Risk Management and Measurement of Risk Management Performance in Complex Projects
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ABSTRACT

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Abstract

In today’s technologically advanced world, every project, especially large, complex projects are very prone to facing different kinds of risks throughout the project timeline. Project complexity plays a major role in the emergence of numerous risks in large projects. In addition, the complexity of projects is on the rise due to various unanticipated characteristics such as, sudden natural phenomena, workplace accidents, increased material costs, etc. Nowadays, project complexity and its corresponding risks are major contributors to project failure. To minimize the impacts of risk, a good and effective risk management (RM) system must be incorporated into every project. An effective RM system should also include the assessment and measurement of its performance, as this can provide real-time updates about its progress, which in turn can be used to make the RM system more effective and efficient.

The aim of this thesis is to gain an insight into risk management literature in the field of complex projects, along with understanding of project complexity and the importance of measuring RM performance. In first part of this research, an in-depth review of literature concerning project complexity, project RM and measurement of RM performance is presented. This is then analyzed and validated using two case projects as examples. The literature review covers how a project can develop complexity, its underlying managerial actions, the type of risks different complex projects may face, their management plan and finally, the effectiveness of measuring RM performance. Following this, a qualitative case study method is followed, whereby two case projects are analyzed in order to gain insights into their RM and risk performance management procedures.

The empirical analysis and findings of this thesis focus on the importance of RM for complex projects. Through the analysis and discussion, major risks faced by complex construction project, management strategies to mitigate them, RM performance evaluation strategies and the impact of alliance contracting in RM can be understood thoroughly. Overall, this research provides an in-depth overview of project complexity, RM and its performance measurement for large complex projects and it can be used as a basis for further research into RM perspectives in complex projects.

Additional Information

Keywords: Risk Management, RM Performance Measurement, Complex Projects, Project Complexity
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During the Risk Management and Advanced Course in Project Management courses, I became interested in risk management and through the practical case studies during this thesis, I was able to gain more insights into this field.

I am deeply grateful to my thesis supervisor Asst. Prof. Kirsi Aaaltonen for all the discussions and ideas during this thesis work. Kirsi, was really helpful and friendly all the time, which made my task much easier. I would also like to express my gratitude to Prof. Jakko Kujala as my thesis reviewer and to Eija Vieri and Jukka Majava for all support with academic matters. I would like to thank specially Mr. Mauri Mäkiaho from Rantatunneli project and Mr. Toni Hytonen from Tampere Tramway project, who gave me the opportunity to do my empirical analysis on these two projects.

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1 Introduction

This chapter introduces the background to this research, along with its objectives, research questions, research scope and structure.

1.1 Background of the Study

Risk management is a very known concept nowadays in industry. In recent years, intense research has been conducted on the field of project risk management (RM). Project RM is considered one of the most important and critical factors in the ten areas of project management listed in the PMBOK Guide, alongside integration management, scope management, time management, cost management, quality management, human resource management, communication management, procurement management and stakeholder management (Project Management Institute, 2016). According to Voetsch et al., (2004), there is significant relationship between the risk managing approach of a business’ management and the project’s success. In the modern and rapidly changing business world, companies have wide access to resources and tend to seek the cheapest and most efficient solution. Many companies focus solely on a core business which makes use of subcontracting via a third party. Thus, companies try to form alliances with other partners on a single project, in order to improve its efficiency and success. However, this typically increases the complexity of the project, as its network grows. Thus, based on these organizational changes and the external environment, many uncertain situations emerge, which in turn make organizations and projects more vulnerable to risk. According to Acharyya (2008), every business function is associated with risk, and this risk can affect the business to a large extent. Besides that, due to the advancement of technology, companies’ expectations of projects have increased significantly. This greater expectation brings additional challenges and as the project becomes more complex, the probability of exposure to risk also increases. This project complexity is the most crucial factor which significantly increases the likelihood of facing risk during the project. Thus, maintaining and efficiently utilising a proper RM system increases the probability of the project’s success.

The RM strategy can improve the likelihood of the project’s success, but it is equally important to maintain measurements of the RM system’s performance on a regular basis. Usually, a company takes various initiatives in order to identify the risk and different
corrective measures to solve them, but often they fail to invest enough resources into monitoring the RM strategy’s effectiveness during the progress of a project (Basova and Mitselsky, 2011). Without proper evaluation of RM, an organization is unable to track the progress of the risk mitigation, which in turn can contribute to a project unsuccessfulness. Thus, it is very crucial to identify the risks, a proper way to manage them and finally, effectively measure management performance properly during a project. It is important that both RM and measurement of RM performance are linked together in any complex project.

1.2 Research Objectives & Research Questions

This research aims to gain an insight into the RM of complex projects and effective ways in which to evaluate RM performance.

In order to achieve this, three research questions were formulated:
RQ1: By what means can project complexity be effectively evaluated?
RQ2: What is the importance of measuring RM performance in complex projects?
RQ3: How can RM performance be most effectively evaluated in complex projects?

The first research question focuses on measuring project complexity and its underlying causes and subsequent impact on the project. The second research question focuses particularly on the evaluation of RM performance and its importance for complex projects. The third research question analyses the different method and ways of measuring project RM performance.

1.3 Scope and Structure of the Research

This study mainly focuses on RM and evaluation of RM performance regarding complex projects. Specifically, this study focuses on identifying different risks and their subsequent impacts associated with complex projects and approaches to mitigate them. This study also places emphasis on RM performance evaluation through analyzing different techniques and tools. Another focus of this research is to analyze two practical complex case projects based on their RM strategies and their performance evaluation.
Figure 1. Research structure.
2 Literature Review

A literature review is fundamentally important in a research project in order to identify any previous research on similar topics and to gain understanding of the field’s recent development. As part of this research, a comprehensive literature review has been undertaken in order to understand project RM, along with RM performance measurement and its impact on complex projects.

2.1 Project Complexity

“Complexity” is a difficult term to define and there has been a long-ongoing debate over how best to define it. As many scientists fail to clearly define “complexity” (Johnson, 2006), it is difficult to give a concise definition here. Complexity can arise when there are variations and frequent chaos. In the context of a project, it is very difficult to definitively determine when this uncertainty and chaos arises. With increasing frequencies of variations and chaos, projects may become more complex day by day. An example of a field which is particularly prone to complexity and risk is the construction industry. This industry is typically in a disadvantaged state, in terms of dealing with the variation and chaos that can arise (Baccarini, 1996). Thus, knowledge about project complexity and ways of dealing with it in different situations are particularly important in impacting project success. Mills (2001) supported Baccarini’s statement by claiming that construction projects are amongst the most volatile and challenging project types and suffer from negative feedback concerning failure to deal with different challenges. These include missed deadlines, budget overrun, scheduling problems etc. This statement is supported by Mulholland and Christian (1999), who add that the construction business exists in complex and vigorous surroundings with the challenge of facing of various risks and uncertainties, which might result in project scheduling issues and costs constraints. Another publication by Bertelsen (2003) states that the construction business is usually thought of as being a linear system which it is managed and organized easily through good planning. However, the high rate of failure of construction projects to keep to their planned time and budget illustrates that the nature of the industry is volatile and unpredictable. Therefore, Bertelsen (2003) views construction projects as being highly complex and nonlinear, from which the development of chaos is inevitable.
Baccarini (1996) stated that “project complexity subsists different interconnected parts which can be managed with differentiation and interdependency”. According to the author, this definition of project complexity can be applied to any dimension of a project and it is important to declare the type of complexity of an issue when utilising the term “project complexity” in order to understand the context. Baccarini (1996) stated that there are two notable types of project complexity: organizational and technological. Baccarini suggested emphasizing the concept of project complexity and its subsequent impact as project develops complexity.

Williams (1999) referred to organizational and technological complexity (Baccarini, 1996) as “Structural Complexity”. Williams expressed the concept of “Structural Complexity” as maintaining a relationship between differentiation and interdependency. This definition can be applied to multiple project types, regardless of field. There are three types of interdependency; pooled, sequential and reciprocal (Williams, 1999; Thompson, 1967). In pooled structural complexity or interdependency, different departments of the organization generally work independently from one another, but each provides small, individual contributions, each of which acts as a part of the wider solution. In sequential interdependencies, one department’s output is used as another department’s input in the model. In reciprocal interdependencies are similar to sequential ones, with the output of one department used toward the input of another, but this model contains cyclical characteristics. These are the most critical and complex to manage, as one department’s performance can significantly affect others. Later, Williams (1999) added “Uncertainty” as another component of complexity. According to him, “Uncertainty and Structural Complexity” are the most critical components which can make the overall project situation very complex and chaotic. Due to this uncertainty, project interdependencies may increase, leading projects to encounter even greater complexity. In order to minimize the effects of uncertainty, the project manager may try to change the goal(s) & project action plan. These modifications to the action plan can then in turn result in increased project complexity two principal areas; the project’s structural complexity and product complexity (Williams, 1999).

Based on the literature concerning “Uncertainty & Structural Complexity”, Gerald & Albrecht (2007) defined three new terms of complexity; faith, fact and interaction. “Faith” complexity mainly relates to the complexity generated by new and innovative creation,
problem solving along with high uncertainty. “Fact” complexity is related to the complexity arising from personnel’s lack of time or other resources in terms of analyzing large amounts of interdependent and interrelated data, thus needing to make decisions with a degree of uncertainty. “Interaction” complexity is related and has effects on both Faith and Fact complexities.

Wood & Gidado (2008) cited Gidado (1996) in their interview on project complexity conducted with experts on the construction industry. According to the outcome of the interviews about project complexity, projects may be summarized as follows:

- Projects in which a high number of systems are required to be synchronized with one another, with many interfaces between them,
- Projects in which many different complexities exist, making it difficult to achieve the project’s target or approach the action plan effectively,
- Projects in which the execution of the project action plan requires consists of a large number of details,
- Projects in which the involvement of many stakeholders is required, along with intensive monitoring and coordination of personnel throughout the project.

Based on the outcome of these interviews with construction industry experts, Gidado (1996) depicted two perspectives of project complexity: the managerial perspective and the operative and technological perspective. In the managerial perspective, different parts of the work are planned and integrated throughout the project, whereas in the operative and technological perspective, different technical difficulties that are being faced in terms of integrating the work into the project are considered. Gidado (1996) also proposed two sources of project complexity which have an impact on the project. He named these sources of complexity as Categories A & B. In category A, complexity is created by components of individual tasks relating to resources, whereas in category B, complexity is created by the different parts that are required to make the project’s workflow.

Therefore, it may be said that complexity is created through many different channels which combine to create chaos in the project. As a project become increasingly complex, it is exposed to greater risks and can potentially become highly vulnerable. This increased
probability of risk typically continues to increase during the project’s life cycle. The literature concerning project complexity indicates that the success or failure rate of any project largely depends upon the degree of project complexity.

2.1.1 Characteristics of Complex Project
A complex project basically consists of several elements along with a large number of stakeholders. A large or “mega” project may also be called a “complex project”, due to its large number of elements and the involvement of multiple. Flyvbjerg (2002) wrote that mega projects require “very large investment”. He also added that a mega project may, for example, be a “multibillion-dollar large infrastructure project” (Flyvbjerg, 2002). Javad et al. (2016) cited Boardman and Sauser (2006), Cicmil (1997) and Vidal et al. (2011a) and explained that the differences between simple and complex projects are dependent upon context, autonomy, belonging, connectivity, diversity, emergence and size. These are summarized in Table 1.

Table 1: Drivers of simple and complex projects (Javad et al., 2016)

<table>
<thead>
<tr>
<th>Factors</th>
<th>Simple Project</th>
<th>Complex Project</th>
</tr>
</thead>
<tbody>
<tr>
<td>Context</td>
<td>Directed</td>
<td>Chaotic</td>
</tr>
<tr>
<td>Autonomy</td>
<td>Conformance</td>
<td>Independence</td>
</tr>
<tr>
<td>Belonging</td>
<td>Centralization</td>
<td>Decentralization</td>
</tr>
<tr>
<td>Connectivity</td>
<td>Platform-centric</td>
<td>Network-centric</td>
</tr>
<tr>
<td>Diversity</td>
<td>Homogeneous</td>
<td>Heterogeneous</td>
</tr>
<tr>
<td>Emergence</td>
<td>Foreseen</td>
<td>Indeterminable</td>
</tr>
<tr>
<td>Size</td>
<td>Small</td>
<td>Large</td>
</tr>
</tbody>
</table>

According to Javad et al. (2016), the environment of and the expectation from complex projects can fluctuate and change continuously. Complex projects have some shared characteristics with simple projects, such as specific goal(s), timeline and budget. However, in addition to these common characteristics, complex projects also typically require a large amount of investment, highly advanced technology, a large number of stakeholders and/or a lengthy construction period, etc. (Baccarini, 1996). These large projects usually consist of
several project subcategories which are managed separately. The larger a project is and the larger its management, the more complex a project becomes. If a project is large, then its underlying technology typically has more advanced features and project management become more complicated. These types of projects have a greater probability of being exposed to different risks in their life cycles.

Hass et al. (2010) presented project complexity characteristics as depicted in Table 2 below, by comparing low, medium and high complexity in terms of project size, cost, uncertainty, etc.

Table 2. Project complexity framework (Adapted from Hass et al., 2010)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Low Complexity</th>
<th>Medium Complexity</th>
<th>High Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time/Cost</td>
<td>&lt;3 months</td>
<td>3-6 months</td>
<td>&gt;6 months</td>
</tr>
<tr>
<td></td>
<td>&lt;$250K</td>
<td>$250-750K</td>
<td>&gt;$750K</td>
</tr>
<tr>
<td>Team Size</td>
<td>3-4</td>
<td>5-10</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Team Composition and Performance</td>
<td>Strong project leadership</td>
<td>Competent project leadership</td>
<td>Project manager is not experienced in leadership</td>
</tr>
<tr>
<td></td>
<td>Internal team</td>
<td>Internal and External resources team</td>
<td>Complex team structure with various competencies</td>
</tr>
<tr>
<td>Urgency and Flexibility of Cost, Time and Scope</td>
<td>Minimized scope</td>
<td>Little flexibility in schedule and budget</td>
<td>Over ambitious scope and schedule</td>
</tr>
<tr>
<td></td>
<td>Small milestones</td>
<td>Achievable scope and milestones</td>
<td>Schedule is strictly fixed</td>
</tr>
<tr>
<td></td>
<td>Flexible schedule, budget</td>
<td>No flexibility in budget and scope</td>
<td></td>
</tr>
<tr>
<td>Clarity of Problem,</td>
<td>Smooth business objective</td>
<td>Defined business</td>
<td>Unclear business</td>
</tr>
<tr>
<td>Opportunity and Solution</td>
<td>Easily understandable problem, opportunity</td>
<td>objective</td>
<td>Objective</td>
</tr>
<tr>
<td>----------------------------------</td>
<td>---------------------------------------------</td>
<td>-----------</td>
<td>-----------</td>
</tr>
<tr>
<td>Problem &amp; opportunity is undefined</td>
<td>Partially defined</td>
<td>Problem &amp; opportunity is undefined</td>
<td></td>
</tr>
<tr>
<td>Requirements, Volatility and Risk</td>
<td>Strong customer support</td>
<td>Moderate customer support</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Requirements are understood, straightforward and stable</td>
<td>Requirements are understood, but changeable</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Modestly complex functionality</td>
<td></td>
</tr>
<tr>
<td>Strategic Importance, Political Implications, Multiple Stakeholders</td>
<td>Straight executive support</td>
<td>Adequate executive support</td>
<td></td>
</tr>
<tr>
<td></td>
<td>No political implications</td>
<td>Minor political implications</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Straightforward communication</td>
<td>2-3 stakeholder group</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Multiple stakeholder group with conflicting expectations</td>
<td></td>
</tr>
<tr>
<td>Level of Organizational Change</td>
<td>Impacts a single business unit, one familiar business process, and one IT system</td>
<td>Impacts 2-3 somewhat familiar business units, processes and IT system</td>
<td></td>
</tr>
<tr>
<td>Level of Commercial Change</td>
<td>Minor changes to existing to existing commercial</td>
<td>Enhancements to existing commercial practices</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Groundbreaking commercial</td>
<td></td>
</tr>
<tr>
<td></td>
<td>practices</td>
<td>practices</td>
<td>practices</td>
</tr>
<tr>
<td>--------------------------------</td>
<td>--------------------------------</td>
<td>--------------------------------</td>
<td>--------------------------------</td>
</tr>
<tr>
<td>Risks, Dependencies and</td>
<td>Considered low risk</td>
<td>Considered moderate risk</td>
<td>Considered high risk</td>
</tr>
<tr>
<td>External Constraints</td>
<td>Some external influences</td>
<td>Some project objectives</td>
<td>Overall project success largely</td>
</tr>
<tr>
<td></td>
<td></td>
<td>are dependent on external</td>
<td>depends on external factors</td>
</tr>
<tr>
<td>Level of IT Complexity</td>
<td>IT complexity are low</td>
<td>IT complexity are moderate</td>
<td>IT complexity and legacy</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>integration are high</td>
</tr>
</tbody>
</table>

From this differentiation between projects with low, moderate and high natural complexity (Hass et al. 2010), it is clear that a project can become complex via many different factors, varying from cost and team size, to external factors, organizational change, etc. As the number of factors with uncertainty and the number of stakeholders engaged in the project increase, there is a high probability of a complex project becoming exposed to high levels of risk.

Turbulence is another important characteristic of project complexity. Nowadays, project environments tend to experience turbulence continuously, making them more complex in nature. Miller & Lessard (2000) depicted two sources of turbulence: exogenous events and endogenous events. Exogenous events are typically external factors, such as natural calamities, political instability, etc. and are somewhat uncontrollable by the project management team or the organization’s board. Endogenous events tend to evolve within the organization or project team, such as conflict within the team, broken alliances, etc. Both types of turbulence have major negative consequences and make the project more complex. Miller and Lessard (2000) developed approaches through which they analyzed the ways in which risk arises within a project, in context of turbulence. They expressed that risk may arise at any time during the project and that risk may occur as “strategic surprise risk” or as “anticipated risk”, which is foreseen by project managers as having a significant probability of occurring. These types of risks can have a large impact on the project and can hinder its success.
Project complexity also arises from the perspective of the project’s network. A project becomes increasingly complex as the number of stakeholders engaged as active parties increases. A complex and large project typically has a large number of stakeholders occupying various roles and depending on the relationships of these stakeholders, many risks and uncertainties arise suddenly during the course of the project. In the context of project network, Artto and Kujala (2008) depicted a project business network framework in which they created relationships within a firm and within projects. In their framework, a single firm may participate either in a single project or in several, or multiple firms may participate together in a single project or in multiple projects.

<table>
<thead>
<tr>
<th>Management of a Project</th>
<th>Management of a Project Network</th>
</tr>
</thead>
<tbody>
<tr>
<td>Management of a project-based firm</td>
<td>Management of a business network</td>
</tr>
</tbody>
</table>

Figure 2. Project business framework (Artto & Kujala, 2008).

According to the Artto & Kujala (2008) framework, when multiple firms participate in a single project, that project is large and complex and includes many risks. The stakeholders associated in a project may be internal or external. Internal stakeholders consist mainly of suppliers, customers, production employees, financiers, etc. who have direct involvement in the project. The relationship between internal stakeholders has the largest impact on the likelihood of the project developing complexity and exposure to risk. Although the management of internal stakeholders is important, external stakeholders also have a notable impact on project complexity and exposure to risk. Aaltonen & Kujala (2010) analyzed the case project of Botnia Pulp Mill in Uruguay, where an entire project was at stake due to the challenges created by external stakeholders. From their analysis, it was proven that external stakeholders can have an impact on increasing a project’s costs and delaying its schedule.
Moreover, Aaltonen (2010) depicted that nowadays, the requirements of external stakeholders form one of the greatest causes of risk and uncertainty within a project.

2.1.3 Complexity Factors and Management Strategies

Vidal (2008) reviewed literature concerning complexity and based on his findings, categorized four types of project complexity factors: (1) the size of the project system, (2) the variety of the project system, (3) interdependencies within the project system and (4) context-dependence (Vidal, 2008). Concerning the first factor, Corbett et al. (2002) stated that to have a complex project indication, the project must have a minimal critical size. Secondly, a project can be said to be complex only when it has multiple dimensional characteristics. Corbett et al. (2002) depicted that variety is always associated with and an initiator of project complexity and the intensity of the complexity depends on how underlying variations interact with each other. The third complexity factor, project system interdependencies, are the most important factors in project complexity. Rodrigues and Bowers (1996) justified their importance by suggesting that interdependencies between different project elements are more complicated than conventional work structures. As every component is dependent and interrelated with others, there is a high chance of risk developing if one factor suffers setbacks. The last project complexity factor, context-dependence, is another essential factor of project complexity, as it is a natural denominator of every complex system (Chu et al., 2003). Every project is unique in its own context and thus it is not applicable to transfer the context of one project to another when considering different organizational dimensions. Therefore, it is typically impossible to manage project complexity without properly analyzing and understanding its underlying context.
The various different complexities of a project can therefore lead to its failure. Management strategies are therefore very important for ensuring the success of a project through minimizing the impact of its complexity in risk development. Each management strategy needs to take into account specific factors relating to the project in hand, in order to tackle its uncertainty and risk. Hass et al. (2010) analyzed literature concerning project complexity and presented some of the most effective management strategies based on different project characteristics. These are summarized in Table 3.

Table 3. Strategies for management of project complexity (Hass et al., 2010).

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Management Strategies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Long Duration Projects</td>
<td>Evolutionary development, time and cost management, Rapid action development, multiple estimating method, Attention to team composition and process, lean development techniques</td>
</tr>
<tr>
<td>Large, Dispersed and Culturally Diverse Project Teams</td>
<td>Team leadership, contractor team management, virtual team management, collaboration</td>
</tr>
<tr>
<td>Urgent Projects with Fixed Deadlines and Inflexible Demands</td>
<td>Flexible high performing team members, Time-boxed schedule, minimize scope, stage-gate or milestone management</td>
</tr>
<tr>
<td>Ambiguous Business Problems, Opportunities and Solution</td>
<td>Business analysis, value chain analysis, root cause analysis, feasibility studies, feature-driven development, edge of chaos management</td>
</tr>
<tr>
<td>Volatile Requirements</td>
<td>Professional business analyst, agile analysis, Test-driven requirements development, effective scope change management, iteration, visualization and communication, interdependency management</td>
</tr>
<tr>
<td>Highly Visible Strategic Projects</td>
<td>Executive oversight, political management strategy, public relations, benefit management, virtual alliance management</td>
</tr>
<tr>
<td>Large Scale Organizational Change</td>
<td>A sense of urgency, the guiding team, the visions, communication for buy-in, Empowerment for action, short-</td>
</tr>
</tbody>
</table>
2.2 Project Risk Management

A project is a temporary, unique and time-limited piece of work, in which multiple activities typically must be carried out in order to achieve specified objectives (PMI, 2018). To carry out those activities, multiple stakeholders from different organizations and based in different locations typically work together. Every project, whether it is simple or complex, small or large, faces different uncertainties throughout its course. This uncertainty is so crucial in determining a project’s likelihood of success or failure, and is referred to as project risk. Hillson (2002) states that risk is mainly related to negative events that occur during a project, whereas the Association for Project Management (APM) and the Project Management Institute (PMI) describe risk as sometimes having positive and sometimes negative impacts on a project.

“Project risk can be defined as an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective, such as time, cost, scope, or quality.” (PMI 2016)

“Project risk is an uncertain event or set of circumstances which, should it occur, will have an effect on achievement of one or more objectives.” (APM 2012)

From these two definitions, we can say that project risk is an uncertain phenomena that can influence the outcome of a project. Thus, in order to ensure that project risk induces minimal negative outcomes, project risk management is essential, especially for large or complex projects.
Many previous publications concur that project failure is closely associated with ineffectual risk management in failing projects (Flyvbjerg et al., 2003, Sharma et al., 2011, Kutsch et al., 2011). Some notable project failures are presented here:

➢ **Yucca Mountain:** A decision was made to build a nuclear waste depository in Yucca Mountain in Nevada in 1987, despite local politicians and citizens protesting against this decision, as there were many inhabited territories nearby. Years of planning and investing to build this depository in Nevada were ultimately wasted, as Obama’s administration scrapped this project in 2009, causing a total loss of $13 bn. According to the report, failure to prioritize risk management to deal with the protest and the issues surrounding it was the main reason for the failure of this project (Swift, 2015).

➢ **Panama Canal:** Panama Canal is considered to be one of the largest and most complex mega-structures in the modern world. It took a decade to build this 48 mile-long canal, with frequent pauses in the work timeline due to floods, mudslides, health diseases and lack of funds. The construction of this canal started in 1870 and was not completed until 1999. The initial budget was $60 m, but the final cost ended up being $921 m. According to the report, issues relating to lack of risk and crisis management were the biggest reasons behind this cost increase and delay (Alarcon et al., 2010).

➢ **Millennium Dome:** The Millennium Dome, another mega-structure built in London, UK, was opened in December 1999 as a museum, which closed permanently in 2000. It was subsequently converted into concert and sports arena. It was built initially to attract tourists, but its lack of vision and poor execution led to failure, due to having no crisis management plan in place (Peter J., 2000).

➢ **Airbus A380:** The project to develop the Airbus A380 aircraft was launched in 2000. When it was during its assembly stage in 2006, a pre-assembled wiring harness produced in Germany which did not fit into the airframe led to a two-year delay in production, cancellation of deliveries and a significant increase in cost (Shore, 2008).
These project examples highlight the enormous impact that RM has on project success and failure. Without a proper RM plan in place, there is a high probability for any project, especially large and complex projects to encounter many uncertainties and ultimately failure. The main goal of project RM is to identify any associated risks and take preventative and corrective measures in order to prevent or minimize negative impacts. Project risk can evolve in many different forms, according to the specific sector. Therefore, a literature review of different types of risk, along with their evolution, process and benefits of its appropriate management will be presented in the following sections.

2.1.1 Brief History of Risk Management

RM studies began emerging after World War II, particularly from 1955 onwards. According to various literature, modern RM strategies were developed between 1955–1964 (Williams and Heins, 1995; Harrington and Niehaus, 2003; Dionne 2013). At that time, no academic had been performed on RM and also there were no published books on this subject (Snider, 1956). In 1963 and 1964, two books were published on RM by Mehr and Hedges and Williams and Heins, who focused purely on RM, failing to take into account the most important financial risks.

According to Harrington and Niehaus (2003), market insurance, which is supposed to protect personnel and companies from different losses relating to accidents, is one of the most important sectors that is associated with RM policies. Though there were no financial risk concepts at that time, a different version of pure RM evolved during mid 1950s as a substitute option for market insurance, when insurance policies became very expensive and complex. Many business sectors were very expensive and complex to insure at the time. Thus, in the 1960s a new contingent planning activity strategy evolved along with different preventive actions and self-insurance instruments, which were very useful in terms of insuring against certain business losses (Dionne 2013).

Though RM in the financial sector did not gain much importance until 1960s, by the 1970s, this scenario had changed. A revolution in financial sector RM occurred in the 1970s, in which many companies experienced price fluctuations due to varying interest rates, stock market returns, exchange rates, prices of raw materials, etc. (Dionne, 2013). During the 1980s, companies started to contemplate financial management and it came to replace pure
RM when financial companies, such as banks and insurance organizations started to give serious consideration to managing market and credit-, operational- and liquidity-RM activities. At that time, financial organizations also started to internally develop different RM models and investment capital calculation formulas, in order to prevent themselves from different unforeseen risks. During that time, RM governance, integrated RM and job positions such as “Chief Risk Officer” were introduced into the market (Dionne, 2013).

Later, in 2002, the Sarbanes-Oxley Act was brought into action in the United States, due to many incidents evolving from poor RM. According to Blanchard and Dionne (2004), Stock Exchanges also formulated RM governance rules for financial organizations. Though all the rules and regulations of RM were formulated based on various practical research, their application and enforcement remained inefficient. This was a major contributor to the global financial crisis of 2007. Thus, risk management has gradually evolved, with more sophisticated techniques developing, from pure RM to RM that also incorporates financial perspectives.

2.1.2 Definition of Risk Management

RM, which is sometimes referred to as “uncertainty management”, can be generally defined as being a systematic process that a company follows in order to reduce the likelihood of unexpected events occurring, in order to maximize profit. Many authors defined risk management as uncertainty management in the literature as risk itself an uncertain thing. The most two popular definitions of RM are published by PMI and APM:

“The systematic process of identifying, analyzing, and responding to project risk. It includes maximizing the probability and consequences of positive events and minimizing the probability and consequences of adverse events to project objectives”. (PMI, 2016)

“A process whereby decisions are made to accept known or assessed risks and/or the implementation of actions to reduce the consequences or probability of occurrence”. (APM, 2012)

Although both organizations similarly define RM, the major difference between these definitions concerns PMI’s consideration of risk as sometimes being positive. Positive “risk”
may also be referred to as “opportunity” in a RM plan. Though many authors have previously described risk only being negative, in which where different measures are initiated in RM plans in order to reduce the probability and impact of negative events, some see certain types of risk as potential opportunities. According to Jaafari (2001) & Perminova et al. (2007), positive risks, although causing uncertainty, can also maximize success or profit, and should therefore be considered in RM strategies, alongside negative risk (Ward & Chapman, 2003).

Others define RM as the minimizing of negative occurrence of risk which causes loss to the organization. Stranks (1994) describes RM in terms of identification, evaluation and control of exposure to each risk that hinders project success. He formulated four basic principles of RM: (1) minimization of negative impacts of risk in a business; (2) recognition, evaluation and economic control of risks that hinder business success and profit; (3) determination of the most relevant way to tackle major and minor risks to a company’s profit; and (4) a procedure for adapting to the impacts of progress.

According to Chong and Brown (2000), risk is a fundamental aspect of RM, the main aim of which is to minimize or maintain risk at a level that is acceptable for an enterprise. RM may be compared to drawing a map of hazards and the probable harm they may cause; the map can then be used to solve the challenges caused by risks, according to their sources (Chong and Brown, 200). Loader (2007) states that, risk management is very important for any business, but that it does not necessarily ensure the ultimate success of a project.

Stephenson et al. (2011) describe RM in terms of two dependent variables: risk identification and risk analysis. In risk identification, all potential risks should be determined within the organization’s boundaries, whereas in risk analysis, probable impact, cause and control over those risks should be determined.

To utilize the available resources and reduce time consumption in the RM process, it is very crucial to have clear knowledge of the risks that a business face. Almost every business faces different types of risk, according to the corresponding sector(s) of the enterprise. Regarding that, each enterprise should focus on identifying the specific risks it faces and take action according to a proper risk response strategy (Institute of Risk Management, 2011). A similar point of view was also presented by Asbury and Ashwell (2013), who wrote that risk is either
negative or beneficial which hinders or helps to achieve the organization's target while Loch et al. (2006) states that risk management is kind of a tool that assists enterprises to confront change.

Thus, RM is a process with the main objective of identifying both the risks and opportunities that the project or business faces in its early stages, and take action according to the necessary response strategy, in order to mitigate or utilize risks for the success of the business. As both risk and opportunity is uncertain, RM can also be called uncertainty management.

2.1.3 Categorization of Risk
A project may face different challenges and uncertainties in the planning, buildup and even post-completion phases. According to the literature, most of the risk that a project faces, arises from uncertainty. Ward and Chapman (2003) identified five types of risk sources that cause uncertainty: (1) variability associated with estimates; (2) uncertainty about the basis of estimates; (3) uncertainty about design and logistics; (4) uncertainty about objectives and priorities; and (5) uncertainty about fundamental relations between project parties (Ward and Chapman, 2003).

Different scholars describe project risk types in different ways, according to their sources and nature. Miller and Lessard (2001) developed a list of examples of some common risks faced by different project types, according to their nature.

Table 4: Types of risks in different industries (Miller and Lessard, 2001)

<table>
<thead>
<tr>
<th>Industry</th>
<th>Exposed Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydroelectric power project</td>
<td>Social acceptability risk</td>
</tr>
<tr>
<td>Urban transport projects</td>
<td>Market, social, institutional and technical risk</td>
</tr>
<tr>
<td>Road and tunnel system</td>
<td>Market and social acceptability risk</td>
</tr>
<tr>
<td>R&amp;D project</td>
<td>Social acceptability and market risk</td>
</tr>
<tr>
<td>Nuclear power project</td>
<td>Technical, social and institutional risk</td>
</tr>
<tr>
<td>Oil platform</td>
<td>Institutional risk</td>
</tr>
</tbody>
</table>
A study conducted by IMEC, a Belgian R&D hub, where 60 complex engineering projects were studied and analyzed. Projects managers were interviewed and asked to name and rank the risks they faced during the early period of the projects they managed (Miller and Lessard, 2001). According to their feedback, market related risks (41.7%) were the principal risk type they faced, with technical and institutional risks making up the remaining 37.8% and 20.5%, respectively. Miller and Lessard (2001) also divided these three risk categories into sub-categories, in which: market-related risks were categorized into demand, supply and financial risks; completion risks into technical, construction and operational risks; and institutional risks into regulatory, social-acceptability and sovereign risks.

At the same time, Jafaari (2001) identified several risk categories that a project may encounter: political, promotion, technical, market, financing, operating, schedule, environmental, cost and organizational risks. Later, Rolstadas et al. (2011) added a new category to this list called contextual risk, which refers to external factors that can influence project performance and lead to negative impacts. Meanwhile, Artto et al. (2011) divided complex project risks into four types: pure risk, business risk, financial risk and area-specific risk:

➢ **Pure Risk:** Unfavorable events such as, fire or other accidents, which cannot be predicted in advance. Although there is a low probability of pure risk occurring, it can cause significant damage to a project. The liability of such types of events lies with the insurance company, thus it is also known as insurable risk.

➢ **Financial Risk:** Risk relating to a project’s financial activities, including funding of the project. This might also have a major impact on the project’s success, as it includes exposure to currency fluctuation, liquidity and operative cash flow.

➢ **Area-Specific Risk:** These risks occur due to specific geographical, cultural, political, national and environmental issues. Sudden natural calamities or political instability of that specific location can have major impacts on the project.

➢ **Business Risk:** Business risks include all other risks aside from those mentioned above. They can arise from small activities that may superficially seem negligible, but may end up affecting the activities of the whole project. Business risks may occur at any time during the project and influence its outcome.
Krane et al. (2010) divided risk categories into operational, short term strategic and long term strategic risk. Operational risk can have an instant impact on the project, whilst strategic risk has an impact on the project’s short or long-term objectives. Later, Thamhain, H. J. (2013) divided risk into four category risks: category I risks are those which have very little or no impact on the project and can be identified easily before any effect is able to develop; category II risks have limited impacts on the project’s performance and can be solved by developing sub-task project activities to mitigate their effect; category III risks have remarkable impacts on the project, which might lead to schedule delays and budget overrun; whilst category IV risks have extremely significant effects on the project and overall business, which are irreparable. Category IB risks may arise from as little as a single issue, yet results in an extremely negative impact on the whole enterprise (Thamhain, H. J. 2013).

Fontaine (2015) divided the risks faced during projects into project risks and technical risks. Project risks can arise during the project building or implementing steps and have impact on the project, whereas technical risks occur during the post-completion phase of the project. According to Fontaine (2015), project risk mainly arises from the following sources: project location, economic, industry and market environment, project size, complexity and uniqueness, financial strength of the project proponent, technology, logistics, communication, design, procurement, construction, commissioning, integration with existing operations, human resources, sustainability, etc. On the other hand, technical risks arise from events such as fires, explosions, chemical contamination, pressure extremes, temperature extremes, mechanical conditions, radiation, electrical conditions, physiological conditions, human factors, control systems, ergonomic factors, vibration, motion, operating modes, etc. (Fontaine, 2015). Technical RM is mainly used in earlier phases of the project in order to guide the overall design of the facilities, whereas in later phases, when the project is completed, RM is used to verify the design that has already been implemented.

According to a website of Project Management (2017), project risks are mainly categorized as costs, schedule and performance risk. There are also other types risks, such as governance, strategic, operational, market, legal and external hazard risks, which ultimately impact on the aforementioned cost, schedule and performance of the project. Aside from project risk, there
can be also project deferral risk, which is associated with failure to complete the project and can also be caused by the aforementioned sources (Project Management, 2017).

### 2.1.4 Risk Management Process

RM is now being widely used in almost all projects, especially large, complex construction and engineering projects. RM is a must-have tool nowadays and its rise has been associated with the trend of projects’ increasing complexity. In order to handle the complex and increased uncertainty of projects, there are several steps to be followed in the context of RM. There are many process models of RM described in the literature and there is a strong consensus regarding RM approach. Among them, the most commonly used and accepted process model is given by Project Management Body of Knowledge (PMBOK).

PMI (2016) divided RM steps into RM planning, risk identification, risk qualitative analysis, risk quantitative analysis, risk response development and risk monitoring and control. During the RM planning steps, a detail plan is produced by the project team on how to approach RM activities during the entirety of the project. The main aim is to inform all stakeholders of the risks and to establish support for and commitment to a clear RM strategy. This planning step is very crucial for project success and if planning is done extensively and covers the relevant areas, there is less chance of project failure. These steps must be started when project planning is finalized and be completed before project initiation.
Figure 4: Project risk management steps (Adapted from: PMI, 2016).

In risk identifying steps, all possible risk that the project may face during the whole period is predicted and categorized, according to their characteristics. The aim of these steps is to inform the whole project team about any possible risks, their arising characteristics and detailed knowledge about them. By identifying risks, all information about risk can be identified and collected through brainstorming, delphi technique, interviewing, root cause analysis, SWOT analysis and use of previous records and be output to a risk register.

In risk qualitative analysis steps, risks are ranked according to their probability of occurrence and their probable impacts on the project. The main aim is to focus primarily on risks which have the highest and most immediate impacts on the project. A probability and impact matrix or risk breakdown structure (RBS) is used extensively to perform qualitative analysis, which
builds a foundation for quantitative and risk response strategies. Later, in quantitative risk analysis, risks are analyzed numerically and prioritized based on their probable impacts. In most cases, the risks which are prioritized in qualitative risk analysis are then again analyzed quantitatively in order to more accurately establish the probability of their impacts on the projects. Probability distributions, sensitivity analysis, expected monetary value analysis, modelling and simulation techniques are used to perform quantitative analysis.

In plan risk response steps, different actions are taken in order to minimize the probable impacts of negative events and also to enhance the probabilities of opportunities. In this step, different resources are applied to the project plan to reduce risk. When any negative events or risks occur, four typical strategies are likely to applied in response: avoid, transfer, mitigate and accept. In a risk avoidance strategy, the project team tries to eliminate risk entirely from its effects on the project, in cases where the risk may change the project objective. In risk transfer strategy, project team transfers the responsibility of probable risk to third parties. This strategy is typically used if there is any financial risk in the project. In risk mitigation strategy, the project team tries to reduce the likelihood of a negative threat from occurring by using a relevant action plan and resources. If a risk cannot be avoided, transferred or mitigated, the project team applies a risk acceptance strategy, in which it decides to do nothing until the risk appears. In contrast, the exploit, share, enhance and accept strategy is used in response against positive risks or opportunities. The exploit strategy is used when the project team wants to eliminate the uncertainty of any opportunities. The enhance strategy is used when the team foresees an opportunity and wants to increase the probability of its occurrence through allocation of resources. The share strategy is used when the team assigns ownership of an opportunity to a third party which is better suited to managing it. The acceptance strategy is used when the team takes advantage of an opportunity if it appears in future.

In the risk control process, the risk response plan is executed, new risks are identified, identified risks are tracked, residual risks are observed and risk process effectiveness is evaluated throughout the project life cycle. The benefit of this process is to enhance the efficiency of the risk management approach in the project timeline. Various techniques, such as risk assessment, risk auditing, variance and trend analysis, technical performance measurement and reserve analysis are used to carry out this step (PMBOK, 2016).
Though the PMBOK RM process is accepted and used worldwide, Fone & Young (2005) states that the RM process should include extra steps. They write that RM should include five steps: RM mission identification, risk and uncertainty assessment, risk control, risk financing and program administration.

Chapman and Ward (2003) expressed a generic RM model named the “SHAMPU” framework which contains nine steps: define, focus, identify, structure, ownership, estimate, evaluate, plan and manage.
In the “SHAMPU” framework, Ward and Chapman (2003) define the first two steps \textit{define and focus} as the basis of analysis, with the next three steps \textit{identify, structure and ownership} forming the basis of qualitative analysis and \textit{estimate and evaluate} as quantitative analysis. Thus, this model can also be defined compared to the five step RM model, which includes basis of analysis, qualitative analysis, quantitative analysis, harness the plan and manage implementation. The objective of basis of analysis steps is to gather a clear idea about the risk management process, the objective of qualitative analysis is to obtain an idea of the probable threats and opportunities along with the ownership and management responsibility, the objective of quantitative analysis is to prioritize the most important risks and diagnose them, the objective of harnessing the plan is to finalize the plan with response strategies and finally to monitor the whole RM process.
D. van Well-Stam et al (2004) also described the RM process in a similar way by splitting the RM process into nine steps. The main characteristic of this model is that it focuses greatly on continuous risk assessment. D. Van emphasizes that, after performing risk analysis, the following evaluation and control phase should continue on a regular basis, as both the evaluation and control phases depend on one other.

Another popular RM framework named Active Threats Opportunity Management (ATOM) was developed by Hillson and Simon (2007) and can be applied for all types of projects. In the ATOM framework, both threats and opportunities can be controlled in a single process by identifying and assessing risk during two-day workshops.

Kahkonen and Artto (2008) also developed a holistic RM process model, in which they divided RM process into core and accessory processes. The reason behind the development of this model was the realization of the authors that most existing RM process models are rigid, which sometimes limits ability to deal with the dynamic nature of the risk. Kahkonen and Artto’s process model focuses on continuous risk registry updates and environment scanning. In this model, core processes are the main drivers, whilst accessory processes support core process both internally and externally.
Table 5: Risk management core and accessory processes (Kahkonen and Artto, 2008)

<table>
<thead>
<tr>
<th>Core Processes</th>
<th>Accessory Processes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Risk identification</td>
<td>Risk management planning</td>
</tr>
<tr>
<td>Risk estimation</td>
<td>Risk communication</td>
</tr>
<tr>
<td>Risk response planning and execution</td>
<td>Risk ownership development</td>
</tr>
<tr>
<td></td>
<td>Risk management strategy</td>
</tr>
<tr>
<td></td>
<td>Risk management control</td>
</tr>
</tbody>
</table>

From the analysis of various RM processes, it is clear that all models are fundamentally similar in nature, but the approach to subcategorizing varies. In a nutshell, according to the literature, the most important steps of RM lie in risk identification. Failure to clearly identify risks early on makes it significantly more challenging to tackle them effectively at later stages of the project. Thus, the success of the later phases of the RM process is largely dependent on the success of earlier risk identification steps (Ward & Chapman, 2003).

2.3 Risk Management Performance Measurement

Performance measurement is an important approach for any project or business, by which an organization’s or project’s success percentage is evaluated. Nowadays, many organizations face extensive problems regarding establishment of performance management criteria which are cost effective and measure performance meaningfully. In performance measurement, a project's outcome is compared with the project’s original goals, along with the performance of individuals, in some cases, in order to make a quantifiable factor upon which a project’s or business’ ongoing performance can be measured. Neely et al. (2002) defined performance measurement as ‘the process of quantifying the efficiency and effectiveness of past actions’. According to this definition, both efficiency and effectiveness are measured, giving an indication of what should be evaluated in performance management. Another definition by Moullin (2002) gives further clear instructions about performance measurement, stating that performance management means “evaluating how well organizations are managed and the value they deliver for customers and other organizations”. Rouse & Puterill (2003) defined performance management as the comparison of the outcomes of a project or business in terms
of its predetermined objective. Performance measurement is the process of setting some specific goal, with continuous evaluation of how efficiently the resources are utilized and transformed into products and services, and how the quality of those outcomes is matched with the predefined goals (Amaratunga & Baldry, 2002).

The basic goal of a performance measurement system is to analyze and assess the project's objective in both financial and non-financial ways. During the continuous evaluation period, the results of the evaluation can also be used to allocate resources in effective and efficient ways (Acharyya, 2007). According to Beamon (1996), inclusiveness, measurability, consistency and universality are four essential PMS characteristics to be considered when assessing project performance. The data gathered from performance measurement is very crucial for the success of a project, as it shows the present position and enables improvement of overall project performance. Goh (2012) states that the main aim of performance measurement is to make the organization more efficient while improving its performance. Measurement must start immediately once the criteria have been selected and should continue throughout the project (Bradley, 2010).

For project-oriented organizations, a proper risk management system acts as an efficient and effective tool for ensuring project success. Thus, to ensure RM system accuracy and efficiency, a performance measurement criterion must be developed. Mitselsky and Basova (2011) emphasizes that the accurate measurement of performance of a project’s RM system which is very crucial for the success of the project. Risk performance measurement also helps to reduce risk factors associated with the project. To ensure the proper selection of an appropriate RM system, risk performance management should be included in the system. RM alone cannot alone ensure project success, as evaluation of current performance is essential for understanding the real scenario of the RM plan.

2.3.1 Performance Measurement Methodologies
Performance management basically has four main components: duty, strategy goal, performance goal and performance index (Seon-Gyoo Kim, 2010). Strategy goal refers to the organization’s policies, which represents the organization’s values as a whole, and in which performance goal is part of the strategy goal. This includes specific performance objectives of a particular project in a specific year. Performance index is the criteria of
successful evaluation of the project goal where quantitative measures are developed for each project. In the literature, there are very few methodologies regarding the RM performance measurement for projects. Among them, the four most used and popular RM performance measurement methods for large projects are: BSC, EVMS & KPI, RMI.

**Balanced Score Card (BSC):**

Balanced scorecard is a methodology of performance management which was introduced by Kaplan and Norton (1991). It is a strategic management method that indulge the top managers for exploration quickly and thoroughly of their running project or business. In addition, this method is also suitable for analyzing traditional finance and accounting performance to overcome the limits and constitute the pathway to establishing a long-term performance management method for a project. BSC depicted the overall performance of the project execution and customer satisfaction in the construction business by introducing performance index. Performance index currently familiar throughout the world which exhibits the operational, internal managerial activities for learning and growing of a company.

According to Kaplan and Norton, the greatest advantage of BCS is that the objectives and mission of an organization can be converted into measurable operational and performance metrics, according to four different perspectives: (1) customer amusement; (2) financial performance; (3) internal process; and (4) learning and growth. The following figure represents the interrelation between the four perspectives of Kaplan and Norton’s BSC method (Beasley, Chen, Nunez, & Wright, 2006).

According to Davis & Albright (2004), non-financial perspectives such as the customer perspective, internal processes perspective and learning & growth perspective are the first priorities in achieving project success and if only these non-financial criteria are accomplished, analysis of financial perspective can be started. In every perspective, there must be a defined objective and evaluation, according to which the project manager can identify and prioritize the most important factors (Kaplan & Norton, 1991).
Table 6: BSC perspectives, goals and measures (Kaplan & Norton, 1991).

<table>
<thead>
<tr>
<th>Perspective</th>
<th>Goals &amp; Measure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Customer Perspective</td>
<td>Lead time analyze, quality, service and customer satisfaction</td>
</tr>
<tr>
<td>Internal Process Perspective</td>
<td>Cycle time, employee skills and productivity</td>
</tr>
<tr>
<td>Learning &amp; Growth Perspective</td>
<td>Design productivity, new product development, improvement of cycle and unit cost</td>
</tr>
<tr>
<td>Financial Perspective</td>
<td>Profitability, growth and shareholder value</td>
</tr>
</tbody>
</table>

In this model, objectives and measures of customer perspective are first analyzed and then is converted into internal process perspectives. These first two perspectives are the most important in achieving success for the business. The third perspective is related to the company’s internal and external value (Kaplan & Norton, 1991). Finally, the financial perspective largely depends on the first three. If the non-financial factors are analyzed successfully, only then can financial perspectives be successful and lead the project to ultimately be successful.

**Earned Value Management System (EVMS):**

Earned value management system is the most extensively used performance management method. This method is very effective for the construction business. It is a systematic process that is used to identify the variance within projects relying on the distinction of work performed and work planned. By analyzing the cost and controlling the schedule, EVMS is considered to be an immensely effective method for project forecasting. It continuously measures the practical work by precisely handling work schedules and management methods for determining the ultimate cost and schedule of a project (Fleming and Koppelman, 1996).

EVMS enables the project manager to ascertain what the variation between the planned budget and the actual cost is. This identification impacts on the overall project and enables improvement of project performance and the budget allocation process. EVMS also has great influence over project scheduling for managing and estimating delay or forecasting future plans, for determining and exploring the budget and cost of the project. Hence, EVMS
heavily relies on the project baseline, which serves as a reference point for project decision-making.

EVMS helps project managers to track the progress of a project through clarifying the project’s current position, along with forecasting its future position. The main principle of EVMS is that the value of the work should be equivalent to the scheduled budget of that project. According to Fleming & Koppelman (2005) and PMI (2005), EVMS has three main variables or data sources: planned value (PV) or budgeted value for the project, actual cost (AC) of the work done and earned value (EV) of work completed. PV is the budget that is approved for a project, along with a specific completion date; EV is the accepted budget for the work that is finished within the targeted date; and AC is the total cost that is required for the completed work within the specified date (EVM, 2017). When these three values have been generated from project analysis, variance analysis is conducted to determine project performance. There are four types of variance analysis: cost variance (CV = EV-AC); schedule variance (SV = EV-PV); cost performance index (CPI = EV / AC); and schedule performance index (SPI = EV /PV) (Fernando Acebes et al, 2013).

Table 7: EVMS variance analysis (PMI, 2005)

<table>
<thead>
<tr>
<th>Cost Variance (CV)</th>
<th>Schedule Variance (SV)</th>
<th>Cost Performance Index (CPI)</th>
<th>Schedule Performance Index (SPI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CV = 0, project is on budget</td>
<td>SV = 0, project is on schedule</td>
<td>CPI=1 or CPI&gt;1, project is favorable condition</td>
<td>SPI=1 or SPI&gt;1, project is favorable condition</td>
</tr>
<tr>
<td>CV = negative value, project is over budget</td>
<td>SV = negative value, project is over schedule</td>
<td>CPI&lt;1, project is in unfavorable condition</td>
<td>SPI&lt;1, project is in unfavorable condition</td>
</tr>
<tr>
<td>CV = positive value, project is under budget</td>
<td>SV = positive value, project is under schedule</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Lipke (2004) proposed an additional variance under EVMS, named earned schedule (ES), as an extension of the PMI (2005) methodology. ES assists in the last phase of the project life cycle by solving problems regarding forecasting capabilities. The integration of EVM & risk
analysis under the same framework eases the project manager’s decision-making, where EVM’s variances focuses on the past and risk analysis focuses on the future analysis (Pajares & Lopez-Paredes, 2011). To integrate the risk analysis under the EVM framework, Parajes & Lopez-Paredes (2011), introduced Cost Control Index (CcOI) and Schedule Control Index (ScOI) which compare EVM measures with maximum values that project should exhibit if project is running under risk according to risk hypothesis. Systematic and structural changes of project that effects on project risk, cost and schedule can be known by these two indexes for a determined confidence level of cost and schedule (ccl% and scl%). If CcOI and ScOI are negative which means the project delay and/or over budget than the expected, management should take the appropriate early decisions (Parajes & Lopez-Paredes, 2011).

**Key Performance Indicators (KPI):**
Key performance indicator is a performance measurement system that measures and monitors business strategies and business-related operations. KPI was introduced in Britain for the construction renovation business. Initially the main purpose of this method was improvement of productivity in the construction business. It was later developed to measure not only the performance of the construction business in terms of cost and duration reduction, but also to maximize the profit and productivity of the business. Cardona (2005) stated that KPI is an evaluation method for analyzing RM system performance and success. KPI basically consists of several indicators, upon which an organization’s RM performance and effectiveness is assessed. KPI helps an organization in assessing the performance of their implemented system, preventing various emerging risks and issues relating to disasters. Although there are some common KPI methodologies that can be used by any type of organization, the exact method is typically selected specifically with the nature and requirements of the project in mind. As it is very useful and important to assess the whole performance of the RM system, it is very crucial to select an appropriate KPI which covers every aspect of RM performance. When developing a KPI for assessing an organization's or project’s performance, four characteristics must be take consideration: tangibility, flexibility, standardization and objective focus (KPI, 2017). Different indicators used, depending on the nature of the project and organization, meaning that KPI may take many forms (Table 8) (2017).

Table 8: Types of Indicators (KPI, 2017)
## Indicators and Characteristics

<table>
<thead>
<tr>
<th>Indicators</th>
<th>Characteristics</th>
</tr>
</thead>
<tbody>
<tr>
<td>Qualitative</td>
<td>Subjective characteristics or qualities</td>
</tr>
<tr>
<td>Quantitative</td>
<td>Based on percentage, counts and ratios</td>
</tr>
<tr>
<td>Leading</td>
<td>Predictive, forecast early on activity</td>
</tr>
<tr>
<td>Lagging</td>
<td>Provide details measures on activity after finishing it</td>
</tr>
<tr>
<td>Input</td>
<td>Measures resources for activity</td>
</tr>
<tr>
<td>Process</td>
<td>Measures productivity</td>
</tr>
<tr>
<td>Output</td>
<td>Measures the final results of activity</td>
</tr>
</tbody>
</table>

To develop an actionable KPI for a project to measure RM performance, some steps need to be followed. The method of setting KPI is similar for all projects, but it must be defined according to an organization’s specific needs. The KPI organization and Unilytics each developed their own five-step approaches to setting up an actionable KPI:

**Figure 8: KPI step (KPI Indicators, 2016).**

- Describe the Intended Results → Understand Alternative Measures → Select Right Measures for Each Objective → Define Composite Indices as Needed → Set Targets and Thresholds

**Figure 9: KPI steps (Actionable KPI, 2013).**

- Establish Goals and Objectives → Establish Critical Success Factors → Establish KPI from CSF → Collect Measures → Calculate Metrics from Measures

There are some top KPI’s found in excellence in risk management survey to manage the RM performance management system which are categorized in the Table 9 (Excellence in risk management, 2011 & 2013)
Table 9: Top RM Performance measurement KPI category (Excellence in risk management, 2011 & 2013)

<table>
<thead>
<tr>
<th>Competitive procurement of risk transfer</th>
<th>Insurance budget management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mitigating liabilities and supporting organizational preparedness</td>
<td>Risk management alignment with company goals</td>
</tr>
<tr>
<td>Build strategic risk awareness across organization</td>
<td>Delivering successful claim results</td>
</tr>
<tr>
<td>Managing and communicating risk management value through TCOR</td>
<td>Regulatory and compliance assurance</td>
</tr>
<tr>
<td>Insurance and claims cost reductions</td>
<td>Operating cash flow</td>
</tr>
<tr>
<td>Total cost of enterprise-wide risk</td>
<td>Business continuity planning</td>
</tr>
</tbody>
</table>

There are some metrics used to measure the RM performance which following (Khameneh et al., 2015)

- Risks avoidance
- Risks mitigation
- Total costs of risks response

According to the various risk experts’ interview, Khameneh et al. (2015) the success of project RM system can be categorized by (a) system implementation and (b) results. Khameneh et al. (2015) divided the top KPI’s found in excellence in risk management survey under this system implementation and results as for KPI for each category and then used the SAW approach to find out the total project risk management score through this KPI.

\[
CS_i = \frac{\sum_{k=1}^{n} (w_k nKPI_{ik} \times 100)}{\sum_{k=1}^{n} w_k}
\]

Where, \( i \) = category number, \( k \) =metric number, \( n \) = total metrics of category, \( CS \) = category score, \( w \) = weight of the metric and \( nKPI \) = normalized key performance indicator

Then, calculate the total risk performance score through incorporating the above formula,

\[
TPRMS = \frac{CS_1 + CS_2}{2}
\]
Where, TPRMS = total project risk management score and CS = category score

**Risk Management Index:**

In the literature, most RM performance evaluation methods are based on indicators. Carreno et al. (2007) introduced the risk management index (RMI) by grouping together different indicators. RMI is used to evaluate the performance of an RM system and provide quantitative measures regarding performance evaluation, based on a qualitative benchmark set by the organization (Carreno et al., 2007). RMI was defined by incorporating four public policies which each have six additional indicators: risk identification index (RMIRI), risk reduction index (RMIRR), disaster management index (RMIDM), governance and financial protection index (RMIFP). These public policies and their parameters can be changed according to the nature of project and organization, but the evaluating parameter should be maintained the same. Thus, Carreno et al. (2007), proposed that the RMI is the average of these four indicators:

\[
RMI = \frac{RMIRI + RMIRR + RMIDM + RMIFP}{4}
\]

The performance of each indicator can be ranked as low, incipient, significant, outstanding or optimal, which can be numbered from 1 (low) to 5 (optimal). Each of the four indicators has an additional six sub-indicators (Carreno et al., 2007):

1. **Risk Identification (RMIRI):**
   - RI1: Systematic disaster and loss inventory
   - RI2. Hazard monitoring and forecasting
   - RI3. Hazard evaluation and mapping
   - RI4. Vulnerability and risk assessment
   - RI5. Public information and community participation
   - RI6. Training and education on risk management

2. **Risk Reduction (RMIRR):**
   - RR1. Risk consideration in land use and urban planning
   - RR2. Hydrological basin intervention and environmental protection
   - RR3. Implementation of hazard-event control and protection techniques
- RR4. Housing improvement and human settlement relocation from prone-areas
- RR5. Updating and enforcement of safety standards and construction codes
- RR6. Reinforcement and retrofitting of public and private assets

3. Disaster Management (RMIDM):
   - DM1. Organization and coordination of emergency operations
   - DM2. Emergency response planning and implementation of warning systems
   - DM3. Endowment of equipment, tools and infrastructure
   - DM4. Simulation, updating and test of inter institutional response
   - DM5. Community preparedness and training
   - DM6. Rehabilitation and reconstruction planning

4. Governance and Financial Protection (RMIFP):
   - FP1. Inter-institutional, multi-sectorial and decentralizing organization
   - FP2. Reserve funds for institutional strengthening
   - FP3. Budget allocation and mobilization
   - FP4. Implementation of social safety nets and funds response
   - FP5. Insurance coverage and loss transfer strategies of public assets.
   - FP6. Housing and private sector insurance and reinsurance coverage

BSC, EVMS, KPI and RMI methodologies are widely used to evaluate RM performance measurement. While the BSC method is mostly suitable for enterprise RM systems, KPI is widely used and acceptable for project RM performance measurement.

2.4 Summary of the Theoretical Review
Project complexity is common in every project, especially large projects. Complexity develops in projects with a large amount chaos and uncertainty. Construction projects are often referred to as being complex, as they have many unknown factors, along with several difficult implementation steps. Due to this complexity, most construction projects fail to meet their schedule and initial budget, thus it can be said that construction projects tend to be volatile and unpredictable. Project complexity arises either from the components of individual tasks connected with resources or from the different parts that are required to
complete the workflow (Gidado, 1996). Complex projects are typically characterised by multimillion dollar investment, as well as by highly advanced technology, a large number of stakeholders, a lengthy project period, etc. Hass et al (2010) presented a framework based on project characteristics such as project size, cost, uncertainty and stakeholders in order to differentiate between low, medium and high project complexity. This is one of the most widely used frameworks for identifying the level of project complexity. Project complexity also frequently arises in turbulent environments or in project networks with multiple stakeholders. A large, complex project typically has many stakeholders in various roles and depending on the relationships between these stakeholders, many risks and uncertainties can arise suddenly in the project.

A project risk is generally defined as an uncertain event which has a certain effect on the project, either negative or positive. Risks can have either negative or positive impacts. Positive risks are often referred to as opportunities. The main goal of project RM is to find the associated risks in the project and take any corrective and preventive measures to minimize their impacts. This project risk can evolve in many forms, depending on sector. Various risk categorisations exist, varying mainly according to project nature. Miller and Lessard (2001) categorized project risks into market, social, institutional and technical risk, whereas Jafaari (2001) divided them into pure, financial, area-specific and business risks. Others divided risks based on the impacts they can cause. For example, Thamhain H. J. (2013) divided the risk in to category I (almost no impact), category II (limited impact), category III (remarkable impact) and category IV (extreme significant impact), whilst Fonatine (2015) classed risks simply as being project or technical risks, whereby project risks may occur during the implementation phase and technical risks may occur during the post-completion phase. As there is trend toward increasing projects complexity, RM is a must-have tool nowadays. In order to handle the complexity and increased uncertainty of projects, there are several steps to be followed in the context of RM. There are many process models of RM described in the literature, but little variation between the fundamental aspects of different approaches. The most common RM steps that are described by many renowned scholars are RM planning, risk identification, risk analysis, risk response development and risk monitoring and control. Risk identification is usually done by brainstorming, Delphi technique, interviewing, root cause analysis, SWOT analysis and use of previous records. For risk analysis, basically quantitative and qualitative method is used worldwide.
Probability and Impact Matrix, RBS structure is generally used for qualitative analysis whereas, Probability distributions, Sensitivity analysis, Expected monetary value analysis, modelling and simulation is used to perform quantitative analysis. When there is any negative events or risk occurs, four strategies are likely to applied in response to that risk and these are, avoid, transfer, mitigate and accept. The RM of every project generally follows these basic steps.

The proper risk management system acts as an efficient and effective tool for the project success. Thus, to ensure about the risk management system accuracy and efficiency, a performance measurement criterion must have to be developed. Many researchers emphasize on the accurate measuring of the performance of the projects risk management system which is very crucial for the success of the project (Basova et al., 2011; Knott, J., 2009; Khameneh et al., 2015). Risk performance measurement also help with reducing the risk factor associated with the project. In literature, there are very few methodologies regarding the risk management performance measurement for projects. Among them, four most used and popular RM performance management method for large projects are: Balanced Score Card (BSC), Earned Value Management System (EVMS) & Key Performance Indicator (KPI), Risk Management Index (RMI), while KPI is most widely used for measuring the RM performance.

3 Research Methodology
This chapter presents the research design methodology along with the data collection empirical analysis methods.

3.1 Research Design
A proper research design plan is very important when carrying out research, as a proper plan can facilitate the research process by giving a clear structure on which to base the research proceed with using the data. According to Coldwell and Herbst (2004), research design acts as a glue which holds research together in perfect rigid shape, providing a framework to carry out the research in its entity. According to Burns and Grove (2003), research design acts as a blueprint through which many factors are analyzed, in order to validate the research
findings. Polit et al (2001) described research design through a testimonial and guide, through which research questioning and hypothesis testing is done.

This study focuses on analyzing the risk management approaches and their RM performance measurement in two complex projects. A qualitative approach is followed in pursuing this research. According to Burns and Grove (2003), qualitative research is a systematic approach which illustrates life experiences and their related situations to provide its meaning. Holloway and Wheeler (2002) state that qualitative research is like a form through which social enquiry is made, in which people interpret their thinking and their experiences about the world they live in. Qualitative techniques are used by many researchers in order to understand the meaning of people’s behavior, experiences, emotions and perspectives. Qualitative approaches in the field of RM involve collecting primary data through verbal interaction such as interviews, as well as through surveys or questionnaires. Data is collected based on participants’ interpretations and perspectives. This means that qualitative data is subjective and not always precise. In qualitative approaches, the accuracy of data depends on both the participants’ ways of thinking and the researchers’ own interpretation of the subjective data they collect.

The rationale behind selecting a qualitative approach for this research is that this research focuses on case studies with different risk identification strategies. As their impact and performance management plans are analyzed, the data regarding the risk identification and how they were tackled in the projects is most appropriately collected through verbal and questionnaire means. As this data is descriptive and not quantitative, the qualitative approach is best suited to analysis of these cases.

3.2 Data Collection
Data collection is an instrument that can be used to measure skills and experiences. In this research, data was collected through face-to-face individual interviews and completion of questionnaires. In reference to the aim of this research, empirical analysis should be conducted on complex projects in order to gain an in-depth understanding of RM. Thus, research into two case projects focused on the city of Tampere in Finland was conducted: the Rantatunneli and Tramway projects. Tampere Rantatunneli project is a very complex project, in which an underground tunnel was built by excavating hard rock in the middle of city under
many residential areas. The Tampere Tramway is a 24 km-long tramway that is currently under construction in Tampere city, in which a large number of sub-contractors are involved. Thus, it is a very challenging project, as it involves building this long track in the midst of active traffic in a busy city. Thus, the high complexity of these two case projects validate the suitability of empirical analysis on these projects for this research. The data for the Tampere Tunnel case study was collected through face-to-face interviews which were semi-structured as a list of questions (Appendix 1), which was given to the interviewee prior to the interview. The interview was recorded through audio tape and was later transcribed for data analysis. This type of semi-structured interview was beneficial in this case, as it made it possible to also discuss many relevant issues which arose during the interview but had not been included in the question list. Face-to-face interview also enables the researcher to interpret the facial expressions and better understand the perspective of participants, as this is an important part of qualitative studies. In this form of interview, interviewers have one major responsibility: to make the interview environment friendly, so that participant feels comfortable during the interview. The data for the Tampere Tramway case study was collected through a questionnaire (Appendix 2). This was very helpful in terms of collecting the most accurate data, as in this form, the participant has their own freedom and time to give the answer according to their own pace. In other forms of interview, the participant may not remember and tell everything accurately, as they have to react quickly during live discussion without having time to think in depth.

### 3.3 Data Analysis Method

In this research, the data that was recorded and transcribed from the interview and questionnaires was analyzed through a thematic content analysis method. This involves organizing the data into different categories based on the relevant themes and features (Alholjalian, 2012). Data from interviews was first categorized based on project complexity, where project timeline, budget and team member size etc. were analyzed based on the qualitative data given by the interviewee. The data was then further categorized into RM steps, risk identification, major and minor risks and performance measurement of those risks. Finally, based on the categorized data, project complexity was validated, a RM process was drawn up, the impact of major and minor risks was calculated, and a risk matrix was drawn. Thus, categorized data helped with the interpretation of collected data.
4 Empirical Study

Empirical studies involve illustrating and analyzing the data collected through qualitative and quantitative approaches for a particular case study or real-life problem, illustrating practical examples rather than theoretical implications. The empirical part of this thesis shows the relevant practical implications using data which has been described in the literature review sections. In this thesis, this empirical study is conducted with respect to the two aforementioned complex project case studies. In this section, the RM and RM performance management processes of the two aforementioned project cases is assessed through determination of their RM processes, risk mapping and categorization and performance evaluation. This empirical analysis highlights the importance of RM practices for all types of projects. The data used for this empirical analysis was acquired through a qualitative approach. Along with the theoretical implications, this research shows what types of risks are typically involved with large complex projects and how project teams respond to these challenges.

4.1 Case Project-1: Tampere Tunnel Project

In this section, the background of the Tampere Tunnel project is outlined, along with its RM and RM performance policies and its risk mapping, risk managing, risk performance measuring areas are discussed based on the interview and online materials.

4.1.1 Background of Tampere Tunnel Project

According to the plan for the Pirkanmaa region and the local authority’s structural plan for 2030, Tampere’s city center is considered to be a prime location and business hub for the region as a whole. In addition, Tampere is considered as “the next Silicon Valley of the Nordic region”. Furthermore, Tampere City Council is focused on building energy-efficient architecture throughout the city, fulfilling the aim of making land-use efficient and meeting climate objectives. Tampere City’s development program also involves creating more residential areas near the city center, particularly in the Ranta-Tampella district and improving access of all residents to lake Nasijarvi, which may increase the appeal of the city (Value for Money Report, 2018).

With respect to the city development program of Tampere City and its urban structure improvement plan, it was decided to build a tunnel through which to pass Highway 12
(Paasikiventie-Kekkosentie). This decision was taken because there was no above-ground space to build both the new Ranta-Tampella residential district and a road with high enough capacity to serve this area. The planning of the building of this road, called “Rantaväylä”, was discussed in the regional and local plan of Tampere City and the road planning work for a massive underground tunnel started in 2008. Highway 12 is the most-used road outside the capital region, is connected with the central route network and acts as a gateway into Tampere, as well as a long-distance gateway to Vaasa, Pori, Jyväskylä, Lahti and Turku. It is also heavily used by Tampere residents and is therefore connected with many intersections. Thus, Rantaväylä has long suffered from traffic congestion due and has been prone to accidents, particularly in Santalahti and Naistenlahti. Thus, to improve traffic safety in Tampere, it was decided to build this underground tunnel (Value for Money Report, 2018).

The Rantaväylä development plan was initially conceived in the 1980s and the tunnel building plan was initiated during the 1990s, when the road become congested. Several developments had then been planned, until the council’s improvement plan for Tampere City sped up the process leading to the building of the Rantatunneli on Highway 12. The main milestones of this project is summarized in Table 9:

Table 10: Rantatunneli pre-development milestones (Value for money report, 2014).

<table>
<thead>
<tr>
<th>Year</th>
<th>Action</th>
</tr>
</thead>
<tbody>
<tr>
<td>1990</td>
<td>General plan for the Santalahti–Näsinsilta stretch of Paasikiventie; City of Tampere</td>
</tr>
<tr>
<td>2000</td>
<td>Ranta-Tampella area planning commenced</td>
</tr>
<tr>
<td>2003</td>
<td>Paasikiventie (VT12) at Onkiniemi and Mustalahti, connection to the Tampella tunnel, Idea plan; City of Tampere and the Finnish Road Administration</td>
</tr>
<tr>
<td>2004</td>
<td>Development report for Tampereen Rantaväylä (VT12 and KT65), Ylöjärvi–Tampere; the Finnish Road Administration, City of Tampere and the Council of Tampere Region</td>
</tr>
<tr>
<td>2004</td>
<td>Rantaväylä tunnel, preliminary plan; City of Tampere and the Finnish Road Administration</td>
</tr>
<tr>
<td>2006</td>
<td>Partial traffic disposition plan</td>
</tr>
<tr>
<td>2007</td>
<td>Begin traffic planning and supporting zone by City of Tampere</td>
</tr>
<tr>
<td>2007</td>
<td>Alternative planning of Rantaväylä through a short tunnel at Onkiniemi and an interchange at Mustalahti, intersections at Tampella and Naistenlahti</td>
</tr>
</tbody>
</table>
The planning project team set some general objectives for the building of the tunnel, along with an environmental impact assessment and road planning. These were mainly set through collaboration between Tampere City Council, Pirkanmaa Regional Council, and the Finnish government. Finally, Tampere City Council and Finnish Transport Agency reviewed the objectives of the project. The main objectives of the project are described in Table 10:

Table 11: Objectives of the project (Rantatunneli Alliance Project Plan, 2013).

<table>
<thead>
<tr>
<th>Category</th>
<th>Objectives</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic System Objectives</td>
<td>- Equal, easy and smooth travel access and opportunities in Tampere city center, despite the increased population</td>
</tr>
<tr>
<td></td>
<td>- Smooth and clear traffic that makes journey planning effortless</td>
</tr>
<tr>
<td></td>
<td>- Rantaväylä traffic accident probability reduction, particularly light traffic accident reduction</td>
</tr>
<tr>
<td></td>
<td>- Smoothness of public transport running through reduction of congestion</td>
</tr>
<tr>
<td>Land Use Objectives</td>
<td>- Create more residential areas near Tampere city center for increased residential capacity</td>
</tr>
<tr>
<td></td>
<td>- Opportunities to utilize the Ranta-Tampella housing development for 3,600 inhabitants</td>
</tr>
<tr>
<td></td>
<td>- Lessening congestion in city area and better pedestrian access from the city center to Onkiemi, Särkänniemi and Lapinniemi areas</td>
</tr>
<tr>
<td></td>
<td>- Smooth access from the city center to lake Näsijärvi shore area</td>
</tr>
<tr>
<td>Making a Vibrant City Centre</td>
<td>- Making Tampere city area as a peaceful environment city for living and working</td>
</tr>
<tr>
<td></td>
<td>- Creating an appealing, hassle-free and pleasing environment and light traffic connections in Näsijärvi area</td>
</tr>
<tr>
<td></td>
<td>- Promote and ensure the Särkänniemi as a prime tourist</td>
</tr>
</tbody>
</table>
Thus, after reviewing the objectives, the City of Tampere and the Finnish Transport Agency signed an agreement in 2008 (later reviewed again in 2012 & 2014). The agreement was based on the road plan for Highway 12, more specifically, the 4.2 km stretch between Santalahti and Naistenlahti, including various roads, bridges, intersection developments and a 2.3 km-long underground tunnel development. It was agreed that rocks would be extracted for developing the tunnel and that Tampere City Council would be the owner of and responsible for any rock that would not be required for developing purposes (Value for Money Report, 2018).

The total budget was initially set for this road implementation plan at €185 m initially in the 2012 budget, in which it was agreed that the cost will be split between Tampere City and the Finnish Transport Agency. According to the budget provision, Tampere City would bear 67% of the cost, whilst the Finnish Transport Agency would bear 33%. Later, in 2016, the budget was raised to a total of €200 m due to the require expansion of the worker team, increased contaminated soil treatment cost, increased soil transport distances and zoning changes. The increased amount was distributed between the two parties according to the previously agreed proportion (Value for Money Report, 2018).

In order to progress with the development plan efficiently and for the efficient use of the invested money, an alliance contract was chosen for this complex development. After tender invitation, the tunnel development work was assigned to Lemminkäinen Infra Oy (now YIT), Riekkola Oy and A-Insinöörit Suunnittelu Oy. In 2018, Lemminkäinen Infra Oy merged with
YIT Oy and now they are collectively known as YIT. Thus, the alliance parties involved in this project are Tampere City, Finnish Transport Agency, Lemminkäinen Infra Oy (now YIT), Riekkola Oy and A-Insinöörit Suunnittelu Oy.

Tunnel excavation work began in March 2014 and the planned opening date for traffic was 15th May 2017. However, the tunnel was completed early and opened for use by traffic in November 2016. The total implementation, including environmental work, was finished in November 2017, earlier than the planned date of summer 2018. The warranties period is currently ongoing and will continue until June 2023.

Figure 10: Rantatunneli implementation timeline (Rantatunneli Alliance Project Plan, 2013)

### 4.1.2 Project Complexity of Rantatunneli

As mentioned in the literature review, a project with a budget of ≥$10 m and incorporating the use of high technologies, environmental challenges, long timeframe and critical activities is considered to be complex. Thus, the Rantatunneli project may be considered to be highly complex in nature. The interview revealed that the Rantatunneli project had some critical characteristics which made it particularly complex in nature, including:

1. Residential area above the tunnel
2. Placement of a hospital above the tunnel
3. Fixed permissible working hours
4. Rock excavation
5. Tunnel position in middle of city center
6. Underground water level
7. Wastewater pipes
8. Relocation of gas pipes and electricity and telecommunication cables

The location of Rantatunneli is near the city center in Tampella area, by lake Näsjärvi. A long-term project near the middle of the city center is very crucial, as many people use this road both with private and public transport and as pedestrians, every day and with a massive frequency. Above the tunnel, there is also a large residential area, along with a hospital. This makes this project more complex as there is a possibility of damaging private property. Moreover, the drilling causes vibration which can have adverse impact along with harsh sound for the hospital and residential areas. To build the tunnel, an almost 2.5 km length of rock had to be excavated. According to Finnish law, rock must be drilled and exploded at the same time during excavation, because of the hardness of the bedrock. This increases the vulnerability of workers and residents living and working above the tunnel. Furthermore, as the tunnel is near lake Näsjärvi’s shore, the groundwater level was high in the area of the development. The project team had to be very careful as during implementation, groundwater level drops significantly upon rock excavation. The team had to pump the water out and measure the tensile strength of all components to determine whether they were prone to sinking if crack would develop. In addition, wastewater and gas pipes and electricity and telecommunication cables needed to be relocated during the implementation. These activities made this project even more complex in nature.

Due to the complexity of the core project features of the Rantatunneli project, the planned implementation length was 46 months, through it was completed within 39 months. The team size was approximately 400 workers, the budget was €180 m, five alliances parties were involved and a total 4.3 km-long route was built. Based on these characteristics, the Hass et al. (2010) project complexity characteristics framework is used to verify that the Rantatunneli project was highly complex.
Table 12: Project complexity framework validation (characteristics for Rantatunneli project are highlighted in red)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Low Complexity</th>
<th>Medium Complexity</th>
<th>High Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time/Cost</td>
<td>&lt;3 months</td>
<td>3-6 months</td>
<td>&gt;6 months</td>
</tr>
<tr>
<td></td>
<td>&lt;$250K</td>
<td>$250-750K</td>
<td>&gt;$750K</td>
</tr>
<tr>
<td>Team Size</td>
<td>3-4</td>
<td>5-10</td>
<td>&gt;10</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Team Composition and Performance</td>
<td>Strong project leadership</td>
<td>Competent project leadership</td>
<td>Project manager is not experienced in leadership</td>
</tr>
<tr>
<td></td>
<td>Internal team</td>
<td>Internal and External resources team</td>
<td>Complex team structure with various competencies</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urgency and Flexibility of Cost, Time and Scope</td>
<td>Minimized scope</td>
<td>Little flexibility in schedule and budget</td>
<td>Over ambitious scope and schedule</td>
</tr>
<tr>
<td></td>
<td>Small milestones</td>
<td>Achievable scope and milestones</td>
<td>Schedule is strictly fixed</td>
</tr>
<tr>
<td></td>
<td>Flexible schedule, budget</td>
<td></td>
<td>No flexibility in budget and scope</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clarity of Problem, Opportunity and Solution</td>
<td>Smooth business objective</td>
<td>Defined business objective</td>
<td>Unclear business objective</td>
</tr>
<tr>
<td></td>
<td>Easily understandable problem, opportunity</td>
<td>Opportunity, problem, partially defined</td>
<td>Problem &amp; opportunity is undefined</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Requirements, Volatility and Risk</td>
<td>Strong customer support</td>
<td>Moderate customer support</td>
<td>Inadequate customer support</td>
</tr>
<tr>
<td></td>
<td>Requirements are understood,</td>
<td>Requirements are understood, but</td>
<td>Requirements are unclear, volatile</td>
</tr>
<tr>
<td></td>
<td>Straightforward and stable</td>
<td>changeable</td>
<td></td>
</tr>
<tr>
<td>Strategic Importance, Political Implications, Multiple Stakeholders</td>
<td>Straight executive support</td>
<td>Adequate executive support</td>
<td>Inadequate executive support</td>
</tr>
<tr>
<td>---------------------------------------------------------------</td>
<td>-----------------------------</td>
<td>-----------------------------</td>
<td>----------------------------</td>
</tr>
<tr>
<td>No Political implications</td>
<td>Minor political implications</td>
<td>Major political implications</td>
<td></td>
</tr>
<tr>
<td>Straightforward communication</td>
<td>2-3 stakeholder group</td>
<td>Multiple stakeholder group with conflicting expectations</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of Organizational Change</td>
<td>Impacts a single business unit, one familiar business process, and one IT system</td>
<td>Impacts 2-3 somewhat familiar business units, processes and IT system</td>
<td>Large scale organizational change that impacts enterprise</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Impacts mainly business process and IT system</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of Commercial Change</td>
<td>Minor changes to existing to existing commercial practices</td>
<td>Enhancements to existing commercial practices</td>
<td>Groundbreaking commercial practices</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Risks, Dependencies and External Constraints</td>
<td>Considered low risk</td>
<td>Considered moderate risk</td>
<td>Considered high risk</td>
</tr>
<tr>
<td></td>
<td>Some external influences</td>
<td>Some project objective are dependent on external factors</td>
<td>Overall project success largely depends on external factors</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of IT Complexity</td>
<td>IT complexity are low</td>
<td>IT complexity are moderate</td>
<td>IT complexity and legacy integration</td>
</tr>
</tbody>
</table>
A spider chart is also presented based on the Hass et al. (2010) frameworks:

Figure 11: Spider chart of project complexity

This spider chart represents the Rantatunneli project complexity level by analyzing eight characteristics. Score 0.1-0.3, 0.4-0.7, 0.8-1.0 is assigned for a simple project, moderately complex project, and highly complex project respectively. The Rantatunneli project team consists of an alliance contract, thus the team was formed through both internal and external personnel who has different skills, expertise, and background. As it also has strong project leadership, thus, the score of 0.7 is assigned for team composition criteria. In this project, there was much advanced technological equipment, but there was not much IT complexity
as it was basically a construction project, thus 0.6 scores are given on this criterion. This project objective was dependent on many external factors, as well as it has many high-risk factors in the construction site, thus 0.9 scores are assigned to this risk, dependencies, and external factors criteria. At the beginning of the project, there were high political implications as opposition leaders strongly opposed this project, thus 0.9 scores are given on this political implication criterion. This project had around 5 years schedule, the budget was around 180 million euro and average personnel was around 400, thus the score of 1 is given on the team, cost and size criteria. This project schedule and budget allowances was fixed, there was no flexibility to change this later, as the final budget and schedule was approved by the higher authority after deep analyze. Thus, 0.8 scores are assigned on this urgency, flexibility of time and scope criterion. The project was highly complex due to many factors and the requirements to complete the project was understood but there was a chance of interfering in many uncertainties. Thus, 0.8 scores are assigned on this volatility and risk criterion.

From the project complexity framework presented by Hass et al. (2010), it is clear that most of the characteristics of the Rantatunneli project were prone to high complexity. Although there were many factors which made this project more complex beside these mentioned ones in the general and framework features, these were the most impactful factors.

4.1.3 Risk Management of Rantatunneli
In the Rantatunneli project, the alliances followed RM process in two phases: development and implementation phases. Risk identification, risk analysis, risk distribution and risk action were followed in both phases as a continuous process throughout the project. The alliances decided not to take account of any risk that is associated with personnel, traffic or tunnel safety; rather, their aim was to use RM tools to reduce or avoid those risks. They had planned to consider all types of risks which could hamper the implementation phase of the project, including both external and internal risk factors. Mr. Mäkiaho stated that “there is no room for technical failure after opening the tunnel, as around 40,000 transports run everyday through this route, thus we have to succeed the first time”. To set up their RM procedure and implement a successful project, the information of the initial road plan assessment was used. Their risk management areas included:

- Risk tolerance definition
- Risk assessment: identifying, analyzing, occurrence probability and impact factor
- Preparation for risks
- Distribution of the risks information
- Train the whole organization regarding RM

In the development phase, the road plan risk assessment was initially updated based on the situation at the time and later the risk that was identified in the road planning phase was distributed and mapped by the technical discipline team.

During both the development and implementation phases, the project team’s responsibility was divided into three main phases, each with different groups of teams. The whole RM project team was divided into three groups, named, Alliance RM group, Workshop group and Technology-specific group. The total RM procedure for the whole project was
determined by these three specific groups and they were solely responsible for any uncertainty and risk of the Rantatunneli project.

Figure 13: RM decision steps.

In the first step, the technical discipline group focused on the risks that were identified for the road plan and dealt with those risks. This was done by separate sub-groups, according to their own technological field. For example, the bridge group only dealt with the risks associated with bridge section and similarly the tunnel group only focused on the risks associated with the tunnel. Along with the identified risks for the road plan, technical discipline groups identified and mapped new groups of risks, according to their own technological field. In this step, groups also measured the severity of the risks through calculating the impact factor and probability of occurrence. The technical groups had to present their work at every meeting. In next step, management methods and responsibilities were assigned to different workshop groups and the severity of risk was recalculated from the perspective of different technological disciplines. These workshop group meetings were held every three months in order to discuss new risks that had been identified by the technical
discipline groups. In the next step, technical discipline groups calculated the direct cost impact based on the occurrence of risks and later this was determined further as the minimum and maximum effects on cost. In this stage, the high-impact risk decision-making was dealt with by the alliance RM group and specialist RM group. The senior management group took decisions about high-risk issues and whether to accept such risks through cost allocating or investigate how to minimize their impact. This alliance RM group guided and monitored the whole RM process. Based on the decisions and instructions of the top management group and workshop groups, specific technical groups implemented action plans to tackle the identified risks.

Risk Classification
In the Rantatunneli project, risks were grouped based on the work of the specialist groups and the phases in which the risks were identified in both the development and implementation phases. The identified risks were categorized as either:

- Risks by specific technological discipline
- Project management risks

The first category risks consisted of individual risks based on specific technological disciplines, such as bridge, tunnel, road and technical systems. Project management risks were additionally categorized into administrative- and production-related risks.

After identifying each new risk, they were defined through attaching some characteristics of it:

- Identifier person & description of the risk
- The type of risk
- Risks severity & impact on cost
- Management methods and assigned responsible persons

During the interview, Mr. Mäkiaho stated that “the risks we have identified during the development and implementation phases are mainly technical risks”. Besides those, some notable risks were identified by the project management team in both the development and implementation phases. Their disciplines and risk categories are noted in Table 12:
Table 13: Risk categories of the Rantatunneli project.

<table>
<thead>
<tr>
<th>Risks Name</th>
<th>Discipline</th>
<th>Risk Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polluted soil</td>
<td>Specific Technological</td>
<td>Technical risk</td>
</tr>
<tr>
<td>Quality of rock</td>
<td>Specific Technological</td>
<td>Technical risk</td>
</tr>
<tr>
<td>Ground water level control</td>
<td>Specific Technological</td>
<td>Technical risk</td>
</tr>
<tr>
<td>People acceptance</td>
<td>Project Management</td>
<td>Social risk</td>
</tr>
<tr>
<td>Tunnel malfunction</td>
<td>Specific Technological</td>
<td>Operational risk</td>
</tr>
<tr>
<td>Staff turnover</td>
<td>Project Management</td>
<td>Schedule risk</td>
</tr>
<tr>
<td>Breach schedule</td>
<td>Project Management</td>
<td></td>
</tr>
<tr>
<td>Increase of material price</td>
<td>Project Management</td>
<td>Market risk</td>
</tr>
<tr>
<td>Subcontractor failure</td>
<td>Project Management</td>
<td></td>
</tr>
<tr>
<td>Political oppose</td>
<td>Project Management</td>
<td>Political risk</td>
</tr>
</tbody>
</table>

(I) **Technical Risks:** The project management team identified some major technical risks, including polluted soil, quality of rock and ground water level control. Polluted soil was one of the biggest risks for the team as it was almost impossible to measure the accurate percentage of pollution, and after eradicating it, soil had to be placed in Nasijarvi lake. This risk cost was not included in the project budget as accurate measurement of the amount of polluted soil was impossible. Thus, the client agreed to incur 75% of the cost of this risk, with the remaining 25% being covered by the project team as their own expense and from their reward share. Dealing with the quality of the rock was another challenging task and risk for the management team, as it needed to drill into and explode hard rock to excavate it. Furthermore, due to the large size of drill holes, the ground water level dropped significantly and required significant resources to control it.

(II) **Social Risk:** Ensuring that the public accepted the tunnel project was another major challenge for the team, as it was conducted near the city center, under an existing residential zone. Many people were afraid that tunnel may collapse and that their property may get damaged.

(III) **Operational Risk:** Another significant risk for the project team was tunnel malfunction. After opening the tunnel, the previous alternative road was closed.
immediately. Thus, if there had been any malfunction in the tunnel after opening, there would have been no alternative routes along which vehicles could pass.

(IV) **Schedule Risk:** The project management team made an initial schedule for the project. Thus, there was uncertainty whether it would possible to complete the project within the specified timeline, because of project complexity and unforeseen technical difficulties. However, the project team was able to finish the project six months ahead of schedule, which can be considered a huge success.

(V) **Political Risk:** When the budget was approved by city council, the opposition leaders at the time opposed the project and its high budget. They tried to stop the project by claiming that the budget was too high for the council to fund and that it was unnecessary to build a tunnel so close to the city center.

(VI) **Market Risk:** There was a risk that material prices may have been increased by suppliers when politicians opposed the project.

**Risk Matrix:**

For risk severity assessment, a risk grading scale method is used, in which a score of 1 represents the lowest probability and impact of risk and 5 represents the highest probability and most major impact on the project.

<table>
<thead>
<tr>
<th>Grading Value</th>
<th>Probability of Occurrence</th>
<th>Impact Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Almost impossible</td>
<td>Insignificant</td>
</tr>
<tr>
<td>2</td>
<td>Improbable</td>
<td>Less significant</td>
</tr>
<tr>
<td>3</td>
<td>Possible</td>
<td>Significant</td>
</tr>
<tr>
<td>4</td>
<td>Probable</td>
<td>Very significant</td>
</tr>
<tr>
<td>5</td>
<td>Almost certain</td>
<td>Critical</td>
</tr>
</tbody>
</table>

Through using this risk grading scale, RPN (Risk Priority Number) was calculated to find out the seriousness of the risk, where RPN = Probability of Occurrence × Impact.
Table 15: Risk severity calculation.

<table>
<thead>
<tr>
<th>Risk Number</th>
<th>Risk</th>
<th>Probability</th>
<th>Impact</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>Polluted soil</td>
<td>5</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>R2</td>
<td>Quality of rock</td>
<td>3</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>R3</td>
<td>Ground water level control</td>
<td>4</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>R4</td>
<td>People acceptance</td>
<td>3</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>R5</td>
<td>Tunnel malfunction</td>
<td>2</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>R6</td>
<td>Staff turnover</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>R7</td>
<td>Breach schedule</td>
<td>1</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>R8</td>
<td>Increase of material price</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>R9</td>
<td>Subcontractor failure</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>R10</td>
<td>Political opposition</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
</tbody>
</table>

This risk severity can be presented graphically through a risk matrix, in which critical, moderate and nominal risks are easily visible.

Table 16: Risk matrix for Rantatunneli project.

<table>
<thead>
<tr>
<th>Probability of Occurrence</th>
<th>Almost certain</th>
<th>Probable</th>
<th>Possible</th>
<th>Improbable</th>
<th>Almost impossible</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R2 &amp; R4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>R10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The risk realization compared to the risk anticipation was mainly notable in 2 areas:

1. Contaminated soil volume at work site
2. Temporary traffic arrangement for both in work site and public alternative route

**Opportunities:**
The project team always attempted to gather new ideas and develop problem solving methods from the beginning of the development phase. The project team was flexible with regards to the planned specifications so that new ideas and opportunities could be implemented in the development and implementation phases. Several workshops were also arranged for the team, in which participants were required to solve different problems related to the project. Several training sessions were also arranged for the team to improve their creative thinking capability, enabling them to think outside the box and establish new opportunities. These workshop and training sessions were also intended as team-building exercises to help foster both individual and team work. Several designs and multiple solutions were taken into consideration when solving problems and the most effective solution with the best opportunities was then selected. The big room concept was used and was located near the project site, where the project team held informal meetings and brainstorming sessions in order to generate new ideas and identify opportunities. The project team also always welcomed local residents to express their thoughts about the project, in order to gain new ideas and opportunities from their opinions. Thus, some of the opportunities realized throughout the project are summarized below:

- The contractors had enough expertise on construction work and more specifically, for tunnel building.
- High technology equipment which facilitated the construction work.
- The project team had sufficient time after design for the testing period.
- The ventilation duct of the eastern end of the tunnel was widened, in order to use it as a work tunnel and the exhaust fans of the eastern side were placed on the ventilation duct.
- Inside the rock, space was made for the required technology, which saved the cost of having to build a separate building.
- It was possible to narrow the right-hand side cross section of the tunnel, as it was used as a safety line.
• Alternative access was created into the tunnel from the Nääshalli area, which shortened the project lead time.
• This tunnel project has opened the door to build newer projects in the city center area, such as building a Technopolis beside the tunnel.
• Suppliers offered low prices for the materials, as it was a public project.
• This tunnel project enabled the building of a new housing district in Ranta-Tampella, which will increase Tampere City Council’s income.

The most notable differences regarding the opportunities realization compared to the initial assumption was mainly in 2 areas:
1. Less spent on supplies
2. Lower final design cost

4.1.4 Risk Management Performance Evaluation
The Rantatunelli project team did not use any specific measurement criteria to evaluate the performance of their RM, but they used some measurement criteria to evaluate the whole project success. This enabled the project team to gain incentives after the project. The Measurement criteria they used were:

1. The Target Outturn Cost (TOC)
2. KPI for Key Result Areas (KRA)
3. Positive and Negative modifiers

These measurement criteria were formulated so that the project could be measured in terms of whether it met the minimum requirement for the project to be considered as a success. Target outturn cost, KPI for KRA and positive and negative modifiers were measured at regular monthly intervals throughout the project.
The TOC: The target outturn cost for project implementation was set by the alliances in the development phase and included the direct reimbursable cost, the risk cost and the fees of contractors. The target was that any leftover money from the TOC would be split between the alliance partners. The final target outturn cost was €195,938,844 and the actual cost was €192,183,048. Thus, the TOC was undercut by €3,755,796, which was due to be paid out as an incentive bonus between the alliances partners.
**KPI for KRA:** The alliance team set some key results area which were, schedule, safety, usability and public image. These result areas may be judged by comparing the minimum performance target with the industry average. Considering the minimum performance level, bonuses are paid, and penalties are imposed. The indicator to measure each of these key result areas was set from -100 to +100 points and defined as follows:

- Up to +100 points for breakthrough and outstanding performance
- Up to -100 points for total failure regarding meeting minimum requirement criteria
- 0 score if the meet minimum requirement criteria are met

Table 17: KPI for KRA for Rantatunneli project.

<table>
<thead>
<tr>
<th>KRA</th>
<th>Target (0 level)</th>
<th>Result</th>
<th>KRA Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Schedule</td>
<td>Complete by 15th May 2017</td>
<td>Completed 15th November, 2016</td>
<td>100 points</td>
</tr>
<tr>
<td>Safety (accident rate &amp; absence due to accident)</td>
<td>14–16</td>
<td>11.9</td>
<td>15.1 points</td>
</tr>
<tr>
<td></td>
<td>160–200</td>
<td>56</td>
<td></td>
</tr>
<tr>
<td>Usability</td>
<td>Constant traffic flow with some disruptions</td>
<td>3 minor disruptions</td>
<td>94 points</td>
</tr>
<tr>
<td>Public image</td>
<td>85–90</td>
<td>88</td>
<td>0 points</td>
</tr>
</tbody>
</table>

**Positive and Negative Modifier:** The positive and negative modifier criterion was used to provide the reward or give penalties to the alliances for those tasks which were very crucial for the project’s success. To set indicator values for this criterion would not have been practical. A positive modifier could add up to 20 points whereas a maximum of 10 points could be deducted for a negative modifier.

Table 18: Positive modifiers for Rantatunneli project.

<table>
<thead>
<tr>
<th>Positive modifier</th>
<th>Target</th>
<th>Result</th>
<th>KRA Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Traffic disturbances during construction</td>
<td>KVL same as before the project</td>
<td>KVL -1% less than before the project</td>
<td>+5</td>
</tr>
</tbody>
</table>
Table 19: Negative modifier s for Rantatunneli project.

<table>
<thead>
<tr>
<th>Negative modifier</th>
<th>Target</th>
<th>Result</th>
<th>KRA Points</th>
</tr>
</thead>
<tbody>
<tr>
<td>Highway 12 traffic disturbances</td>
<td>Traffic stopped for 6–24 hr</td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Train traffic disturbances</td>
<td>Train stopped for 6–24 hr</td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td>Grey economy</td>
<td>Observed once</td>
<td>None</td>
<td>0</td>
</tr>
<tr>
<td></td>
<td>Observed twice</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Based on the calculation of the weighted KRA, contractors received €4,681,509 as an incentive bonus. This was split so that LMK Infra Oy received €4,100,299, A-insinoorit Oy received €331,008 and S&R Oy received €250,202.

In summary, the target outturn cost was reduced a slight amount, the schedule was undercut and the project was finished 6 months early, usability was good and public image also improved throughout the course of the project, as the tunnel cut travel time significantly and there was no sign of any major events or accident. Thus, the project performance was significantly higher than expected, as it fulfilled all of the key objectives.

4.2 Case Project-2: Tampere Tramway Project

This section will cover the background of the Tampere Tramway project, along with its RM process, risk mapping, major and minor risk discussion and RM performance steps. This project began in 2017 and is therefore still under construction. Therefore, the principle of
RM and RM performance management is still not finalized yet and is being updated continuously.

### 4.2.1 Background of Tampere Tramway Project

The Tampere city is the third largest city of Finland after Helsinki and it is one of the IT business hubs of this country. The city’s population is increasing and demand to live and work in Tampere is currently growing steadily. Thus, to manage the growing population’s transportation demands, Tampere City Council decided to construct a modern tramline. The main objectives of the tramway project are:

- To make everyday life easier for workers and residents of Tampere
- To provide smooth and sufficient transportation facilities for the growing population of the municipality
- To support the development growth of urban area
- To increase the appeal of Tampere city to workers and residents
- To increase the appeal of Tampere city to tourists
- To reduce energy consumption through the use of tram cars
- To reduce city traffic congestion

In order to ensure development of an efficient project solution, an alliance was formed to build the tramway, in which City of Tampere is the main client and the construction subcontractors were YIT Construction Services, VR Track Oy and Pöyry Finland Oy. These three construction service providers are responsible for designing and constructing tramline infrastructure, as well as tram depot area. The Tampere city will finish the procurement of tram cars during the construction phase. The interfaces that are required for tram cars to place on the track have already been designed during the development phase and will be further inspected and modified throughout the implementation phase if necessary (Tramway Implementation Plan, 2017).

The tramline’s construction is being implemented in two sections. In the first section, construction started simultaneously with an eastbound two-branch line from Pyynikintori to Hervantajärvi, with a branch from Tampere University Hospital (Tays) connecting to Pyynikintori. In the second section, a westbound tramline will be built from Pyynikintori to
Lentavanniemi via Lielahti. The alliance team has fixed the implementation content for section one, which covers:

- Building the tramline and its stops
- Groundwork (earth and road) required for the tramline
- Building of power supply stations and tram depot area
- Additional construction of side road and bridges
- Required underground cable transfers
- Technical system implementation

The characteristics of the track of section one is shown in Table 19:

Table 20: Tracks of section 1 of Tampere Tramway (Tramway Implementation Plan, 2017).

<table>
<thead>
<tr>
<th>Tracks of Section 1</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of line tracks</td>
</tr>
<tr>
<td>Length of depot tracks</td>
</tr>
<tr>
<td>Width of tracks</td>
</tr>
<tr>
<td>Number of stops</td>
</tr>
<tr>
<td>Number of new bridge</td>
</tr>
<tr>
<td>Number of renovated bridge</td>
</tr>
<tr>
<td>Number of lines</td>
</tr>
<tr>
<td>Maximum speed of line</td>
</tr>
<tr>
<td>Number of cars</td>
</tr>
<tr>
<td>Passenger capacity of each car</td>
</tr>
</tbody>
</table>

The implementation phase of section one is scheduled to last four years. Its construction started in 2017 and will continue until 2021. The implementation phase of section 2 will commence in 2021 and is due to be completed by 2024. The construction of section 1 started
simultaneously at different sites at Pyynikintori, Hameenkatu, Itsenaisyydenkatu, Sammonkatu, Hevanan Valtavyla, Insinoorinkatu, Atomipolku, Hermiankatu and the depot area in Hervanta. The running construction work of section one is being monitoring continuously by the alliance’s team and its target is to cause as minimal hassle for residents and road traffic during the whole construction period as possible. The tramway implementation plan is outlined in Figure 16:

![Tampere Tramway Implementation Schedule](image)

Figure 15: Tampere Tramway implementation schedule (Tramway Implementation Plan, 2017).

The projected total cost for this project is approximately €282.9 m, of which €238.8 m is for section 1 and €44.1 m is for section 2. The total cost estimate for section 1 includes the fee of the alliance and its required procurement, risk reserve and bonus pool cost. The owner of the tramway is Tampere City and the tram cars will be used for public transportation within Tampere city. Existing bus lines and service will be coordinated with the tramline once it opens.

### 4.2.2 Project Complexity of Tramway Project

According to the characteristics of project complexity, Tampere Tramway project is a very complex project in its nature. In the questionnaire interview, Mr. Toni Hytonen, the head of RM of Tramway project, defined this project complexity with following characteristics:

- Total budget is €283 m
- Total implementation schedule for both sections is seven years
- 23 km-long tram track is under construction
- Average number of personnel is 450
- Multiple stakeholders’ involvement
- Construction on busy city center roads
- A large number of residential areas near and between the construction route
- Blockage of active and busy traffic and arrangement of alternative traffic solutions
- Relocation of water pipes and electricity cables

Based on these characteristics, the Hass et al. (2010) project complexity characteristics framework verifies that this the Tampere Tramway project has a high degree of complexity.

Table 21: Tampere Tramway project complexity framework validation (characteristics for Tramway project are highlighted in red)

<table>
<thead>
<tr>
<th>Factor</th>
<th>Low Complexity</th>
<th>Medium Complexity</th>
<th>High Complexity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Time/Cost</td>
<td>&lt;3 months, &lt;$250K</td>
<td>3-6 months, $250-750K</td>
<td>&gt;6 months, &gt;$750K</td>
</tr>
<tr>
<td>Team Size</td>
<td>3-4</td>
<td>5-10</td>
<td>&gt;10</td>
</tr>
<tr>
<td>Team Composition and Performance</td>
<td>Strong project leadership</td>
<td>Competent project leadership</td>
<td>Project manager is not experienced in leadership</td>
</tr>
<tr>
<td></td>
<td>Internal team</td>
<td>Internal and external resources team</td>
<td>Complex team structure with various competencies</td>
</tr>
<tr>
<td></td>
<td>Formal methodologies</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Urgency and Flexibility of Cost, Time and Scope</td>
<td>Minimized scope, Small milestones, Flexible schedule, budget</td>
<td>Little flexibility in schedule and budget, Achievable scope and milestones</td>
<td>Over ambitious scope and schedule, Schedule is strictly fixed, No flexibility in budget</td>
</tr>
</tbody>
</table>

Based on these characteristics, the Hass et al. (2010) project complexity characteristics framework verifies that this the Tampere Tramway project has a high degree of complexity.
<table>
<thead>
<tr>
<th>Clarity of Problem, Opportunity and Solution</th>
<th>Smooth business objective</th>
<th>Defined business objective</th>
<th>Unclear business objective</th>
</tr>
</thead>
<tbody>
<tr>
<td>Easily understandable problem, opportunity</td>
<td>Opportunity, problem, partially defined</td>
<td>Problem &amp; opportunity is undefined</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Requirements, Volatility and Risk</th>
<th>Strong customer support</th>
<th>Moderate customer support</th>
<th>Inadequate customer support</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requirements are understood, Straightforward and stable</td>
<td>Requirements are understood, but changeable</td>
<td>Moderately complex functionality</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Strategic Importance, Political Implications, Multiple Stakeholders</th>
<th>Straight executive support</th>
<th>Adequate executive support</th>
<th>Inadequate executive support</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Political implications</td>
<td>Minor political implications</td>
<td>Major political implications</td>
<td></td>
</tr>
<tr>
<td>Straightforward communication</td>
<td>2-3 stakeholder group</td>
<td>Multiple stakeholder group with conflicting expectations</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Level of Organizational Change</th>
<th>Impacts a single business unit, one familiar business process, and one IT system</th>
<th>Impacts 2-3 somewhat familiar business units, processes and IT system</th>
<th>Large scale organizational change that impacts enterprise</th>
</tr>
</thead>
<tbody>
<tr>
<td>Minor changes to existing to existing commercial</td>
<td>Enhancements to existing commercial practices</td>
<td>Groundbreaking commercial practices</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Level of Commercial Change</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
A spider chart is also presented in Figure 17, based on the Hass et al. (2010) framework:

![Spider Chart of Project Complexity](image)

**Figure 16: Spider Chart of Project Complexity**

This spider chart represents the Tramway project complexity level by analyzing eight characteristics. Score 0.1-0.3, 0.4-0.7, 0.8-1.0 is assigned for a simple project, moderately complex project, and highly complex project respectively. The Tramway project team consists of an alliance contract; thus, the team is formed through both internal and external personnel who has different skills, expertise, and background. Thus, the score of 0.8 is
assigned for team composition criteria. In this project, there is much advanced technological
equipment, but there is not much IT complexity as it is basically a construction project, thus
0.6 scores are given on this criterion. This project objective is dependent on many external
factors, as well as it has many high-risk factors in the construction site, thus 0.9 scores are
assigned to this risk, dependencies, and external factors criteria. At the beginning of the
project, there were not many political implications but there was the challenge in approving
the project from the political authority, thus 0.7 scores are given on this political implication
criterion. This project has around 7 years schedule, the budget is around 283 million euro
and average personnel was around 450, thus the score of 1 is given on the team, cost and size
criteria. This project schedule and budget allowances are fixed for now, though there are still
scoping to change the budget and timeline, as the first phase of the project just begun, and
the second phase is still not started yet. Thus, 0.7 scores are assigned on this urgency,
flexibility of time and scope criterion. The project was highly complex due to many factors
and the requirements to complete the project is understood but there is a chance of interfering
in many uncertainties. Thus, 0.8 scores are assigned on this volatility and risk criterion.

From the Hass et al (2010) project complexity framework and the spider chart based on that
framework, it is clear that this tramline project is very complex in nature. Building a 23 km-
long tram track in the middle of a busy city while having large amount of active traffic is a
very challenging task, thus indicating the high complexity of this project.

### 4.2.3 Risk Management of Tramway Project

The RM approach of this project is divided into two phases: development phase and
implementation phase. Initially, the RM was planned for section 1, as the section 2
development phase will not start until 2020. In the development phase, after identifying the
risks, the alliance’s team used a Monte Carlo simulation model in order to calculate the risk
value and risk level. The basic risk management steps the project team is currently following
is depicted in Figure 18:
Figure 17: Risk management process of Tampere Tramway project.

The risk responsibility was categorized separately by the alliance’s management and project teams. The alliance’s management team is mostly responsible for identifying and managing major project risks, which might have major impact and could hamper the project’s goals, whilst the project team is mostly responsible for operational risks.
Figure 18: Risk management team responsibilities.

**Risk Category:**
According to the participant of the questionnaire interview for this project case, many risks were identified during the development phase. As the implementation phase is already underway, some risks continue to emerge day-by-day. During the development phase, identified risks were mainly related to cost and constructability. Later, in the implementation phase, risks related to work safety, project, cost, schedule and operation are being identified. The most notable risks of the tramway project along with their categories are outlined in Table 22:

Table 22: Risks and risk categories of Tampere Tramway project.

<table>
<thead>
<tr>
<th>Risks Name</th>
<th>Risk Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Active urban environment</td>
<td>External</td>
</tr>
<tr>
<td>Project permission</td>
<td></td>
</tr>
<tr>
<td>Construction collapse</td>
<td></td>
</tr>
<tr>
<td>Contaminated soil</td>
<td>Operational</td>
</tr>
<tr>
<td>Worker accident</td>
<td>Work safety</td>
</tr>
<tr>
<td>Staff turnover</td>
<td>Management</td>
</tr>
<tr>
<td>Breach schedule</td>
<td>Schedule</td>
</tr>
<tr>
<td>Material price increase</td>
<td>Cost/Market</td>
</tr>
<tr>
<td>Subcontractor failure</td>
<td>Market</td>
</tr>
<tr>
<td>Adverse weather</td>
<td>Environmental</td>
</tr>
</tbody>
</table>

(1) **External Risk:** The most notable external risks for this project have been the active urban environment and gaining project permission. Initially, it was very challenging to gain permission for the project’s large budget from the local authority. There was a risk of significant delay to the project, if an appeal would have been launched against the permission granted to the proposal. Furthermore, the project is ongoing in the midst of an active urban environment, including between multiple residential zones, the city center and a hospital. This possess a high risk in terms of managing the busy traffic and providing as little disruption as possible to the city’s residents and businesses.
(2) **Operational Risk:** Some of the most notable operational risks that the project faces include risk of the construction collapsing and contaminated soil. Though these risks are very common for any type of construction project, they have potential to impact the project. For example, a collapsing trench is a relatively common type of failure which can cause severe danger to work personnel and extra costs. On some construction sites, soil contaminated with heavy metals or other contaminants can also pose a minor risk in terms of requiring additional budget and manpower to decontaminate the area.

(3) **Work Safety Risk:** One of the most common risks for any construction project is work safety. Although the project team has planned to ensure maximum protection regarding the safety, there is always a risk of facing uncertainties. During the course of the tramway project, the project team has already faced five minor work safety incidents during the construction period. Though these incidents were not severe, they had an impact on the workers’ productivity and the project schedule.

(4) **Schedule Risk:** Another common project risk is schedule delay, which occurs in a large proportion of projects due to other types of risk emerging. In particular, complex projects suffer the highest percentage rate of schedule delays compared to less complex projects. Delays require additional budget and can contribute towards other external problems for the project. However, the tramway project’s construction period is currently running according to schedule.

Beside these risks, some other market and environmental risks are anticipated for this project and have the potential to cause notable impacts, should they occur.

**Risk Matrix:**

The risk grading scale presented in Table 23 (according to chapter 4.1.3), RPN (Risk Priority Number), was used to calculate the degree of risk faced by the Tampere Tramway project, where, RPN = Probability of Occurrence * Impact:
Table 23: Risk severity calculation for Tampere Tramway project.

<table>
<thead>
<tr>
<th>Risk Number</th>
<th>Risk</th>
<th>Probability</th>
<th>Impact</th>
<th>RPN</th>
</tr>
</thead>
<tbody>
<tr>
<td>R1</td>
<td>Active urban environment</td>
<td>5</td>
<td>4</td>
<td>20</td>
</tr>
<tr>
<td>R2</td>
<td>Project permission</td>
<td>4</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>R3</td>
<td>Construction collapse</td>
<td>4</td>
<td>4</td>
<td>16</td>
</tr>
<tr>
<td>R4</td>
<td>Contaminated soil</td>
<td>3</td>
<td>3</td>
<td>9</td>
</tr>
<tr>
<td>R5</td>
<td>Worker accident</td>
<td>3</td>
<td>4</td>
<td>12</td>
</tr>
<tr>
<td>R6</td>
<td>Staff turnover</td>
<td>2</td>
<td>3</td>
<td>6</td>
</tr>
<tr>
<td>R7</td>
<td>Breach schedule</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>R8</td>
<td>Material price increase</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>R9</td>
<td>Subcontractor failure</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>R10</td>
<td>Adverse weather</td>
<td>4</td>
<td>3</td>
<td>12</td>
</tr>
</tbody>
</table>

The risk severity can also be presented graphically through a risk matrix, in which critical, moderate and nominal risks are easily visible:

Table 24: Risk matrix for Tampere Tramway project.
The following anticipated risks have been realized significantly so far during the project’s implementation:

- Traffic management in an active urban environment
- Contaminated soil in some construction area
- Some minor accidents on worksites

4.2.4 Risk Management Performance Measurement

The Tramway project implementation phase started in 2017 and is currently ongoing, thus, the RM process and its performance measurement criteria are being continuously upgraded. The project team has not finalized any performance measurement criteria such as KPI yet, as they are still in the process of improving the plan.

At present, the team is temporarily judging its RM performance through comparison of the number of open hazards with the number of controlled or removed hazards. In its current RM performance measurement system, the project team follows the steps presented in Figure 20:

![Figure 19: Tampere Tramway project risk management performance measurement process steps.](image)

The main goal of the project’s mitigation measures is to reduce any identified risks to an acceptable level or remove them completely. The project team is using the following mitigation measures:

- Remove the hazard
- Separate the hazard
- Lower probability and consequences
- Warning and instructions
4.3 Cross Case Analysis

Cross case analysis is very useful for presenting the themes, similarities and differences in research involving multiple case studies. The core RM processes and RM performance measurements of these two case studies are compared in Table 24:

Table 25: Cross-case analysis.

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Tampere Rantatunneli</th>
<th>Tampere Tramway</th>
</tr>
</thead>
<tbody>
<tr>
<td>Project content</td>
<td>Construction</td>
<td>Construction</td>
</tr>
<tr>
<td>Source of capital</td>
<td>Public</td>
<td>Public</td>
</tr>
<tr>
<td>Complexity</td>
<td>Complicated</td>
<td>Complicated</td>
</tr>
<tr>
<td>Risk management</td>
<td>Identification → analysis → distribution → action</td>
<td>Identification → Estimation → mitigation → monitoring &amp; review</td>
</tr>
<tr>
<td>Risk management</td>
<td>Measured through project success</td>
<td>No fixed criteria yet, measuring through available and eliminated number of risk</td>
</tr>
</tbody>
</table>

1. Both Tampere Tramway and Tampere Rantatunneli are construction projects which rely upon public funding as their sources of capital.

2. Tampere Rantatunneli had an alliance team consisting of five partners, a budget of €180 m, a four-year implementation schedule, a team size of around 400 and concerned the construction of a 4.3 km-long, including a 2.3 km tunnel. Tampere Tramway has an alliance team consisting of four partners, a budget of €282.9 m, a seven-year implementation schedule, a team size of around 450 and concerns the construction of a 24 km-long tram track. Both projects are therefore considered to be highly complex.

3. Some of the major risks of the Rantatunneli project that contributed to its complexity included excavation of hard rock, construction of a long underground tunnel near the city center, proximity of residential areas and a hospital, reduction of underground water
levels upon excavation and relocation of wastewater and gas pipes and electricity and telecommunications cables. Some of the major risks of the tramway project that contributed to its complexity include construction on active city roads, proximity to multiple residential areas, blockage of traffic and arrangement of alternative traffic solutions and relocation of electric cables.

4. The RM of Runtatunneli was carried out during two phases of the project, development and implementation. In both phases, a path of risk identification → analysis → distribution → action processes were followed. The RM team was divided into three groups: a technology specific group, a workshop group and the alliance’s RM group. Similarly, the tramway project is also conducting their RM process during both the development and implementation phases, with a path of identification → estimation → mitigation → monitoring and review stages being followed.

5. The Runtatunneli project team did not set any specific criteria to measure their RM performance; rather it set project success criteria, through which to judge its RM performance. Though they usually used to judge RM performance effectiveness through tracking the identified risk and managed risk. This risk tracking process also used as the continuous RM improvement tool as management was able to identify any gap and later improve that lacking. The main criteria it used for measuring success were Target Outturn Cost (TOC), KPI for key result areas and Positive and Negative Modifiers. The KPI that was set for measuring success were schedule, safety, usability and public image. At the end of the project, success was achieved in all four areas of the KPI. On the other hand, as the Tampere Tramway project has just begun, the project team is defining its RM and RM performance measurement plan continuously, by measuring the number of identified risks and number of eliminated risks, using a risk level calculation. No fixed KPI for measuring RM performance has been set so far.

5 Discussion
Risk and uncertainty management in a project is considered to be an essential part of smart project management, through which many positive project outcomes can be achieved. The
practical case analyses used in this project help to demonstrate the benefits of risk RM in complex projects.

Project alliancing, a special type of project delivery, is considered to be very useful for the complex, high risk projects. In this research, the subjects of both case studies used alliance contracting. In the Tampere Rantatunneli project, the alliance parties were Tampere City, Finnish Transport Agency, Lemminkäinen Infra Oy (now YIT), Riekkola Oy and Alinsinöörit Suunnittelu Oy. As a contractor of this project, Lemminkäinen Infra Oy (now YIT), Riekkola Oy and Insinöörit Suunnittelu Oy had their own expert team, which had previous successful experience with this kind of project. Tampere Rantatunneli project faced many high risks and due to its high complexity, an alliance contract was deemed to be most suitable for this project. Project alliancing has both positive and negative aspects, although in this case, the positive results outnumbered any negative ones. In the Rantatunneli project, alliance parties played a very crucial role in the project’s success, as each partner brought their own specific expertise. The project team was formed through collaboration between the members of three contracting companies and based on their opinions and discussion, the initial schedule and budget was set. In terms of RM, it was somewhat easier to identify the potential risks through the alliance project team than it would have been for partners to do so separately. As the project team consisted of partners with different expertise, they each identified potential risks beforehand and planned accordingly to remove them completely or minimize their impacts. “Big Room” concept was used where alliance team join in an open space and discussed among themselves about project risk management issue. The opinions of contactors’ team members were collected in order to identify potential risks and decide upon mitigation measures. Another positive outcome of this alliancing contract was its effect on the final schedule and cost of the project. The project was finished six months ahead of schedule and the actual outturn cost was less than predicted. Moreover, with an alliance contract, risks are shared equally between all the parties and owner with a pain/gain method instead of risk allocating to one party. Despite the alliance project team’s crucial role in this success, there were also some negative aspects of alliancing on RM during the project. In Rantatunneli project, initially, there were some opinions and arguments between the team members during the project management discussion about RM managing issue, such as, identifying method of risk, risk mitigating way, risk responsibilities, contrast decision with risks accepting or removing or transferring and about fixing the risk reserve budget etc. Moreover, there was
an argument about the ownership or responsibilities of additional risk cost that may emerge beyond the risk reserve budget. It was expected to have the argument in setting the risk management issue, as every organization used to follow their own specific method and each one will try to incorporate their own method in the alliance as it brings suitability to them. Although there were many opinions and arguments, after some time team were agreed upon on a specific way. These negative aspects of project alliancing were expected, as the team consisted of team members from multiple companies and professional backgrounds. Managing the risk in the alliance contract usually bit complex than the individual firms. The Tampere Tramway project also has an alliancing contract between the parties of Tampere City, YIT Construction Services, VR Track Oy and Poyry Finland Oy, in which the latter three are the contractors. As this is an ongoing project and construction work only recently started, the benefits or negative aspects of the alliance contract on RM cannot be determined yet. However, the questionnaire interview showed that the initial planning concerning the project timeline, budget, risk and uncertainty management and quality control was done by the alliance team and until now, the project team has made successful progress in terms of work progress, RM, cost controlling and timeline maintenance according to the initial plan.

The term, complex project, and risk are very interlinked to each other as the complex project are always prone to high risk. According to literature, a project becomes complex when it has a high amount of investment, advanced technology, a long project timeline, multiples stakeholder’s involvement etc. (Baccarini, 1996; Javad et. al, 2016; Flyvbjerg, 2002). Many researchers stated that specifically, construction projects are always very risky due to its high complexity and almost all of them cannot meet the timeline and budget constraints (Baccarini, 1996; Mills, 2001; Christian, 1999; Bertelsen, 2003). In this research, both case project of Tampere Rantatunneli and Tampere Tramway are construction project, and both are named highly complex project in terms of its schedule, budget, alliance contract, multiple stakeholders’ involvements, challenging project location, team composition, and size etc. Though both case projects are construction projects and named highly complex according to researchers’ project complexity characteristics, Rantatunneli project was finished as a successful project with ahead of schedule and less than the actual budget. Similarly, Tramway project is also on their target timeline and on the budget in terms of their work progress though this has just begun. As these two projects were highly complex, there was the possibility to face many uncertainties during the project. Thus, both the project teams put
the high emphasis on the risk management issue. The project team of these two-case project followed the basic risk management process of risk identification, evaluation, mitigation and monitoring which is also stated by many previous researchers (PMBOK, 2016; Kahkonen & Artto, 2008; Ward & Chapman, 2003). In addition to that, risk workshop concept, organized once in each month, is also followed in every stage of both project risk management process, where identified and potential risks were discussed and decided on the action for those were used to be taken. After the identification of the risks, the Monte Carlo simulation method was used to calculate the risk impact level. From the analysis, it was found that risk identification stage was considered as the most crucial stage on both implementation and development phase for projects RM department which acted as a foundation for their whole RM process. The importance of risk identification phase was also emphasized by many researchers in the literature (Ward & Chapman, 2003; D. van Well-Stam et al, 2004). Apart from that, every personnel of the team were aware of risk management and everyone was responsible to track and identify any potential risk. Moreover, Rantatunneli project team maintained a balanced risk reserve budget in their final budget plan. In literature, researchers stated that KPI & EVMS analysis are most used method to measure the RM performance which can make RM process more efficient and effective (Moullin, 2002; Rouse & Puterill, 2003; Acharyya, 2007). Surprisingly, though Rantatunneli team emphasized much importance on the RM process, but they didn’t focus specifically on setting any standard criteria to measure their RM performance. Instead of that, the project team focused on quantifying the overall project success through implementing KPI for some key result areas, positive and negative modifier. Rantatunneli project team measured their RM performance by measuring their overall project success as it tells them how they were successful in managing the RM. On the other hand, tramway project team is planning to implement some KPI for measuring the RM performance and at this moment, they are measuring their RM performance through comparing the number of identified risks and number of controlled risks.

It is quite surprising that, both project team consists much-experienced personnel, but the realization about the importance of measuring the RM performance was overlooked by the project team, though Tramway project team are on the implementing stage on this. The reason to overlook about this might be having an existing project success measuring criteria for Rantatunneli project, thus, the team might not think any necessity to implement any separate criteria. Another reason might be having the negative aspects of the alliance team
where personnel are from different background and organizations and they might not agree to implement separate criteria to assess RM performance instead of regular tracking. The project team also might not realize the necessity of having specific criteria to assess RM performance because of their well-balanced risk tracking and mitigation process where they might think that everything is going well and under control. Though they did not use any specific RM performance measurement criteria, their RM was quite successful. The project team identified successfully the most risk and managed them in efficient way as they used to track the risk mitigating condition in periodical manner. Although Rantatunneli project risk management was quite successful, implementing a specific measure to assess RM performance might help the team to get more efficient results of their risk managing and mitigating progress. Though risk management has got the utmost attraction by the project team, measuring the RM performance is yet on the table of improvement. Despite not having any specific measure to assess RM performance, the effective project management skills of Rantatunneli team enables them to achieve the project success with ahead of schedule and less than the actual budget. The Rantatunneli project team might incorporated the RM assessment in their other project management areas for example, cost management or schedule management plan. The effective project management skills of Rantatunneli team would be the smart budget plan including an efficient risk reserve, skilled and experienced project alliance team, achievable target schedule, better communication inside the team, effective risk management process, continuous monitoring of the work progress, responsibility of each personnel, backup plan for emerging and sudden uncertainty etc. Thus, this research findings support the literature regarding the construction projects high complexity but opposed the statement about the complex projects timeline and budget restrictions. With a properly planned and balanced project risk management, any complex projects risk can be managed with efficiently and effectively which can lead to the success of the projects even before the actual timeline and with less budget.

The first research question concerned identification of the projects’ complexity. Generally, a project is considered to be complex when it has a ≥$10 m budget, long development period and implementation time and multiple stakeholders, along with other complex factors. There are various methods and frameworks for evaluating the level of project complexity. In this research, the project complexity framework of Hass et. Al (2010) was used to evaluate the project complexity of both case studies. Using this framework, the high complexity of both
Tampere Rantatunneli and Tampere Tramway projects was validated (Section 2.1.1, 4.1.2, 4.2.2).

The second research question concerned defining and understanding the RM performance measurement for complex projects. In brief, RM performance measurement can be defined as the identification and assessment of the efficiency and effectiveness of the RM process conducted by the project RM team. The basic goal of a RM performance measurement system is to analyze and assess the project's objective in both financial and non-financial terms. During the continuous evaluation period, results can also be used to reallocate resources in an effective and efficient way. RM performance measurement also helps reduce the risk factors associated with the project. To ensure a suitable RM system is used during a project, RM performance management should be included in the system, along with the risk RM process itself (Section 2.3).

The third research question concerned the evaluation of the RM performance measurement. In the literature, there are very few methodologies regarding project RM performance measurement. Among them, the four most commonly used RM performance management methods for large projects are Balanced Score Card (BSC), Earned Value Management System (EVMS), Key Performance Indicator (KPI) and Risk Management Index (RMI), with KPI being the most widely used. At both organizational and project levels, KPI is used to evaluate the performance of specific departments. In this research, the Tampere Rantatunneli team did not directly specify any indicators or performance assessment criteria for the measurement of RM performance; rather it set some goals, along with some fixed KPI, TOC and positive and negative modifiers in order to measure the project success. On the other hand, the Tampere Tramway project team is yet to determine KPI parameters in order to assess its RM performance, as this project has only recently begun, but it is following risk mitigation measures, with the number of open hazards being compared with the number of controlled or removed hazards. To do measure the RM performance, the RM management program might include with the managements KPI and also it might be included in organizations compliance audit. Some KPI might be implemented to measure the RM performance through establishing objectives and performance measures which presented in Table 26 with KPI example (Section 2.3, 4.1.4, 4.2.4).
Table 26: KPI for RM Performance Measurement (Farrar 2016)

<table>
<thead>
<tr>
<th>Objectives</th>
<th>Performance Measures</th>
<th>KPI</th>
</tr>
</thead>
<tbody>
<tr>
<td>All personnel should be trained under RM program by Q3</td>
<td>% personnel trained by Q3</td>
<td>95% by Q3</td>
</tr>
<tr>
<td>Risk registers need to be developed for all functional areas by Q3</td>
<td>% functional areas developed risk registers</td>
<td>98% by Q3</td>
</tr>
<tr>
<td>All new risks should be included in the risk register and assigned the responsible person within the 24 hour of risk identification</td>
<td>% new risk included in the risk register by 24 hour of risk identification</td>
<td>100%</td>
</tr>
<tr>
<td>All risks need to be managed by specific timeline</td>
<td>% risk managed by the timeline</td>
<td>95%</td>
</tr>
</tbody>
</table>

6 Conclusion

The main goal of this research was to provide a deep understanding of the science of project complexity and its underlying impacts, through identifying complexity characteristics, the role of project RM in complex projects through presenting risk identification, its prioritization and management of implementation, and finally, the importance of measuring the effectiveness and efficiency of RM performance. Large construction projects are typically considered to be some of the most complex types of project, thus in this research, the empirical analysis of project complexity, RM and measurement of RM performance measurement was conducted on qualitative feedback concerning two large, complex projects. The research was carried out by performing an extensive literature review on project complexity, RM and measurement of RM performance, followed by real case analysis through a semi-structured interview and a questionnaire.

The literature demonstrates that project failure (Raz et al., 2002; Flyvbjerg et al, 2003; Mulcahy, 2003) has been increasing over the last few decades, due to rising project complexity (Baccarini, 1996; Philbin, 2008). General RM standards are not always sufficient
to deal with this rising uncertainty, especially in terms of complex project environments (Atkinson et al, 2006). Construction projects suffer the highest rates of failure and project RM has therefore become an essential and integral part of project management. Any type of risk which might affect any objectives of the project should be identified early and a plan should be formulated in order to tackle them. In-depth risk analysis and an effective plan can contribute significantly towards project success. In order to be effective, a RM plan should also include RM performance measurement (Basova and Mitselsky, 2011; Goh, 2012). RM alone cannot guarantee project success, as without evaluation of current performance, the project manager cannot know the true scenario of the RM plan. Ultimately, an efficient and effective RM strategy, along with RM performance measurement, helps organizations to achieve success in their projects, enables efficient use of resources and maximizes profitability.

6.1 Practical Implications

This study reveals the different method in measuring project complexity, organizing risk management and evaluating the RM performance on complex projects and their importance on the projects. The findings from this study point out the alliance contracting impacts on RM, effective use of RM tools and the importance of RM performance measurement. Thus, the findings and analysis of this study will help the other project managers in following manners- (1) Forming the alliance contract for large, complex projects for the efficient use of resources, (2) Contracting with well expertise alliance team to get the best possible project results, (3) Forming the similar culture alliance team to get rid from the complexity between the alliance team members, (4) Focusing on the RM process and the decision by judging project complexity level as high complex projects possess high risks and thus RM process needs more close attention, (5) Making a well-balanced RM plan with regular tracking of the identified risks as it reduces the risk occurrence probability, (6) Having a well-balanced risk reserve cost in the final budget (7), Maintaining the risk workshop concept periodically to get and track about any new emerging risk in order to have the project team well informed about those, (8) Giving the risk tracking and managing responsibility to every person of the project team, (9) Focusing on implementing RM performance measuring criteria to make sure the efficient and effective uses of RM resources.
Thus, project managers must make sure a well-balanced RM plan along with a proper RM performance measurement criterion in order to get the desired project success. Though every project, nowadays, give utmost focus on the RM, RM performance measurement must also get incorporated with those RM plan to get most efficient project results.

6.2 Limitations and Scope for Future Research

This research was performed using a qualitative approach, in which an interview was carried out. Data was interpreted and analyzed, which can lead to subjective or biased interpretation. Whilst an attempt was made to limit bias, it cannot be completely ruled out. In both of the case studies, one interview was taken from a senior member of personnel of each management team, which may have led to limited information being revealed. Unfortunately, it was not possible to conduct more interviews, due to the organizations’ protocols. Additionally, being present in the company as an internee or thesis trainee during the project’s development and implementation phases might result in more effective observation and more accurate results. Furthermore, the empirical analysis of this research only concerned construction projects, whereas other studying different types of complex projects may have given different perspectives. One of the case projects analyzed in this thesis is currently only in the early phase of construction, thus information about its RM performance measurement plan was limited.

To further improve of this study, more case analysis could be included for empirical analysis and compared to other types of complex projects, such as technological projects. A similar type of study could also be performed with projects including multiple international stakeholders, which may give a different perspective and reveal additional issues. Another scope might be to use both qualitative and quantitative approaches together, to increase the reliability and impact of this study. Further research should continue, specifically, on developing RM performance management methods on complex projects as there is little study on this topic. Establishing specific and efficient KPI for measuring RM performance for complex projects would be another scope for future research.
7 Reference

Aaltonen, K. (2010). Stakeholder management in international projects. Doctoral Dissertation, Aalto University School of Science and Technology, Department of Industrial Engineering and Management, Espoo, Finland


Alarcon, L., Ashley, D. & Hanily, A. (2010), Risk Planning and Management for the Panama Canal Expansion Program, Journal of Construction Engineering and Management. 137 (10), November 2010


Association for Project Management (APM), (2012). Project Risk Analysis and Management Guide. APM Publishing Limited, High Wycombe, Buckinghamshire


Beasley, M., Chen, A., Nunez, K., & Wright, L. (2006). Working Hand in Hand: Balanced Scorecards and Enterprise Risk Management-Taking a total look at all the potential risks to a company, or enterprise risk management, is becoming the minimum standard. Strategic Finance, 87(9), 49-55


Rantatunneli alliance project plan (2013, June 26), retrieved, from https://www.liikennevirasto.fi/documents/20473/23134/Hankesuunnitelmarapo_ENGL_1312 nettiversio.pdf/1beb79fb-8b65-46b3-ad4d-4f94c4afdeb1


Appendix-1

Tampere Runtatunnell Interview Questions

1. Can you please briefly describe your professional background?
2. How would you characterize this tunnel project? In what ways is it complex? In what ways is it not complex?
3. What kinds of risks did you identify during each of the different phases of the project?
4. What methods did you follow in order to forecast the risk?
5. What new risks emerged during the project implementation phase?
6. What internal and external stakeholder risks did you face during the project?
7. Were there any positive risks you faced during the project?
8. What Risk Management, risk mitigation and risk categorization methods/approaches did you implement?
9. What method did you follow to analyze the risks, i.e. qualitative or quantitative?
10. Did you plan to identify and manage risks by studying similar types of previous project risks?
11. Did you face any Black Swan events during the project?
12. What was your plan to tackle any evolving uncertainty during the project?
13. Did you hire any RM specialists/consultants to assist in taking care of the risks?
14. How did you evaluate RM performance? What indicators inform you of whether the RM strategy has been successful? What kinds of measures do you use?
15. How were the anticipated risks realized during the project?
16. What was the impact of measuring RM performance during your project?
17. What is your evaluation of RM performance of the whole project? How would you rate it?

Appendix-2

Tampere Tramway Interview Question

1. How would you characterize this tramway project? Why is it complex?
2. What kinds of risks did you identify during the different phases of the project?
3. Are there any new risks emerged except the identified ones during the project phase?
4. What are the name of major and minor risks you identified during the project?
5. What methods you followed to forecast the risk?
6. What about the internal and external stakeholder risks you are facing in the project?
7. How did you plan to mitigate/solve those identified major, minor, stakeholder risks?
8. Are there any positive risks/opportunity you are facing during the project?
9. What about your Risk Management process/steps?
10. What method you followed to analyses the risks? I.e. qualitative or quantitative?
11. Have you planned to identify and manage risks by studying previous similar type of projects risk?
12. What is your plan to tackle any evolving uncertainty during the project?
13. Have you hired any RM specialist/consultant for taking care of the risks in this project?
14. How are you evaluating RM performance? When do you know (what are the indicators) whether RM has been going successful? What kinds of measures do you use?
15. How did the anticipated risks realize during the project?
16. What is the impact of measuring RM performance regarding your project?