than staying within budget and schedule**:
   Design changes are inevitable in such large and complex projects. One should always embrace the design change as an opportunity to reach the project goals since at the end of the day, it's more important that you deliver something which meets the clients need rather than staying within budget and delivering on time. Hence, you must be realistic by learning these new things and finding ways to alter or adapt to the changes throughout the project.

3) **Embrace, communicate and celebrate the achievements in the project**:
   Release management approach should be used which suggests dividing the path of different phases: Design, Execution and Installation, with small milestones leading to achieve the final goal of the project. After every milestone is achieved, its success should be communicated in the project and it should be celebrated with all the stakeholders. This enhances their motivation and develops positive attitude which keeps the stakeholders engaged to strive for the success of next milestone.

4) **Empower the stakeholders:**
   Implement a strong and strategic communication plan such that it is understood by every stakeholder and promotes open communication without fear. Such a plan should empower stakeholders to communicate every small deviation openly because when there is an open mind, people can approach anytime and be updated with the right project information. This will avoid misinterpretation with regards to the actions taken in the project. Also, provide equal benefits, divide roles with transparency and possibility of shared financial bonus to the stakeholders.

5) **Focus on improving Personal Relationships:**
   Frequent changes in project environment can improve personal relationships among the stakeholders and enhancing positive work environment. Sessions should be organized outside the regular workplace, where it is more relaxed to stimulate collaboration amongst different parties. This provides independence in the environment and thus gives them time to spend quality time with each other.

7.2.2. Recommendations for Future

The research has addressed the limited availability of research on Lead indicators and ways to measure and influence them. Although, as previously mentioned, the discussion and limitations of the findings open up space for further recommendations on the academic knowledge of KLI. Following are recommendations for further scope of research:

1) More research on the KLIs leading to positive incidents. This can add value to the lack of literature on KLIs for positive aspects of a project.

2) Researching on the correlation between the identified KLIs which can help to demarcate their character strongly.

3) Identifying the KLIs based on different phases of the project which can help to control the performance of project more efficiently.

4) Researching on more concrete steps to measure the identified KLIs. As the steps provided by this research are based on the experiences of limited number of practitioners and also the nature of lead indicators which makes it harder to measure them compared to influence them.

5) Researching the influence on the project objectives when the identified KLIs are not acted upon.

6) A similar research with quantitative methodology, and a greater number of interviews can improve the generalizability of the research.

7) Researching similarly on other type of projects apart from railway projects and across more countries in Europe

8) Researching on impact of implementing the recommendations for practice of this research.

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Appendix A
EWS of Nikander

This appendix provides the detailed list of all 68 EWS from the literature of Nikander (2018) which are clustered into 11 main groups. Each EWS will also be described in the Table 24; Appendix A - Description of EWS below.

Table 24; Appendix A - Description of EWS (Nikander, 2001)

Early warnings	Percent share basic (%)	Percent share case (%)	Description
Gut feelings	4.7	2.6	Anticipatory feelings are the signals the least easy to detect, identify and interpret. intuitive feeling
Personnel, project group	38.2	21.7	
Non-verbal information	3.8	1.4	Various non-verbal messages observed in meetings are the most important signals of reference for the negotiators in meetings
Personnel behavior	15.7	14.2	A large group of various behaviors
Personnel behavior in general	2.3	4.0	'Abnormal' or inconsistent behavior of the contractor/supplier almost always means trouble for the project
Mood, attitude	1.7	4.7	A mood of non-satisfaction in the Personnel
Conflicts	2.6	3.5	Conflictive situations
Talking behind the back			Talking behind the back (unnecessary criticism)
Indecision			The organization is stalling the progress of the project
Frank talks			Lack of trust expressed in no uncertain terms
Commitment	1.7		Weak commitment to the project expressing itself in many ways
Cliques			
Authority disputes			
Making excuses			Typical to consultants, but not rare for contractors either
Lack of contact with the client			A phenomenon specific to each project
Unrealistic Planning			When it becomes obvious that Planning cannot meet all the requirements
Lack of resources		3.1	A lack of working staff noticed
Changes in Personnel			A "phenomenon" especially common to consultants; changes in project Personnel
Professional skills			The professional and project-related skills of Personnel
Project manager, management	1.2	8.3	
Project manager as a person			The personal qualities of the project manager
Management style		6.1	
Project planning	4.5	13.0	
Preliminary plans		3.8	The level and quality of preliminary plans
Project plans			Inadequacies in project plans
Tender material			Deficiencies and insufficiencies in tender material
Contract		5.7	A contract drawn up unprofessionally or unambiguously
Contract with issues			A contract consciously drawn up to have little room for changes
Budgeting, budget contents			The budget has been poorly drawn up, the basis is insufficient and the budget is undersized
Advance material			Reference material
Project control and reporting	6.8	5.0	
Progress control	3.1	3.5	Classical schedule-based monitoring of progress
Monitoring	2.8	1.4	Classical methods of project activity
Monitoring in general			
Availability of materials			The contractor's (or the supplier's) ability to acquire materials
Working level, quality and speed			Speed and quality of work at the site
Budget corrections			Tendencies to change the budget without proper reason
Working within the project	7.7	10.4	
Work initiation	3.5	0.7	The efficiency of initiating work, its sluggishness is often revealing
Mobilization			Mobilization at the work site, slow initiation of work, and/or poor turnout at the site
Initial information/lack of information	3.0	6.9	Lack of initial information for Planning, their being late is very typical in projects
Same things repeatedly			If the same things come up again and again in meetings etc
Organization type		2.4	
Communication	7.8	5.2	
Communication	4.9	2.6	
General miscommunication			Messages lost along the way
Tone of messages			The tone of messages, especially when it changes, suggests that something has happened

Early warnings	Percent share basic (%)	Percent share case (%)	Description
Letters			Writing letters
Conflicting knowledge			Conflictive information
Insinuation	3.0	2.6	Many problems detected due to insinuation. People are not willing to say things straight out
Expressed by parties	8.9	9.2	
Typical to client	7.1	9.2	
No decisions	2.6	4.0	Delayed decisions, especially those caused by the client, is one of the worst factors causing problems in projects
Trust disappears			A third party notices the problem
End users		2.4	Late recruitment of production Personnel (staff)
Freezings			The "no decisions" group also includes not being able to "freeze" the design principles
CEO			No support from the company CEO for the project
Additional research			Very typical during a brand tendering phase
Procurement			Matters relating to procurement, delays etc
Supplier/Contractor	1.7		
Advance billing			Willingness for advance billing may be manifest already as Planning factors in negotiations or as a request for change
Documents	11.0	9.9	
Reporting	2.6		Quality, tone and lateness of reports are revealing factors
Schedules: level/quality/receiving	5.4	4.3	
Symmetry Being logical			The level of the schedules can be estimated on the basis of the "symmetry" and readability
Receiving/Level			How quickly a contractor will deliver schedules after reaching an agreement
Technical plans		4.3	Changes in plans, especially when there are lots of them, become warning signals
Incorrect revisions			Old drawings turning up at the site is a sign of communications problems
Responsibilities unclear			This situation relates to organizational problems
Differences and deficiencies in project culture	4.0	9.2	
First contact (to client)			First impression and the observations in first contact between parties are a good source for signals in the opinion of the interviewees
First impression			Observations made during meetings with the client
Project terminology			Differences in project terminology or low proficiency in the terminology reveal inexperience with projects
Lack of experience		3.8	Inexperience is revealed quickly and in many ways
American culture		2.6	A phenomenon specific to each project
External source	2.4	1.2	External sources; insinuation, may include unambiguous numerical data
No early warnings obtained	2.8	0.5	It is difficult to observe early warnings
Small groups and scattered signals		3.8	
Total	100	100	

Appendix B
Interview Questions

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Table 25; Interviewee Details

Case	Interviewee Name	Role	Organization
C1	*Mr. Riggert Anderson*	*Chief Executive Director*	*FUT*
	Mr. Stefan Persson	*Manager of Authority Processes; Director of Planning*	*FUT*
C2	*Mr. Pelle de Wit*	*Project Leader; Commissioning Manager*	*AT Osborne*
	Mr. Gerard Scheffran	*Project Manager; Construction Director; Commissioning Manager*	*AT Osborne*
C3	*Mr. Sigi Herzog*	*Project Coordinator*	*OBB*
	Mr. Karl-Johann Hartig	*Head of Railway department; Project Manager*	*OBB*

Part 1: Experience (10 min)

1. Can you tell us more about your role in the project?

2. How many years of Experience do you have with this role?

3. In which phases did you work in this project?

B: KLIs for Events (35 min)

Selected events of the project will be mentioned. While interrogating on each of these events, link the indicators to it during the interrogation. If not mentioned, ask for it directly or indirectly.

Positive Event

4. What were the challenges which led to this event?

5. What went right in this case and how did it result?

6. Remembering the course of the project, what were the first indicators that could possibly predict solutions which led to this event?

7. Were there any External factors which were out of control of the management team?

8. How did these External factors influence this event?

9. Which human behaviours could have been significant that would have led to this event?

Negative Event

10. What were the challenges which led to this event?

11. What went wrong in this case and how did it result?

12. Remembering the course of the project, what were the first indicators that could possibly predict problems which led to this event?

13. Were there any External factors which were out of control of the management team?

14. How did these External factors influence this event?

15. Which human behaviours could have been significant that would have led to this event?

C: KLIs of Literature (40 min)

Disclosing each KLIs of Literature. Enquiring the importance of each KLIs in general and in case specific. Interrogating if each KLIs was identified in the project and how they were used. Suggestions on usage of each KLI for future projects and its influence.

16. Do you think this KLI is important in any project? Why?

17. Do you think this KLI was important for this Project?

    a) If yes, was it identified?

    b) If no, why?

18. If this KLI was identified in the project, was there any reaction taken?

    a) If yes, how was it acted upon?

    b) If no, why and how should it have been used?

19. How can this identified KLIs be used in future projects?

    a) What can be done by using it in a better way?

    b) From your perspective, how can it influence the project?

D: Closure (5 min)

20. What did I forget to ask?

21. What do you take from this interview? (Did it help you?)

22. Is there anything else you would like to share?

Appendix C
Expert Consultation Meeting

Table 26; Expert Panel

Expert Name	Role	Organization
Mr. Rudolf Rijkens	*Consultant*	*AT Osborne*
Mr. Alex Miggelenbrink	*Consultant*	*AT Osborne*
Ms. Sandra Brouwer	*Consultant*	*AT Osborne*
Mr. Mark Roelofsen	*Consultant*	*AT Osborne*

The table 27 below lists out all the steps to measure and influence the identified KLIs. The KLIs name is marked in Red coloured rows. If there is "(E)" mentioned next to the name of KLI, it indicates that it is an external KLI.

Table 27; Measuring and Influencing the KLIs

KLIs
Stakeholder Engagement
To Measure 1. Check if a good stakeholder management plan is being followed which involves personal engagement, good structure and promotes dialogue. 2. Frequent surveys should be carried out in the project organization where people are asked about their feelings of being involved in the project. It can show if people are "Proud" to be a part of the project or if they are "unsatisfied" with it. This can also speak very much about the project environment. 3. At a personal level, surveys should be carried out to know if the employees are satisfied with their own progress and goals. This can show the motivation of the group or their efforts that are being put into the project. **To Influence** 1. Involve stakeholders on time and frequently when they still can influence and add value to the project. 2. Promote activities for empowerment of stakeholders and fun activities which can promote team building and collaboration. 3. Make clear and transparent agreements and contracts in person with the stakeholders. 4. Use of Release management approach by dividing the path of Execution and Installation phases with small milestones leading to achieve the final goal of the project. After every milestone is achieved, its success should be communicated in the project and it should be celebrated with all the stakeholders. This enhances their motivation and develops positive attitude towards the project to strive for the success of next milestone.
Stakeholder Benefits
To Measure 1. By frequently checking the stakeholder's stake in the project and the value he is achieving. 2. The level of urgency or need of the project can talk much about whom it does benefit. 3. Checking the satisfaction levels of the client before thought out the project. **To Influence** 1. The project should be taken forward if every stakeholder is benefitting else it can raise conflicts in the project. 2. Frequent meetings with stakeholders to discuss their role in the project can provide ideas to influence their benefit or stake out of the project. 3. If there is/are stakeholder which doesn't benefit much from the planned project, flexibility in the planning should be provided so that somethings can be added which can benefit both the project and the stakeholder on the cost of increased scope.
Transparency in role division
To Measure 1. Frequently checking the organizational chart, if there are clear roles and responsibilities, mandates about who can make the decisions. Once this is checked, most important, evaluate if people obey this chart.

KLIs
To Influence 1. Prefixed written agreements in place before starting off the project so that if there is any discrepancy or lack of clarity, the document can be referred and adapted.
Commonality of goals
To Measure 1. Frequent interaction with all stakeholders to know their vision. If the vision is common, it indicates that all the stakeholders have a common goal. 2. Opportunities included for each stakeholder which are to be decided in early phases of the project. **To Influence** 1. The contractual arrangements should include provision for shared financial rewards/bonuses on achieving the milestones. Shared bonus system drives combined efforts amongst different parties hence keeping them motivated to achieve the goal of the project (i2.1)
Level of Experience
To Measure 1. Thoroughness of the recruitment process is a direct measure for Level of Experience. 2. Checking the profile of employees involved in the project. This includes their experience by number of years in practice, educational background, past achievements in the field of their role. **To Influence** 1. The hiring team should involve the project team while recruiting, it can improve the level of experience of people that are being hired. 2. To be careful in the procurement phase by making sure that both the parties get the best price and value. 3. Checking the experience of the contractors before hiring them based on their past performances can influence the level of experience. 4. Hiring more experienced person for a limited time who can train the project managers from the clients side, who generally tend to lack experience in complex projects, but still are a part of it because since are appointed from the client. It will influence the number of avoidable failures in the project. 5. Hiring external personnel or outsourcing the work if necessary, i.e., if in case there are less experienced people in the team (i.2.2, i3.2)
Commitment
To Measure 1. Use of scrum tool in the project organization reflecting every individual's task to be achieved/achieving/achieved in parallel to the allotted time frame for each task can help to see if the employee is actively achieving the tasks in the given time. This reflects the level of commitment in each individual. However, this doesn't guarantee if the person is really guaranteed. Commitment is really soft and integral part of a human. Being a soft factor, makes it hard to be measured. **To Influence** 1. As discussed earlier, Use of Release Management
Attitude
To Measure 1. Personal attitude is reflected by body language, way of speaking in the project meetings. **To Influence** 1. It is believed that changing or influencing one's attitude is rather difficult than measuring it. If there is a lack of attitude towards the project, it reflects the lack of interest of a person. Personal interaction with the person to know the reason behind that attitude is the first step which can guide to take further steps to improve the attitude. If the further steps are not possible, its good to replace the person which can be beneficial for both the project to evolve and the person's interest.

KLIs
Design Change
To Measure 1. The expert meet suggested changes in design can be measured by counting the number of unexpected and major changes. This excludes the changes which are initiated from the innovators state of art. This way the measure helps to understand if there is any action needed to be taken to influence the occurrence of design change in future. Also, the measures listed below can act as a cautionary measures before design changes. 2. It has been observed frequently that design change is an LI led by the KLI of Lack of Experience. Hence, it's quite clear that when there is a lack of experience with different project phases, there are most probable chances of design changes. 3. Complexity of the planning phase, for instance: producing different designs for different stakeholders which can be complex, complexity of project itself is also a measure of design changes. 4. Number of stakeholders can be a measure since if there are a greater number of stakeholders, it surely comes with more requirements and hence leading to design changes. **To Influence** 1. From the experience of different interviewees, it suggested that having people with experience in different phases of project can help to influence on design the design changes. Hence, hiring at least one highly experienced person for one or more phases who can lead the team throughout that phase can be an influencing factor. 2. In a classical view of project management, changes are bad things. But, in complex projects changes are inevitable. One should always embrace the design change as an opportunity to reach the project goals since at the end of the day, it's more important that you deliver something which meets the clients need rather than staying within budget and delivering in time (i2.2). Hence, one must be realistic by learning these new things and find ways to alter or adapt to the changes coming throughout the project. 3. The client should also work closely with the contractors, from the experience of the North South Line Project. 4. Completeness of the technical framework before starting design phase can influence the existence of probable major design changes in later phases of the project.
Communication
To Measure 1. Measuring the frequency of interaction between the stakeholder groups can provide the precision of communication in the project. 2. Measuring the percentage of consensus when decisions are being made can tell about how well the project information is being communicated to different individuals of the organization. **To Influence** 1. Making and following a time schedule of open meetings between different stakeholders to discuss: What is achieved, what are the problems, what is the way forward etc. which can help to keep the project organization clearly and completely informed (i3.2). 2. Implement a strong and strategic communication plan which is understood by every stakeholder. Such a plan should empower stakeholders to communicate every small deviation openly because when there is an open mind, people can anytime approach one to be updated with the right project information. This will avoid misinterpretation with regards to the actions taken in the project. 3. Ensure experienced communication staff is hired, especially the director of communication, who should be a part of the top management (i1.1). 4. Update correct and necessary information on the project website like what is being doing; how the public living near to the construction site can react if they experience something wrong. This can avoid lack of communication with the public.

KLIs
5. Conduct meetings in-person with the nearby residents and public to discuss about the planning process, about what exactly is being building, how it will be affecting them and the environment. This creates transparency and enhances communication with end-users.
Project Environment
To Measure 1. When stakeholders are complaining or blaming each other consistently, it depicts that there is somewhere a lack of trust or collaboration between them. Hence, constant observation off complaints or blames related to stakeholders says a lot about the project environment since the environment might not be supportive for their collaboration (i2.2). When it is observed that people can work with fun, it's an indication of positive side of this KLI. **To Influence** 1. Hiring a special team with a sole purpose of identifying and analysing the project work culture. Because, for instance observations of conflicts and blames might not be recognizable by a normal person who might be working towards achieving his own goals. This team should be involved in the meetings and across the coffee machines where there are more chances to notice what the people think about the work culture, 2. Frequent sessions should be organized outside the regular workplace, where it is more relaxed to stimulate collaboration between different parties. This gives them time to spend quality time with each other,
Decision Making
To Measure 1. It is observed that slowness in decision making was an LI led by the KLI of Lack of Experience. Hence, the level of experience in the project organization is a measure to identify the speed of decision making. 2. The following aspects also help to measure the slowness of decision making in the project: Fear of Negative Consequences; No clear mandates; Formal governance; Insufficient funds; Underperformance of contractors etc. If analysed these factors, all of them contribute to slower the process of decision making. Nevertheless, the opposite of these factors can fasten the process. Hence, these are also a few measure of Decision Making. **To Influence** 1. Decisions that needs to be taken from client's side (Public body) might sometimes take time. Hence, being in close contact with the client can make sure that the necessary decisions are handled speedily (i1.1). 2. Sometimes, there might be reasons behind the slow decision like for example: to make substantial decision; or when there is a lack of information provided. Sometimes a no decision is also a wise decision (i2.1). So, decision making is important but sometimes it is just a part of how the client is involved in the project; So, provision of complete and relevant information plays a major role to influence decision making. 3. The clients should be confronted with examples, stories, lessons learnt (eg. With respect to past projects) that can affect the project in monetary terms or in terms of schedule depending on the speed of decision making. This alerts the client about the necessity of Decision Making. 4. In advance, a clear and well-prepared decision-making process should be planned. Enough budget and time should be available as a contingency. 5. The client should be informed early about what kind of decisions must be taken. As early as it is informed, it can be consequently planned in their agenda, which is a key to influence decision making process.
Political Decision
To Measure 1. The satisfaction level of the client with the decision should be checked. **To Influence**

KLIs
1. Political decisions cannot be influenced much. Although, contingency plans can be made to adapt the project to those decisions. 2. The politician must be truth fully confronted early with the expected consequences of their decisions.
Decision making from external parties
To Measure 1. It's important to have a note of number of parties that may influence the speed of decision process/ by not making decision soon. 2. Count the number of decisions that each party must make. **To Influence** 1. Planning the appointments far ahead of decision making with the external parties would make them feel important and responsible towards the execution of decision. It can influence the speed of decision making. 2. Although they are not a part of the stakeholders, investing in the external parties and keeping them engaged with project would give them a sense of responsibility.
Unknown Knowns
To Measure 1. Questionnaires for each key function in the senior management that measures the relationships between the level of awareness and project outcomes. 2. The depth of surveys (technical, organizational) being carried out can measure the possibility of knowing unexpected things. **To Influence** 1. There is not much that can be done when something that should have been know was identified later. Investment of money and time in identifying these unknows would be on suggestion. 2. To make a thorough and good planning. 3. Strict measures to carry out thorough ground surveys, as observed in the case of Stockholm metro project.
Weather Conditions
To Measure 1. Keep a close check on the weather forecast and warnings. It also depends on the type of project which you are working on. For example, if it's an underground subway construction then the weather conditions wouldn't matter much. If it's a project in an open environment, then you should follow the weather conditions closely. **To Influence** 1. Make sure that the schedule is planned correctly according to the weather forecasts to mitigate any risk. 2. It can't be completely influenced but it can be mitigated by taking it into account in quantitative risk matrix
Price Fluctuations
To Measure 1. Identify the goods or commodities needed for the activities of the project which can have the greatest impact on the project if the prices of them fluctuate. Measure the price fluctuations of those activities similarly. **To Influence** 1. Forecast the fluctuations and make reservations in the budget. Take care that the prices are estimated for a longer period and be careful with the stakes of the contractor. 2. For projects having long durations, price fluctuations are inevitable. Sometimes, you just need to accept this change and adapt to it.
Economic conditions

KLIs
To Measure 1. Since such large infrastructure projects are owned by the public bodies who are the clients of the project, governmental indicators about the market performance and industry performance can be used to measure the economic conditions. **To Influence** 1. Creating fall back options for the project like: Postponing the project; Reducing the scope; Finding additional budget sources.
Changes in Laws and Regulations
To Measure 1. It can be measure by observing the level of political stability in the country. 2. Major events across EU can be an aspect to measure changes in laws and regulations. Although, cooperation between countries across EU leads to the unification of laws and regulations across Europe. **To Influence** 1. Nothing can be influenced on the sudden changes in laws and regulations
Financial condition of Contractors/Subcontractors(E)
To Measure 1. Studying the history of project portfolio of the contractor and their risk appetite can give an indication about their capability to handle large infrastructure projects. 2. Keep a check on their financial performance or yearly reports or stock prices (if they are a listed company). 3. Checking if the contractors have availability for bank guarantee. **To Influence** 1. Do not accept contractors with a bad position in contracting process, if they have quoted a very less amount. 2. Avoiding hiring of contractors with opportunistic behaviour. 3. Fair division of risks should be taken up based on the financial capacity of the contractor.
Political Stability(E)
To Measure 1. Looking at the history, measuring the number of elections that caused a changes in the project objective which would have resulted in a different project outcome will picturize the scenario of the political stability related to such large infrastructure projects **To Influence** 1. Elections should be considered to make the schedule of the project. 2. Decisions should be taken prior to the elections to adapt in early phase to the possible elections outcomes. 3. Efforts should be put to perform a thorough stakeholder management.