Ludvig Hahnsson

Improving financial forecasting for a project-based corporation in the infrastructure construction business

Master’s Thesis
Aalto University
School of Engineering
Department of Civil Engineering

Thesis submitted as a partial fulfilment of the requirements of the degree of Master of Science in technology

Helsinki, 25 November 2019
Supervisor: Professor Leena Korkiala-Tanttu
Advisor: Roope Korpela M.Sc. (Tech.)
Cost and schedule overruns are a frequently appearing issue associated with projects in the infrastructure construction business. During the life cycle stages of a project, several factors can influence project procedures negatively and have severe financial consequences. The impact of insufficient cost management procedures may lead to cost escalations, and it is usually not identified until the damage has already occurred. This emphasizes the importance of financial forecasting. The cooperation between the project and corporate management within a company is essential during the different stages of the project and contributes to maintain a sustainable performance.

This thesis focuses on the four areas of project cost management in the infrastructure construction business, and additionally covers the procedures of project forecasting and uncertainty analysis. The content encompasses the identification of the most common factors that result in cost and schedule estimate inaccuracy. The research further introduces four selected forecasting methodologies and techniques frequently used in the business, which incorporate the forecasting of project cost and schedule. Individual characteristics of the reviewed forecasting methods; Judgmental forecasting, Reference Class Forecasting (RCF), Quantity Rate Analysis, and Earned Value Management (EVM), are evaluated to conclude their appropriateness.

Through a qualitative case study, the aim was to broaden the insights in financial forecasting and provide managerial guidelines regarding planning and implementation proceedings. The purpose of these complements supports to acquire desired results in the project. The empirical study considered fundamental elements, obtained from the literature research, which were reflected onto the case company, GRK Infra Oy, that currently are re-structuring their internal forecast reporting procedures.

Acquired results from the research determined that project overruns occur due to a combination of insufficient performed procedures but vary based on specific situations. Furthermore, the results identified a significant variation in forecasting techniques among project managers at the case company and underlined the importance of harmonized procedures that facilitate business operations.
Författare: Ludvig Hahnsson

Avhandlingens titel: Förbättrar finansiell prognosiering för ett projektbaserat koncernföretag inom infrabranschen

Utbildningsprogram: Geobyggnad

Kod: ENG23

Huvudämne: Vägteknik

Övervakare: Professor Leena Korkiala-Tanttu

Handledare: Roope Korpela M.Sc. (Tech.)

Datum: 25.11.2019

Sidantal: 73 + 7

Språk: Engelska


Erhållna resultat från studien kunde fastställa att projektöverskridningar orsakas av en kombination bristfälligt utförda procedurer, men varierar beroende på specifika situationer. Dessutom kunde resultaten identifiera en betydande variation av prognosieringstekniker bland projektledarna i fallstudiens företag, och poängterade vikten av harmoniserade förfaranden inom företaget.

Nyckelord: Prognosiering, Finansiell prognosiering, Kostnadsshantering, Kostnadsöverskridning
Tekijä  Ludvig Hahnsson

Työn nimi  Talousennustamisen parantaminen projektiperusteiseen konsernijyritykseen infrarakentamisalalla

Maisteriohjelma  Georakentaminen  Koodi  ENG23

Pääaine  Tierakentaminen

Työn valvoja  Professori Leena Korkiala-Tanttu

Työn ohjaaja  Roope Korpela M.Sc. (Tech.)

Päivämäärä  25.11.2019  Sivumäärä  73 + 7  Kieli  Englanti

Kustannus- ja aikataluylijykset ovat usein esiintyviä ongelmaa infrarakentamisen projekteissa. Projektin elinkaaren aikana on useita tekijöitä, jotka voivat vaikuttaa negatiivisesti projektin menettelytapoihin ja jopa aiheuttaa taloudellisia seuraamuksia. Riittämättömän kustannushallinnon seurauskena voi syntyä kustannusten ylityksiä, mikä usein ei ole tunnistettu ennen vahingon tapahtumista, mikä korostaa projektihallinnon merkitystä. Projektijohdon ja yritysjohtojen välinen yhteistoiminta on välttämätöntä projektin eri vaiheiden aikana ja edistää asianomaisen ja kestävän suorituksen säilymistä.


Kvalitatiivisessä tutkimuksessa, tavoite on laajentaa projektienhallinnon ymmärrystä ja tuoda esille johtamisohjeita liittyen suunnittelu- ja toteutustoimintoihin. Esitettyjen täydennysten tarkoitus on tukea toivottujen projektitoiveitten saavuttamista. Empirinen tutkimus huomioi kirjallisuustutkimuksesta saavutettuja peruselementtejä, jotka peilataan tapausyritykselle, GRK Infra Oy, jolla parhaillaan uudelleen järjestetään heidän sisäistä raportointijärjestelmäänsä.

Tutkimuksesta saavutetut tulokset näyttävät, että kustannusylitysten syy on yhdistelmä monista riittämättömistä menettelyistä, mutta ne vaihtelevat tilanteen mukaan. Lisäksi, tulokset identifioivat laajaa variatiota projektijohtajien ennustamismenetelmissä tapausyrityksessä, ja korostivat yhtenäisten menettelytapojen tärkeyttä.

Avainsanat  Projektiennustaminen, Talousennustaminen, Kustannushallinta, Kustannusylitys
PREFACE

As this thesis is completed, I would like to express my appreciation towards my colleagues at the case company, GRK Infra Oy, who suggested this topic and have provided me with essential information along the way. I would like to thank my advisor Roope Korpela for the assistance in compiling the important aspects of this topic, and for the beneficial insights. I highly appreciate Professor Leena Korkiala-Tanttu, for quickly taking on the task as my supervisor.

With this master’s thesis, that has been my final assignment at Aalto University, my studies have come to an end. The education path I chose to take, has not only been interesting but very rewarding as well. It is a relief to realize that all the hard work has finally paid off.

I would like to extend my gratitude to my family that has supported me throughout these years, and to all the people I have connected with along the way. Thank you to all my beloved friends, it really has been a good time.

Final credits go to you Neea, for your invaluable support during my studies and the completion of this thesis – thank you!

Ludvig Hahnsson

Helsinki, November 2019
## TABLE OF CONTENTS

PREFACE ................................................................................................. iv
LIST OF FIGURES ................................................................................ vi
LIST OF TABLES ..................................................................................... vi
TERMINOLOGY ....................................................................................... vii

1 INTRODUCTION ......................................................................................... 1
  1.1 Research Background ................................................................. 1
  1.2 Purpose and Goals .................................................................... 2
  1.3 Research Methods ................................................................... 3
  1.4 Research Limitations ............................................................... 3

2 FINANCIAL FORECASTING IN INFRASTRUCTURE PROJECTS ................. 4
  2.1 Extent of The Infrastructure Business ....................................... 4
  2.2 Starting Points of Financial Modelling ....................................... 6
  2.3 Project Delivery Methods (Design-Bid-Build & Design-Build) ....... 9
  2.4 Project Cost Management .......................................................... 11
    2.4.1 Plan Cost Management ...................................................... 12
    2.4.2 Estimate Costs .................................................................. 13
    2.4.3 Determine Budget ............................................................ 15
    2.4.4 Control Costs .................................................................. 16
  2.5 The Impact of Corporate Structure on Forecasting ....................... 18

3 Challenges and Risk Factors of Forecasting ........................................... 21
  3.1 Challenges in Financial Forecasting of Infrastructure Construction .... 21
  3.2 Influencing Risk Factors in Forecasting ....................................... 24

4 CURRENT GENERAL FINANCIAL FORECAST MODELS ........................... 27
  4.1 Forecast Models on Project Level ................................................. 27
    4.1.1 Judgmental Forecasting Methods ..................................... 28
    4.1.2 Reference Class Forecasting Method ............................... 29
    4.1.3 Quantity Rate Analysis Method ...................................... 32
    4.1.4 Earned Value Management ............................................ 34
  4.2 Comparison of Reference Class Forecasting and Earned Value Management .... 38
  4.3 Combination of Forecasts ............................................................ 38

5 PROJECT-LEVEL FORECASTING IN EXAMINED CORPORATION ............. 42
  5.1 Presentation of Examined Corporation ......................................... 42
  5.2 Present Condition of Forecasting at The Case Company ................ 43
  5.3 Current Forecasting Models and Procedures ............................... 45
    5.3.1 Interviews with Project Managers .................................... 45
    5.3.2 Response from Site Managers ......................................... 51
    5.3.3 Pilot Project Reporting System in Progress at The Case Company ... 54
  5.4 Composition and Use of Project Forecasting ................................ 55
  5.5 Reliability and Accuracy of Project Forecasting ............................ 56

6 DEVELOPMENT PROPOSAL ................................................................... 58
  6.1 Functionality of Current Forecast Models ..................................... 58
  6.2 Development of Forecast Models .............................................. 60
  6.3 Applicability of Company Reporting System ................................ 62
  6.4 Update Cycle and Demand of Forecast ....................................... 63
  6.5 Summary of Development Proposals ......................................... 64

7 CONCLUSION ..................................................................................... 65

REFERENCES ......................................................................................... 69
Appendices
Appendix 1: Infra classifications list
Appendix 2: Advantages and disadvantages of functional-, projectized- and matrix organizations
Appendix 3: Identification and assessment of risk factors affecting construction projects
Appendix 4: Earned Value Management key metrics and formulas
Appendix 5: Interview agenda for project managers and site managers
Appendix 6: Interview agenda for corporate managers

LIST OF FIGURES
Figure 2-1: Future infrastructure requirements (Pollalis et al., 2012) .......................... 5
Figure 2-2: Business analytic process (Schniederjans et al., 2014) ............................ 7
Figure 2-3: The benefits of Design-Build delivery method (Consolidated Construction, 2018).................................................................................................................. 11
Figure 2-4: Project cost management overview (Project Management Institute, 2017) ....11
Figure 2-5: Cost Baseline, Expenditures, and Funding Requirements (Project Management Institute, 2017)............................................................................................................. 16
Figure 2-6: Earned Value, Planned Value, and Actual Costs (Project Management Institute, 2017) .......................................................................................................................... 18
Figure 3-1: Uncertainty – Information Trade-Off (Yoe, 2000) ..................................... 25
Figure 4-1: The fundamental differences between Traditional Project Cost Management and Earned Value Management (Fleming & Koppelman, 2005) .............................. 35
Figure 4-2: Structure of Earned Value Management, including the most important components (Vanhoucke, 2009)............................................................................. 36
Figure 4-3: Managerial adjustments of quantitative forecasts (Sanders, 2017) ........... 39
Figure 4-4: Mechanical combining of managerial and quantitative forecasts (Sanders, 2017). ................................. 39
Figure 4-5: Managerial opinion as input to model building (Sanders, 2017) ............... 40
Figure 5-1: A complete overview of the GRK Group structure .................................. 42
Figure 5-2: Services provided at GRK (GRK, 2019c) ............................................... 43
Figure 6-1: Procedure to determine adequate forecasting processes based on project characteristics .......................... 62

LIST OF TABLES
Table 2-1: Major infrastructure sectors as the built environment (Penn & Parker, 2011). ....4
Table 2-2: Common features of financial models (Samonas, 2015) ............................... 6
Table 2-3: Types and purposes of analytics (Schniederjans et al., 2014) ..................... 7
Table 2-4: Categories of forecasting methods (Sanders, 2017) ..................................... 8
Table 2-5: Judgmental versus statistical forecasting methods (Sanders, 2017) ............ 9
Table 2-6: The twelve steps of a high-quality cost estimating process (GAO, 2009)........ 13
Table 3-1: Common challenges of uncertainty analysis (Johansen et al., 2014) .......... 24
Table 3-2: Cost changing factors causing project delay or variations to original cost estimates (European Commission, 1998) ................................................................. 24
Table 3-3: Factors causing cost and schedule overruns in construction projects (Abd El-Karim, et al., 2015) ................................................................. 26
Table 4-1: Typology of specific technical causes for cost escalations in transport projects (Flyvbjerg & COWI, 2004) ................................................................. 32
Table 4-2: Pricing of measurement estimates to establish unit rates (Ostrowski, 2013) .... 33
Table 4-3: Comparison of strengths and weaknesses of Analogous-, Parametric-, and Bottom-up cost estimating (Smartsheet, 2019) .................................................. 34
Table 4-4: Rules to adjust statistical forecasts (Sanders, 2017) ........................................... 40
Table 5-1: A list of respondents from the conducted interviews and the survey .......... 44
Table 5-2: Project managers’ answers to Q7 from the interview agenda ......................... 47
Table 5-3: Project managers’ answers to Q8 in the interview agenda ......................... 47
Table 5-4: Project managers’ answers to Q17 in the interview agenda ......................... 50
Table 5-5: Site managers’ answers to Q21 ....................................................................... 52
Table 5-6: Site managers’ answers to Q17 ....................................................................... 53
Table 5-7: Features of the new reporting system at GRK .................................................. 55
Table 5-8: Project managers’ answers to Q21 ................................................................. 55
TERMINOLOGY

Client: Towey (2012) expresses the term ‘client’ as “an individual, partnership, group of persons, organization or business from the public or private sectors that seeks and pays for building works”. Koskenvesa et al. (2018) continue that the client is the contracting party to the contractor, who has ordered the work performance to get the project realized.

Contractor: Towey (2012) further describes the ‘main contractor’ as the party that “constructs a project in accordance with a binding agreement it has with the client”. Project works are usually realized through subcontracts which allow the contractor to focus more on site-management, maintaining the budget, and controlling the quality of project works.

Cost/Expenditure: The output of the total use or consumption of money. Project expenditures should be known and identified to determine the profitability, productivity, and economy of the business. In construction, the cost is the amount of money needed for a specific work task, performance, or service based on resource use and bidding prices (Koskenvesa et al., 2018).

Price: The amount of money a contractor, supplier, or service provider is willing to make for a work performance or service. Different terms that are included in the price are labor, material, equipment and business services. The price is time and regionally variable in accordance to the market situation. (Koskenvesa et al., 2018).

Tender period: During the tender period, the competing contractors receive the General arrangement drawings (GAD) and calculate the bid and submit the tender for a contract. The contractor of the awarded tender bid will advance to the implementation phase after negotiations with the client (Koskenvesa et al., 2018).

Financial forecasting: Corporate Finance Institute describes the term ‘Financial forecasting’ as “the processing or estimating or predicting how a business will perform in the future” (CFI, 2019).

Financial modelling: The term ‘Financial modelling’ is defined as “the process of creating a summary of a company’s expenses and earnings in the form of a spreadsheet that can be used to calculate the impact of a future event or decision” (Investopedia, 2019).
1 INTRODUCTION

Results from studies by Flyvbjerg et al. (2004) show that 9 out of 10 transport infrastructure projects suffers from cost escalations. Conclusions from the study indicated that project managers have not learned from previous mistakes regarding the accuracy of cost estimates, since the amount of cost escalations have not decreased during the last 70 years. The main challenge has been to identify and recognize factors causing the costs to escalate and how to prevent similar events from occurring in the future (Flyvbjerg et al., 2004). Infrastructure construction projects require large investment sums, and the common goal is to complete the project within the set budget. Nevertheless, exceptionally little knowledge exists about costs, benefits, and risks involved in implementing the projects (Flyvbjerg et al., 2005). Misleading results, lack of information, and biased decisions have contributed to inaccurate forecasts in construction projects for decades (Flyvbjerg, 2006).

This thesis systematically encompasses the most fundamental aspects of financial forecasting in the infrastructure business. Moreover, the selected forecasting models and methodologies that monitor performance, finance, and mitigate risk during the different stages of a project, are approached. The aim is to create a more comprehensive understanding in forecasting and provide structural procedures that consider the most significant factors that can cause cost and schedule overruns. The thesis thoroughly covers relevant literature that is being reflected with acquired results from conducted interviews with managers and executives at the case company, GRK Infra Oy.

1.1 Research Background

Expenditures and cost management are closely associated with the scope, schedule and quality of the project. During the planning phase, prior to implementation, the project management should focus on establishing common goals on a realistic, comprehensible, and enforceable level. The integrity of a project is generated by the schedule, quality, and cost, which is pursued to be balanced for a successful completion. Systematical and continuous procedures benefit the results of cost management. Although most of the project costs are determined during the planning phase, a proper setting of target estimates and design management does not guarantee any success without constant on-site supervision. The project costs are mainly substantiated during the implementation phase, and reliable target estimates should involve information about execution options, site practices, resources, schedule, and intermediate goals. Proper cost management procedures incorporate the monitoring and controlling of realized costs, collection of data, and continuous analysis of the situation. The financial performance of the project is checked on a regular basis and obtained cost information is updated for future use (Koskenvesa et al., 2018).

Cost management is vital to the successful outcome of a construction project and there are many influencing factors causing both opportunities and problems to operations on the construction site. If construction projects of a company repeatedly fail financially, the business will not be profitable in the long run, regardless of the effort put on schedule and quality management. Without profit, the business is not sustainable. News reports about cost overruns and delays in construction projects appear in a frequent manner. Therefore, unsuccessful construction projects attract attention and raise many questions regarding the
procedures of project cost management and the proficiency of the contracting company. Circumstances causing the occurrence of cost overruns can be difficult to identify and can quickly escalate to a greater extent if not taken care of.

The competition between contractors is tough during the tender period of a project, which could result in a reduction of the final tender price. From a contractor’s perspective, this usually leads to smaller profit margins and almost no room for errors during implementation. The opportunity to include ‘buffers’ or other additional cost reserves intended to cover for unexpected events occurring on site, is rarely an option. However, the contractor is still responsible to keep construction operations in line with the estimated budget for the project to be successful, despite the tight margins. Tender bids are generally ‘fixed price’, which means that the bidding sum stays unchanged after the contract is awarded, unless significant adjustments are made to the original scope and design. This highlights the emphasis on project planning during the tender period where the challenge is to create accurate project cost estimates under high uncertainty.

1.2 Purpose and Goals

This thesis concentrates on forecast models and methodologies currently used in infrastructure construction projects. As initial requirements, the methodologies should encompass the monitoring of project costs and schedule during implementation. The content of this thesis presents the fundamental aspects of proper cost management during the different stages of a project. Additionally, the study approaches the main challenges of cost estimating and cost controlling post-contract. The purpose of this thesis is to identify the main factors that cause inaccuracy in cost estimates and to present suggestions how to more accurately uncover uncertainties in infrastructure construction projects. The goal is to cover individual characteristics of reviewed forecasting methods and compare them with current forecasting procedures at the case company. Potential findings could lead to development suggestions regarding optimized forecasting methods, or a combination of techniques. Results obtained from the literature study are compared with the results from interviews with managers at the case company. There is a high probability of finding distinct contrasts in the forecasting and cost controlling methods currently used by project and site managers. Any potential findings may enable to suggest improvement options, regarding forecasting methods, that could be further integrated into the operations of the case company.

The main research questions are listed below:

*RQ1:* What causes infrastructure construction projects to fail financially, and why?

*RQ2:* Which forecasting models, monitoring project cost and schedule, are most practically implementable into infrastructure construction projects?

*RQ3:* How can current project forecasting procedures at the case company be optimized?
1.3 Research Methods

The literature review in this thesis is based on studies about project cost management and forecasting models in the infrastructure construction business. Project cost management, along with project forecasting in the construction business, is a well-researched area and the theory part is based on examining a wide range of relevant documentation and publications.

The empirical research is conducted as a qualitative case study where the data is collected through interviews with managers on project and corporate level at the case company. Reviewed forecasting methodologies and techniques in the literature study, are reflected onto the case company to conclude any similarities or divergencies compared to current proceedings. By combining literature content with results from interviews and the case study, possible development suggestions can be identified and further presented.

1.4 Research Limitations

In this thesis, the content is limited to project cost management and project forecasting in the infrastructure construction business, along with insights in the scope of infrastructure construction. The research part covers the challenges of cost management and the general complexity of the infrastructure construction business. In terms of appropriate forecasting methods, this thesis reviews one qualitative method and three quantitative methods, all currently used in infrastructure construction projects. The quantitative forecasting methods are limited to Reference Class Forecasting, Quantity Rate Analysis, and Earned Value Management. Reviewed methodologies and techniques all encompass the monitoring of project costs and schedule. The qualitative method is represented by judgmental forecasting, to support the results generated by the quantitative methods.

The empirical part of the thesis aims to obtain practical results through interviews with managers on both project and corporate level at the case company. Obtained results are summarized to create a comprehensive perspective of current forecasting procedures.

Financial forecasting in construction projects is performed during implementation, and therefore the focus lies on procedures that are carried out post-contract. However, since all stages of project cost management are relying on the usually ‘fixed price’ tender bid, the importance of pre-contract risk assessment, where uncertainties are uncovered, cannot be excluded from consideration. The procedures prior to contract, are included to create a more comprehensive understanding of the entity of project cost management and forecasting.

The thesis focuses on the main contractor of the project and does not consider project procedures of the client such as cost management, obligations, and general participation in the project. The study does not either account for the different project delivery methods in its entirety, except for the characteristics of Design-Bid-Build and Design-Build delivery methods which are compared from a contractor’s perspective. Stages where project costs are overseen occur both before and after the project contract is awarded. For that reason, it is essential that the study provides a clear picture of how project cost management is generally executed in order to comprehend the more advanced and complex aspects. As an example, a poor analysis of existing site conditions during the tender period, can substantially influence work efficiency and further result in large cost overruns during implementation.
2 FINANCIAL FORECASTING IN INFRASTRUCTURE PROJECTS

The content of this chapter provides a comprehensive view over the subject of forecasting in infrastructure construction projects. The chapter begins by introducing the fundamental aspects of the infrastructure construction business and how external factors can influence operational procedures. Further content proceeds to the starting points of financial modelling which enclose a brief introduction in the basics of business analytics, as useful tools for problem solving. The various stages of project cost management set the foundation for the procedures of financial forecasting in construction projects and are therefore explained in detail. In the context of project cost management proceedings, features of the most common project delivery methods Design-Bid-Build and Design-Build are compared to identify any administration divergence. Although, this chapter does not account for the different project delivery methods in its entirety. Differing circumstances and characteristics of the construction project, determine which methodologies are suitable, and could limit the number of available options of how each methodology should be approached.

2.1 Extent of The Infrastructure Business

Cambridge Dictionary explains the term ‘Infrastructure’ as “the basic systems and services, such as transport and power supplies, that a country or organization uses in order to work effectively”. Almost every action of citizens daily life is featured by functioning infrastructure systems which the society today depends upon. Moreover, it is concluded that the surrounding infrastructure is occasionally taken for granted, on the account that it is not always visible to the population. A well-functioning infrastructure system is not drawing as much attention as a nonfunctioning one. Society tends to assume that the infrastructure will automatically continue to serve the need for modern demand. Due to these circumstances, authorities and people in the line of business are facing a huge challenge extending the infrastructure systems to meet such demand. The business must be moderately innovative and account for a rapidly growing urban population and adapt to the changes of social, economic, environmental, and technological nature (Penn & Parker, 2011). In modern society, the built environment consists of several infrastructure sectors and are presented in table 2-1. Of these major sectors, the first nine comprise the civil infrastructure.

Table 2-1: Major infrastructure sectors as the built environment (Penn & Parker, 2011).

1. Transportation systems (roads, highways, bridges, tunnels, canals, locks, ports, airports, mass transit, and waterways)
2. Structures (including buildings, bridges, dams, and embankments)
3. Water supply and treatment systems
4. Wastewater treatment and conveyance systems
5. Solid waste management systems (collection, reuse, recycling, and disposal of wastes)
6. Hazardous waste management systems
7. Stormwater management systems
8. Parks, schools, and other government facilities
9. Energy systems (power production, transmission, and distribution)
10. Communications systems (telephone, computer, etc.)
A significant amount of responsibility is put on the infrastructure companies, as a result of changing trends in the society along with tightened regulations and future requirements set by government authorities or international unions. The operative infrastructure business needs to correlate with current rules and requirements to effortlessly proceed. External factors that influence infrastructure requirements, are presented in figure 2-1. As a result, construction companies are forced to re-structure their operational business strategies and additionally identify and further implement new solutions and work practices that comply with the rapidly changing circumstances. The capability to foresee and take preventive measures in an early stage, will be a valuable advantage for the operating infrastructure companies (Pollalis et al., 2012).

Sustainability is a relevant and actively debated discipline, with the idea that Pollalis et al. (2012) defines as “meeting the reasonable needs for the current generation while enhancing the lives and systems of future generations”. The integrity of sustainability is composed by environmental, social, and economic sustainability within a local, regional, and global context. During the past years, one of the most heated issues discussed in the society, is climate change and environmental sustainability. Climate change issues linked to the construction business, incorporates possible solutions such as energy efficiency, low carbon transportation and production, and the use of low embodied energy construction materials. Additionally, changes and development in energy, transportation, and water treatment technology directly influence available construction options and the future of infrastructure (Pollalis et al., 2012). Both infrastructure and the natural environment have a great impact on each other, hence it is vital to increase such awareness. Aiming to optimize planning and designing procedures of infrastructure systems will contribute to maintain the sustainability that future trends are demanding (Penn & Parker, 2011).

![Figure 2-1: Future infrastructure requirements (Pollalis et al., 2012).](image)

The Assembly of the Building Information Foundation RTS in Finland, have developed a classification system for both the construction business and the infrastructure construction business on a national level. The compiled classifications list serves as a guide throughout
the specific stages of the project containing guidelines, construction tolerances along with quantitative, financial, and qualitative information which contribute to facilitate project works. The table of content from the infrastructure classifications list can be found in Appendix 1. The classifications support the general understanding of operational matters in infrastructure construction projects by systematically review each stage of a certain process. Particularly the diversity of the works presented in the list, raises an insight of the complexity in the infrastructure construction business (INFRA, 2015).

2.2 Starting Points of Financial Modelling

The term financial modelling has a different meaning, that is dependent on the business focus and the perspective. The extent of scope, together with use and purpose, are factors that make financial models vary in both size and complexity. Simple models do not require perplexed functions, while more advanced models with a higher demand to display accurate and precise results, may consist of dozens of worksheets in order to be reliable enough. Both decision-making and forecasting are considered processes in financial modelling that covers disciplines of a large area in the context of finance. Although modelling procedures could be used to mitigate a company’s financial representation on the current market, it can be adapted to measure the financial situation of a project as well. Despite the complexity or simplicity of financial models, table 2-2, presents common features used in most of them.

<table>
<thead>
<tr>
<th>Features</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1&lt;sup&gt;st&lt;/sup&gt;</td>
<td>The most basic feature comprises the study of historical data to facilitate the forecasting process.</td>
</tr>
<tr>
<td>2&lt;sup&gt;nd&lt;/sup&gt;</td>
<td>Futuristic projection of the three financial statements: income statement, the balance sheet, and the cash flow statement.</td>
</tr>
<tr>
<td>3&lt;sup&gt;rd&lt;/sup&gt;</td>
<td>Identifying flaws in the system by calculating profitability, liquidity and solvency ratios.</td>
</tr>
<tr>
<td>4&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Estimating the approximate value of an asset or business.</td>
</tr>
<tr>
<td>5&lt;sup&gt;th&lt;/sup&gt;</td>
<td>Carry out sensitivity analysis to monitor impact or changes on forecast model outputs.</td>
</tr>
</tbody>
</table>

Schniederjans et al. (2014) introduce the terms of analytics, business analytics (BA), and business intelligence (BI) as quantitative methods that are closely associated. Analytics is the process that involves statistical techniques and computing power together with certain research methodologies, to extract information from a set of data. The three (3) major types of analytics can be categorized as descriptive, prescriptive, and predictive components of analytics, which purpose is described in table 2-3. Business analytics (BA) is defined as the process that deals with data sets associated to the business. By combining the three major analytical components, the aim is to gain valuable information that facilitates business decision-making. Finally, Business Intelligence (BI) covers the tools and processes that enable extraction of valuable information from large data sets to determine why current events are happening, based on past decisions. Such information supports decision-making.
### Table 2-3: Types and purposes of analytics (Schniederjans et al., 2014).

<table>
<thead>
<tr>
<th>Type of Analytics</th>
<th>Definition and Purpose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Descriptive</td>
<td>An application describing <em>the things that have already happened</em>, that uses simple statistical methods to obtain information from a data set or a database to provide knowledge about past- and ongoing trends in a process.</td>
</tr>
<tr>
<td>Predictive</td>
<td>An application predicting <em>the things that could happen</em>, that creates predictive models to identify forthcoming trends based on variables discovered through advanced statistical research methods which are not already detected in the descriptive analysis.</td>
</tr>
<tr>
<td>Prescriptive</td>
<td>The application prescribing <em>the actions that should be done</em>, that uses science and numerical analysis (algorithms) to optimize the benefits from calculated trends identified in the descriptive and predictive sections.</td>
</tr>
</tbody>
</table>

The general goal with the business analytic process is to pursue solutions that possibly will enhance business performance. The principle behind the combination of the three components, attempt to extract any kind of information from the data sources that would be beneficial and useful to the business. ‘*What has happened? What is happening? What will happen? What should we do?*, contribute to find and predict possible opportunities related to business, and further support the optimization of the system. Nevertheless, the amount of available data can in some cases become too extensive and complex to manage which puts a huge emphasis on the descriptive analytics phase, where the data is categorized into groups (Schniederjans et al., 2014). Figure 2-2 displays a response pattern as part of the business analytics procedure.

![Diagram](image)

*Figure 2-2: Business analytic process (Schniederjans et al., 2014).*
**Forecasting categories**

In the late 80’s, Makridakis & Wheelwright (1989) categorized current forecasting approaches as *judgmental, quantitative, and technological*. Meanwhile, Sanders (2017) states that “nothing has changed forecasting as much as technology”. Existing technology equipment and computing power enables the processing of larger data quantities in complex analyses, which allows for better and more accurate forecasts (Sanders, 2017).

As the methods brought up by Makridakis & Wheelwright (1989), Sanders (2017) only indicate on forecast methods being either *judgmental* (qualitative) or *statistical* (quantitative). This kind of viewpoint may allow for the possibility that technology already is considered admissibly incorporated in modern systems to not need a separate method.

*Table 2-4: Categories of forecasting methods (Sanders, 2017).*

<table>
<thead>
<tr>
<th>Forecasting methods</th>
</tr>
</thead>
<tbody>
<tr>
<td>Judgmental forecasts</td>
</tr>
<tr>
<td>Statistical forecasts</td>
</tr>
<tr>
<td>Judgmental, subjective, based on opinions</td>
</tr>
<tr>
<td>Objective, consistent. Based on mathematical concepts</td>
</tr>
</tbody>
</table>

As of table 2-4, judgmental forecasts are founded on subjective opinions by, in this context, project managers who generally possess information about past, ongoing, and future operations on site. Statistical forecasts are on the other hand based on analytical grounds like mathematical and statistical analyses that can manage large amounts of data to extract complex information. Statistically measured forecasts are objective and consistent, hence generally more accurate than judgmental forecasts. Necessary to point out, is that each forecasting method does not eliminate the other, although both methods has its strengths and weaknesses, as shown in table 2-5 on the next page. Instead, they compensate for each other on the account that one’s weakness is another one’s strength.

Working and experimenting with both forecasting methods increase the probability of a more reliable forecast. The challenges many companies face in forecasting are the insufficient amount of available and reliable information extracted from a project. Several techniques and methods can be applied in forecasting, which vary from case to case. Usually advanced technology has a substantial impact on the forecast accuracy, which complicates the procedure of implementing a proper forecasting process into the system. While the extraction of useful information from statistical analyses can be arduous, human judgments are usually more easily accessible. Anyway, it has been discovered that both methods provide beneficial information and for that reason, a successful forecast process should rely on judgmental and statistical forecasts in order to acquire satisfactory results (Sanders, 2017).
Table 2-5: Judgmental versus statistical forecasting methods (Sanders, 2017).

<table>
<thead>
<tr>
<th>Judgmental (qualitative) forecasting methods</th>
<th>Statistical (quantitative) forecasting methods</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strengths</strong></td>
<td><strong>Weaknesses</strong></td>
</tr>
<tr>
<td>■ Reacts quickly to changes on site</td>
<td>■ Distractibility (limit of attention)</td>
</tr>
<tr>
<td>■ May include exclusive information</td>
<td>■ Restricted memory</td>
</tr>
<tr>
<td>difficult to measure</td>
<td>■ Not recognizing relationships</td>
</tr>
<tr>
<td>■ Not sensitive to unpredicted events on</td>
<td>■ One-sided, lacking consistency,</td>
</tr>
<tr>
<td>site</td>
<td>manipulative, optimistic</td>
</tr>
<tr>
<td><strong>Strengths</strong></td>
<td><strong>Weaknesses</strong></td>
</tr>
<tr>
<td>■ Deal with complex analytics</td>
<td>■ Depended on quality of data and model</td>
</tr>
<tr>
<td>■ Objective and Consistent</td>
<td>■ Reacts slowly to change on site</td>
</tr>
<tr>
<td>■ Process large amounts of data</td>
<td>■ Not adapted to model prejudiced</td>
</tr>
<tr>
<td></td>
<td>information</td>
</tr>
<tr>
<td></td>
<td>■ Requires technical skills</td>
</tr>
</tbody>
</table>

The purpose of forecasting, performed by either human judgments or statistical models, is to support decisions during uncertainty circumstances. A statistical model developed to assist the forecasting process, is only an algorithm in a computer program that translates statistics into understandable information. How advanced algorithms a model consists of, is usually dependable on individual purpose, organizational targets, and on the knowledge of the creator itself. Both forecast methods contain elements from each other, meaning that human judgments can be partially revised in a statistical forecast as well as statistical information may influence human judgments. A proper combination of the forecasts is established in order to meet the set organizational requirements (Kolassa & Siemsen, 2016). Furthermore, participating team members of the project should be given understandable directions about individual responsibilities and essential managerial areas in order to obtain adequate information about the forecast model. This can become a challenge among forecasting specialists not being sufficiently management-oriented and focusing too much on model characteristics to acquire the desired information. Therefore, forecasts should be created to correspond with consistent organizational procedures and support beneficial decision-making (Makridakis & Wheelwright, 1989). The 4th Chapter describes more comprehensively the theory of combining forecasts.

### 2.3 Project Delivery Methods (Design-Bid-Build & Design-Build)

The purpose in this chapter is not to comprehensively undergo the different delivery methods of construction projects. However, it is essential to state how the individual characteristics of the two most common delivery methods, Design-Bid-Build (DBB) and Design-Build (DB), reflect on some of the processes in project cost management. A brief definition of delivery methods will contribute to increase the overall understanding of benefits and challenges, as well as potential complications in project forecasting. Figure 2-4 presents the project structure of Design-Bid-Build and Design-Build delivery methods, from which
contrasts in the structure of the agenda can be identified. Such differences signify that some methodologies in project cost management require a different approach in order to work properly and for that reason, this chapter briefly defines the reviewed delivery methods.

**Design-Bid-Build projects**

Design-Bid-Build projects are quantitatively the current most traditional delivery method used in the infrastructure construction business. The client engages a professional design firm to develop the project design and create the bill of quantities (BOQ) that traditionally is used to show the measurement of construction works in the project. The project contract is not awarded to any contractor before the design is complete. In a Design-Bid-Build case, the tender documents consist of a detailed description of the works and a complete project design. Tendering contractors can more confidently rely on the provided documents in order to calculate the bid for the project (Porter, 2016; Towey, 2012).

**Design-Build projects**

If a client wants to take a more passive role in the project, the design stage can be partially left out by only providing preliminary drawings available for tendering. This act will reduce the use of resources and transfer the risk for the specification of quantities to the tendering contractors. From a client’s perspective, Design-Build projects are typically a faster option to reach the tender period, as a reason for the left-out design. Tendering contractors (design-builders) are now individually responsible for establishing a suitable design that meets the set requirements in the provided documents. This stage is usually accomplished through a partnership between the tendering contractor and a consultant. Together they interpret the provided concept design and select the most suitable and cost-efficient procurement option. Even with the increased responsibility that is required in Design-Build procurements, the contractors are given an opportunity to better mitigate the risks and create a design that bypasses such risks. After tender expiration, the client selects the contractor that can deliver an acceptable and complete solution that meets the initial requirements stated in the tender documents (Porter, 2016; Towey, 2012).

In conclusion, the tender bid of competing contractors can be either based on a complete design in addition with the BOQ (DBB-projects) or based on a developed design including generated quantities from preliminary drawings (DB-projects). Factors that play an essential part in the Design-Build development process are experience, knowledge, and negotiating skills. The possession of adequate managerial skills enhances the probability to engage consultants to develop a certain design and to compromise with subcontractors and other suppliers how the works should be carried out (Porter, 2016; Towey, 2012).

Contracting companies should aim to expand the project portfolio, by considering participation in projects with various delivery methods in order to increase the knowledge of the different sectors of the industry. Common project delivery methods in the infrastructure construction business are Design-Build (DB), Design-Bid-Build (DBB), Construction Management at Risk (CMR), Alliance and Integrated project delivery (IPD), and Public-Private-Partnership (3P) (Towey, 2012, Skwiot, 2014).

Figure 2-3 on the upcoming page, illustrates the benefits of Design-Build projects compared to Design-Bid-Build projects, and additionally present the different stages up to construction.
2.4 Project Cost Management

Project Cost Management deals with the administration of project costs throughout the life cycle stages of a project: planning, implementation, completion, and maintenance. The aim is to keep project costs within the frame of the budget. The fundamental methodologies of project cost management, shown in Figure 2-4, are interacting to create a structural view of the procedures. Each methodology consists of individual inputs, tools and techniques, and outputs which all are equally important to the case (Project Management Institute, 2017).

Figure 2-4: Project cost management overview (Project Management Institute, 2017).
Depending on the extension of the scope in a project, some of the processes such as estimating costs and determining budget can overlap each other and may consequently be executed as a single combined process. Fundamental efforts of project cost management are to define the scope at an early stage in order to effectively be able to influence project costs. Adequate knowledge and understanding of practical functions in each methodology support decision-making, coordination, and progress (Project Management Institute, 2017).

A critical process in project management is the Work Breakdown Structure (WBS) that provides a systematic overview of the content in a project by dividing construction work into more controllable elements. Details concerning definition of activities, estimation of activity duration, and the management of schedule can all be obtained from decomposition of the project scope. WBS ‘work packages’ are the result of decomposing the project scope construction works into highly detailed components that will support the monitoring and controlling of time and cost on site. Control accounts are a control point that includes the scope, budget, and schedule. Each control account holds two or more work packages of the WBS and is given an individual code (classification) that represents a specific type of works or deliverables. These accounts are further linked to the project cost accounting system (Project Management Institute, 2017).

### 2.4.1 Plan Cost Management

The process of Plan Cost Management sets the principles for suggestive practice and procedures in a project along with the preparation of documentation for managerial responsibilities. Together, these principles support the management of project costs throughout the implementation phase. The Plan Cost Management encompasses cost-related decisions, including detailed information about project works extracted from the WBS. Project guidelines regarding controlling methods, responsibilities, and main objectives are further prepared for the management of the project. The enterprise environmental factors involve an evaluation how organizational structure, market conditions, and standards of the industry influence project procedures. Plan Cost Management is based on subjective judgments from site personnel and involves insights and knowledge of analytical techniques used in current and past projects. With this kind of domain knowledge, the aim is to discover efficient ways on how to efficiently finance and use the resources. Project members are obligated to attend arranged meetings where the Cost Management Plan, that represents methods of planning and controlling the costs in the project, is developed. Such significant information includes for example units of measure, levels of precision, control thresholds, rules of performance measurement, and reporting formats (Project Management Institute, 2017).

Different project delivery methods may require separate approaches regarding project cost management. For example, a Design-Bid-Build project includes a complete design that is provided prior to tender, which the awarded bid is based on. This implies that the contractor generally does not have the authority to give inputs regarding the design and must for that reason stay inside the frame of given requirements. In DBB-projects, the client will stand responsible for any deviations occurring to the scope. From the client’s perspective, it is considered a lost opportunity, where a more cost-efficient solution with a higher value could have been available. Therefore, the procedure of Plan Cost Management in Design-Bid-Build projects is more about discovering effective procedures how to maintain project costs inside the frame of the pre-stated scope (Kubba, 2017).
Ireland (1985) characterizes Design-Build procurements as “a single financial transaction under which one person or organization designs and builds to the firm order of the customer”. In Design-Build procurements, the contract is signed before the scope has been defined by complete documents. This situation allows the contractor to focus on improving the forecasts in terms of quality, schedule, and costs during the development stage of the design (Lesniak et al., 2012). Meanwhile, different design options have different consequences on scope, time, and costs which means that the contractor needs to actively pursue an efficient option of design to maximize the results (Lahdenperä, 2001). This scenario indicates that some methodologies of project cost management must be combined as a result of an incomplete design, where the plan cost management together with cost estimating and cost budgeting are simultaneously carried out, as the design is developed.

### 2.4.2 Estimate Costs

One of the main purposes of cost estimating is to support the process of cost budgeting by providing reliable information and requirements to productively carry out project work (DOE, 2018). The estimating process aims to assess the required resources and costs to complete a specific quantity of project works. Cost estimates are based on current available information and are repeatedly reviewed throughout the life cycle of a project. In practice, this means that cost estimates are established during the tendering process, clarified in the planning phase, and repeatedly updated accordingly to progress during the implementation phase (ADB, 2014). Project-related costs arise from resources, materials, quality, communications, and risk response planning which should all be included in the WBS work packages to support the cost estimating process (Norman, et al., 2008).

A process benefitting the development of high-quality cost estimates, is the *12 steps of cost estimating*, presented in table 2-6. When the structure is followed correctly, each of the twelve steps plays an important part in generating cost estimates of high quality and supports decision-making (GAO, 2009).

*Table 2-6: The twelve steps of a high-quality cost estimating process (GAO, 2009).*

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Define estimate’s purpose [Scope]</td>
</tr>
<tr>
<td>2</td>
<td>Develop estimating plan</td>
</tr>
<tr>
<td>3</td>
<td>Define project parameters</td>
</tr>
<tr>
<td>4</td>
<td>Determine estimating approach [Work Breakdown Structure (WBS)]</td>
</tr>
<tr>
<td>5</td>
<td>Identify ground rules and assumptions</td>
</tr>
<tr>
<td>6</td>
<td>Obtain data</td>
</tr>
<tr>
<td>7</td>
<td>Develop point estimate and compare to an independent cost estimate [WBS element]</td>
</tr>
<tr>
<td>8</td>
<td>Conduct sensitivity analysis [Best vs. Worst case costs]</td>
</tr>
<tr>
<td>9</td>
<td>Conduct risk and uncertainty analysis</td>
</tr>
<tr>
<td>10</td>
<td>Document the estimate</td>
</tr>
<tr>
<td>11</td>
<td>Present estimate for management approval</td>
</tr>
<tr>
<td>12</td>
<td>Update estimate to reflect actual costs and changes</td>
</tr>
</tbody>
</table>
Despite individual features of the project at hand, project managers actively use historical data together with their domain knowledge which can support the selection of the estimating approach most suitable for the project. Statistical analysis can extract numbers from previous projects with comparable measurements which can facilitate the general understanding of the extent of the project (DOE, 2018). However, there are still certain risks of collectively using historical data and expert judgments. Managers have a tendency of becoming overly optimistic while looking at lessons learned from past comparable projects. In consequence, the cost estimates for the project at hand must consider obvious differences in scope, schedule, and risk compared to the analyzed historical data. With the aim to exclude bias from the procedures, generated cost estimates will become more consistent, accurate, and reliable (GAO, 2009).

Historical data can show parametric cost information, such as expenses and/or duration for the realization of a specified work element from previous projects. Even though previous parameters display a realistic picture of actual duration and costs, important to remember is that no project has completely identical features as another. To account for possible uncertainties and risks in cost estimating of a project, ‘contingencies’ are individually priced through a three-point estimating technique. This method displays costs of an activity in three different scenarios. The Most likely scenario ($cM$), covers the realistic costs required for completing an activity. The Optimistic scenario ($cO$), presents the best possible way an activity can be completed, and the Pessimistic scenario ($cP$), deals with the worst possible outcome for an activity. Theoretically, each activity in a project is given three independent estimates that represent a different outcome. The expected cost, ($cE$), is the average value of an activity and determined through an interpolation of the estimates $cM$, $cO$, and $cP$. The formula for triangular distribution is $cE = (cM + cO + cP) / 3$ (Project Management Institute, 2017).

In the 12-step cost estimating process, shown in table 2-6, step 9 (Conduct Risk and Uncertainty Analysis) deals with analysis regarding risk and uncertainty which sets the base for contingency reserves. As a part of Project Risk Management, ‘contingency reserves’ are created to properly address risks through a ‘buffer’ in the budget that accounts for known uncertainties, and act as a protection against the effects of cost overruns. More information becomes available as the project progresses, which leads to the uncertainty of cost estimating being progressively reduced. This supports the decision whether a contingency reserve must be used, modified, or even excluded from the system (Yoe, 2000). On the contrary, ‘management reserves’, i.e., the management of unexpected events, make up for risks that have not yet been identified in a project. Management reserves are included in the project budget, but excluded from the cost (Project Management Institute, 2017). Risk factors of project forecasting are more comprehensively described in chapter 3.2.

Processes and techniques presented above need to be accomplished properly in order to generate reliable cost estimates. The Basis of Estimates (BOE) includes a documentation of used techniques, assumptions, restrictions and indications of price ranges, and accuracy levels which supports the cost estimates. This document enables a more thorough understanding of the procedures behind the determination of the estimates (Project Management Institute, 2017).
2.4.3 Determine Budget

The process of cost budgeting combines the results generated from the planning and estimating procedures. Essential elements in budgeting are the cost management plan, schedules and procedures, WBS work packages, and cost estimates along with the basis of estimates (BOE) as supporting documentation (Callahan et al., 2011). Development of the cost baseline is implemented through an allocation of cost estimates for individual work packages, and further aggregated into larger parts to incorporate overall project costs (Norman et al., 2008). The budgeting process can be assisted with judgmental inputs provided by experienced project managers. Such expertise may concern the management of contingency reserves, the use of historical information, and parameters from previous projects. Collectively, the aforementioned information supports the development of reliable mathematical forecasting models (Project Management Institute, 2017).

Only a small amount of information is generally available in the early stages of a project. This indicates that accuracy and reliability of estimates are in the lower end of the scale, while risks concerning the occurrence of unexpected events are high. In consequence, the definition of total costs at an early stage of the project is difficult to predict. Such concerns place pressure on the budget process and the information it is based on. If a budget is developed on inaccurate estimates, the emphasis should be placed on controlling and frequently updating the cost estimates. This can be achieved through an integration of cost management components into a circulating system that contains determination and modification of estimates, establishment of budget, and management of unavoidable project changes. By using this method, each component covers only the latest and most accurate information which contribute to accurate cost determination of the entire project (Rad, 2001).

Minor changes to cost estimates do not necessarily require adjustments to the budget. On the other hand, if variances between current and forecasted costs become excessively large, the budget should be adjusted in order to maintain the accuracy of the forecasts. It is suggested that current available information, regarding possible future events, are used productively. This becomes necessary, especially during cost overruns, that requires adjustments to the budget and where the contingency reserves are brought into use. Project managers tend to use the contingencies prematurely to simply equalize the effect of unexpected changes which further could escalate into cost overruns (Rad, 2001).
The cost baseline in figure 2-5, displays how the project budget is consumed over time and is generally used to compare forecasted costs with real monitored results. Control accounts containing the cost estimates of work packages and contingency reserves, are components, that when combined, initiate the cost baseline. As earlier explained, management reserves are not included in the cost baseline. Nevertheless, by adding the management reserve as an external fund to the cost baseline, it will act as an insurance for unforeseen changes to the project. The funding requirements of the project, also displayed in figure 2-5, can be either total or periodic, and are derived from the cost baseline to illustrate identified costs and periodical payments (Project Management Institute, 2017).

### 2.4.4 Control Costs

Project budgetary control (cost control) is the process what Ross & Williams (2013) simply describe as “a system in which actual income and spending are compared with planned income and spending, so that management can determine if the pre-project plans are being followed and whether those plans need to be changed in order to make a profit”. In other words, the base for identifying any deviations in costs from the original plan are provided from the controlling procedure. This may empower the site management to take promptly corrective actions needed for reducing existing risks and the effect of future risks (Project Management Institute, 2017).

Determining the current financial status of a project is a major part of cost controlling that encompasses the analysis of project performance value from a work activity, in relation to used expenditures intended for that activity. Significant tasks of cost controlling include the management of changes that influence implementation costs. Factors causing change must be identified, approved, and managed in order to prevent additional impact. Site managers have the responsibility to inform company management about impact from changes, and further exclude unapproved changes from reports containing cost and resource data (Project Management Institute, 2017).
Regarding the center of attention in cost controlling, Rad (2001) suggests that the focus should lie on limiting the effects from unavoidable changes, instead of desperately trying to keep project costs parallel to the cost baseline. Unexpected events can easily change the project environment and usually have a direct negative impact on cost, schedule, and scope. The impact of unforeseen events generally complicates the work tasks for project managers. Common reasons that lead to project change are variations in client’s perspective, unforeseen site environment, adjustments to the design, errors in design or budget, together with errors in construction works (Rad, 2001).

In order to increase controlling accuracy, the responsibility areas of cost controlling should be subdivided and assigned to the site management. Site managers will be responsible for operational and procurement procedures in individual work areas. This approach allows site managers to collect data from monitored progress and to take early corrective actions in the occurrence of unexpected events. Obtained information from the previous monitoring cycle is thereafter provided to the accounting system. Nonetheless, if realized expenditures for a specific activity appear to exceed the cost target at completion, the factors causing the escalation must be evaluated by the management in order to take adequate corrective actions. Possible cost reduction strategies for a specific activity may require modification of the team, change in materials or work equipment, evolving the stage of premanufacturing, or assigning the work task as a sub-contract. After all, possible operational changes with cost savings as the main purpose, cannot in any way have a negative impact on construction quality nor work safety (Koskenvesa et al., 2018).

**Earned Value Management**

An effective method for monitoring and controlling the project progress is Earned Value Management, later referred as EVM. In this chapter, the method is briefly introduced while a more comprehensive definition is presented in the 4th chapter.

The methodology EVM encompasses a detailed and systematical analysis of correlations between real progress vs. planned progress, and real expenditures vs. planned expenditures in the project. Results from the analysis provide site managers with valuable information and a clear overview of the planned, current, and predicted value of the project (Norman, et al., 2008). The graph in figure 2-6, comprise project progress information generated from EVM, and displays how the cumulative costs progress over time. EVM is represented by three fundamental components. The *planned value (PV)* is the designated budget to complete a project work activity, and the *earned value (EV)* expresses the status of work performance in progress (percentage of completion), which in the end of the project, cannot exceed the planned value. As the third component, *actual costs (AC)* shows the realized costs from work performance to date. Additional information displayed in figure 2-6, is the Budget of Completion (BAC) that generally represents the total planned value. Furthermore, the Estimate at Completion (EAC) is based on the BAC but fluctuate proportionately with the Cost Variance (CV) that indicates actual cost difference from the BAC. Finally, the Estimate to Complete (ETC) represents forecasted costs of remaining on-site works based on current available information and is the extension of actual costs to date (Project Management Institute, 2017).
Outputs from the cost controlling process will, if accomplished thoroughly, provide insights in projections of cost together with the consequences from changes that may need preventive or corrective actions. The results will additionally determine the demand to update estimates, the cost baseline, or the cost management plan to more accurately correlate with reality (Project Management Institute, 2017). Progress monitoring should encourage project team members to perform required procedures in order to achieve adequate and accurate information. A system that appears to be difficult and lacking simplicity, will only have a negative impact on efficiency and creativity of the team members. Carefully obtained data from monitoring project progress supports the procedures of forecast modelling and further contributes to establish a valuable data base for future projects (Rad, 2001).

2.5 The Impact of Corporate Structure on Forecasting

Organizations are like systems, where components work together to generate a result that could not have been done independently. The OPS-concept (Outcomes, Performance, and Structure) is a method developed for improving organizational and human performance. The term outcomes indicate the goals and objectives of an organization. In order to support the overall mission, the outcomes need to be well defined. Performance covers the procedures, that employees of an organization provide to achieve the outcomes. Fundamental issues in performance are strategies and activities that help employees to reach common goals. The structure of an organization is the element that can either enhance or reduce the capability to reach the outcomes through performance. Depending on how straightforward the outcomes and performance strategies have been set, the structure of the organization is decisive (Gallery & Carey, 2014).

In a rapidly changing environment, organizations need to identify the market potentiality and adapt their operations to correlate with market changes. Such actions could result in maintaining sustainable competitiveness and gain advantage on the market. Corporate performance during changing market conditions, is achieved through initiating a collective understanding about organizational goals and directing the attention of project managers to
essential issues (Vorhies & Morgan, 2005). While some organizational structures enhance performance forecasting, other structures may influence the process in a negative way. Reduced organizational performance may be a result due to inaccurate forecasting estimates and poor decisions made by company managers (Chindia & Pokhariyal, 2015).

A company can structure the organization based on its operational business, its experience, and its environment. Depending on the structure of the organization, these factors can be subdivided into groups, or combined to establish administrative units. Infrastructure companies may divide their operational works based on the construction sectors such as bridge building, railroad construction, and civil engineering. These construction sectors are separated because of the various knowledge that is required in each area. On the other hand, if an organization has national or international subsidiaries, the structure is generally divided based on geographical area or in a combination with field specific works (Ross & Williams, 2013).

Organizational structures can be divided into three categories: functional, projectized and matrix, and usually go from top to bottom in a hierarchic chart. (Wilson, 2015) Regardless of the path the structure follows, it should support the same things. Each organizational structure should incorporate clear responsibilities, bottom-up reporting procedures as part of the hierarchical relationships, and the ability of interdepartmental assignment delivery. Additionally, coordinated organizational policies and procedures contribute to maintain the performance of the company by guiding the employees in the right direction (Zaki et al., 2015).

**Functional organizations** – have its structure divided into separate departments based on different core businesses. To maintain sustainability, each department has specified goals. Goals that are supported by a stable managerial hierarchy, where department managers report to higher executives until the information is transferred all the way to the top of the structure (Wilson, 2015). The operations and products that the organization provides, are usually of a repetitive nature with little variations in the production process. A solid relationship between departments is established and each department possesses expert knowledge in its own operations. The functional organization structure is only suitable for single-managed projects and better fits operations of lower diversity. More extensive projects or project-based organizations should consider the projectized or matrix structure (Lester, 2017).

**Projectized organizations** – have the optimal structure that allows managers to efficiently control all operations of the entire project (Lester, 2017). Each project is assigned with an individual ‘taskforce’ holding all the objectives regarding the project at hand. Projectized organizations normally have only one department that incorporates all the current ongoing projects (Wilson, 2015). This type of structure promotes interactive communication which reduces the likelihood of misconceptions. Furthermore, it integrates a larger part of the project cost management processes, such as planning, cost control, and accounting, into the project organization. In a projectized organization, the ultimate responsibility of the project is held by the project manager. Therefore, managers must possess the ability to assign and distribute tasks forward in order to reduce the workload. The site management should be encouraged to productively assist in ensuring a sustainable performance in the project. By maintaining the flow of information between managers in a project, increases the likelihood of achieving accurate estimates and reliable forecasts (Lester, 2017).
**Matrix organizations** – are presumably the most used type of structure in project-based organizations and developed to support everyday operations in each department. The site management, including the project manager, is responsible for the cost, schedule, and quality in the project. The chain of command proceeds from the site management, via the project manager, that reports appropriate information forward to the manager at department level (Lester, 2017). While functional managers at a department level administer the assigned projects with responsibility, each project has an allocated project manager that supervises and holds an equal responsibility for the performance of the individual project (Wilson, 2015).

In the end, it is up to the individual organization to structure its business and resources in the most efficient way in order to meet the requirements and demand set by customers and the market. The management structure could have a significant impact on forecasting and controlling procedures, both on project level as well as on organizational level (Wilson, 2015). Matrix- and projectized organizations generally include more comprehensive methods of financial accounting, compared to the functional organization. The procedures of controlling the costs and establishing the forecasts throughout the implementation phase of the project, must be repeatedly checked. If necessary, the procedures are optimized in order to correlate with goals and objectives for both the specific project as well as for the organization (Lester, 2017). Individual advantages and disadvantages of functional-, projectized-, and matrix organizational structures are presented by Harrin (2018) in *Appendix 2.*
3 Challenges and Risk Factors of Forecasting

In the previous chapters, the basics of forecasting, including the most appropriate processes, are presented together with fundamental management aspects that may occur throughout the life cycle of the project. This chapter introduces the factors that are out of a contractor’s control and, if not taken into consideration, can significantly complicate the forecasting process. Such challenges encompass the complexity of project and human procedures, along with aspects of environmental and geographical character. The risk assessment during planning is considered critical, and therefore the content in this chapter provides suggestions on how to thoroughly identify risk and effectively reveal uncertainties prior to construction.

3.1 Challenges in Financial Forecasting of Infrastructure Construction

In terms of project characterization, Holmes (2014) clarifies the difference between simple, complicated and complex classifications in a project. Complicated projects encompass more components than simpler projects. Concurrently, a project can include a collection of simple components, that in combination with each other, create a complicated unit. Project complexity is not based on the number of components but focus more on qualitative rather than on quantitative aspects. The structure of the project should be decomposed into manageable and predictable pieces, but the decomposition of complex projects can be extremely challenging for the management to carry out. Complex projects are created by irregular and interdependent components that are difficult to breakdown due to limited predictability. In such cases, even the effect from minor deviations could have dramatic consequences. Large and complex infrastructure projects have a lower probability to be implemented, due to an extensive amount of information required that must be extracted to generate a thorough overview. Hence, complex projects are more challenging than complicated projects. As a result, the project management should aim to disclose as much information about the project, before the start of the implementation phase in order to reduce the risks (Holmes, 2014).

Environmental and geographical challenges

During the last decades, environmental compliance in the construction business have increased significantly and many factors play a more central part in the scope of cost estimating and forecasting. A larger emphasis must be put on the knowledge and expertise of project managers who are responsible of creating the estimates. As updated regulations by authorities often demand contractors to invent improved approaches on how to implement the works properly, the task becomes more challenging. Environmental aspects regarding the project should be carefully considered by the site management in order to support the estimating and forecasting process. Such aspects concern the type and location of project, management of waste and wastewater, management of air emissions, management of noise and vibration, and the start and completion date of project (DOE, 2018).

Requirements concerning abovementioned aspects, are typically set by the client or national government authorities and directly influence which operations are allowed on site. Contractors must meet the obligations in order to achieve approval for starting the construction works on site. The required standards often force the contractor to adjust
operating protocols, which generally lead to increased costs. Contractors need to ensure that permits are requested without delay, since the client’s consideration period may last several weeks and could affect the schedule, if not requested in time (DOE, 2018).

Geographical characteristics play an essential part in the process of cost estimating. For instance, the distance to suppliers varies heavily depending on the site being in a rural or urban environment, as well as the climate and weather conditions limiting the number of available construction approaches (European commission, 1998). Project contractors must additionally possess adequate knowledge of existing ground conditions on site before starting the construction works. Initial steps in the site characterization process include investigation of location, topography, ownership, prior land use, site access, and possible environmental or landslide hazards. Field-testing methods (geophysical or in-situ geotechnical) encompass the determination of soil conditions such as depth to bedrock, type and thickness of soil layers, strength parameters of soil, and level of groundwater table. Such information is provided by the client from prior site investigations. Yet, it is up to the project managers to verify the adequacy and reliability of received information (Anirban, 2016).

Results from the site characterization process may after all not always be comprehensive enough. Additional discoveries about site conditions are usually obtained during the implementation phase, which could negatively influence costs and schedule. Such discoveries can concern buried materials like concrete, timber, and metal. Moreover, there may be uncertainties in the environmental conditions as a result of insufficient input from the client regarding powerlines, water or gas pipelines underground. The management of environmental hazards, such as toxic substances in the soil, requires cautious processing, since the investigation may not display the extent of the hazardous area (Rodriguez, 2019).

Weather planning for seasonal changes is a crucial task regarding the management of costs and schedule in the project. Team members participating in the planning phase should have a comprehensive understanding about weather planning. Historical data can, if available, reveal consequences that adverse weather conditions have had on the productivity of previous projects. Default weather conditions combine variations in humidity, wind speeds, temperatures, daylight durations, and aerial particle conditions. The various forms of precipitations such as rain, snow, hail, and sleet should all be considered in weather planning. Work activities that are weather dependent should therefore be identified during the planning phase and examined separately from the non-dependent work activities (Carson et al., 2014). The contractor needs to ensure that the performance of seasonal or weather dependent work is scheduled for the right time, since inappropriately planned work activities may result in disruptions and delays that will increase the costs (Keane & Caletka, 2015).

Disruptions or complications in project works, as a result of adverse weather, have a direct negative impact on project performance. Wet weather conditions may lead to interruptions in earthwork activities or limiting on-site accessibility due to slippery pathways. Snowy and cold weather conditions may require ice removal and could cause interruptions in concrete or roofing activities, and high wind speeds could disrupt lifting or conveying operations of tower cranes on site. While certain weather conditions, such as abnormally dry weather periods, may result in the project performance progressing faster than expected, dry weather periods usually require increased dust control measures on site. The weather plan should rely on appropriate sources that provide accurate information about seasonal weather conditions in order to be as realistic as possible (Carson et al., 2014).
Delays

In the construction business, delays are the most common factor resulting in unexpected costs that additionally influence the schedule. The possession of adequate knowledge by project managers facilitates the identification of appearing damages in the project. The *cause & effect* is the main goal of delay analysis and consists of two major approaches. *Prospective* is the first approach of the delay analysis methodology and will mainly focus on calculating the hypothetical effects from delaying events instead of expressing the actual incident. This method fundamentally comprises the probable consequences caused by the delaying event and shows the impact on the schedule. The second approach is *retrospective* and describes the actual reasons that caused the delay in the first place. By systematically examining actual work activities and project progress, this method shows the deviations from original plans that will result in the cause of the delay (Keane & Caletka, 2015).

Delays can be arranged into four contractual categories, depending on the cause, and whether it is either the client or the contractor that stands responsible. The categories of delays are *Non-excusable, Excusable non-compensable, Excusable compensable,* and *Concurrent.* From a contractor’s perspective, delays can arise from errors in project work, while the client can cause delays by prolonging decisions regarding project specifications, or by having issues with the design (Gibson, 2015).

*Non-excusable delays*

Delays where the contractor stands responsible and are usually a result of inappropriate on-site procedures by the contractor. Delays caused by negligence, mistakes, underestimations or setbacks are considered predictable and/or preventable, which gives the contractor no relief.

*Excusable non-compensable delays*

Delays that are caused by nonpredictable factors, such as force majeure, and are beyond a contractor’s control. In similar situations, where neither party (client nor contractor) stands directly responsible, the risk of delays is usually shared. Cost overruns are generally not compensated, but the contractor can be permitted additional time due to the delaying event.

*Excusable compensable delays*

Delays that arise from instructional changes to the project contract, such as contractual breaches or scope changes, which are authorized or caused by the client. Common adjusted articles causing the delays are contract changes, differing site conditions, and suspensions. The contractor is not responsible for these delays, hence entitled to compensation and additional time.

*Concurrent delays*

The scenario where multiple delays appear at the same time or partially overlap each other, where all delays affect the schedule negatively. Several reasons can cause concurrent delays, which complicate the process of solving the situation. It can be challenging to locate the origin of each delay, and in situations of concurrent delays, contractual details must be taken into consideration to determine the outcome. Received compensation and time extension due to concurrent delays can to the contractor be full, partial, or none, depending on the case (Gibson, 2015).
**Other challenges**

Uncertainty as a part of forecasting, is more comprehensively explained in the upcoming chapter 3.2. However, table 3-1 presents five common challenges, identified by Johansen et al. (2014), that frequently appear during uncertainty analysis of which all significantly influence the result of such analyses.

*Table 3-1: Common challenges of uncertainty analysis (Johansen et al., 2014).*

<table>
<thead>
<tr>
<th>Type of challenge</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>The expected value:</td>
<td>arise when the focus of project management lies on the wrong aspects of the analysis process. The true expected value falls short because of underestimated uncertainties. Expected value is based on “guesstimations” which leave no promise of accuracy.</td>
</tr>
<tr>
<td>The detail:</td>
<td>comprise the analysis of uncertainty that may be lost in the estimation process as more detailed information is added. I.e. the uncertainty is “calculated away”.</td>
</tr>
<tr>
<td>The deviation:</td>
<td>develops from uncertainty analyses that fail to show realistic uncertainty in larger projects.</td>
</tr>
<tr>
<td>The human/team:</td>
<td>is depending on experience, skills, and attitude of project managers in the cost estimating process. Buffers (contingencies) or unrealistically high uncertainty factors are added to the cost estimates to generate a satisfactory expected value.</td>
</tr>
<tr>
<td>The lost opportunity:</td>
<td>concerns the ratio between identified opportunities – threats in the project. Usually the high number of threats get more attention, and quite few opportunities get exploited in the end. Possible reasons are too strict design-requirements, or that a modification of the design to a desired extent is not accepted by the client.</td>
</tr>
</tbody>
</table>

Environmental and geographical factors can cause large cost overruns and delays in construction projects if not taken into consideration. Although the upcoming chapter 3.2 thoroughly encompass cost and schedule overruns, table 3-2 presents a list of factors frequently causing overruns in infrastructure construction projects.

*Table 3-2: Cost changing factors causing project delay or variations to original cost estimates (European Commission, 1998).*

- Unexpected Ground Conditions
- Design Changes
- Poor Project Management
- Land Acquisition Costs
- Force Majeure
- Funding Problems
- Inappropriate Contractors
- Exchange Rate
- Shortage of Material and Plant
- Inflation / Relative Price Changes

### 3.2 Influencing Risk Factors in Forecasting

Contracting companies in competitive tendering must be successful in their cost estimates in order to be awarded contracts and make profit on project works. The awarded tender bid
sets the outer budget frame for the project (Yoe, 2000). Especially in Design-Build procurements, where the project design is not completely determined prior to tendering, the contractor should focus on creating a design that significantly reduces uncertainty and continues to correlate with the scope budget (NAP, 2006). Risk analysis supports the cost estimating process by providing valuable input regarding uncertainties and cost-related risks. All available options to improve the quality of cost estimates should be considered during the planning phase of the project. Figure 3-1 shows how uncertainty is greatest at the initial stage of the project but will progressively diminish as the project make progress and more information is revealed. Project managers need to evaluate the ratio between acquired information and residual uncertainty to finally determine an acceptable balance. In unfortunate cases, where the disclosure and reduction of uncertainty is unavailable nor sufficiently cost effective to carry out, the issue can be defined in other ways in the cost estimates (Yoe, 2000).

![Figure 3-1: Uncertainty – Information Trade-Off (Yoe, 2000).](image)

Yoe, (2000) expresses that uncertainty is not necessarily risky, while risks are always uncertain, and further states that “uncertainty is a situation in which a number of possibilities exist and which of them has occurred, or will occur, is unknown”. Identifying all risks that possibly could occur during a project is not practically achievable. Generally, it is only the realized risks, that in the end of the project, are the ones identified. The aim with risk management is still to obtain an understanding as comprehensive as possible, in terms of risk and uncertainty in the project. It is not possible to consider unidentified risks in the risk management process, which always is a liability. There is usually a cause for a risk becoming reality. For that reason, project managers should evaluate the situation at an early stage of the project and take corrective actions to eliminate or reduce the effects of risks and uncertainty. Systematical risk management consists of identifying risk sources, measuring and assessing risk effects, developing managerial risk response, and defining residual risk to project estimates (Smith et al., 2014).
The subject of risk can be divided into three dimensions: risk occurrence probability, degree of risk occurrence, and impact of risk occurrence. These three dimensions create a formula \( R = P \times I \), where the variable (R) represents the degree of risk and is the product from the risk occurrence probability (P) and the impact of risk (I) (Odeyinka et al., 2008). This is an effective technique that supports the risk assessment procedure and integrates the evaluation of identified risk factors causing cost and schedule overruns in construction projects. Identified risk factors can moreover be integrated into a risk distribution chart that creates a clear perspective of the risk situation in the project. Appendix 3 presents available tools for the project risk assessment that contribute to evaluate risk probability and its impact on cost and schedule (Abd El-Karim et al., 2015).

Through literature studies and a questionnaire to experts in the construction business, common factors that frequently generate cost and schedule overruns in construction projects were identified. The results presented in table 3-3, are typical components of the risk assessment in a construction project that should be considered (Abd El-Karim et al., 2015).

| Table 3-3: Factors causing cost and schedule overruns in construction projects (Abd El-Karim, et al., 2015). |
|---|---|---|
| Criteria | Sub-criterion | Attributes/risk factor |
| Site conditions | Environmental Sub-surface | earthquake, unpredicted weather conditions, pollution, unexpected surface conditions, archeological survey, geotechnical investigation |
| | Site location | construction area (rural/urban), access conditions, on-site congestion, delay in permits and licenses, security requirements, safety regulation, differing site conditions |
| Resources | Labor | labor availability and skill level, labor accidents, human resource planning, working hours restrictions |
| | Equipment | quality, breakdown, maintenance, and malfunction of equipment |
| | Material | delivery, storage, theft & damage, procurement, and monopoly of material |
| Project parties | Owner | owner type, management strategy, organization structure, work/labor permits, on site access |
| | Engineering and Design | team experience, project goal, complexity of design, ad-hoc consultants, design error |
| | Contractor | contractor pre-qualified, new technology, defective work, rework, number of subcontractors, contractor reputation, number of current projects |
| | Project management | management experience, owner quality assurance, scope definition, quality control process, type of contract, availability of variations |
| Project features | Financial | type of funds, fluctuation in prices, invoices delay, change in currency rate, owner financial capacity, progress payment, rate of interest, tax rate, foreign currency, project size |
| | Political | bribery and corruption, wars and revolutions, changes in laws and regulations |
| | Schedule | fast track schedule, project duration |
4 CURRENT GENERAL FINANCIAL FORECAST MODELS

The content of this chapter incorporates a detailed description of four (4) different forecasting methodologies commonly used in the infrastructure construction business. All modelling methods measure and monitor project cost and schedule to some extent. Reviewed quantitative methodologies are Reference Class Forecasting (RCF), Quantity Rate Analysis, and Earned Value Management (EVM). As the fourth reviewed methodology, the judgmental forecasting method is selected to qualitatively support the quantitative procedures. Individual methodologies can be used per se, or in combination with other models to generate a more comprehensive unity of the forecast.

The reviewed forecasting methodologies were selected based on what type of information is received, and how that information is generated. Each methodology comprises the processing of project cost and schedule data which, in this case, is the most fundamental feature of the forecast models. Besides from individual methodologies, three different combining methods are introduced to demonstrate various patterns between qualitative and quantitative methods.

The original purpose of the selection process was to find forecast methodologies that encompass information about project cost and schedule. A significant part of the reviewed statistical (quantitative) models included Time Series and Regression modelling. Although some of the models did focus on cost and schedule, they did not incorporate forecasting on project level. In chapter 2.2, Schniederjans et al, (2014) explain Time Series modelling as a part of the predictive analytics, which is a component of business analytics, that extends the forecasting horizon long into the future. Received information then provide decision-makers with a more accurate view of ‘what will happen’. Time Series generally include the modelling of trends, seasonality, and different variations, while Regression modelling consists of dependent and independent variables. The number of variables determine whether the process categorizes as a simple of a multiple regression to forecast linear trends.

Nevertheless, the abovementioned forecasting models (Times Series & Regression) may be applicable in the infrastructure construction business but are not considered relevant to the context of this thesis, since an infrastructure project does not act linearly. Frequently changing circumstances in the project make Times Series and Regression models inappropriate. The infrastructure business is not enough automatized, and it is challenging to perform detailed long-term forecasts, especially on project level. Considering that the aim is to identify basic forecasting models that are applicable for the project management to administer, Time Series and Regression Models are not believed to meet such demand and are therefore excluded. The forecast model should facilitate the creation of reliable and accurate results, and therefore a simple and adapted user interface, is a requirement for effortless forecast modelling.

4.1 Forecast Models on Project Level

This part is limited to judgmental forecasting, RCF, Quantity Rate Analysis, and EVM as the selected forecasting techniques and methodologies. Characteristics of each methodology are described in detail and individual advantages and disadvantages are presented to determine their applicability.
4.1.1 Judgmental Forecasting Methods

Judgmental forecasting methods are appropriate when historical information is not available, or when an unexpected event has occurred in the project. Judgmental methods are widely used in practice, as they authorize situations to be more easily explained and understood by involving parties. Hence, judgmental methods are highly responsive to changes. The two most common methods of judgmental forecasting are executive opinion and the Delphi method. Both methods are relatively simple techniques and based on domain knowledge and contextual information by people in the organization such as project managers, directors, and field specialists. Domain knowledge is described as the knowledge professionals gain from work experience that increase overall understanding and supports decision-making, while contextual information is relevant ad-hoc information that can influence forecasting. Domain knowledge by project managers facilitates the assessment of contextual information in the process of deciding what is most important, and what is not. Judgmental forecasting is most beneficial when domain knowledge is available and based on contextual information (Sanders, 2017).

Executive opinion

The executive opinion method comprises the gathering of expert people in the organization to collectively develop a forecast by combining contextual information from different knowledge areas. Through discussion and sharing of opinions, this method contributes to determine the latest information and the understanding of present and future trends on the market, together with strategies to deal with change (Sanders, 2017). The executive opinion method is considered valuable, especially in cases where historical data is not available for quantitative forecasting, or when changes have been made to existing patterns on the market. The method is frequently used for making qualitative adjustments to quantitative forecasting results. On the contrary, typical shortcomings in decisions made from group discussions are limited overall competence and strongly biased judgments. Strong opinions from dominant executives have sometimes led to inaccurate results (Moon, 2013).

Delphi Method

The Delphi Method is performed almost in the same way as the executive opinion method, only with a minor difference that limits the subject of being biased. Experts involved in the process can be either employees within the company or external people from outside the company. The main difference is that the experts are requested to anonymously provide independent and honest opinions, including reasoning to a specified matter. This allows to collect contextual information that is much less biased than information compiled from group discussions (Moon, 2013).

The next step of the procedure incorporates the summarizing of all anonymously provided opinions into a single document that is returned to each participant for potential re-evaluation. This reciprocated process continues until the topic has reached consensus among the officials. The consensus will then represent the final forecast. The Delphi method is considered most suitable for long-term forecasting, since it is a time-consuming procedure. Due to the complicated evaluation process that is required to develop a unanimous forecast, the method is expensive to execute. Besides the method being slow, another disadvantage is the unreliability that is caused by the various competence of the participants whose main attention may not be the matter in question. To compensate for this issue, the participants
are provided ad-hoc information regarding the subject in order to increase their understanding and reduce the bias (Moon, 2013).

4.1.2 Reference Class Forecasting Method

As an introduction to the problem, the conservative methodology ‘inside view’ emphasizes its focus on the current project, considering it a unique task with unique features and does not rely on previous references. When only concentrating on the specific task at hand, the mindset tends to become narrow and result in an incomprehensive overview of the project. The ‘inside view’ comprises the extrapolation of future trends together with a calculation of required resources and materials. This procedure can however become complicated and insufficient, due to the lack of comparable reference classes. Forecasts of the ‘inside view’ tend to become highly optimistic and unrealistic as a result of strongly biased decisions from group members (Lovallo & Kahneman, 2003).

On the other hand, a project can be examined from an ‘outside view’ that compares it to relevant past projects or reference classes. Information from realized projects can provide project managers with valuable detailed knowledge that is generated through a coarse distribution of outcomes based on historical data from the reference projects. This information can be implemented into the planning phase of the current project, and further improve the forecasting accuracy. As one of the main improvements, the ‘outside view’ or Reference Class Forecasting, later referred as RCF, provides a more objective viewpoint over the project and bypasses the cognitive and organizational bias appeared in the ‘inside view’ procedure (Lovallo & Kahneman, 2003). RCF reduces the probability of project cost overruns which usually are caused by strategic misconceptions and over-optimistic decisions (Liu et al., 2010).

Theories that concern decision-making under uncertainty established the fundamental principles for the RCF methodology. It was first developed by psychologist David Kahneman together with Amos Tversky in 1979, which later led to Kahneman being awarded the Nobel prize in economic science in the year 2002 (Kahneman & Tversky, 1979; Kahneman, 1994). In the year 2004, the method was further practically adapted into project planning by professor Bent Flyvbjerg & COWI who compiled the information into a guidance document for The British Department for Transport. By benefitting from RCF, the three significant steps proposed below facilitate to structure the process properly.

1. The first step identifies and carefully selects past projects with relevant characteristics to the current project. It is necessary to have a comprehensive reference class that has just the right number of comparable projects (Flyvbjerg et al., 2005). Lovallo & Kahneman (2003) add that “the key is to choose a class that is broad enough to be statistically meaningful but narrow enough to be truly comparable to the project at hand”.

2. The second step uses historical data from the reference projects in order to establish an adequate analytical probability distribution of outcomes.

3. The third step places specific characteristics of a project in relation with the probability distribution generated from the reference projects. The most probable outcome of the project is presented from generated results (Flyvbjerg et al., 2005).
RCF allows project managers to leave out assumptions and imaginations about unfounded possible future outcomes and is most usable for nonroutine projects. Nevertheless, there might be some state-of-the-art characteristics in every project which outcomes cannot be generated from a reference class. The main point is still to identify and extract the fundamental works and procedures from comparative previous projects, in order to utilize from RCF (Flyvbjerg et al., 2005).

**Causes of optimism bias**

Optimism or cognitive bias can be categorized into four different groups (technical, psychological, economic, and political) based on the nature and character of cause. In this context, technical and psychological causes are the most relevant, since they comprise procedures during the design phase of a project, i.e., after approval status from authorities. Economic and political causes arise before the project has reached the status of approval and are therefore not considered relevant. During the planning phase, project planners should comprehensively cover potential uncertainties that could occur during the project. Furthermore, contingencies should be established into the budget and the cost baseline, as a protection for cost overruns caused by unexpected future events. Yet, contingencies are established only for reviewed scenarios and may consequently be inadequate due to optimism bias in each category (Flyvbjerg & COWI, 2004).

**Technical causes** to optimism bias appear during the development stage of the project and evolve from long planning perspectives in a complex environment. Project scope tend to change which requires updated planning in order to be implemented properly. This matter can be subdivided into three groups where each one covers a separate issue (Flyvbjerg & COWI, 2004).

- **Imperfect information** is associated with poor procedures and techniques used during the forecasting process, i.e., available inputs that lack adequacy, together with general mistakes made by humans. Planning in an uncertain environment may be difficult, and as a result, mistakes occur. It is considered that the applicability of forecasting techniques has not improved over time, as for the level of optimism bias, on the account that a significant number of projects still suffering from overruns.

- **Scope changes** are a common issue during the development phase and further the implementation phase of the project. Such changes can have a major impact on schedule, resources, and cost, and often requires revised planning that interrupt project progress.

- **Management** can lead to optimism bias and moreover result in cost overruns. As earlier mentioned, planning and operating in an uncertain environment is a challenging task but does not excuse for a poor risk analysis and even less for a poor management. It is not the level of complexity that determine whether a project is being successful or not, it is more about the adequacy of the project management (Flyvbjerg & COWI, 2004).

**Psychological causes** can be explained as when project planners become overly optimistic about realizing a project. During the stage of development, appraisal optimism interferes with reality and errors can easily occur which cause the forecasts to be inaccurate and unrealistic (Flyvbjerg & COWI, 2004).
RCF is widely used by clients and authorities in the preapproval stage of the project. During the preapproval stage, the scope is being evaluated to determine whether it correlates with available financing or not. The economic causes cover the underestimation of construction costs during the preapproval planning phase which later can influence the construction works when the costs have exceeded the baseline, and the project starts to suffer from uncontrolled negative cash flow. Political causes encompass the stage where the clients consider institutional funding options to ensure that the project reaches approval status by authorities (Flyvbjerg & COWI, 2004).

Since these causes extensively surround the period before a project has received approval status by the authorities, the contractor is not affected by such measures, and therefore economic and political causes are not relevant to this context.

**Explaining inaccuracy**

RCF comprises practical results from comparable previous projects with the aim to prevent misrepresentation and bias that have an unfavorable effect on the forecasting accuracy of the new project. The factor determining whether RCF is the appropriate forecast modelling method or not, depends on the circumstances whether earlier forecast inaccuracy is caused by (a) optimism bias or (b) misconceptions. Below is a justification of alternative procedures.

**Optimism bias:** Obtained inaccuracy caused by bias, is the result from honest human mistakes. Assuming these mistakes were not intentionally made, forecasters should be open to improve forecasts by using more relevant techniques. In this case, RCF is considered a relevant option (Flyvbjerg, 2006).

**Misrepresentation:** Batselier & Vanhoucke (2016) state that obtained inaccuracy caused by misrepresentation, is generally defined during the period before a project has been granted by authorities. This indicates that project budget estimates need to correlate with funds and investments reserved for the specific project. Furthermore, Flyvbjerg (2006) continues that misrepresentation, aside from political causes, could also be a result from organizational decisions. Performance pressure from corporate executives could lead to forecasts being manipulated in order to achieve favorable results. In this situation, RCF is ineffective, since the interest in accuracy is low. A possible solution for this matter, is to establish a system that supports accurate forecasts and rejects inaccurate ones. Nonetheless, manipulated forecasts do not change the reality and will eventually be revealed.

Flyvbjerg (2006) additionally proposes that forecasters should consider uplifts or contingencies, i.e., an increase in the budget that is added to the cost, to correlate with the acceptable chance of cost overruns. By comparing the outcomes of past similar projects, the contingency-magnitude can be determined (Flyvbjerg, 2006). Statistics show that the possibility of cost escalations in transport projects are almost 90% and has not decreased during the last 70 years. This signifies that project planners have not learned from past mistakes. Further skepticism indicates on an intentional underestimation of costs by project planners and forecasters in order to conveniently reach approval status of projects (Flyvbjerg et al., 2003).
Limitations of Reference Class forecasting

Flyvbjerg et al. (2005) presented the three required steps to properly perform RCF, but every step includes somewhat vague individual requirements which complicate the actions. Batselier & Vanhoucke (2016) state that RCF is only accurate when the reference class consists of highly similar projects with reliable historical data. The responsibility of compiling a ‘sufficient number’ of relevant projects is not always possible, due to shortage in applicable projects to assemble a reference class comprehensive enough.

The method suggests finding reference classes “broad enough to be statistically meaningful but narrow enough to be truly comparable”. On the other hand, this is a rather imprecise definition of one of the most important requirements. The decision, whether the reference class is truly comparable or sufficiently big, is a subjective judgment (Lovallo & Kahneman, 2003). Table 4-1 displays common technical causes for cost escalations in transport projects, of which as many as possible, should be considered to truly benefit from RCF. Environmental aspects of the current project should be carefully considered, when comparing them to the reference class. Factors like environment, geo-techniques, archaeology, and interfaces generally determine the procedures on site. If information about such environmental aspects is insufficient, RCF is not reliable.

Table 4-1: Typology of specific technical causes for cost escalations in transport projects (Flyvbjerg & COWI, 2004).

- Standards (changed requirements such as speed, road width, road type)
- Routing (changed routing)
- Norms (changed safety norms or building norms)
- Environment (tighter environmental standards)
- Geo-techniques (complex or extensive works on geo-techniques, water or mountain)
- Archaeology (unexpected archaeological finds)
- Expropriation costs (underestimated expropriation costs)
- Complex interfaces (urban environment, links to existing infrastructure)
- New or unproven technology (limited experience base)
- Construction costs (business cycle or competitive situation)
- Calculation approach (calculations based on everything goes as planned)
- Delays due to weather

4.1.3 Quantity Rate Analysis Method

Quantity Rate Analysis (Unit Rate Analysis) is considered the main traditional cost estimation method for building projects. The method involves subdividing project works into smaller manageable components that are individually quantified and then multiplied with the given unit rate. All costs emerged from the construction units are added together, which will result in the Estimated Total Construction Cost for the project (Shabniya & Dilruba, 2017). Previous chapters mention the bill of quantities (BOQ) that represents the complete list of tasks to be carried out in order to complete the project at hand.

Table 4-2 displays fundamental components of the unit rate analysis method to be considered in the cost estimating process. The BOQ is the most essential document during the tender
period of the project. Whether the BOQ is completely or partially provided prior to tender, depends on the delivery method of the project, e.g., Design-Bid-Build or Design-Build (Towey, 2012).

Table 4-2: Pricing of measurement estimates to establish unit rates (Ostrowski, 2013).

- Cost of labor, rate of pay
- Time necessary to do works, labor constant (labor productivity)
- Cost of plant, rental cost
- Time necessary for plant to do work, work rate
- Cost of the material
- Amount of material that is necessary
- Preliminaries necessary to carry out work
- Overheads that management requires
- Profit level to be achieved

There are several ways to cost estimate, of which the most used methods are Analogous- or Top-Down estimating, Bottom-up estimating, and Parametric estimating. After all, it is essential to keep in mind that no single estimating method is suitable for all projects. Abovementioned methods all comprise the work breakdown structure (WBS) as an essential part of the construction project (Goodpasture, 2004).

Top-down estimating / Analogous estimating

Top-Down estimating or analogous estimating is commonly used to forecast project costs and duration (Project Management Institute, 2017). The technique comprises domain knowledge such as experience, market and consulting information, and benchmarking data that usually comes from managers involved in the project. Additionally, the method uses historical data, if available, from past comparable projects as input to the model. Compared to parametric estimating models, the Top-Down model is simpler to perform and less complex, but simultaneously also more inaccurate. The experience of project managers plays a critical role, since the aim is to consider as many characteristics of past projects as possible in order to achieve accurate estimates. On the contrary, this method could be subject to bias due to assumptions regarding project characteristics made by managers (Rad, 2001).

Parametric estimating

Parametric estimating or modular estimating are built on algorithms that additionally include parameters from past projects to estimate cost and/or duration for specific works (Project Management Institute, 2017). Historical data regarding cost and duration from similar projects, serves as input for the parametric model that, through a regression analysis, will display forecasts for the specific work task (Goodpasture, 2004). This estimating technique is suitable when construction works are highly repeatable. By subdividing project construction works into individually measurable parts, parametric estimating allows to multiply the units with cost and duration history data from previous projects. The technique is useful for repeatable project works, such as length of pipelines, length of curbstones, area of paving stones etc. However, the model will not work for innovative projects with little repeatability, due to its inability to account for details (Smartsheet, 2019).
Bottom-up estimating

Bottom-Up estimating or analytical estimating is accomplished through analysis of the WBS of the project. Detailed project deliverables of the WBS enable a more accurate result. The project team analyzes each work package to which they are establishing a cost estimate. Estimates of all work packages are then combined to create the estimates for the total construction costs of the entire project (Smartsheet, 2019). According to Goodpasture (2004), the bottom-up estimating technique also comprises the method of three-point estimating, that was mentioned in chapter 2.4.2. The methodology involves the scenarios of most likely (cM), most pessimistic (cP), and most optimistic (cO) to generate a comprehensive perspective of expenditure outcomes of a specific work task. To increase accuracy and prevent the procedure being subject to bias, the Delphi method can be adapted (Goodpasture, 2004). While the bottom-up technique is applicable to most projects and simultaneously the most accurate one, as far as the WBS is carefully carried out, it is also the most time-consuming technique (Smartsheet, 2019).

Table 4-3 provides an extensive overview of the estimating techniques, presenting the strengths and weaknesses of analogous, parametric, and bottom-up cost estimating, as well as areas of application.

<table>
<thead>
<tr>
<th>Method</th>
<th>Strength</th>
<th>Weakness</th>
<th>Application</th>
</tr>
</thead>
</table>
| Top Down/ Analogous | Requires little data
                  | Based on actual data                    | Subjective adjustments                | When little data is available    |
|                  | Reasonably quick                         | Accuracy depends on similarity of items  | Rough order of magnitude estimate |
|                  | Good audit trail                         | Difficult to assess                     | Cross-check                      |
|                  |                                         | effect of design change                 |                                  |
|                  |                                         | Blind to cost drivers                   |                                  |
| Parametric/ Modular | Reasonably quick                         | Lacks detail                            | Budgetary estimates              |
|                  | Encourages discipline                    | Model investment                        | Design-to-cost trade studies     |
|                  | Good audit trail                         | Cultural barriers                       | Cross-check                      |
|                  | Objective, little bias                   | Need to understand                      | Baseline estimate                |
|                  | Cost driver visibility                   | model’s behavior                        | Cost goal allocations            |
|                  | Incorporate real-world effects (funding, technical, and risk) |                                         |                                  |
| Bottom-Up/ Analytical | Easily audited                           | Requires detailed design                | Production estimating            |
|                  | Sensitive to labor rates                 | Slow and laborious                      | Software development             |
|                  | Tracks vendor quotes                     | Cumbersome                               | Negotiations                     |
|                  | Time honored                             |                                         |                                  |

4.1.4 Earned Value Management

Traditional techniques of project cost management compare the realized costs with the budget in order to determine information about the financial performance of the project. However, it does not measure the progress relative to the planned schedule. This type of
limitation usually complicates the analyzing process with the aim to identify the factors generating deviations in either cost or schedule estimates. As a result, the forecasting of final actual costs is often inadequate and unreliable, due to the progress not being measured properly. The traditional controlling of cost and schedule as part of project management, got its roots from the developed U.S. standard Cost and Schedule Control Systems Criteria (C/SCSC) in the 60’s (1967). The Standard was further developed in the 90’s (1996), resulting in Earned Value Management System, later referred as EVM (Pelin, 2011).

Figure 4-1 displays the fundamental differences between traditional project cost management and EVM, that includes an increased number of measurable variables that develop a three-dimensional real-time picture of the cost and schedule situation in the project (Fleming & Koppelman, 2005).

<table>
<thead>
<tr>
<th>Traditional Project Cost Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned funds = $300K</td>
</tr>
<tr>
<td>Actual costs = $300K</td>
</tr>
</tbody>
</table>

Variance from an expenditure plan = (0K)

<table>
<thead>
<tr>
<th>Earned Value Management</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planned Value = $300K</td>
</tr>
<tr>
<td>Earned Value = $200K</td>
</tr>
<tr>
<td>Actual costs = $300K</td>
</tr>
</tbody>
</table>

Variance from the planned schedule = (-$100K)

The "true" cost variance = (-$100K)

*Figure 4-1: The fundamental differences between Traditional Project Cost Management and Earned Value Management (Fleming & Koppelman, 2005).*

EVM is nowadays a widely used project controlling technique that incorporates the elements of cost, schedule, and scope as base information to the procedure. The technique supports project managers to monitor project performance with the consideration of both cost and schedule (Batselier & Vanhoucke, 2016). EVM measures can be performed for specific job tasks, work packages, management cost units, or for the entire project. Depending on the nature of the project, the most adequate practices for the project at hand are used (Pelin, 2011). EVM can be carried out at any time during the implementation phase. How frequently project performance reports are requested, depends on the project together with regulations set by the organization. Standard reporting frequencies vary between once a month, every other month, on a quarterly basis, or twice a year. EVM provides information about the present condition of the project. Real-time performance information regarding cost and schedule, enables project managers to identify variance in an early stage and take corrective actions in time (Batselier & Vanhoucke, 2016). A list of EVM key metrics and formulas can be found in Appendix 4.

**Earned Schedule (ES)**

One major flaw of the technique, that has been known since the creation of EVM in 1967, concerns the schedule-related indicators that are not practically appropriate. The defined shortcoming involves the indicators of Schedule Variance (SV=EV-PV) and the Schedule
Performance Index (SPI=EV/PV), where EV = Earned value and PV = Planned value. As a result of this imperfection, the technique only accounts for schedule performance, measured in currency, and not in actual time. As the project moving towards completion, the value of SV will approach zero (0), as well as the formula for SPI will approach the value equal to one (1). From a mathematical perspective, this indicates that the project cannot run behind schedule. In the early stages of the project, the schedule-related indicators are however accurate. On the contrary, after the project has passed its halfway point, the indicators SV and SPI start to become distrustful. As a result, project managers will not have any reliable information about progress according to the original schedule (Budd & Budd, 2009).

In the year 2003, a complement to EVM got developed when engineer Walt Lipke established the metrics of Earned Schedule, later referred as ES, to account for the instability of EVM. The developed metrics comprise the duration, instead of cost, for the measuring of schedule performance. As an improvement, ES pinpoints in which time period project costs have occurred. The indicators of schedule function accordingly to project progress throughout the entire project period, by displaying updated cumulative values of ES (Lipke, 2003). The metrics of Earned Value Management, including formulas, are listed in Appendix 4, where all indicators represented by a suffix (t) or ($$) including the metric AT, are indicators of Earned Schedule.

![Figure 4-2: Structure of Earned Value Management, including the most important components (Vanhoucke, 2009).](image)

**Earned Value Management drawbacks and limitations**

In a case study, Batselier & Vanhoucke (2016) discovered that measured EVM performance was not consistent in the beginning of the implementation phase and turned out to be far from the truth. Such incorrect results incorporated the indicators of EAC-CPI (Estimate to
Complete through the Cost Performance Index) and ESM-SPI (Earned Schedule Method through the Schedule Performance Index). The incorrect results point out that the initial data, by the time the performance is measured, is insufficient. If any relevant information regarding cost and schedule is missing or false, the forecast will generate highly misleading numbers. In the beginning of the construction phase, potential inaccuracy of EVM forecasting is the highest, as a reason to the small amount of available data. When estimating the cost and time at completion, errors easily occur if available data is not comprehensive enough. As the project progresses, more information is revealed and the share of completed works have increased, which support the accuracy of EVM that continues to grow towards project completion (Batselier & Vanhoucke, 2016).

Additional limitations and shortcomings of EVM that need to be taken into consideration are listed below.

- First, EVM does not suggest how to correct an identified variance, since the result does not include the cause of why cost or schedule deviate from the plans. Anyway, EVM still informs that a variance is real, and it also points to the location of the variance. The final step of how to correct the overrun or how to optimize the operations on site, are up to the managers to decide.

- Second, another risk of EVM concerns manipulation of received information in order to show favorable results. For example, a poor performance or interruption to a construction operation on site can be withheld, where the damages are revealed not until later. Unaccounted poor performance can not only misguide the project managers with inaccurate forecasts, but also result in expensive repairing works in the future. Such circumstances can be avoided by encouraging site workers that construction projects are about teamwork, and that honesty is always respected. Immediate reports of damages are easier to correct than non-existing ones.

- Third, this limitation is connected to the previous one, where the reliability of acquired information is crucial for generating consistent results. It is necessary to confirm that utilized information is correct.

- Fourth, EVM does display information regarding the cost and schedule, and present the general performance level of the project. The method does not however measure quality, which means that besides EVM, project managers should have additional quality control procedures scheduled for determining the earned quality of the performed construction works (Griffin, 2013).

Bear in mind that EVM requires large supervision effort in order to function properly. Managers will have less time to supervise on-site operations, which can become a problem during periods where concurrent ongoing construction tasks requires attention. By establishing a distribution of responsibilities, together with a policy how to collect desired information, the procedures of EVM becomes more structural (Parikh, 2017).

Abovementioned limitations are not a reason to exclude EVM as a potential control methodology. Adequate knowledge regarding the features of EVM must be possessed by the organization and the site management in charge. Advantages and disadvantages should be appropriately evaluated before putting EVM into use (Griffin, 2013; Parikh, 2017).
4.2 Comparison of Reference Class Forecasting and Earned Value Management

This subchapter presents results made by Batselier and Vanhoucke (2016), where RCF was compared to EVM in a real construction project. The content is limited to the forecasting methods of RCF and EVM, since the methods of cost estimating are performed pre-implementation, and therefore do not comprise the same the areas as RCF and EVM.

Results from the study stated that between the compared forecasting methods, RCF was the most user-friendly. The content of RCF is clear with a simple execution procedure, while EVM requires multi-step calculations in order to display accurate periodical forecasts (Batselier & Vanhoucke, 2016).

Project planners usually choose the ‘inside view’ as prime method. Therefore, project planners are considered as part of the problem, and not the solution Flyvbjerg et al. (2005). While RCF contributes to provide valuable insights in non-routine projects, it can only be practically used during the planning phase, i.e., pre-implementation. This simply results in a fixed forecast that is developed prior to construction, and that remains constant throughout implementation. If circumstances change during the implementation phase, the forecast becomes inaccurate. Even though RCF simply produces a forecast prior to construction, results show that it outperforms EVM in accuracy, stability, and timeliness. However, RCF is only applicable when the degree of similar past projects are high enough. RCF clearly outperforms EVM during early stages of the implementation phase, as a reason to its consistent results (Batselier & Vanhoucke, 2016).

Batselier & Vanhoucke (2016) presume that an improvement to project forecasting could be made through an integration of both RCF and EVM. The prime forecast for the entire project should be based on results obtained from RCF, while the construction performance is mitigated through EVM. A combination of these methods would support the identification of change and allow for high reactivity which improves the overall project control procedure.

4.3 Combination of Forecasts

In chapter 2.2, it was mentioned that both judgmental and statistical forecast models have their individual strengths and weaknesses, although the strength of one method can compensate to some extent for the weakness of others. This signifies that forecasts should rely on both judgmental and statistical methods, in order to be reliable and accurate.

Sanders (2017) presents various methods for combining judgmental forecasts with statistical forecasts and demonstrates certain criteria for the combination process. The initial phase starts with each forecasting method being created separately without any risk of influencing the other. Secondly, both forecasts should rely on exclusive information, e.g., the statistical method being based on objective (hard) data when subjective (soft) data is the source for judgmental methods. Different information sources allow the combination of forecasting methods. Thirdly, judgmental forecasts should be based on expert opinions such as domain knowledge or contextual information that contribute to focus on the essential aspects of the forecast. However, domain knowledge is primarily not included in statistical forecasting (Sanders, 2017).
Method 1: Managerial adjustments to quantitative forecasts

This method displayed in figure 4-3, is considered the most popular forecast combination and it comprises the results of a statistical forecast being adjusted with judgmental inputs. Despite this method being a simple way of integrating human judgments with quantitative results, it also has the lowest accuracy of all combining methods and is the one that is most likely to be biased (Sanders, 2017).

![Diagram](Image)

*Figure 4-3: Managerial adjustments of quantitative forecasts (Sanders, 2017).*

Method 2: Mechanical combining of managerial and quantitative forecasts

In order to reduce the bias potential when integrating forecast methods, each forecast should be generated separately to increase the independency, as of figure 4-4. There are two essential procedures that allow the given results from forecasts to be combined. Both procedures rely on a mathematical combination of the results from the forecasts, where the first one creates an average value of each equally prioritized forecast. The other procedure places a varying degree of priority, measured in percentage, onto both results from the judgmental and the statistical forecast, where the sum of the priorities is equal to 100 %. Mathematical combination of forecasts is less subjective than judgmental adjustments and generally provides an improvement to forecast accuracy. On the contrary, due to the mathematical determination of the forecast, project managers may yearn for more control which this method does not provide (Sanders, 2017).

![Diagram](Image)

*Figure 4-4: Mechanical combining of managerial and quantitative forecasts (Sanders, 2017).*
Method 3: Judgment as an input to model building

Figure 4-5 displays the third combining method presented by Sanders (2017), where project managers use their expert opinions to select patterns, variables, and parameters to the statistical forecasting procedure. The method is considered to have the lowest potential of subjective bias and is simultaneously the most efficient method. Nevertheless, a significant disadvantage of the method is the amount of adequate knowledge required from project managers, regarding the advanced features of the quantitative forecast. While this issue complicates the practical implementation of the forecast, the method additionally tends to react slowly to change. On the contrary, judgmental inputs is the only combining method that include contextual information before the forecast is generated, which contributes to its objectiveness.

![Figure 4-5: Managerial opinion as input to model building (Sanders, 2017).](image)

To keep the combination process from becoming biased, table 4-4 presents ten (10) rules on how to properly combine forecast methods. The guidelines can educate project managers about the essential aspects of adjusting statistical forecasts with judgmental inputs to create a forecast as accurate as possible (Sanders, 2017).

<table>
<thead>
<tr>
<th>Rules</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rule 1:</td>
<td>Adjustments to statistical forecast should always rely on contextual knowledge.</td>
</tr>
<tr>
<td>Rule 2:</td>
<td>Adjustments should be carried out during high uncertainty.</td>
</tr>
<tr>
<td>Rule 3:</td>
<td>Adjust to compensate for identified influencing changes.</td>
</tr>
<tr>
<td>Rule 4:</td>
<td>Create a systematical procedure for adjustments.</td>
</tr>
<tr>
<td>Rule 5:</td>
<td>Keep record of all performed adjustments.</td>
</tr>
<tr>
<td>Rule 6:</td>
<td>Monitor forecast performance to determine accuracy of adjustments.</td>
</tr>
<tr>
<td>Rule 7:</td>
<td>Use the available data to forecast.</td>
</tr>
<tr>
<td>Rule 8:</td>
<td>Keep the forecast simple.</td>
</tr>
<tr>
<td>Rule 9:</td>
<td>Focus the adjustments to series with high volatility.</td>
</tr>
<tr>
<td>Rule 10:</td>
<td>Due to limited attention span, the forecast should focus only on important data.</td>
</tr>
</tbody>
</table>
The importance of domain knowledge in forecasting

Sanders & Ritzman (1992) debate about the importance of domain knowledge in forecasting and further present detailed results from a comparison between statistical forecasts and judgmental forecasts. To determine the value of judgmental inputs under diverse circumstances, they initiated each forecast with a varying amount of domain knowledge and contextual information. The results confirm that judgmental forecasts based on domain knowledge are far more accurate than forecasts that were not based on domain knowledge. Not even statistical forecasts were as accurate as judgmental forecasts, when domain knowledge was present (Sanders & Ritzman, 1992).

In a study from 1995, Sanders & Ritzman concluded that when integrating judgmental forecasts with statistical forecasts, a higher priority should be placed on the judgments to increase the accuracy in an uncertain environment. Statistical forecasts do not have the ability to oversee uncertainty to the same extent as judgmental forecasts. While statistical forecasts surpassed judgmental forecasts in accuracy when the uncertainty was low, judgmental forecasts got more accurate than statistical forecasts as the level of uncertainty increased. The most significant findings from the study suggested that forecasts should be combined when the level of uncertainty is low. Nonetheless, judgmental forecasts are still more accurate alone than in combination with statistical forecasts, especially during high levels of uncertainty (Sanders & Ritzman, 2001).
5 PROJECT-LEVEL FORECASTING IN EXAMINED CORPORATION

This chapter introduces the empirical part of this thesis and comprises the results from a study at the case company, GRK Infra Oy. The content focuses more closely on how the forecasting process is carried out, and practical results are obtained through interviews with managers in different positions at the company.

The purpose of this chapter is to reflect the findings from the literature study with the current procedures of forecasting at the case company in order to determine whether any relationships exist. A pilot project has recently been launched with the intention to improve general reporting procedures at the company, since the current reporting system is outdated and needs an upgrade. Obtained information from conducted interviews with company managers provides a broad perspective of the present forecasting situation at the case company.

5.1 Presentation of Examined Corporation

The commissioner of this thesis, GRK Infra Oy (former: Graniittirakennus Kallio Oy), later referred as GRK, is a Finnish infrastructure construction group originally established in year 1983 that primarily concentrated its business on real estate and construction contracting. In the year 2007, the company expanded its operations to infrastructure construction which gradually became the main line of business. After some years of creating a solid position on the national construction market, the expansion progressively continued as the company established subsidiaries in both Sweden and Estonia. During the past years, the company has expanded its knowledge area beyond regular infrastructure construction into the railway business and the paving business. The company has since the year 2010 maintained a continuous growth in business volume, revenue, as well as in staff. Year 2018, GRK incorporated over 500 professionals and a turnover of 250 M€ (GRK, 2019a; GRK, 2019b).

![Diagram of GRK Group structure]

*Figure 5-1: A complete overview of the GRK Group structure.*

The infrastructure construction business is continuously affected by changes in the operating environment. Therefore, the understanding along with foresight and effective response, play
an important part in the development of company services. The core competence of the company incorporates the realization of demanding infrastructure construction projects and a wide-ranging expertise in railway construction. In the comprehensive business of infrastructure, GRK provides complete services in road, environmental, and industrial construction, along with skill building. The services include all stages of planning, implementation, and maintenance. Through successfully realizing demanding infrastructure projects, the company has gained an extensive experience and have a clear picture of how projects should be carried out. Figure 5-2 displays the complete services provided at GRK.

---

**Our services**

![Engineering Construction](image)

**Engineer Construction**

![Road Construction](image)

**Road Construction**

![Railway Construction](image)

**Railway Construction**

![Paving](image)

**Paving**

![Circular Economy and Environmental Construction](image)

**Circular Economy and Environmental Construction**

*Figure 5-2: Services provided at GRK (GRK, 2019c).*

---

### 5.2 Present Condition of Forecasting at The Case Company

In earlier chapters, the most fundamental aspects of financial and project forecasting have been presented, as well as the most significant factors impacting the procedures. In order to develop any practical solutions to this subject area, the task is to obtain a comprehensive insight of the current condition regarding forecasting in the case company, and further compare the methods with the theory. Relevant information was received through an interview study with executives in key positions at the company, together with project managers and site managers. This pattern enables to collect information directly from the project site through the project management. Two separate interview agendas have been prepared, one for the project and site managers and one for the corporate management. The agendas can be found in *Appendix 5 & Appendix 6*.

**Interviews**

The interviews were conducted in person with corporate managers and project managers. In total, two (2) interviews were conducted with corporate managers, and four (4) interviews with project managers. To more effectively reach out to the site managers, who are located on the project sites and not at the headquarters, the interview agenda was sent as an inquiry by email. Out of eight (8) site managers that received the agenda, seven (7) responded and returned the inquiry form.
Table 5-1: A list of respondents from the conducted interviews and the survey.

<table>
<thead>
<tr>
<th>Code</th>
<th>Title of candidate</th>
</tr>
</thead>
<tbody>
<tr>
<td>CM1</td>
<td>CEO</td>
</tr>
<tr>
<td>CM2</td>
<td>CFO &amp; FM</td>
</tr>
<tr>
<td>PM1… PM4</td>
<td>Project Manager</td>
</tr>
<tr>
<td>SM1… SM7</td>
<td>Site Manager (survey correspondent)</td>
</tr>
</tbody>
</table>

Forecasting at the case company

As a standard procedure at the case company, the forecast reports from all ongoing projects are requested from the project managers on a monthly basis, where both the Executive Board and the Board of Directors review the delivered reports. A summary of project reports is prepared monthly, while corporate-level reports are prepared quarterly that includes the profit and loss statement and balance sheet of the company.

“The existing frequency of requested forecast reports is appropriate, since now we are able to receive updated information on a regular basis in order to maintain a functional system.” (CM2)

The financial reports have not always been requested as regularly as today, but since the strong growth of the business, it has become more critical to establish a straightforward procedure in order to maintain a sustainable system. Yet, the main concern is still to pursue the validity of the reports. If the reports present wrongful numbers, the whole system fails, which automatically will affect the business negatively. The CEO of the case company examines individual forecast reports with the project managers present.

“The current reviewing procedure [of reports] does only work to some extent. Unfortunately, the limit of the method has been reached for this business volume.” (CM1)

Defined responsibilities of the project management are fundamental for maintaining efficient operational procedures in the projects. Chapter 2.4.4 suggests that site managers are assigned with individual responsibility areas of the project during implementation. The question is, are the responsibilities defined at the case company?

“Yes, the responsibilities are defined. Project managers deliver the forecast reports once a month. The people involved in forecasting should be aware of required tasks, which they manage pretty well.” (CM1)

“In our opinion, the responsibilities are well defined, at least the procedure of forecasting and cost control, which is the project managers’ responsibility. We must provide a system with tools, that support cost management more thoroughly. [...] Project cost information will be automatically added to the reporting system, as of the upgrade, which will lower the threshold for project managers to discard from the Excel-world.” (CM2)
The case company does not actually have a structure that can be compared to any of the reviewed organizational structures in chapter 2.5, since it is yet considered undefined. On the other hand, it evidently supports forecasting on project level, although corporate managers agree that the procedures can be further developed.

“The organizational structure supports forecasting procedures, since there are not any unnecessary middlemen to potentially influence the forecasts. People in charge of the projects are competent and must possess contextual information about procurement prices etc. [...] Our challenge is to get the margin of error from incorrect forecasts, that are common in loss-projects, counterbalanced during implementation, e.g., by optimizing or renegotiating contracts with subcontractors and material suppliers.” (CM1)

“The structure supports forecasting, but there is still room for improvement. Due to the extensive growth of the company, certain procedures need to be optimized in order to facilitate access to cost information. It is not appropriate to continue with the same reporting system anymore, since the business volume has multiplied during the last years.” (CM2)

Interviewed project managers unanimously agree that the organizational structure at the case company supports forecasting on project level. They share the opinion that people in charge of the projects are aware of the required protocols to be performed on site.

### 5.3 Current Forecasting Models and Procedures

The financial reports from ongoing projects, including forecasts, are required on a monthly basis, as mentioned earlier. There are no specified requirements at the case company how project level forecasts should be extracted, which allow project managers to individually choose a suitable method of their own that generates the forecasts. On the other hand, individual project forecast reports must contain the following required information:

1. The final turnover of the project
2. The final cost of the project (revenue/sales margin)
3. The percentage of completion (PoC) at the end of the year

Received information is further added to the financial performance system to generate a complete overview of company operations. For that reason, the variety in extraction of the forecasts could have an impact on the degree of reliability. Some project managers can choose to forecast subjectively with pen and paper, while other project managers have developed advanced Excel sheets that forecast the performance mathematically to a more detailed extent.

### 5.3.1 Interviews with Project Managers

The interview agenda for the project managers, in Appendix 4, incorporates twenty-three questions of different character. The questions were either yes/no questions, questions with pre-stated options to be crossed, or questions that required explanations. All project managers responded unanimously that financial forecasting is important and that the
reporting frequency of forecasts, once a month, is reasonable. On the other hand, smaller infrastructure projects with a more basic scope, do not require revision of the forecasts as frequently, since changes in minor projects have less implications than in larger projects.

“In larger projects, forecasting once a month is appropriate, as financially significant changes occur more frequently. In smaller projects, I think it should be acceptable to update the forecasts every other month.” (PM4)

Apparently, there is a confusion regarding the reporting frequency at the case company, since some managers are not aware of existing instructions. How frequently forecasts are created among site managers, can be examined in the chapter 5.3.2.

“I personally want to know the percentage of people forecasting according to the requirements, because I have not received any written notice stating that forecast reports must be delivered every month. My forecasts are updated every other month, if no significant changes have occurred. If something however happens, the forecasts are immediately corrected.” (PM4)

All interviewed project managers are moderately satisfied with their way of creating the forecasts. Based on the responses, an ‘accurate enough’ forecast is apparently reasonable. The experience of site managers still plays a significant role concerning the accuracy of forecasts, since forecasting is called a ‘skill’. Generated results from the forecast supports, at least to some extent, the optimization of construction operations on site. If any cost or schedule deviations are identified, the management must react and, according to the situation, optimize the efficiency of the operations. However, it is considered that the damage has already been done, when the site management starts to improve inappropriate on-site work operations.

Project managers agree that the site management continuously participates in the forecasting process by providing valuable insights and ad hoc information regarding project progress. Such assistance is considered an asset.

“[Discussing on-site forecasting] The majority of site managers understand the idea of forecasting really well, and they want to participate in the procedures. They become motivated from observing an opportunity of improvement.” (PM4)

**Cost forecasting**

Cost forecasts are created and regularly updated by all interviewed project managers, as of the monthly requests from the company CEO. 50 % of project managers periodically re-evaluate the schedule forecasts, because the project client requires schedules that are up to date. Although, none of them crossed the answer box that stated the risks are updated. It is still presumed, that the risk assessment from the tender period is frequently monitored and corrected as needed during implementation.

“The cost risks are not registered enough, and that is my personal ‘weakest link’. The identification of risks is consciously left out, since directives from the board indicated we are not allowed to do so.” (PM4)
In the interview agenda for the project managers, question 7 (Q7), encompasses how the costs are being forecasted during the tender period. The respective answers are listed in the table below, followed by individual opinions from each of the project managers.

<table>
<thead>
<tr>
<th>Q7: How do you forecast costs during the tender period?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Options</strong></td>
</tr>
<tr>
<td>a. Based on judgments (domain knowledge)</td>
</tr>
<tr>
<td>b. Based on previous references (RCF)</td>
</tr>
<tr>
<td>c. Based on unit price/quantity-calculations</td>
</tr>
<tr>
<td>- Bottom-Up estimating</td>
</tr>
<tr>
<td>d. Other or self-developed method</td>
</tr>
</tbody>
</table>

“It is a combination of options a, c, and d. Reference information can be extracted from every project and is usually compared only when the subcontracts are not competed. The accuracy and applicability of unit prices extracted from reference projects, vary significantly and are sometimes inappropriate." (PM1)

“Reference information can be used, but also risky. The cost for the same work can be completely different, depending on the complexity of the construction site. While tender unit prices are based on several important factors, historical data may not consider all relevant ones.” (PM2)

“I believe it is a combination of all options. Sometimes the costs are simply ‘guesstimated’, since there is no post-calculation available from realized projects. I think post-calculation is pointless, due to significant difference between projects. However, some lessons can always be learned from past projects.” (PM3)

“The unit price is established by decomposing the work tasks into smaller parts, and further defined by pricing individual work phases.” (PM4)

Furthermore, question 8 (Q8), encompasses how the costs are forecasted during the implementation phase. Table 5-3 indicates that cost and schedule control is the most popular method, along with personal adjustments, to provide desirable results. Significantly used variables comprise actual costs and the remaining amount of works, in order to determine the percentage of completion, later referred as PoC, of the project.

<table>
<thead>
<tr>
<th>Q8: How do you forecast costs during the implementation phase?</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Options</strong></td>
</tr>
<tr>
<td>a. Based on judgments (domain knowledge)</td>
</tr>
<tr>
<td>b. Based on Cost- and Schedule control (EVM)</td>
</tr>
<tr>
<td>c. Other or self-developed method</td>
</tr>
</tbody>
</table>

Table 5-3: Project managers’ answers to Q8 in the interview agenda.
“The performance is verified in conjunction with the site manager, since they possess the latest updates from the project. I require information that concerns the current capacity on site, currently active work tasks including PoC, and an estimate of when the project is ready. Any alteration works, changes, or unexpected events, are managed cooperatively. The site management creates their own forecasts, and I create mine, then we compare which one is more accurate.” (PM1)

“I personally work with a self-developed method that uses the tender calculations to create the forecasts. Project cost data is available from Visma (the accounting system at GRK). The PoC is evaluated visually, but I rarely forecast it. In larger projects, completed work tasks are gradually removed from the calculation. When the costs are compared with the estimated PoC, you receive an approximate estimate of final profit margins.” (PM3)

“The control and forecast calculations in Excel, are based on PoC-estimates together with work packages that include the tender budget, target budget, and realized costs. I initiate forecast coefficients to account for variations in the productivity, regarding the construction costs of individual work tasks, from which the actual forecast is established. However, PoC is easier to visually verify on site.” (PM4)

Accurate forecasts rely to a great extent on realized costs and costs that are emerging in the future. Invoices are received by the accountants at the case company and added to the accounting system where the project cost data is accessible. All cost data must be included when the forecast is updated, otherwise it will not be accurate. Three out of four project managers agree that it is not difficult to verify the realized costs and quantities, although different types of projects incorporate different challenges.

“[About verifying realized costs in water supply projects] It can sometimes be difficult, since authenticated and prime quantities never correlate as a reason to alteration works. In the end, it is all about guessing.” (PM1)

“Cost data is easily accessible, and I am sure the quantity estimates could be more accurate, but that requires additional resources. How do you determine whether something is done sufficiently efficient? In general infrastructure projects, this method is good enough for the company.” (PM3)

“The costs are in general quite easy to determine, but the quantities are sometimes difficult depending on the amount of measurable quantities on site. All the quantities are eventually received, but it is a time-consuming task for the surveyor engineer to get everything measured.” (PM4)

Future costs are not considered difficult to forecast, since many of the subcontracts are tied to quantity units. From a financial perspective, this means that the costs for a specific task cannot escalate, regardless the work efficiency, as far as the quantities do not change. On the other hand, there is always a risk of future work tasks being affected by other project tasks that are running behind schedule, regardless whether they are tied to quantities of not.
Considering that almost all the construction works are performed outdoors, adverse weather conditions can significantly limit available work approaches. The arrival of winter strongly determines the continuance of weather-critical operations which cannot be carried out during cold conditions. Finishing works, paving, and stonework, are examples of work tasks that are not performed during the winter, mainly due to frost heave and low work productivity.

“[Discussing forecasting in the fall] This is a challenging issue, when we go towards winter. We must decide if it is possible to complete weather-critical construction works before the winter, or if we are forced to construct weather guards which significantly reduces work efficiency and increases the costs. If the pavement cannot be applied before the winter, the base course layer of the road must be prepared again, since it is damaged over the winter.” (PM1)

Schedule forecasting

The project managers were asked how they create the schedule forecast, both during the planning and implementation phase. The preliminary schedule is usually based on the defined project time and determines the amount of resources required to effectively complete the work tasks. During the planning phase, the project management must create the most appropriate work scheme to maintain a satisfactory progress during implementation. The topic of schedule forecasting introduced several significant factors that influence the schedule, but simultaneously also affect the costs, as they are closely associated.

“[Schedule forecasting during the tender period] The prime schedule emerges from the work capacity and the existing quantities, which are reflected on the project time. We need to ensure that the works can be completed inside the given time frame. Occasionally, domain knowledge is used to create the forecasts.” (PM2)

“The schedule is estimated on a very rough level and is based on obtained information from previous similar tasks. If preparation of the schedule is not required, as it is in most cases, then it is left out. Cost data in terms of quantity units [m, kg, m², m³], that is collected from past projects, are examined to confirm the price level of materials including work productivity. This kind of information is created within my mind and does not rely on post-calculations, because such information is not available and neither collected at GRK.” (PM4)

A project might contain time targets or milestones defined by the client, which require a certain PoC of the project at a specific time. If the specific target or milestone is not reached in time, the main contractor could be fined. Therefore, the preliminary schedule is updated as required during implementation in order to meet the current demand.

“A more accurate view of the schedule is achieved by combining the prime schedule, the subcontracts, and the boundary conditions of the client. (PM1)

“My schedule forecast is linked with the cost forecast. Actual data is verified from realized costs and on-site measurements. The coefficients determine the duration for each work task. If I notice that the productivity is lower than expected, I raise the coefficient to counterbalance for the deviation.” (PM4)
Forecasting in uncertain and changing environments

Chapter 2.4.2 primarily covers common cost estimating procedures and techniques, together with different ‘reserves’ as a part of the uncertainty analysis. While ‘contingency reserves’ are intended for the identified uncertainties, the ‘management reserves’ act as a protection for unidentified uncertainties. Project risk assessment is an essential task during the planning phase, where the consequences of risk occurrence are estimated. Apparently, the effectiveness of the risk assessment significantly varies from case to case.

Table 5-4: Project managers’ answers to Q17 in the interview agenda.

<table>
<thead>
<tr>
<th>Options</th>
<th>PM1</th>
<th>PM2</th>
<th>PM3</th>
<th>PM4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of risks</td>
<td></td>
<td></td>
<td>X</td>
<td>X</td>
</tr>
<tr>
<td>Magnitude of risks and probability occurrence</td>
<td>X</td>
<td>X</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Evaluation of schedule variations</td>
<td>X</td>
<td></td>
<td></td>
<td>X</td>
</tr>
</tbody>
</table>

“[Discussing work efficiency in urban areas] Depends how well the work progresses with the surrounding traffic, and whether it is possible to perform the works without interruptions or not? [...] In projects where the pipes are renewed, surprises and alterations occur on a regular basis during implementation, which means that the works will be interrupted. In case of interruptions, that could last several days, the workers are forced to switch work tasks. [...] EVM only serves in unbuilt areas, where there are not any obstacles or old unmapped substructures. Things always get complicated with existing municipal infrastructure.” (PM1)

“Basically, all of them. However, risks are generally managed well and quite little do they accumulate. You can insure yourself by putting a price on the risk.” (PM4)

Management reserves or ‘buffers’, act as a protection for unexpected events that are not considered in the cost estimates, i.e., unidentified uncertainties. The project managers responded how they relate to different reserves, and to what extent they can be used throughout the stages of the project.

“[Regarding the use of management reserves] In basic infrastructure projects, it is not possible to use ‘buffers’, since the competition does not allow for such additional margins. The tender bid must be precise, otherwise the company is not awarded any projects. On the other hand, subconsciously there might always be a small ‘buffer’.” (PM1)

“I only use implementation ‘buffers’, that are established from optimized work tasks, because the cheapest tender bid gets the job. If any potential cost-reduction solutions are identified during the planning phase, I do not necessarily include them all in the tender bid. Consequently, the construction costs are reduced as a result of improved implementation procedures.” (PM3)
The PoC of the whole project is generated through the level of progress from all the work tasks. Based on the response from project managers, various techniques are used to estimate the percentage of completion. However, the PoC of the project is generally underestimated in order to withstand the impact from potential unexpected events.

“[Discussing about unfinished work tasks] Forecast ‘buffers’ are frequently required. Work tasks should absolutely be fully completed before switching to other tasks, otherwise things are left undone, and the forecasts fail.” (PM2)

“I generally underestimate the forecasts to create a margin, in case all the invoices have not arrived. Invoices can sometimes be sent a half year after the respective work has been done and will come as a surprise, if it is not bookmarked.” (PM3)

“The PoC must be precisely evaluated, otherwise the forecasts fail! However, I undervalue the result that is reported forward, to create a small ‘buffer’.” (PM4)

Potential improvements to reporting the forecasts

There is a unanimous opinion among the project managers, that there should be available an easier system where the forecasts are managed. Everybody creates the forecasts through their own methods and there is no general system at the case company that manages project reports. A significant need exists for a prefilled reporting form that automatically includes real-time cost information from the project. Such improvements would significantly narrow down the scope of forecasting. On the other hand, some managers state they are happy with current procedures and do not think there are ways that would lead to substantial improvements.

“The reporting procedure is quite easy. I do not think that there are simpler methods than the ones currently in use. However, I am confident that there are better and more accurate methods, but how much more value do they add?” (PM3)

“Yes, you always wish for improvements, such as a more automated accounting system that requires less manual work. Currently, the cost information is manually collected and inserted to the forecast in Excel. In my opinion, such things should definitely be updated automatically. The ability to calculate the point of time a specific work task is completed, according to given coefficients, is a desired feature that the reporting system should manage to perform. Required manual work would only comprise the updating of the situation of alterations, unreceived invoices, subjective elements, the coefficients, and the PoC.” (PM4)

5.3.2 Response from Site Managers

Since the interviews with corporate management and project managers were conducted through a discussion face to face, they generated more information than the inquiry form delivered to the site managers. It is understandable that the inquiry raised some confusion, due to the absence of the interviewer, and the shortage of additional information to potentially achieve more extensive answers. In some unfortunate cases, the received inquiry form had several answers missing from the respondents. Although the response from the site
managers was expected to be more overlying, the entity from all received answers was still comprehensive enough conclude the site managers’ point of view.

For example, all site managers agreed that forecasting is important and that forecasts are created on a regular basis, although the received answers indicate on a significant variation in the regularity. To question (Q6), 16 % of the respondents create forecasts once a month, 50 % every other month, and 33 % create forecasts quarterly. According to the required reporting frequency of once a month at the case company, this is a high deviation, more accurately 83 %. The irregularity in forecasting frequency could imply, that the project manager in charge is the one responsible and does not necessarily require the site manager to report the forecasts on a monthly basis. Furthermore, the amount of support in terms of forecasting, that comes from the site manager, differs substantially according to the number of hours spent on forecasting each month.

Table 5-5: Site managers’ answers to Q21.

<table>
<thead>
<tr>
<th>Q21: How much time do you spend on forecasting each month?</th>
<th>SM2</th>
<th>SM3</th>
<th>SM4</th>
<th>SM5</th>
<th>SM6</th>
<th>SM7</th>
</tr>
</thead>
<tbody>
<tr>
<td>1h, a couple of hours</td>
<td></td>
<td>10h</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...on demand forecasting</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...depends on the situation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>...daily scheduling</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Site managers have different opinions, regarding whether the organizational structure of the case company supports forecasting on project level. On the other hand, what has been compromised between the project manager and the site manager, varies from case to case, since some site managers indicate that they only forecast for themselves, and do not report the results forward. While 60 % of respondents, in Q4, agree that the structure of the case company supports forecasting, 40 % indicate they have not experienced any support.

“At least for me, the forecasts are only created for personal use. I do not report them forwards.” (SM2)

“I guess, you have to have a personal interest in the financial and running status of the project. It is not necessarily dependent on the structure of GRK, neither do I find their support remarkable in this matter. Nevertheless, I have got the required assistance when I have asked for it.” (SM7)

Since the site managers usually do not participate in the tender proceedings, the answers were not considered adequate to generate an extensive perspective. However, most of the contacted site managers create forecasts for both cost and schedule which are based on quantities from the tender bid. Alike the project managers, the reports are intentionally underestimated in order to withstand any impact from future surprises that normally causing changes to the forecasts. Yet, site managers unanimously agree that schedule control is an essential managerial responsibility. Obtained information indicates that the productivity of individual work tasks should be constantly monitored and reflected on the estimates, in order to determine the remaining duration. These procedures will contribute to sustain the progress of the project.
There is a disagreement between the site managers, whether their personal forecasting methods are appropriate or not. Some managers state they are satisfied with their methods, while others admit the accuracy varies from case to case and moreover report that too optimistic forecasts, regarding the schedule, are frequently made. After all, the forecasts are still considered to be on an adequate accuracy level. The desire of improved forecasting methods among the site managers is further divided and does not provide any development proposals. One correspondent suggests that managers personally must develop a suitable forecasting method.

“Personally, I would not necessary gain anything from them [improved forecasting methods], but it could be valuable on corporate level.” (SM5)

Received project specific invoices are filed and accessible for the project management in the accounting system of the case company. According to the site managers, it is generally not difficult to verify realized costs, since all invoice data is accessible. The forecasting of future costs does not either seem to be a challenge for most site managers, as far as the scope does not change significantly. The tender budget provides the forecasts with valuable information.

“There is a considerable amount of information available, but it does not account for unexpected events that frequently occur on site. Work tasks are often interdependent and must be taken into consideration in the forecast procedure.” (SM4)

Table 5-6 presents the most critical challenges recognized in forecasting. These results emphasize the importance of schedule control along with the estimating of risk magnitude and probability occurrence.

**Table 5-6: Site managers’ answers to Q17.**

<table>
<thead>
<tr>
<th>Options</th>
<th>SM1</th>
<th>SM2</th>
<th>SM3</th>
<th>SM4</th>
<th>SM5</th>
<th>SM6</th>
<th>SM7</th>
</tr>
</thead>
<tbody>
<tr>
<td>a. Identification of risks</td>
<td>X</td>
<td>-</td>
<td></td>
<td>X</td>
<td>-</td>
<td></td>
<td></td>
</tr>
<tr>
<td>b. Magnitude of risks and probability occurrence</td>
<td>X</td>
<td>-</td>
<td></td>
<td>X</td>
<td>-</td>
<td></td>
<td>X</td>
</tr>
<tr>
<td>c. Evaluation of schedule variations</td>
<td>X</td>
<td>-</td>
<td></td>
<td></td>
<td>X</td>
<td>-</td>
<td>X</td>
</tr>
</tbody>
</table>

Finally, question 23 (Q23), asked which factors influence forecasting accuracy the most. Unfortunately, the response does not allow for any comprehensive conclusions to be drawn, since three out of seven respondents (43 %) left the question unanswered. The answers were simply insufficient and considered vague, as one respondent additionally stated the influential factors as ‘case-specific’. Acquired information highlights the experience and understanding of finance as fundamental components of forecasting accuracy.

“[Regarding the factors influencing forecast accuracy] The ability to conceptualize the totality of the project is vital. The implementing order of dependent work tasks must be determined, together with the required amount of resources.” (SM4)
5.3.3 Pilot Project Reporting System in Progress at The Case Company

Administrative managers at the case company have observed that especially the financial reporting system has been lagging in development as a result of the strong growth of the company. The current system is considered to no longer be appropriate for this amount of business volume. Issues are related to non-optimally collected cost data, lack of transparency, and a poor vision of real-time information. It is concluded that the outdated reporting system should be upgraded, as it currently does not meet the present demand.

“[Discussing the summary of information from forecasts] The issue is with accounting records, where the procedures of accessing relevant information is inappropriate. Concerning the overall financial situation of the company, in terms of accuracy and motion [of the forecasts], we have a lot to improve on.” (CM1)

“The transparency is almost nonexistent for accounting managers, who require improved and more sustainable follow-up possibilities. […] Currently, there is no information about the forecasting activity among project managers.” (CM2)

As an attempt to solve the issue, the case company has launched a pilot construction project with the purpose of developing practical reporting procedures within the organization. It is intended to create more sustainable and systematical proceedings, with tools that promote continual cost control and forecasting on project level.

The upgraded web-based reporting system will promote the maintenance of forecasting information and will not be limited to its users. Currently, the contextual information possessed by individual managers is not accessible for others. Practical changes within the project organization, such as managers switching from one project site to another, will be partially reduced. Characteristics of the system are required to enable the information to flow in both directions, and to be effortlessly accessible for the administrative management. Such improvements increase transparency and stability of the forecasts, since the data is stored on a server online, and not on a computer.

“The new tool [upgraded reporting system] enables more structural procedures, which facilitates forecasting. […] A compatible operations model provides improved monitoring opportunities for the corporate management, because the forecasts are not located on personal computers anymore. […] Fluctuations in the forecasts will be possible to identify, since previous data is logged.” (CM2)

While the development procedures are still under progress, the vision of the resulting product is clear. Table 5-3 presents the most significant characteristics and improvements of the future reporting system. The presented features of the system are collected from the interview with the Chief Financial Officer and the Financial Manager at the case company.
Table 5-7: Features of the new reporting system at GRK.

- An internal structured and optimized template customized for project forecasting at GRK
- Pre-collected and updated cost data from procurements and subcontractors
- Present tender bid and WBS to support expenditures on classification level
- Risk assessment (R&O) from tender period is present and connected to classifications
  - Object description, sum, and occurrence probability
  - Opportunity to adjust current R&O’s and add new objects
- Space to add specific information of scope changes, i.e. Additions & Alterations (A&A)
  - Type and extent of A&A, including supporting documents
  - Status of ordered A&A's delivered to and from the client
  - Status of Granted/Denied A&A's from the client
- Individual classification for Penalty charges & Bonuses can be manually established

The system:
+ primarily only requires future cost information from project managers
+ shows real-time information of forecasts
+ facilitates forecasting procedures by pre-adding cost information from accounting
+ allows for a more transparent view between Earned Value & Actual Costs compared to the Planned Value
+ enhances to rectify and optimize the forecasts, as required
+ keeps forecasting history and displays present changes made to the forecast
+ assists with scope changes and Risk & Opportunity-estimates
+ increases internal supervision and transparency for corporate management to interact

5.4 Composition and Use of Project Forecasting

Despite the high interest in forecasting by the project managers, there is a large variation in time that is spent on creating the forecasts. Apparently, different techniques and methods require a different amount of time in order to achieve desirable results.

Table 5-8: Project managers' answers to Q21.

<table>
<thead>
<tr>
<th>Q21: How much time do you spend on forecasting each month?</th>
<th>PM1</th>
<th>PM2</th>
<th>PM3</th>
<th>PM4</th>
</tr>
</thead>
<tbody>
<tr>
<td>~4-6 h, despite several ongoing projects</td>
<td>~2-6 h. It is a continuous task</td>
<td>...a couple of hours</td>
<td>Large projects 20-30 h/pcs</td>
<td>Small projects 2 h/pcs</td>
</tr>
</tbody>
</table>

None of the project managers checked the answer box of Reference Class Forecasting, when being asked how the costs are forecasted during tender in question 7 (Q7). Although most of the managers use previous cost and schedule data in the planning of new projects, the amount of available historical information at the case company is not on a comprehensive level. This indicates that project managers must intuitively estimate the work efficiency and rely their estimations mainly on domain knowledge.

"The logging of historical data is only made to some extent, but no favorable improvements have been made. Post-calculation in the infrastructure construction..."
business could be completely pointless, if there are radical changes between the projects in terms of work tasks, prices, and environment. The use of historical data requires rationality and domain knowledge in order to effectively adapt it to the current project. However, if such data is available, it should be utilized.” (PM2)

“Smaller projects are carried out based on intuition, where historical data is irrelevant. Personally, I collect historical data from my own projects, but otherwise post-calculation is not done at GRK. Reference Class Forecasting could be advantageous in the calculation of project entities, but you cannot blindly rely on the prices. Previous projects are carried out during a different time when the market situation could have been completely different. If you request for a proposal for special equipment during high season, the price level can be doubled.” (PM4)

5.5 Reliability and Accuracy of Project Forecasting

Information from the monthly delivered forecast reports has generally been in line with realized results and is, according to corporate management, considered to be on a satisfactory level. Obtained results from conducted interviews imply that managers unanimously agree that continuous forecasting procedures throughout the implementation phase is essential for ensuring the financial health of the project. However, the corporate management demands an improved transparency that facilitates the interpretation of the forecasts.

“The current reporting system does not display the information that the forecasts are based on. Our work gets complicated when the current system does not automatically compare actual cost data with prime estimates. (CM2)

Inaccurate forecasts are common in projects that are financially unsuccessful. In almost every case where the project starts to run late and at a financial loss, the forecasts inevitably become unreliable. Especially during tight market conditions, several reasons may lead to false unit prices and forecasts. In cases of incorrect forecasts, the project management should aim to identify the cause of cost and schedule overruns, at the earliest, to immediately take corrective actions. These inconveniences are generally a result of inefficient work tasks, weak logistics, or the occurrence of unexpected events.

“[Discussing forecast inaccuracy] When market conditions are tight, accounting managers intentionally start haggling prices in advance, believing a reduced tender bid increases the chances of getting the project. The risk assessment has also been made too optimistically, which could eventually backfire. [...] In some unfortunate loss-cases, managers have withheld ‘bad-news’ from the corporate management, and not reported it until later. Such acts instantly cause the forecasts to fail.” (CM2)

The aftermath from damages caused by inappropriately created unit prices and forecasts, indicates that unit prices should always be accurately calculated. On the contrary, the Risks & Opportunities of the risk assessment allows to be adjusted to suite the final tender bid. The accuracy of the tender calculations is critical, due to small margins and the tough competition between competing contractors. Apparently, the losses in loss-projects are usually substantial, right from day one, which put an emphasis on the tender accuracy.
“Since planned profit margins only lie around a few percent [4-5 %], significant surprises are not allowed to occur. Even a minor error in the calculations could eliminate the whole estimated profit.” (CM2)

The CEO at the case company receives the monthly forecasts upon request, and the only prerequisite regarding the forecasts, is accuracy. A continuous monitoring of on-site operations is a fundamental point of forecasting. All interviewed project managers indicated their forecasts as consistent and accurate, even though final quantities can occasionally be difficult to estimate. While the forecasts tend to become more consistent towards the end of the project, the aim is to verify the propriety of tender calculations and the risk assessment as early as possible.

“In the beginning of implementation, after the largest procurements are locked, the accuracy of cost estimates gets verified. Sometimes you can create internal ‘buffers’ for upcoming tasks, with savings from optimized work tasks. If these savings are not used by the end of the project, they remain as profit.” (PM1)

“My forecasts can intermittently become too accurate, which is favorable, because I get the propriety verified. [...] Calculation errors are sometimes inevitable and occur every now and then. In case of such errors, the ones with a negative financial effect are immediately pursued to be corrected with temporary contracts and different working methods during the implementation phase.” (PM4)

Chapter 3.2 presented common factors that cause cost and schedule overruns, while chapter 4.1.2 explained the issues with forecasting inaccuracy. The response from project managers, to question 23 (Q23), includes a wide range of factors influencing forecast accuracy. It appears that the most common challenges in forecasting is the estimating of work efficiency, duration, and the PoC, due to multiple concurrent ongoing tasks on site. The surrounding environment is additionally considered to limit appropriate work methods.

“On-site logistics and the commitment of site management are the most significant factors. [...] A 3D-database of existing structures would facilitate the procedures, because insufficient data and unmapped structures are currently causing too many problems. [...] In sub-contract projects, additional problems arise when contractors are using different vertical coordinate reference systems.” (PM2)

“Estimating the work efficiency is challenging, since the difference in productivity on undisturbed project sites are significantly higher than in urban areas. [...] On highway construction projects, the on-site logistics management must be thoroughly planned in order to maintain a proper progress in the project.” (PM3)

“Forecasts are contingent on the decomposition of work tasks, together with the number of work packages that establish the overall cost. A higher number of work packages and relevant parameters in the forecast (real-time cost and schedule information), result in higher accuracy. The forecasts are finally reliable when the schedule of work tasks is determined, and the currency of costs is honestly performed.” (PM4)
6 DEVELOPMENT PROPOSAL

This chapter encompasses results obtained from the theory and the case study, including interviews and the survey. The results are analyzed and reflected with each other to create a universal conception of the current forecasting process at the case company. The purpose of this chapter is to identify and present common factors that cause forecast inaccuracy in infrastructure construction projects, together with actual imperfections and limitations of used procedures at the case company. The determination of influencing factors and shortcomings contributes to suggest reasonable development proposals that potentially could result in more appropriate forecasting processes, and further improve on-site proceedings.

During the growth of the case company, the prime focus has been to ensure that the demand from existing projects are met, in terms of current workload in relation to available workforce. Therefore, the development procedures have during the last years mostly concerned the employment of additional project staff, such as managers and foremen, to ensure that the work capacity meets present demand. Since the focus has been on administering the managerial capacity in the projects, development of the internal infrastructure, such as IT, is left behind and currently lacks adequacy. Nevertheless, the case company has recently started to expand the administrative competence by initiating special field positions for directors and managers in areas of finance, law, information, together with future and innovation. Such administrative competence supports company welfare and facilitates the operations to be more appropriately performed.

6.1 Functionality of Current Forecast Models

There is a significant variation in currently used forecasting models, as well as the time project managers at the case company spend on forecasting each month. Despite differences in the creation and supervision of the forecasts, it is deliberated that as far as the forecasts display reliable and adequate figures, it does not matter how they are generated. Most of the interviewed project managers have extensive experience from management positions in the infrastructure construction business and are confident in their work performance. Since there are not any forecast templates available at the case company, several responses suggested that managers must personally develop a desirable forecasting model. Among the interviewees, it is concluded that knowledge is gained by carrying out repetitive procedures and learning from experience which further enables to optimize performance.

While the forecasting of costs seems to be under moderate control, there are doubts about the forecasting of schedule that appears to be challenging for most project managers. In case of prolonged work tasks, the costs per se are not necessarily increased, as far as the work performance is tied to quantities, e.g., paving and stonework. If the work performance is hourly rated and not tied to any quantities, such as excavation and man-hours, interruptions and extended work duration will instantly increase the costs and additionally cause delays. Emphasis is placed on identifying interdependent works on site, since a prolonged operation can heavily influence the general schedule and cause further interruptions to upcoming tasks. It is suggested, that on-site procedures are continuously monitored and optimized as required to ensure a sustainable progress of the project.
On the interview agenda for the corporate management, question 2 (Q2) asks how well the projects are implemented by the case company. The purpose of the question was not to determine a statistically accurate percentage-distribution of how well the projects are implemented, since the boundaries of given options were intentionally defined vaguely. The objective was about acquiring a general conception of accomplishments in the company, and therefore a hypothetical appraisal of the current situation was acceptable. Considering the results are based only on two (2) interviews with corporate managers, a combination of the answers does not provide more than an approximate result. It is still concluded, that over 80% of implemented projects by the case company are evaluated to be at least average or better, in terms of both finance and schedule. Regarding the quality and safety, close to 95% of implemented projects were considered average or better. These numbers are significantly better than the ones presented by Flyvbjerg et al. (2004), where the study implied that 9 out of 10 transport infrastructure projects suffers from cost escalations.

It was brought up that loss margins in financially unsuccessful projects at the case company are generally substantial which influence the profit and loss statement. Although the actual reasons behind the losses in project have not been identified in this study, post-calculation data from comparable projects could presumably contribute to reduce the cost overruns.

**Evaluation of project managers’ forecasting models**

As previously mentioned, the forecasts are considered appropriate as far as they generate figures of adequate accuracy and reliability. The project managers at the case company possess overlying domain knowledge about infrastructure construction and must continuously deal with the challenges of the business. It is not suggested that extremely radical changes would solve any current issues regarding forecasting, since the procedures themselves do not improve the quality of on-site construction works. However, universal forecasting processes that systematically assist and guide the project management towards the ‘most appropriate’ forecasting model, based on specific project characteristics, have the potential to be a valuable tool. After all, with a professional project management the company ensures a higher possibility of successfully realizing projects in terms of quality, safety, finance, and schedule. A persistent cooperation between managers further supports the flow of information and contributes to sustainable and effective practices on site.

**Directives of forecasting preparations**

The procedures of construction economics begin during the tender period, where the general budget of the project is established. Depending on the complexity of the project, it can be challenging for competing contractors to be able to disclose relevant information, such as details in the surrounding environment, during the given time of the tender period. Especially in Design-Build projects, where the design is not completely provided prior to bidding, overlooked details or an insufficient risk assessment can have a crucial impact on future cost and schedule. It is therefore suggested that enough time and work capacity is reserved for the tender calculations to comprehensively include all relevant details of the project.

As far as the preparatory work regarding cost and schedule is appropriately conducted, managers of the project are able put more focus on actual site supervision and logistics. Thoroughly performed estimations of cost and schedule, together with the risk assessment during early project stages, contribute to enhance the confidence among managers and the probability of success during implementation.
6.2 Development of Forecast Models

While the general understanding of actual and future costs in projects at the case company is believed to be on an appropriate level, the main issues are with the schedule and assessment of risks. An experienced project manager can gain valuable information, if historical data from previous projects has been collected. During the tender period and the planning phase of a new project, the initial schedule is created, and the risks are assessed. However, since post calculation is not available at the case company, personally collected information is approximately the only data source that can facilitate such procedures.

Every construction project has different characteristics compared to another project. If there are not any significant contrasts in terms of scope, then usually the soil conditions, substructures, and surrounding environment varies. Constructing in urban areas with heavy traffic and narrow construction sites, such as highways and city centre renovation works, instantaneously reduces the work productivity compared to project in undisturbed areas. In cases where these external factors are substantial, the use of historical data from comparable projects would increase the consciousness among managers and serve as an asset. Nevertheless, the characteristics of the data must be carefully reflected with the features of the project at hand, to effectively be advantageous. A systematical risk assessment procedure during the tender period of the project could improve the extent of uncertainty disclosure and the accuracy in evaluating occurrence probability of identified risk factors.

In terms of forecasting the schedule, the most essential aspect is the understanding of productivity and work duration that is required to complete certain construction works. If the duration estimating process is made too optimistically, or otherwise simply inaccurately, the whole project will be delayed. The project management should always aim to acknowledge delay events as early as possible in order to reduce the consequences. In situations where delays are not recognized, the risk of cost overruns is excessive.

Most of the project managers control the costs and schedule during the implementation phase of the project. While the costs are based on received invoices, the schedule is determined by visually evaluating the percentage of completion (PoC) of ongoing project work tasks. How accurate the PoC is evaluated, is strongly depending on the managers’ experience. In case of scope changes and alteration works, it can be quite challenging to accurately determine the overall PoC of the project, and therefore the monitoring must be continuous. Regarding this issue, it is suggested that the progress, in terms of schedule, should be more numerically analyzed. This can be accomplished by integrating mathematical functions that, aside from the visual evaluation of the PoC on site, additionally consider the progress relative to the remaining time and the realized costs relative to the target budget. The metrics of the Earned Schedule methodology could be useful to more comprehensively undertake forecasting of the schedule, since it recognizes in which time period the costs have appeared.

Nonetheless, it is important to remember that an accurate forecasting procedure does not change the reality by any means. It only provides a statistical view over how the financials and the time are used in relation to original estimates in the project. An appropriate forecasting procedure can additionally display approximate future scenarios, based on the efficiency of current on-site operations. Such information is essential and allows the project management to take corrective actions to direct the project in accordance with the plans.
Improvement of tender period proceedings

Considering the frame of the project budget is determined during the tender period, the bid should always be as accurate and reliable as possible. In projects of complex nature, the process of preparing the bid often requires involving an increased workforce in order to effectively and systematically carry out the required tender tasks within the given time.

The tender bid calculations at the case company are currently prepared in an Excel worksheet, regardless of project delivery method. A complete list of required project works, including quantities, is further compiled to establish the work breakdown structure (WBS). As mentioned earlier, the complexity in extracting the work tasks and quantities is highly dependable on the delivery method. While the client provides a complete bill of quantities (BOQ) prior to tender in Design-Bid-Build projects, the contractor must separately collect corresponding information in Design-Build projects. Table 4-2 presented the measurement estimates to establish unit rates, which all must be considered in these calculations.

The Excel worksheet is not very user-friendly which additionally can complicate the process. There is a high probability that the functions of the worksheet become invalid if modifications are not made correctly. A common challenge in tenders of complex projects is to maintain structural and efficient managerial procedures and may require input from experts with domain knowledge. In cases where several people are simultaneously working on requesting proposals for different required equipment and material for the project, the responsibilities must be defined to avoid overlapping. Especially since the tender calculations are not prepared in a web-based software, the most recent revised worksheet must remain accessible on the company server and be available to the project colleagues. Any difficulties regarding this matter, will only result in lack of knowledge among the participants and eventually slow down the process.

Automated forecast modelling

Based on the results from conducted interviews in the case study, any advice regarding automation of the forecasting process was not brought up. The infrastructure construction business is still highly dependent on manual work and many operations are not even automatable. Regarding the project management, a remarkable part of managerial responsibilities heavily relies on human judgments, such as monitoring and evaluating performance. The acquisition of such information cannot be automatized, and therefore it remains manual. If technology can bring any additional value, it is during the actual modelling process where certain features of the system could provide computerized assistance. Forecasting models can become very smart and account for several parameters simultaneously, as far as their features are properly created.

A procedure for determining the forecasting process

Since the case company does not have any general forecasting guidelines, the establishment of a universal and systematical process would potentially benefit internal operations. By creating a procedure that assists in determining the forecasting process for specific projects, displayed in figure 6-1, the forecasts would presumably become more harmonized, consistent, and easier to monitor by corporate managers. The features of the procedure could suggest the most appropriate forecasting approach based on the characteristics of the specific project. On the other hand, this option requires that project managers can manage several
forecasting methods, and that every available forecasting method is thoroughly developed to fulfill its function.

![Diagram](image)

*Figure 6-1: Procedure to determine adequate forecasting processes based on project characteristics.*

By following the pattern suggested in figure 6-1, the procedure guides the project manager towards a suitable forecasting process for the current project. Alternative options for Project type can be; road construction, municipal engineering, bridge construction, or harbor construction. After selecting the Project size, the procedure proposes appropriate Forecasting models and finally advises a complete Forecasting process to be carried out in the project. Other project criteria, in addition to project type and project size, may be further required. The final process could recommend the aspects that should be considered, such as forecasting scope, the level of forecast detail, and the reporting frequency. This suggestion would require a lot of development effort from the case company but could simultaneously be advantageous to a great extent in the long run.

### 6.3 Applicability of Company Reporting System

Several elements of the outdated reporting system of the case company must become more efficient in order to meet the demand such as the accessibility of realized cost information. It is not productive to spend excessive time on project information acquisition, and therefore more automated features would contribute to facilitate the work. There is a strong possibility that a successful improvement of the reporting system will result in persistent forecasts that additionally enhance the proceedings of reporting financial modelling within the company. However, the challenge will be to consider and identify all the insufficiencies of present measures, in order to develop a system as adequate as possible that meets the demand.

The developed reporting system is currently at a Beta-version stage and contains most of the desired features that were concluded from the interviews. A remarkable part of the manual work has been replaced with automatic features, such as the insertion of realized costs from received invoices. Central mathematical functions of the system comprise the financial balance of each work package which gives an accurate financial view of project progress.

At the start of the project, the system establishes a complete list of required project-specific work packages or classifications. Project managers can now manually insert the target budget to every work package, before beginning with the actual forecasting procedure. Another feature of the system is the possibility to update on-site additions & alteration works (A&A). If the site management identifies any scope changes or additional work of financial significance, the A&A’s can be added to the project file. Revised cost information must
thereafter be manually distributed to respective work packages to count for the cost increment, since the system does not automatically account for the change. The system enables the forecasts to be revised, and additionally logs every modification separately which allows the users to correct any typing errors.

Development proposals for the upgraded reporting system

While the financial PoC of every work package is displayed in the system, it does not consider the progress with reference to the schedule. Project manager PM4, stated in the interview that by linking the schedule with the cost forecasts, the initiated coefficients facilitate to account for the progress in relation to the estimates. If the system could enable the estimated duration of work packages to be added, the schedule management would be facilitated and the general view of the progress much more clarified. It is assumed that project managers have not yet had the opportunity to test run the beta version of the reporting system. Either the system still requires further development before a trial run becomes relevant, or the managers have simply not been requested to provide insights. It is not suggested that the system is developed completely without consultancy with the primary users (project managers), to ensure a successful and appropriate product. However, only after the release of the system, the practical appropriateness can be verified. Further improvements are still considered possible in the future, if the demand within the company or among the users change.

Transition from Excel sheet forecasting to the web-based system

Despite the effort of developing a tool that improves the general reporting procedure at the case company and simultaneously reduces the manual work, the difference in practical proceedings, is at this point difficult to determine. The future will tell how much the project managers are willing to discharge themselves from their personally developed forecasts in Excel. There is a possibility that the change from the upgraded reporting system becomes too overwhelming to immediately be put into use, and therefore a transition period or step by step procedures may be required. It is requested that project managers are given the possibility of becoming familiar with the Beta-version, before the launched. This reform must take into consideration that most of the project managers are used to carry out tasks in a certain way, which might complicate the adaption to the new system. Once the reporting system is released, potential re-development may be required to facilitate a complete transfer of forecasting procedures to the web-based system. If any shortcomings of the system significantly complicate forecasting, it is likely that project managers will not use it at all.

6.4 Update Cycle and Demand of Forecast

A matter that significantly attracted attention from the interviews and the survey, was the varying frequency in update cycles of the forecasts among project and site managers. Although the forecasts are being requested by the company CEO on a monthly basis, the majority of site managers apparently do not adhere to the stated principles, see chapters 5.3.2 and 5.4. It appears that all project managers are not even aware of current reporting frequencies at the case company, due to insufficient information flow. It is strongly advised that the information flow between corporate and project managers remains consistent to maintain sustainable relations. Any modification having to do with administrative proceedings, must be clearly defined and informed to managers affected by the change.
The forecasting frequency at the case company should be reflected to the project at hand, in order to determine the suitable interval. Basic infrastructure construction projects of smaller scale (100,000-500,000 €) are usually carried out within a quarter of a year and the amount of ‘money in motion’ is relatively small, compared to large projects (> 10,000,000 €). Therefore, it is suggested that forecasts in projects of less financial significance, do not necessarily require to be updated as repeatedly as in projects of larger scale.

For a large corporation, the maintenance of a stable financial balance is important for company welfare and additionally keeps the board and the stakeholders informed about operational performance. As mentioned before, the main prerequisite in terms of forecast reports is accuracy, which is pursued to be preserved.

### 6.5 Summary of Development Proposals

Since the case company has grown into a major actor on the Finnish construction market and continuously gaining market share in the northern countries, the internal procedures must be appropriate to enable and ensure success. It is believed that by initiating structural and universal processes within the company, the overall performance will eventually improve in all the operational and administrational areas associated. Moreover, system support is a potential prerequisite for enhancing forecasting. In order to comprehensively reiterate the relevant content in this chapter, the most significant development proposals are presented in a brief summary.

- For a large construction company, such as GRK, defined forecasting processes including measures for project steering, are initial requirements in order to maintain sustainable performance. Harmonized and adequate proceedings are in general favorable, although some managers do not perceive benefits from improved forecasting.

- It is suggested that more emphasis should be placed on disclosing information about cost overruns in loss projects, to create insight in the root causes and further develop solutions to prevent similar events from occurring in future projects.

- Post-calculation from realized projects should be considered, at least to some extent. By identifying and evaluating the reasons behind past mistakes as well as past success, obtained information can be adapted into future projects.

- Since the tough competition does not allow for large profit margins, the tender bid procedures should be carefully carried out through appropriate measures that ensure the important factors are comprehensively reviewed. Moreover, this includes the improvement of registration and assessment of cost risks, both during the tender period and during implementation.

- By improving the forecasting procedures, the case company has a great opportunity to truly benefit from internal optimizations.

64
7 CONCLUSION

The content of this thesis was limited to three major research questions, which are assessed in this chapter. By examining the literature that comprised cost and schedule overruns in the construction business, with focus on infrastructure projects, the most common factors causing such misfortunes were comprehensively detected. The reviewed forecasting methodologies increased the awareness of important aspects in the controlling of project cost and schedule and contributed to recognize the critical elements of forecasting. Together with identified factors causing variations to project economics, the procedures of project management during the life cycle stages of a project can be improved. Obtained information from reviewed literature, implies that the cause of project overruns is usually a combination of poorly performed events that collaboratively lead to failure. Although the case company has maintained a continuous business growth, the internal infrastructure has been lagging in development which recently has become a serious problem. This chapter presents reflections of the development proposals from the 6th chapter and further encompass the limitations and future research of this thesis.

Assessment of research questions

To summarize the research scope in this thesis and increase the overall understanding of current issues in the infrastructure construction business, the research questions are assessed below. While RQ1 and RQ2 incorporate analysis of general business procedures, the third research question, RQ3, concerns internal operations of the case company, GRK Infra Oy.

RQ1: What causes infrastructure construction projects to fail financially, and why?

In order to highlight the most significant causes of financial failure in the infrastructure construction business, it is suggested that the subject is systematically approached to acquire the most comprehensive results. The 2nd chapter of this thesis, briefly presented the extent of the infrastructure construction business, along with external factors that may influence operational proceedings. Changes in governmental regulations, changing demand in society, and developing technology, are examples of such factors. These changes place a lot of pressure on the contractors who are forced to adapt their operations to correlate with the demand and current regulations. An adequate mindset, such as business analytics, can increase the potential to effectively manage and overcome existing barriers. The components of descriptive, predictive, and prescriptive analytics can support the identification of any imperfections and contribute to make corrective actions.

The managerial procedures during the different stages of the project, should be as systematical as possible in order to enhance financial success. The 3rd chapter presents the most common factors causing escalations to the cost and schedule estimates and highlights the emphasis that should be placed on the uncertainty analysis during early stages of the project. These factors enlighten the importance of appropriately carried out tasks prior to implementation. This indicates that a poorly calculated bid, together with an insufficient risk assessment during the tender period, can jeopardize the whole financial future of the project. On the other hand, regardless whether the cost estimates and risk assessment are adequate, a poor site management can equally cause cost and schedule overruns.
RQ2: Which forecasting models, monitoring project cost and schedule, are most practically implementable into infrastructure construction projects?

Determining which methodology and technique is the most suitable for project forecasting is largely dependent on the project at hand and the theory states that no single estimating method is appropriate for all projects. The 4th chapter introduces Judgmental forecasting, Reference Class Forecasting (RCF), Earned Value Management (EVM), and Quantity Rate Analysis as the reviewed forecasting methods and techniques.

Most of the managers utilize universal cost estimating methods during the tender period of a project, and especially the Bottom-Up estimating technique. This technique allows the work tasks to be decomposed and further individually priced in order to establish the final unit price. The Bottom-Up technique is considered quite effective as it incorporates all the required details of each work task required to achieve an accurate cost estimate.

Initial hypothesis implied that RCF would primarily contribute to accurately highlight important aspects of a new project, by providing valuable insights from past comparable references. While this method certainly could improve the planning and tendering procedures of new projects, it requires complete information from reference projects. The results from conducted interviews with managers at the case company, indicated that it would be practically challenging to use reference class information correctly. The critical differences between projects must be identified in order to gain any knowledge from the comparison. RCF is currently not considered an appropriate forecasting method, as far as post-calculation data of historical information is not extensively collected.

Cost controlling methods utilized by project managers during the implementation phase contain characteristics that are similar to EVM, although none of the managers recognized the term Earned Value Management. On the contrary, individual cost control methods were not examined to verify the variance in proceedings between managers, nor to determine the degree the methods correlated with the metrics of EVM. Regarding the schedule, only one project manager stated that the schedule is controlled mathematically, which indicates that the metrics of Earned Schedule could improve the accuracy of schedule forecasting.

If, however, data from realized projects were to be collected, it is believed that managers could benefit from an integration of RCF and EVM, as proposed by Batselier & Vanhoucke (2016). Since these forecasts rely on completely different information, they would generate a versatile forecasting entity that could improve the overall accuracy.

The last part of the 4th chapter incorporated the combination of qualitative methods (mainly domain knowledge) with quantitative methods. Now, since there currently are not used any quantitative methods that numerically generate outcomes at the case company, the objective was mostly to disclose the recurrence of subjective and biased decisions. The results suggest that, if historical information is not accessible, the most practical and appropriate way to solve any issues regarding the project, is to use domain knowledge.

RQ3: How can current project forecasting procedures at the case company be optimized?

This question has already been answered in the 6th chapter.
Refer to development proposals

Since Flyvbjerg et al. (2004) stated that 9 out of 10 transport infrastructure projects suffers from cost escalations, the reality indicates that some managerial procedures could not have been carried out appropriately. This thesis therefore aimed to identify and characterize the most common factors that cause deviations to project cost and schedule estimates, as one of its main purposes. The interviews however concluded that the share of unsuccessful projects by the case company is remarkably lower than what Flyvbjerg et al. stated, although it is believed that the referred projects were of larger scale and more complex nature.

In addition to determining critical factors influencing the project performance, different forecasting methodologies were examined to discover which methodologies would provide the most accurate results. By thoroughly considering fundamental practices during the tender period of a project, a vast amount of potential failures occurring during implementation can be avoided. An appropriate assessment of risks, a decomposed structure of work tasks (WBS) together with structural procedures, increase the chances of succeeding financially.

Regarding the reviewed forecasting methodologies, there was no specific technique that convincingly distinguished from the others, in terms of adequacy and accuracy. On the other hand, since there obviously is no ‘ultimate way’ to forecast, the most appropriate method for the individual project must presumably be evaluated or customized to maximize the benefit. Yet, forecast models must remain simple and enable effortless maintenance in order to function properly. It is believed that by combining at least two of the introduced forecasting methods, the outcome could surpass any result generated from a single forecasting method, in terms of consistency. While forecast accuracy alone does not solve any issues with project economy, the financial success is ensured by placing emphasis on achieving tender bid and risk assessment accuracy, along with adequate project steering measures.

The content in this thesis provides valuable insights on how to improve managerial proceedings during the tender period, the planning phase, and the implementation phase. Results from conducted interviews additionally highlight the comprehended appropriateness of current forecasting procedures within the case company. There is a strong desire for a more appropriate forecast reporting system among managers, which has required the case company to restructure its proceedings. The potential benefit from a successfully developed reporting system, is substantial. Fundamental characteristics of the upgraded reporting tool will require less manual work from its users and contribute to narrow down the field of forecasting. However, it is important that the transitional phase to the web-based system provides managers with the possibility to progressively transfer their forecasting practices to the new platform, without interruptions.

In general terms of project forecasting, the organizational structure has a significant impact on company operations. The structure is suggested to continuously support the project management, by providing the management with systematic tools that facilitate operational procedures in order to achieve desired results. Structural and stable project management enhances the managerial performance and contributes to sustainable practices on the project site. In cases where the reality starts deviating from the plan, the management must evaluate the situation from an objective perspective. By carefully identifying the reasons behind the occurrence of inconvenient events, and immediately proceeding to corrective actions, the consequences of financial significance will effectively be reduced.
The *summary to development proposals* in the previous chapter, encompasses the most important and favorable aspects which are practically implementable into existing operations at the case company. The presented development proposals are hopefully considered by the corporate management, since they comprise the central matters the company is dealing with. Currently, there are too large variations in performed forecasting procedures by the project management, and it is only a matter of time until the limit of present procedures is reached. As additionally stated in the summary, it may require plenty of effort to practically implement these proposals. However, assuming the business will continue to grow, the case company is in an excellent position to benefit from improved internal procedures that more extensively correlate with present and future demand.

**Limitations and approaches for future research**

In order to determine the examined subject of this thesis, and propose any future research of similar nature, the stated limitations must be taken into consideration. The limitations of this thesis are mostly relying on the boundaries of the reviewed literature, the objectives behind the selection of analyzed forecasting models, and the approach to the case company.

Reviewed literature concluded a vast array of on-site tasks and operations related to the infrastructure construction business. However, the thesis did not disclose the causes behind cost and schedule overruns in realized projects by the case company. Additional case studies were decided to not be included, for the potential risk of removing the focus away from the subject of forecasting, and presumably extent the research scope. Case studies concerning realized projects at the case company could have contributed to more practical determination of why projects tend to fail financially but would have simultaneously resulted in an increased effort to acquire enough detailed information.

The conditions and terms behind the selection of the reviewed forecasting methods were strongly depended on the complexity of the specific models, the interpretability, and the reflection of cost and schedule on project level. Other variants of forecasting, such as Times Series or Regression models, were excluded mainly due to a limited amount relevant literature and the lack of correlation with defined prerequisites. Consequently, the adequacy of such forecast models in the context of this thesis was not further verified. The practical review of the Reference Class Forecasting methodology was intentionally left out, due to insufficient collected historical data from past projects. Regarding the Quantity Rate Analysis and Earned Value Management techniques, the functional flow was more easily recognizable, by virtue of the experience among the interviewed managers.

Practical examination of the reviewed forecasting methods, with the purpose to determine their appropriateness on performed projects within the case company, was not considered relevant. The reviewing of past projects would presumably have become an excessively challenging task, mainly due to the substantial lack of transparency and the complexity to subsequently disclose project details.
REFERENCES


71


### Appendix 1: Infra classifications list (BuildingSMART, 2018).

<table>
<thead>
<tr>
<th>Code</th>
<th>Designation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1000</td>
<td>Soil structures, substructures and rock structures</td>
</tr>
<tr>
<td>1100</td>
<td>Existing structures and construction parts</td>
</tr>
<tr>
<td>1200</td>
<td>Contaminated soil and structures</td>
</tr>
<tr>
<td>1300</td>
<td>Foundation structures</td>
</tr>
<tr>
<td>1400</td>
<td>Sub-soil structures</td>
</tr>
<tr>
<td>1500</td>
<td>Rock sealing and reinforcement structures</td>
</tr>
<tr>
<td>1600</td>
<td>Soil cuts and excavations</td>
</tr>
<tr>
<td>1700</td>
<td>Rock cuts, excavations and tunnels</td>
</tr>
<tr>
<td>1800</td>
<td>Embankments, earth dams and fills</td>
</tr>
<tr>
<td>2000</td>
<td><strong>Pavement and surface constructions</strong></td>
</tr>
<tr>
<td>2100</td>
<td>Pavement components and railway substructure</td>
</tr>
<tr>
<td>2200</td>
<td>Kerbs, gutters, steps and protections against erosion</td>
</tr>
<tr>
<td>2300</td>
<td>Planting constructions</td>
</tr>
<tr>
<td>2400</td>
<td>Railway superstructure</td>
</tr>
<tr>
<td>3000</td>
<td><strong>Systems</strong></td>
</tr>
<tr>
<td>3100</td>
<td>Water supply and sewerage systems</td>
</tr>
<tr>
<td>3200</td>
<td>Safety and signalling systems</td>
</tr>
<tr>
<td>3300</td>
<td>Electrical, telecommunications and mechanical systems</td>
</tr>
<tr>
<td>3400</td>
<td>Heat and gas transmission systems</td>
</tr>
<tr>
<td>3500</td>
<td>Ventilation systems</td>
</tr>
<tr>
<td>3600</td>
<td>Automation systems</td>
</tr>
<tr>
<td>4000</td>
<td><strong>Constructional structural elements</strong></td>
</tr>
<tr>
<td>4100</td>
<td>Non-itemized constructional structural elements</td>
</tr>
<tr>
<td>4200</td>
<td>Bridges</td>
</tr>
<tr>
<td>4300</td>
<td>Piers</td>
</tr>
<tr>
<td>4400</td>
<td>Foundations and retaining structures</td>
</tr>
<tr>
<td>4500</td>
<td>Environmental structures</td>
</tr>
<tr>
<td>4600</td>
<td>Constructions and furnishings</td>
</tr>
<tr>
<td>4700</td>
<td>Water transport structures and dams</td>
</tr>
<tr>
<td>4800</td>
<td>Concrete structures in underground facilities</td>
</tr>
<tr>
<td>4900</td>
<td>Other building elements</td>
</tr>
<tr>
<td>5000</td>
<td><strong>Project-related tasks</strong></td>
</tr>
<tr>
<td>5100</td>
<td>Construction management tasks</td>
</tr>
<tr>
<td>5200</td>
<td>Corporate functions of the contractor</td>
</tr>
<tr>
<td>5300</td>
<td>Construction site tasks and special site-related costs</td>
</tr>
<tr>
<td>5400</td>
<td>Site services</td>
</tr>
<tr>
<td>5500</td>
<td>Site equipment operations</td>
</tr>
<tr>
<td>5600</td>
<td>Design tasks</td>
</tr>
<tr>
<td>5700</td>
<td>Construction management and ownership tasks</td>
</tr>
<tr>
<td>5800</td>
<td>Real estate maintenance services of the owner</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Functional organization</th>
<th>Projectized organization</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Advantages</strong></td>
<td><strong>Advantages</strong></td>
</tr>
<tr>
<td>• Suitable for smaller teams and projects</td>
<td>• Strong identity sets for strong team culture</td>
</tr>
<tr>
<td>• People work in the same area and are easily accessible.</td>
<td>• Team is dedicated to the project and focused on common goals</td>
</tr>
<tr>
<td>• Procedures can be kept simple because of the team size</td>
<td>• Sets the base for improving project management skills</td>
</tr>
<tr>
<td>• Increased teamwork and more enthusiastic team members</td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td></td>
<td>• An expensive option. Suitable mostly for big projects</td>
</tr>
<tr>
<td></td>
<td>• People find it hard to maintain workflow after being interrupted.</td>
</tr>
<tr>
<td></td>
<td>Transition of team members after sealing a project is crucial.</td>
</tr>
<tr>
<td></td>
<td>• Risk of being let go after closing a project, if upcoming project does not have an available work spot.</td>
</tr>
<tr>
<td></td>
<td>• Dedicated team to only on project can limit the number of simultaneous operations in a company.</td>
</tr>
<tr>
<td><strong>Disadvantages</strong></td>
<td><strong>Disadvantages</strong></td>
</tr>
<tr>
<td></td>
<td>• Conflicts may arise between projects fighting over the same resources.</td>
</tr>
<tr>
<td></td>
<td>• Projects may reserve the people with the most appropriate skills, not making them available to other projects.</td>
</tr>
<tr>
<td></td>
<td>• Project managers prioritizing different tasks could confuse project work for individuals.</td>
</tr>
<tr>
<td></td>
<td>• The choice of advancement options can be difficult. Although, it is a good thing having options.</td>
</tr>
</tbody>
</table>
### Figure 1. Probability matrix.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Descriptor</th>
<th>Description</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>Almost certain</td>
<td>Even chance</td>
<td>&gt; 50 %</td>
</tr>
<tr>
<td>High</td>
<td>Likely</td>
<td>One in every 4 projects</td>
<td>&gt; 25 %</td>
</tr>
<tr>
<td>Moderate</td>
<td>Possible</td>
<td>One in every 10 projects</td>
<td>&gt; 10 %</td>
</tr>
<tr>
<td>Low</td>
<td>Unlikely</td>
<td>One in every 20 projects</td>
<td>&gt; 5 %</td>
</tr>
<tr>
<td>Very low</td>
<td>Rare</td>
<td>Less than 1 in every 20 projects</td>
<td>&lt; 5 %</td>
</tr>
</tbody>
</table>

### Figure 2. Impact matrix.

<table>
<thead>
<tr>
<th>Rank</th>
<th>Schedule</th>
<th>Cost</th>
<th>Safety</th>
<th>Quality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Very High</td>
<td>&gt; 3 months</td>
<td>&gt; $10 million</td>
<td>Fatality</td>
<td>&gt; 10 %</td>
</tr>
<tr>
<td>High</td>
<td>2-3 months</td>
<td>$5-10 million</td>
<td>Severe injury</td>
<td>5-10 %</td>
</tr>
<tr>
<td>Moderate</td>
<td>1-2 months</td>
<td>$2-5 million</td>
<td>Medical treatment</td>
<td>3-5 %</td>
</tr>
<tr>
<td>Low</td>
<td>2-4 weeks</td>
<td>$1-2 million</td>
<td>First Aid</td>
<td>1-3 %</td>
</tr>
<tr>
<td>Very low</td>
<td>&lt; 2 weeks</td>
<td>&lt; $1 million</td>
<td>No injury</td>
<td>&lt; 1 %</td>
</tr>
</tbody>
</table>

### Figure 3. Strategies for negative risks.

- **Avoid**: eliminate cause of risk
- **Mitigate**: reduce probability or impact of risk
- **Accept**: contingency plans of risk
- **Transfer**: have third party take on responsibility of risk (insurance)
### Appendix 4: Earned Value Management Key Metrics and Formulas

(Batselier & Vanhoucke 2016).

**Batselier & Vanhoucke, 2017 (35) 28-43 – Table of EVM Key Metrics and Formulas.**

<table>
<thead>
<tr>
<th>Metric</th>
<th>Definition/formula</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>PD</strong></td>
<td>Planned duration, the planned total duration of the project</td>
</tr>
<tr>
<td><strong>BAC</strong></td>
<td>Budget at completion, the budgeted total cost of the project</td>
</tr>
<tr>
<td><strong>AT</strong></td>
<td>Actual time</td>
</tr>
<tr>
<td><strong>PV</strong></td>
<td>Planned value, the value that was planned to be earned at <strong>AT</strong></td>
</tr>
<tr>
<td><strong>EV</strong></td>
<td>Earned value, the realized value earned at <strong>AT</strong></td>
</tr>
<tr>
<td><strong>AC</strong></td>
<td>Actual cost, the realized costs incurred at <strong>AT</strong></td>
</tr>
<tr>
<td><strong>ES</strong></td>
<td>Earned schedule, the time which the EV should have been earned according to the plan, ( ES = t + \frac{EV - PV}{PV_{t+1} - PV_t} ), with ( t ) the (integer) point in time (i.e. tracking period) for which ( EV &lt; PV_t ) and ( EV &gt; PV_{t+1} )</td>
</tr>
<tr>
<td><strong>EAC(t)</strong></td>
<td>Estimated duration at completion, the prediction of RD made at <strong>AT</strong></td>
</tr>
<tr>
<td><strong>EAC($)</strong></td>
<td>Estimated cost at completion, the prediction of RC made at <strong>AT</strong></td>
</tr>
<tr>
<td><strong>RD</strong></td>
<td>Real duration, the actual total duration of the project</td>
</tr>
<tr>
<td><strong>RC</strong></td>
<td>Real cost, the actual total cost of the project</td>
</tr>
<tr>
<td><strong>SV</strong></td>
<td>Schedule variance, ( SV = EV - PV )</td>
</tr>
<tr>
<td><strong>SPI</strong></td>
<td>Schedule performance index, ( SPI = EV / PV )</td>
</tr>
<tr>
<td><strong>SV(t)</strong></td>
<td>Schedule variance (time), ( SV(t) = ES - AT )</td>
</tr>
<tr>
<td><strong>SPI(t)</strong></td>
<td>Schedule performance index (time), ( SPI(t) = ES / AT )</td>
</tr>
<tr>
<td><strong>CV</strong></td>
<td>Cost variance, ( CV = EV - AC )</td>
</tr>
<tr>
<td><strong>CPI</strong></td>
<td>Cost performance index, ( CPI = EV / AC )</td>
</tr>
<tr>
<td><strong>SCI</strong></td>
<td>Schedule cost index, ( SCI = SPI * CPI )</td>
</tr>
<tr>
<td><strong>SCI(t)</strong></td>
<td>Schedule cost index (time), ( SCI(t) = SPI(t) * CPI )</td>
</tr>
<tr>
<td><strong>TCPI (BAC)</strong></td>
<td>To-Complete Performance Index (BAC), ( TCPI (BAC) = (BAC - EV) / (BAC - AC) )</td>
</tr>
<tr>
<td><strong>TCPI (EAC)</strong></td>
<td>To-Complete Performance Index (EAC), ( TCPI (EAC) = (BAC - EV) / (EAC - AC) ) (Fleming &amp; Koppelman, 2005)</td>
</tr>
<tr>
<td><strong>EAC</strong></td>
<td>Estimate at completion, total cost at completion of project, typically ( EAC = AC + Bottom-up ETC )</td>
</tr>
<tr>
<td><strong>ETC</strong></td>
<td>Estimate to complete</td>
</tr>
<tr>
<td><strong>EAC (1)</strong></td>
<td>EAC forecast for ETC performed at budget rate, ( EAC = AC + (BAC - EV) )</td>
</tr>
<tr>
<td><strong>EAC (2)</strong></td>
<td>EAC forecast for ETC performed at present CPI, ( EAC = BAC / CPI )</td>
</tr>
<tr>
<td><strong>EAC (3)</strong></td>
<td>EAC forecast for ETC considering SPI &amp; CPI, ( EAC = AC + [(BAC - EV) / (CPI * SPI)] )</td>
</tr>
<tr>
<td><strong>VAC</strong></td>
<td>Variance at completion, ( VAC = BAC - EAC ) (PMBoK, 2017)</td>
</tr>
</tbody>
</table>

---

\(^a\) In these definitions, **value** always alludes to the cumulative value over all activities up to certain point in time.

\(^b\) In some papers, the estimated cost at completion is simply abbreviated by EAC, without the addition of the dollar sign. However, in other papers just as in this one, it is preferred to add the dollar sign anyhow in order to make a clearer distinction between the cost context and the time context (the latter is always indicated by a suffix \( t \)).
Appendix 5: Interview agenda for project managers & site managers.

Q1. Are you creating project financial forecasts?
   a. Yes ☐
   b. No ☐

Q2. Is it in your opinion important to forecast?
   a. Yes ☐
   b. No ☐

Q3. What kind of forecasts are you carrying out inside the forecasting period?
   a. Cost forecasts ☐
   b. Schedule forecasts ☐
   c. Risk updates ☐

Q4. Does the organizational structure of GRK support forecasting on project level?
   a. Yes, please justify ☐
   b. No, please justify ☐

Q5. Is the forecasting frequency at GRK (once a month) appropriate?
   a. Yes ☐
   b. No ☐

Q6. How often are you carrying out financial forecasts?
   a. Once a month ☐
   b. Every other month ☐
   c. Quarterly ☐

Q7. How do you forecast costs during the tender period?
   a. Based on judgments (Domain Knowledge) ☐
   b. Based on previous references (RCF) ☐
   c. Based on unit price/quantity-calculations ☐
   d. Other or self-developed ☐

Q8. How do you forecast costs during the tender period?
   a. Based on judgments (Domain Knowledge) ☐
   b. Based on cost- and schedule control ☐
   c. Other or self-developed method, please explain ☐

Q9. How do you forecast schedule during the tender period/planning phase?

Q10. How do you forecast schedule during the implementation phase?

Q11. Does your forecasting method work? Are you satisfied?
   a. Yes, please justify ☐
   b. No, please justify ☐

Q12. Do the forecasts guide on-site operations?
   a. Yes ☐
   b. No ☐
   c. To some extent ☐
Q13. Is it difficult to verify realized costs/quantities? (is enough information available?)
   a. Yes, please justify ☐
   b. No, please justify ☐

Q14. Is it difficult to forecast future costs/quantities? (is enough information available?)
   a. Yes, please justify ☐
   b. No, please justify ☐

Q15. Are your forecasts consistent? Are they accurate enough?
   a. Yes, please justify ☐
   b. No, please justify ☐

Q16. Do you wish there were better/easier/more accurate forecasting methods?
   a. Yes, please justify ☐
   b. No, please justify ☐

Q17. What is the biggest challenge in forecasting?
   a. Identification of risks ☐
   b. Magnitude of risks and probability of occurrence ☐
   c. Evaluation of schedule variations ☐

Q18. Are you using buffers (contingencies) How many %?
   a. Yes ☐
      Are the buffers: Open ☐ or Hidden ☐?
      Magnitude of buffers (in percentage): ___ % (per cent)
   b. No ☐

Q19. Is the percentage of completion (PoC) of a work task generally,
   a. Overestimated, please justify ☐
   b. Underestimated, please justify ☐

Q20. How much does the site management participate in the forecasting process?
   a. Very much ☐
   b. Sufficiently ☐
   c. Fairly enough ☐
   d. Nowhere near enough ☐

Q21. How much time do you spend on forecasting each month?

Q22. How much do you use previous cost- and schedule information in new the planning of new projects?
   a. In every project / always ☐
   b. Almost in every project / quite much ☐
   c. Not that much / rarely ☐
   d. Not at all / never ☐

Q23. Which factors influence forecast accuracy the most?
Appendix 6: Interview agenda for corporate management.

Q1. What are the most important development plans at GRK, in terms of project forecasting?

Q2. How well are the projects implemented by GRK?

<table>
<thead>
<tr>
<th></th>
<th>FINANCE</th>
<th>SCHEDULE</th>
<th>QUALITY</th>
<th>SAFETY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Poor</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
<td>100%</td>
</tr>
</tbody>
</table>

Q3. Is the required information available in the forecast reports enough to assess the financial situation of the company?

Q4. How well do the forecasts correlate with actual figures?

Q5. What additional information is needed from the reports to improve the forecasting process?

Q6. Do you believe that the forecasts will become more accurate, when the reporting system is developed based on answers from the previous question (question 5)?

Q7. Are the responsibilities of the project organization clear enough, e.g., in terms of cost control and forecasting? Have the responsibilities been defined?

Q8. Is the forecasting frequency at GRK (once a month) appropriate?
   a. Yes [ ]
   b. No [ ]

Q9. Does the organizational structure of GRK support forecasting on project level?
   a. Yes, please justify [ ]
   b. No, please justify [ ]