The Causes for Cost Overruns in Infrastructure Projects

A Case Study on Bombardier Transportation[1]

Yuan Tan

Stockholm School of Economics

Department of Finance

Master's Thesis

May 2021

Abstract

This thesis analyzes the underlying reasons for cost overruns in Trackside signalling projects at Bombardier Transportation focusing specifically on man-hours. Despite the increasing public, political and academic interest in the issue of cost overruns in infrastructure projects during the past decades, limitations related to data access have made it difficult to shed light on the prevalence and causes of cost overruns. Thus, this paper uses quantitative and qualitative data to provide real-life insights into the causes leading up to cost overrun through a case study. This thesis finds that cost overrun is positively corelated with the project duration and occurs mostly during the early phase of a project. Additionally, I analyzed eight projects and interviewed twenty-five stakeholders to identify the main reasons for cost overrun, these being "unstable, incomplete, or incorrect input from clients," "scope changes" and "lack of experience".

Key words: Cost overrun, cost estimation, project management, case study

---

[1] Former Bombardier Transportation, now part of Alstom

[2] I want to thank my tutor Peter Aleksziev for his guidance and support during the course of writing this thesis. I would also like to extend a very special thank you to the people who made this case study possible by participating in the interviews and providing crucial information, especially Jamshid Okhravi, Anna Lundkvist and Aidan Fyfe.

Table of contents

1 Introduction

Finishing an infrastructure project on time and without any cost overruns is considered the most important aspect of successful projects (Kaming et al., 1997; Stumpf, 2000; Chan et al., 2004). However, for reasons such as changes in design, ineffective planning, technical complexity and unforeseen problems as well as resource constraints, it's common to see projects overrun their planned schedules and budgets. Flyvbjerg et al. (2003) examined the accuracy of cost estimates in 258 rail and road projects from twenty countries that were constructed between 1927 and 1998 and discovered that 86% of the projects overspent their budget, with the average cost overrun of 28%. Morris (1990) investigated 290 public infrastructure projects in India and found that 186 of them had cost overruns. The problem of unexpectedly high expenses is often accompanied by reduction of profit margin, project failure and loss of reputation.

Many studies have investigated the reasons for cost overruns in the past and a number of causes have been identified in the literature. Flyvbjerg et al. (2003) grouped the typically mentioned explanatory factors into three classifications – technical, psychological and political, while other studies present very long lists of factors collected through real case studies and questionnaire surveys (Long et al., 2008; Aljohani et al., 2017; Abderisak et al., 2016; Hamed et al, 2016; Jackson, 2002). However, most of the studies only focused on projects in the public sector due to limited access to data on private-sector projects. "In general," write Dantata et al. (2006), "collecting project data is a major undertaking; relevant reports are difficult to obtain and the information about the date of estimates is not readily available." As a result, there is little academic coverage of real projects at private firms especially in the Nordic region. Accordingly, this research is carried out to investigate the reasons for the deviation between the estimated figures and the actual results in infrastructure projects by examining empirical evidences and learning from proprietary data through a case study on Bombardier Transportation. This paper answers the following research question:

What caused the deviation between the estimated costs and the actual costs in infrastructure projects?

According to Lind and Brunes (2015), the basic definition of "cost overrun" is that the final cost is higher than was budgeted in an earlier stage. Himansu (2011) believes that cost overruns refer to the extent to which the final cost of a project exceeds the "base estimate". In this paper, cost overrun is defined as the variance between the actual cost and the estimate produced during the bidding phase. According to Erik and Clifford (2018), project costs encompass 1) labour costs, 2) capital, equipment and material cost, 3) expenses, primarily management and administrative costs, and 4) contingencies. In this paper, the focus is only on man-hours, which is a primary determinant of labour costs. Man-hour is a unit used to measure the amount of time required to finish a task by labour resources. The rationale behind the focus on man-hours is that normally man-hours are the most expensive part of a project. Investigating only man-hours simplifies the problem and meanwhile ensures the key issue is discussed carefully. Another reason is that it relates to both project schedules and project costs, meaning that an increase in man-hours not only shows the project will cost more, but also indicates that the project will likely be delayed.

This study relies on a case study on Bombardier Transportation and generates both quantitative and qualitative data. The quantitative part summarized the characteristics of selected projects, measured historical project performance, and explored the correlations between important project parameters. The results show that 65.6% of ongoing projects and 48.15% of completed projects considered in this analysis have hour increases. Furthermore, the results of the t-test suggest that the length of a project and its variance are positively correlated and most variances happen during the early stage of a project. In the qualitative part, I investigated the causes for cost overruns with a focus on man-hours by conducting interviews and collecting information from project reports. The result indicates that the main causes for the increase in man-hours are "unstable, incomplete, or incorrect input from clients", "scope changes" and "lack of experience." It also yields two new causes "hours moved from other projects" and "members with different management cultures", which have never been discussed in previous studies and are specific to Bombardier Transportation. The findings were compared against similar studies in Sweden and other countries.

The purpose of this study three-fold. First, this thesis shall contribute to the existing literature concerning reasons for cost overruns in infrastructure projects. Second, it shall reveal how estimates are produced and controlled throughout the project lifecycle in real life. The last purpose of this thesis is to create a foundation for improving the management of man-hours in the process from bidding to feedback loop at Bombardier Transportation.

In terms of academic contribution, this paper aims to expand the literature on causes for cost overruns in infrastructure projects in Sweden from an empirical perspective with new causes identified through interviews. As an additional study focusing on a specific country, it can be used for future international comparisons. Moreover, this paper uses proprietary data that are not publicly available and investigates relationships between the variance at the beginning of a project and the actual variance at the completion of the project, which to my knowledge has never been examined. Finally, although the topic related to accuracy of estimation has been extensively studied by academics, very few of these studies focus on the estimation and control process itself. According to Argyris (1952), the way managers use information has a huge impact on the outcome of a project. Thus, it is important to understand how knowledge is shared and used throughout the process. This paper describes the estimation and control process in different phases and provides insights of how estimates are produced and managed in practice.

2 Literature review

In this section, literature concerning the budgeting process and causes for project delay and cost overrun is covered. While the budgeting process does not specifically relate to the cost estimation process in infrastructure projects, there are many similarities between them. I believe that rich findings of the budgeting process can help to better understand the role of planning and identify its weaknesses. Thus, the literature as regard to the budgeting process is discussed.

2.1 Review of the Budgeting Process

The range of literature concerning the budgeting process is broad, from risk in the budgeting process (Paul and Anthony, 2002) to incentive issues (Christopher, 1988; Michael, 2003). Budgets are one of the most important management control tools to “institutionalize” a firm’s aims, monitor the progress of both the business and products, and measure the performance of managers (Christopher, 1988). According to Michael (2003), budgets had critical impacts on capacity planning and internal resource harmonization. Coordinated actions assisted by budgets would lead to high output, low cost, high quality, low inventories and satisfied customers.

Though budgeting is widely adopted by firms worldwide, researchers have identified many drawbacks in the process. First, the whole process is very time-consuming. Michael (2003) described a traditional budgeting process adopted at most multinational companies. To start with, the top management produces an overall target based on historical performance and analysts' forecast, and then the head of each business unit prepares a preliminary forecast. The difference between the sum of business units' forecast and the overall target will be eliminated through multiple negotiations and iterations until final agreement is achieved. Subsequently, a similar process to set targets within each business unit begins. Another problem that has been extensively discussed is budgeting gamesmanship. According to Christopher (1988), budget numbers are supposed to be as honest and accurate as possible given the available information. However, after conducting in-depth interviews with product managers in eight large multinational firms, he found that budgeting gamesmanship was a widespread practice in six of the eight firms. Product managers use colorful terms such as "cushion", "contingency" and "secret reserve" to have flexibilities over their product's profit margin. According to Michael (2003), such behavior has become expected and is perceived as reasonable in most corporate cultures because managers' bonus and promotion are closely related to the achievement of their targets. Based on a substantial review of academic literature and interviews with executives in over 40 firms, Neely et al. (2001) concluded 12 criticisms over planning and budgeting, which can be found in Table 1.

So what does a good budgeting process look like? Neely et al. (2001) found that companies with efficient and effective planning and budgeting systems, such as Electrolux and Cisco, had replaced their independent solutions and local uses of spreadsheets with an integrated global database, which gives these companies a single view of the latest data. Ford, who used to have 19 different local systems to produce revenue forecasts using 5 different methods, now has 1 method and system in Europe requiring 1 hour to estimate revenues for each market. Another feature of a good budgeting process is the separation of bonus and achievement of the budget.

Table 1. Significant Weaknesses Exist in The Traditional Approaches to Planning and Budgeting

1	Budgets are time consuming and costly to produce
2	Budgets limit responsiveness and flexibility and are often a barrier to change
3	Budgets are barely strategically focused
4	The value budgets contribute is not worth the effort required to prepare them
5	Budgets focus on cost reduction rather than value creation
6	Budgets strengthen vertical command and control
7	Budgets do not reflect the emerging network structures that organizations are adopting
8	Budgets encourage gamesmanship and substandard behaviors
9	Budgets are developed and not updated frequently
10	Budgets highly rely on unsupported assumptions and good guess
11	Instead of encouraging knowledge sharing, budgets strengthen departmental barriers
12	Budgets make people feel undervalued

Source: Neely, A., M. R. Sutcliff, and H. R. Heyns (2001)

When bonus is separated from budgets, negotiation between management and managers becomes easier and clearer, making the budgeting process more efficient. At BP and Handelsbanken, most people's bonuses are based upon outperforming competitors. Also, the authors discovered a trend towards a focus on key figures in a budget rather than detailed reviews. Such a shift can reduce the level of effort required when producing budgets and increase effectiveness by focusing attention on the real issues. Finally, they observed that leading companies adopted a forward-looking forecasting approach. Instead of comparing the actual results against the initial estimate, those companies forecast and explain variances in advance of the variance actually occurring and take actions to improve performance or close the gap. Some good practices are found in the manufacturing area. In Wight's (1988) paper, he stated that an accurate forecast requires clear accountability, a thorough knowledge of all areas affecting the forecast, well-documented assumptions, and involvement of multiple stakeholders as well as feedback loops.

2.2 Review of the Causes for Project Delay and Cost Overruns

The literature concerning the causes for project delay and cost overruns is very rich. A great number of causes have been identified, which provides a good basis for solving the research question. Aljohani et al. (2017) conducted a comprehensive study of literature concerning cost overrun in construction projects in 17 countries. After reviewing 17 papers, the authors identified 173 potential causes, among which poor cost estimation, frequent design change, contractors' financing, payment delay for completed work, and lack of contractor experience were the most frequently mentioned ones. Abderisak et al. (2016) used a similar research approach to investigate possible explanations for cost overrun and project delay. Based on an analysis of a literature selection consisting of 40 journal articles, they found that management-related problems ranked the highest compared to other causes. As most of the literature collected data by questionnaire survey and interviews, possible explanations for different results included different profiles of respondents, different questionnaire design and dissimilar statistical methods (Hamed et al, 2016).

The reasons vary by geography and culture and are constantly evolving over time. In Sweden, two previous studies have investigated the causes for project cost overrun through either real case analysis or questionnaire survey. Both studies focused on infrastructure projects, primarily road and railway projects. In Lundman's research (2011), the author conducted a case study of underground road and railway projects in Sweden and found that most of the cost overruns in the nine projects he examined occurred during the early planning phases. He noted that the technical, environmental, and structural requirements and scope were often not well defined during the early phases of a project. As a result, a project has to start based on uncertain inputs. Lind and Brunes (2015) arrived at a similar conclusion based on the results of a questionnaire sent to project managers working at the Swedish Transport Anministration (Trafikverket) and project managers from the three largest contractor companies in Sweden (Skanska, PEAB and NCC). They found that most cost overruns are related to design changes, which often happens between the initiation stage of a project and the phase when more detailed specifications or functional demands are made. Lind and Brunes (2015) also discovered that unexpected technical problems are another most important explanation for cost overruns, resulting in the need for additional material or work hours.

As shown in Table 2, causes are ultimately classified as being either external or internal to the project (Aljohani et al., 2017). The first category refers to uncontrollable and unpredictable factors that can affect the performance of the project, such as weather conditions and strikes. When a problem arises because of external reasons, no one within the organization should be assigned blame. However, it may indicate there is insufficient risk assessment in place.

According to Jyh-Bin et al. (2013), the main causes of schedule delays in construction projects were change orders, changed scope of the work, and weather, which were all external to a project. The authors analyzed 79 litigation cases with respect to causes of construction delays in Taiwan and built a comprehensive causation model that categorized the causes of these delays. In Baldwin et al.'s study (1971), a survey of architects, engineers, and contractors was conducted in order to identify the causes for cost overrun and delay in building projects in the United States. The authors found that the most important reasons were weather conditions and delays by sub-contractors. An example is the Great Belt link project, which connects East Denmark with continental Europe, overrun its budget by 50 % due to environmental concerns and accidents with flooding (Flyvbjerg et al., 2003). Overall, weather conditions, increasing material prices, changed scope, high inflationary pressure and poor performance of sub-contractors are the most common external causes for delay and overrun (Aljohani et al., 2017).

Internal causes, such as inadequate project planning and lack of communication between project's stakeholders, reflect the efficiency and effectiveness of the estimation and control process within an organization. Unlike external causes, they can be controlled and managed within the group. They are further divided into financial, organizational, technical and psychological subclassifications. Internal causes for delay and cost overrun identified by analyzing historical projects can be used to find weakness in a company's organizational structure, project management process and other aspects. Improvements can be made to increase forecast accuracy and to improve projects' planning in the future. An example of project cost overrun caused by internal factors is the British Library project (Jackson, 2002). The British Library,

Table 2. Studies on the External and Internal Causes for Delay and Cost Overrun in Construction Projects

External Causes	
Social/Political	Social and cultural impacts
	Obstacles from local government
	Increase in manpower cost due to environment restriction, insurance premiums and other social expenses of the workforce
Financial	High Inflationary pressure
	Change in exchange rates between currencies
	High interest rates charged by banks on loans
Contractor/Supplier	Increment of materials prices
	Poor performance of subcontractor
Owner	Client's over influence/interference on the construction process
	Change in the scope of the project asked by client
	Slow and delay payment of completed work
Others	Effect of weather conditions
	Litigation

Internal Causes	
Financial	Cash Flow and Financial difficulties
Organizational	Poor organizational structure
	Poor project management practices
	Delays in decisions making and work approval
	Lack of coordination/communication between project's parties
Technical	Deficient tender documentation (design, bills of quantities and specification)
	Lack of detail and definition, incomplete, or incorrect Design brief
	Inadequate project preparation and planning
	Unrealistic/Inaccurate cost and time estimates
	Lack of cost planning, monitoring and controlling during pre-and post-contract stages
	Poor cost advice, inadequate contingency allowance or assessment of risks
	Frequent design changes
	Insufficient information/investigation about ground conditions
	Mistakes during construction due to inadequate construction method
	Shortage of available skilled and non-skilled labour
	Lack of experience
	Reworks
Psychological	Over-optimism biases
	Deception

Source: Aljohani, A, Dominic A.D., and David M. (2017)

completed in 1998, had a final cost three times over the original budget because of continuous change in the project's personnel and their responsibilities. According to Flyvbjerg et al. (2003), technical issues, especially lack of realism in initial cost estimates, were the main reason why actual costs overrun the budget. Building on Flyvbjerg's view, Joaquim and Luc (2016) emphasized that the primary problem with initial cost estimates was imprecise project concept design planning and poorly organized bidding processes. Memon et al. (2011) claimed that poor design and lack of experience explained most of the overruns.

3 Case Study Methodology

This paper is a case study of Bombardier Transportation and generates both quantitative and qualitative data. According to Yin (2006), case studies should rely on an understanding of what is to be studied, or in other words a preliminary theory. In this paper the preliminary theory is based on the common observation demonstrated by the existing literature: infrastructure projects frequently overspend their budgets due to different reasons. This paper provides empirical evidence that is consistent with the theory.

The case study includes a quantitative analysis of project performance and a qualitative study based on data collected through personal interviews, focusing on Trackside signalling projects in the Swedish business unit at Bombardier Transportation. Trackside projects are those which involve the installation of signalling equipment on the railway track infrastructure. Section 4.3 further explains how a Trackside signalling system works. The rationale behind the focus on Trackside signalling project is that they are relatively routine and repetitive with similar activities across different projects. In addition, the uncertainty of Trackside projects is low and organizational coordination is relatively easily accomplished. Therefore, it is less challenging to understand the process and identify problems that may exist in other types of projects. Sweden is chosen because Bombardier Transportation owns more than 90% of Sweden's Trackside signalling system market. Such a strong market position reduces the impact of external business environment and dynamic competitive landscape. Moreover, the Swedish business unit has a culture of openness and transparency that makes investigations easier and more in-depth.

The following paragraphs further explain the rationale behind adopting this approach and the main steps of conducting this case study.

3.1 Research Design

The case study method has been commonly used by studies in different domains. Though some researchers are concerned that case studies are too situation-specific and conclusions relied on this type of approach can't be generalized, the idea that case studies provide a unique means of developing theories by providing insight into empirical phenomena and their context has been widely recognized (Dubois and Gadde ,2002). Also, this method helps to gain in-depth knowledge about real situations and to convert abstract concepts into concrete and straightforward impressions. Therefore, this paper uses the case study methodology to investigate the research question.

This case study relies on a combination of quantitative and qualitative analysis. In order to measure project performance, I performed quantitative research by collecting and analyzing data from selected projects within the Trackside Sweden Business Unit. The purpose of the qualitative analysis is to understand the causes for cost overruns and uses a process of collecting data through interviews, analyzing data and assessing the results. In this case study, eight projects are chosen for a 'deep-dive' and twenty-five stakeholders are interviewed to get insights. Each interviewee is considered a separate source for determining the causes and learnings are synthesized to draw the conclusion.

3.2 Quantitative Analysis

The quantitative analysis covered 1) descriptive statistics to summarize the characteristics of the data set, including project size and project length, 2) variance analysis to assess the difference between the baseline and actual performance, 3) comparison between the performance of ongoing projects and that of completed projects, and 4) t-tests to explore the correlation between the length of a project and the variance as a percentage of the baseline, as well as between the estimated variance at the beginning of a project and the actual variance when a project completes.

In order to understand whether the duration of a project will affect the size of its variance, t-test (1) is performed, with the null hypothesis H_1 that the length of a project has no significant effect on its variance. The dependent variable is project length and the independent variable is project variance (%). T-test (2) is conducted to test whether a variance at the beginning of a project will lead to high variance when the project is finished. The null hypothesis H_2 is that the estimated variance at the beginning of a project has no significant effect on the actual variance. The dependent variable is estimated variance (%) and the independent variable is the actual variance (%). Additionally, I performed a complementary t-test (3) to see how the rest of the variance (%) affects the actual variance (%), of which the null hypothesis H_3 is that there is no correlation between the rest of the variance and the actual variance.

All data is provided by Bombardier Transportation and processed using Microsoft Excel and R. Details over data sources and sampling are discussed in Section 6.1.

3.3 Interviews

Yin (2009) suggests that findings will be more convincing and accurate if multiple information sources are used. In this case study, twenty-five interviews were conducted between February and May 2021 with stakeholders of different perspectives and positions, including eight project managers, nine line managers and two sales managers. The position of interviewees is shown in Table 3. The eight project managers were selected because their projects had variances higher than 10% based on the results of the quantitative anlaysis, and the nine line managers were interviewed as they are critical labour resource providers to the projects. The interviews followed a semi-structured approach. A formalized list of questions designed on the basis of literature were asked together with more open-minded questions, which were often followed by free discussions *(see Appendix 1: Interview Questionnaire)*.

Table 3. Interviewee Position

Interviewee Position				
Project manager	Line manager	Financial controller	Sales manager	PMO expert
8	9	1	2	5

Source: Own analysis based on interviews with stakeholders within BT

All interviews were conducted remotely via Teams and recorded and the average length of the interview was approximately 45 minutes. Immediately after the interviews, the conversations were transcribed and key points were summarized to ensure information is kept in a precise way and the interviewees' words can be accurately quoted in this thesis. When possible, the insights obtained from interviews were combined with information in project reports. As a result, I was able to get a broad picture of the current situation and successfully implemented the case study.

4 Company Overview

In this section, an introduction of Bombardier Transportation is provided from the viewpoint of spring 2021. It is important to note that the company was acquired by Alstom on January 2021, which will be explained in more detail below.

4.1 Company Background

Bombardier Transportation, formerly a subsidiary of Bombardier Inc., was the fourth largest rail-equipment manufacturer globally. The company produced a wide range of products including locomotives, high-speed trains, trams and signalling systems. Headquartered in Berlin, Germany, Bombardier Transportation had 63 manufacturing and engineering locations around the world. With over 36,000 employees, Bombardier Transportation generated revenues of $8.3bn in 2019.

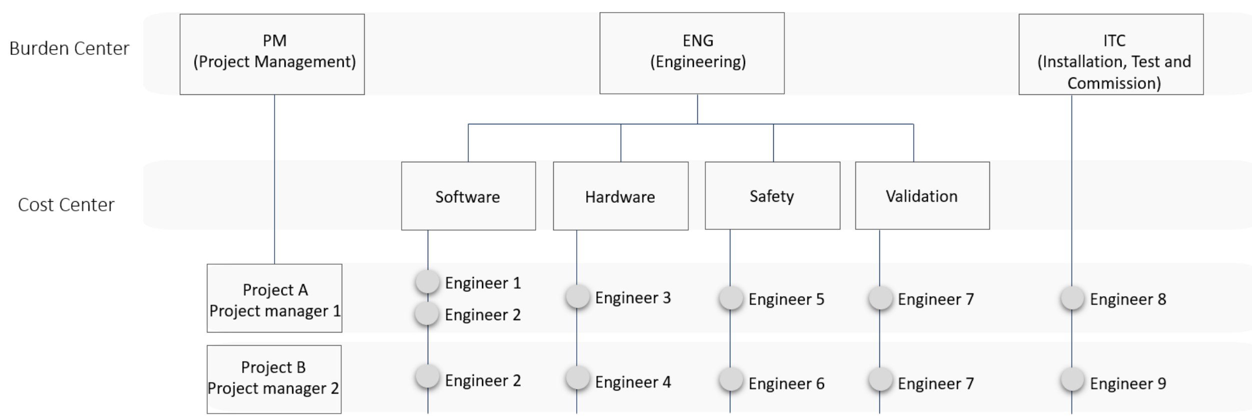
With the whole transportation industry hit hard by the coronavirus pandemic, the owner Bombardier Inc. faced severe liquidity issues and made a net loss of $568mn during year 2020. As a result, Bombardier Inc. sold Bombardier Transportation to Alstom for €5.5bn. The deal was announced on 16th September 2020 and completed on 29th January 2021. Alstom is a French rolling stock manufacturer holding the third largest market share in the global rail transportation market. After the completion of this acquisition, the enlarged Group became the second largest manufacturer in the rail sector with 75,000 employees in 70 countries.

Currently the two companies are under a transformational phase to combine operations and integrate solutions and assets. It's still uncertain how the organizational structure and business units will change. Section 4.2 described the original organizational structure of Bombardier Transportation.

4.2 Organizational Structure

Bombardier Transportation has a matrix organizational structure with two chains of command – one along functional lines and the other along project lines. The organization is grouped into three 'burden centers': Project Management (PM), Engineering (ENG), and Installation, Test and Commission (ITC), and four 'cost centers' under Engineering: Software, Hardware, Safety and Validation. Members within each function need to report to both their line and project managers. To better explain how the matrix organizational structure works, two examples are provided. As Figure 1 presents, five people from ENG and one person from ITC are assigned to project A on either a part-time or a full-time basis. Engineer 2 and 7 work on project A and B simultaneously, dividing their time and energy between these two projects. Engineer 5 not only needs to update Project Manager 1 on their work status, he/she also reports to the Safety manager. Similarly, Project Managers report to the head of Project Management, who supervises all projects.

Figure 1. Matrix Management at Bombardier Transportation



Source: Own analysis based on interviews with stakeholders within BT

According to Clifford and Erik (2000), the matrix structure optimizes the use of resources and expertise within the organization by enabling individuals to work on several projects and be capable of performing normal functional duties. However, the authors also warn that such a structure could cause tension between project managers and line managers due to different accountabilities and conflicting agendas. Additionally, they mentioned that it could be very stressful for members working in a matrix organization because they need to report to at least two bosses. Not to mention if they work on multiple projects at the same time.

4.3 Trackside Signalling System

A Trackside signalling system is a complex system that combines hardware and software to enable communications between trains and the rail control center. The function of information transmission is accomplished through two processes: first, the on-board hardware radiates energy waves to activate the ground equipment on the track, and then the ground equipment sends signals back to each train, which are ultimately received by the control center. Through these two processes, the control center is able to determine the precise location of trains running on these tracks and their real-time speed and thus provide feedback to trains with instructions on how to operate. Therefore, the Trackside signalling system is fundamental for train operation safety *(see Appendix 2 Example of Trackside Signaling System).*

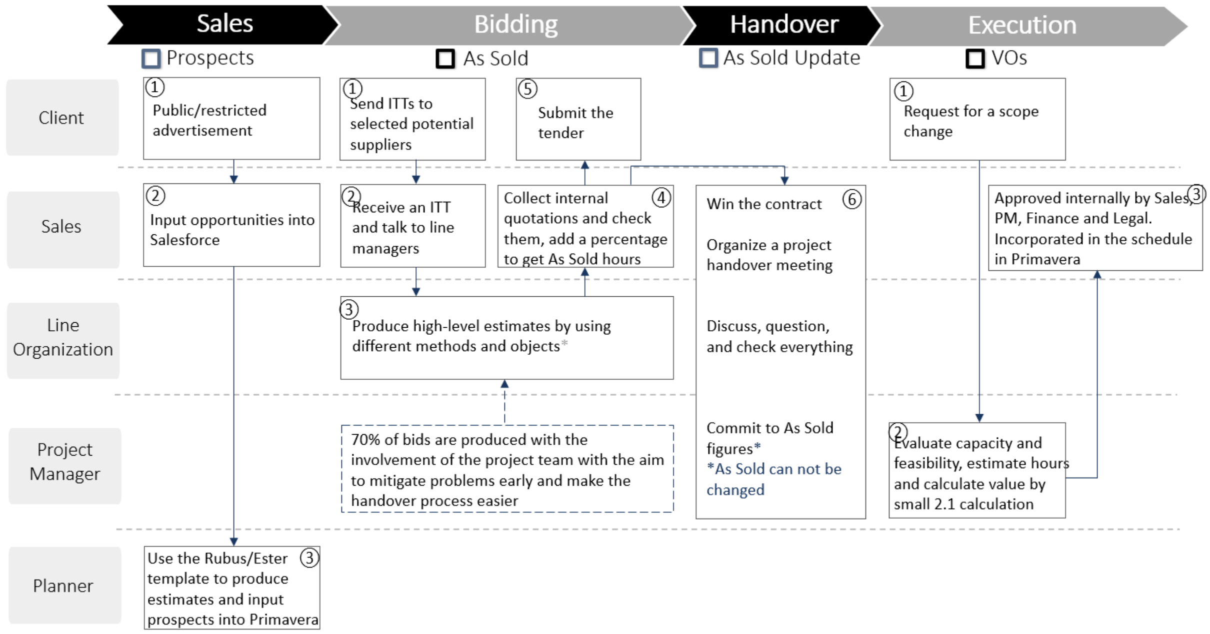
5 Estimation and Control Process Analysis

The following section will explain the project life cycle of trackside projects in Sweden, from estimation during the sales phase to feedback loop when projects are finished. As said before, the focus in only on man-hours. Section 5.1 presents the estimation process, which is subdivided into four stages, and explains the different estimates produced at each stage. Section 5.2 shows how projects are controlled and managed, mainly by Project Managers with assistance from Project Planners. Finally, Section 5.3 discusses the feedback loop.

5.1 Estimation Process

Figure 2 shows the four estimates produced at different levels from sales to execution phase, which are covered separately below. It can be briefly summarized as a Sales Representative defining a prospect and making rough estimates, knowledgeable members producing a 'bottom-up' As Sold figure and differences being reconciled when the project is handed over for execution.

Figure 2. Estimation Process



Source: Own analysis based on interviews with stakeholders within BT

5.1.1 Prospects During the Sales Phase

When the Sales team sees an opportunity, they input information such as client name, order value, expected margin and probability of winning into Salesforce. At the same time, sales produce a figure *X* based on the expected order value and their experience, which is used to calculate how many hours this project will need at a very high level. Given that Trackside signalling projects are very much alike and the activities involved are similar across different projects, a template called *Rubus/Ester* which includes standard hours and a standard activity schedule is used for all prospects. A coordinator multiplies the existing hours in the template by the figure *X* to get the total number of hours needed for this project, and then he/she models the prospect hours and schedule in Primavera, a project planning and scheduling tool used at Bombardier Transportation. However, the prospects in Primavera do not have a one-to-one relationship. Instead, they are summed up by quarters for simplicity. One-to-one relationships only exist for some big prospects. As an example, the Primavera file may be modelled as ‘Q1 2023’ and may include multiple prospects.

5.1.2 As-Sold During the Bidding Phase

Bidding starts when the Sales team receives an invitation to tender (ITT) from the client, which consists of drawings, documents and requirements describing the content of the project. It is a formal management decision to submit a proposal on a project. Upon receiving it, the Sales team will update the information in Salesforce and meanwhile talk to line managers, distributing the documents to them. If the line manager is experienced, he/she will directly produce estimates himself/herself using a template built on experience. Otherwise, the line manager will work with a knowledgeable engineer within the line organization to estimate how many hours the work will take.

All forecasts are produced at the work package level where a project is broken down into small and controllable activities, for example, Software Development and Software Testing, and each line manager is accountable for his or her estimates *(see Appendix 3 Extract from an example Project WBS)*. Since the tasks are very repetitive, the template based on experience gives relatively accurate estimates under normal assumptions. Major parameters such as the number of stations, tracks, signals and machines and the length of the project are used to produce estimates. For example, having worked on many similar projects, an engineer found that normally Configuration Management takes 10 hours a month. If the calendar time is 30 months, then 300 hours will be needed for this activity (10*30=300). Likewise, upon receiving the documents and drawings from a client, a hardware engineer will check the number of cabinets needed. Since experience tells him/her that each cabinet will require around 80-hour work, he/she will multiply the number of cabinets by 80 hours and get the estimated hours. These estimates are adjusted for complexity and a little contingency is added to reduce the risk of overspending. The estimation by each function is done independently, which means everyone only focuses on his or her own part of the work. For big projects, coordination meetings are held where estimators discuss and make adjustments to the figures. Afterwards, the Sales team will collect internal quotations from each function and double check the numbers by comparing them against those of similar previous projects. An additional percent is usually added to internal quotations for development and improvement reasons. The estimates become As-Sold and serve as the baseline in the future, of which the accuracy is highly dependent on the inputs of the client and the understanding of the scope of the project.

5.1.3 Updated As-Sold During the Handover Phase

Once BT wins a contract, a project team including a Project Manager, Engineers, a Project Planner and a Financial Controller will be formed. The members in the project team are not necessarily the same as those involved in bids due to limited resources available at different line organizations. Together the project team will review the As-Sold figures in detail, discussing, questioning, and checking everything during the project handover meeting where sales, representatives of all functions, and project team members present. At best, the project team agrees to the schedule and estimates and commits to following them during the project execution phase. Theoretically, if the project team thinks the baseline is unrealistic and refuses to make a commitment, the initial estimates should be re-examined and even revised. In reality, however, since the contract has already been signed and everything is decided, the As-Sold hours can no longer be changed.

To mitigate problems early and make the handover process easier, the company encourages the involvement of the project team during the bidding phase. If a project is of very significant value and/or strategic importance, it's mandatory to pinpoint a Project Manager who is going to work on this project and involve him/her in the bidding team. According to the head of Swedish Trackside Portfolio, 70% of bids are produced with the involvement of the project team.

5.1.4 Forecasts During the Execution Phase

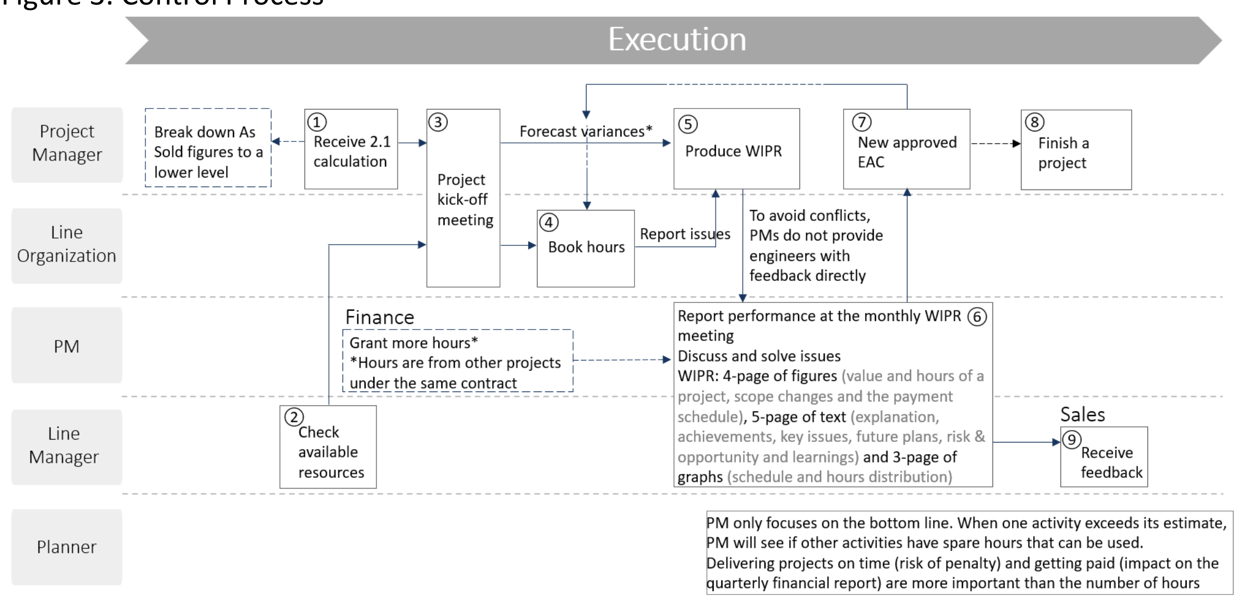
As a project progresses, members within the project team are required to check their forecast monthly based on the remaining workload and their working efficiency. The Project Manager will then check to see if the forecasts are realistic and if more hours should be added. Take forecasts for Safety Coordination as an example. During the execution phase, the Project Manager will consider how much scope has been completed and therefore, estimate the number of hours needed to finish the rest of the work. Another example is the forecasts for Project Management. A project is expected to finish in 6 months. Assuming the Project Manager is working on 5 projects at the same time and will work full-time for the upcoming 6 months, he/she will devote around 20% of their working hours into this project, which is around 180 hours in total (150*20%*6=180). This process involves strict control and constant contacts with different stakeholders, which will be discussed in detail in Section 5.2.

Additionally, there are often changes in the scope of work resulting from Variation Orders (VOs) placed by the client after a project starts, such as increasing the quantity of stations and changing material. The As-Sold hours of VOs are forecasted in the same way as those of the original contract but by the project team directly. Such changes, once approved internally by PM, Finance, Legal and Sales, will be incorporated in the schedule in Primavera so that the full scope of activities and hours are integrated and modelled during the periods where they are required. However, only hours of big VOs are tracked separately from those of the original order. The project will be re-baselined when scope changes are made with the client.

5.2 Control Process

Figure 3 shows how a project is controlled during the execution phase. As payments from client are made at certain pre-agreed-upon stages, it's essential to ensure that a project progresses as expected and achieves the gate to get paid in cash.

Figure 3. Control Process



Source: Own analysis based on interviews with stakeholders within BT

5.2.1 Project Manager – Monthly Review

The Project Manager's monthly review of project performance is based on the Workpackage Integrated Project Review (WIPR) report, a project summary report containing 4-page of figures, 5-page of text and 3-page of graphs for each ongoing project in Sweden. The figures show current performance, value and hours of a project at a high level, a list of all VOs and the payment schedule. The text explains the deviation between As-Sold and the Estimation at Completion (EAC), a metric used to detect project delay and cost overrun and calculated by adding actual hours spent and forecast hours together. The text also reports achievements and key issues, presents future plans, risk and opportunity, and summarizes learnings. The graphs display the schedule and hours distribution which indicates how well a project is planned.

Every month, all Project Managers, Line Managers and the Head of Project Management, as well as the Financial Controller organize a WIPR meeting, where Project Managers present their WIPRs and report issues. When variances occur or the Project Manager expects the project will need more hours than As Sold after checking with his/her team members, he/she will bring this up during the meeting and the issue will be discussed and resolved. If agreed at the meeting, Finance will move hours from another project under the same contract that has spare hours to the project in need of more hours. Thus, everything is good at the contract level. In that case, when more hours are given after a project has started, an approved EAC will be generated, which becomes the new baseline that the project team needs to commit to.

It' s each Project Manager's responsibility to manage his/her project and ensure the project is delivered on time and within budget. Instead of controlling hours at the work package level, most project managers only focus on the bottom line, which is the total number of hours for all work packages. When the hours of one activity run over its estimate, the project manager will see if other activities have spare hours that can be used. As long as the total EAC is close to the As Sold, the project is performing well from the Project Manager's perspective and no issue needs to be reported.

5.2.2 Project Management Office (PMO) - Monthly Control Process

In addition to the control activities happening at the Project Management function, the PMO supports project managers in project control through the Monthly Control Process. During the project execution phase, project team members report the number of hours they have already worked on this project at the Work package level, which are the actual hours, and forecast how many remaining hours will be needed for the rest of their work *(see Appendix 4 Example of Hours Booking in Monthly Control Process).* The distribution of these hours is the planned expenditure across time, which will then be reported monthly to Regional Management and used for decision making, e.g. for resource planning. By knowing where the project stands each month in terms of forecast hours and schedule dates, Regional Management is better able to understand the project status and can then make early decisions on possible mitigation measures such as prioritizing certain critical resources or submitting claims to the client.

If the current EAC is significantly out of line with As Sold, a 'deep-dive' analysis will be conducted by the Project Planner, Project Manager and work package owners together to find the root causes. If the planned hours are no longer sufficient to complete the rest of the work, the issue will be brought up to senior management. However, not all projects have their own Project Planner to assist with these calculations as the work is heavy and takes a lot of time. Only projects of very significant value and/or strategic importance are closely examined by Project Planners every month. Small projects are solely handled by Project Managers.

5.3 Feedback Loop

Lessons learned are discussed at the WIPR meeting and Line Managers directly receive feedback as regard to the performance of their team members. The feedback will be further delivered from Line Managers to the individuals who conducted the work. If there is a miscalculation made by Bids found by the project team after a project starts, feedback will be provided to Sales Managers, who have the final say in the value of As Sold figures. Consequently, Line Managers will adjust their template used to produce estimates based on feedback from project teams. For example, previously the item "Project Engineering & Safety Coordination" had very few hours and the hours were calculated by multiplying the project size by a small percentage. Many Project Managers realized that the number of Project Engineering & Safety Coordination hours was too low from the beginning and informed the Sales team. As a result, adjustments were made to the way Project Engineering & Safety Coordination hours were produced during bids.

6 Quantitative Analysis

In this section, a quantitative analysis is performed by using data provided by Bombardier Transportation to measure performance of ongoing and completed Trackside signalling projects. In total, 27 completed projects and 32 ongoing projects in Sweden are considered in the analysis.

6.1 Data

Currently there are 57 ongoing Trackside projects in Sweden, with the longest one dating back to August 2014. Firstly, 15 projects that have lasted no longer than 6 months are removed from this sample because they are too new to provide reliable data for analysis. Secondly, 3 "Pre-study" projects are excluded because these projects don't have initial estimates needed for this analysis. Thirdly, 2 development projects are filtered out as their scope changes so frequently and dramatically that the original As Sold can no longer serve as the baseline for the purposes of comparison *(see Appendix 5 EAC Changes of the Two Projects)*. Fourthly, 1 VO and 2 test tracks are removed. Finally, 2 projects with missing data are dropped. In total this results in 32 projects that can be used for this analysis with the start date ranging from November 2015 to August 2020.

As these 32 projects are not yet complete, the final number of hours spent for each project is not available. Thus, the current EAC (Estimate At Completion) at Feb 2021 is used to measure the number of hours actually needed. As-Sold hours collected manually from '2.1 calculation' serve as the baseline.

The data for the completed Trackside projects was extracted from archived database. The projects executed between January 2005 and November 2020 are included in this sample which gave an original dataset of 154 projects. Unfortunately, many projects in this dataset have missing data – they don't have either the project finish date or As Sold figures. After excluding "Pre-study", "Risk & Opportunities" projects, development projects, training projects as well as projects with missing data, this yields 27 projects for the analysis.

Table 3. Data and Sources

	Ongoing projects	Completed projects
The size of the dataset	57	154
The size of the sample	32	27
Time span	2015.11 till now	2015.01 - 2020.11
Baseline	As Sold *Source: 2.1 Calculation*	As Sold *Source: 2.1 Calculation*
Actual performance	Estimated EAC *Source: BUBT*	Actual EAC *Source: Archived data*

Source: Own analysis

6.2 Results

The average As-Sold of the 27 completed projects amounts to 13,121 hours and the average project duration is 35.6 months, with the longest project lasting 70 months. For the 32 ongoing projects, the average As-Sold is 17,435 hours. This key parameter is strongly influenced upwards by one project, which has an estimate of 117,747 hours. After filtering this project out, the average As-Sold decreases considerably to 14,199 hours. In terms of project length, these ongoing projects have been running for 21.2 months on average. Most of the projects in this sample are at their early stages. Specifically, 15 (46.9%) projects have lasted no longer than a year and 8 projects started around 6 months ago.

As Table 4 shows, out of the 27 completed projects, 13 (48.15%) projects have positive variances, which means the EAC is higher than the As-Sold and, on average, each project used 2,300 hours more than the initial estimates. For the 32 ongoing projects, 21 (65.6%) of them have positive variances and the average positive variance is 1,618 hours. This indicates that completed projects are less likely to use more hours than the As-Sold compared to ongoing projects, but the variance is higher when overruns occur.

In total, the ongoing projects have an overrun of 23,672 hours. Among the 21 projects with positive variances, 12 of them have a positive variance as a percentage of As-Sold less than 10%, 7 projects fall within the range between 10% and 20%, and 2 have a variance higher than 20%. The remaining 11 projects whose EAC is lower than the As-Sold have substantial negative variance. On average, their EAC is 14% lower than the As-Sold, which is minus 937 hours in absolute terms. However, the sum of negative variances is much smaller than that of positive variances, so they are not big enough to make up for the increase in man hours of the other 21 projects.

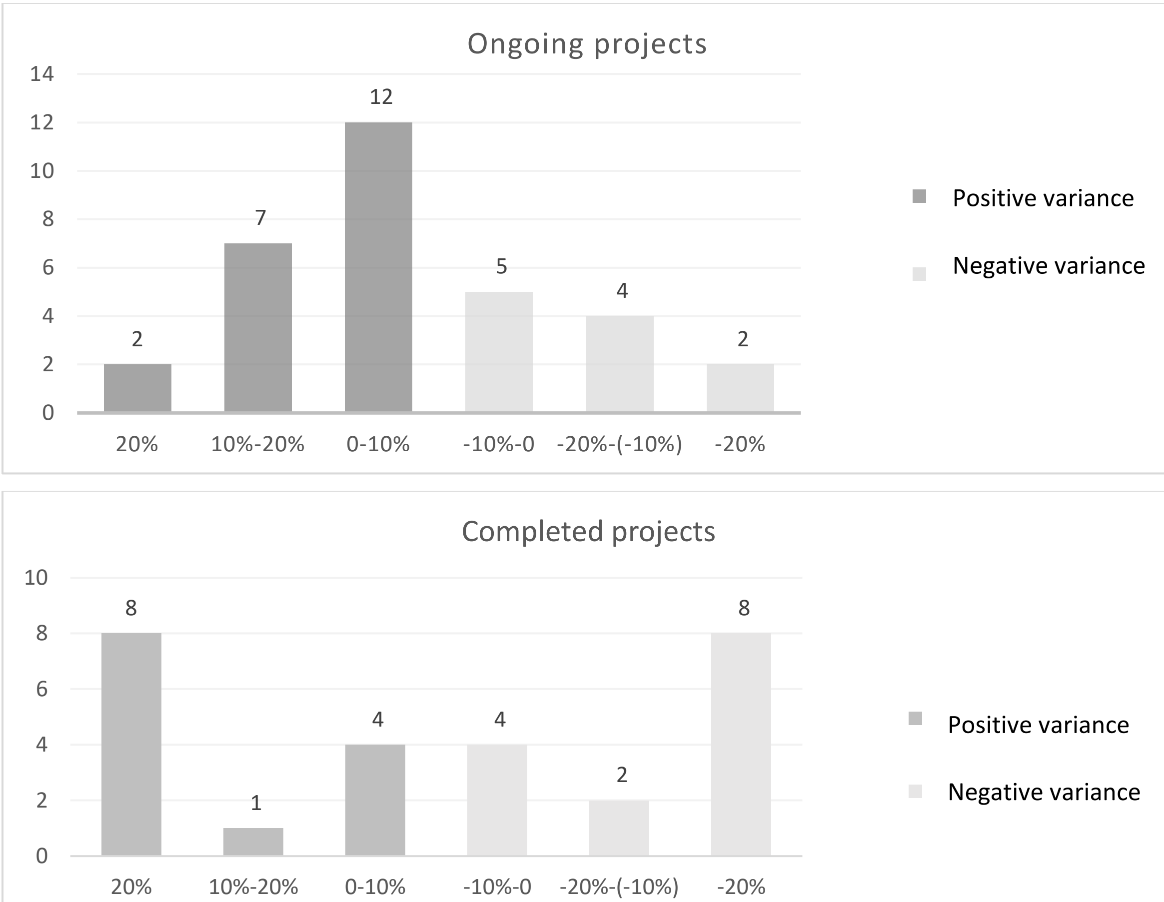
Table 4. Comparison of the Variances of Ongoing Projects and Completed Projects

	Ongoing projects	Completed projects
Average As Sold	17,435	13,121
Average length	21.2	35.6
# of projects with positive variance	21 (65.6%)	13 (48.15%)
Average positive variance	1,618	2,300
Average positive variance (% of As Sold)	11%	33%
Sum of positive variance	33,974	29,901
# of projects with negative variance	11 (34.4%)	14 (51.85%)
Average negative variance	-937	(4,765)
Average positive variance (% of As Sold)	-14%	-28%
Sum of negative variance	-10,302	(66,709)

Source: Own analysis based on data from BT

Among the 27 completed projects, 13 (48.15%) projects have positive variances, which adds up to 29,901 hours in total. Hours decrease is occurring as commonly as hours increase as around 52% have the actual EAC lower than the As Sold. Surprisingly, for the 14 projects whose EAC is lower than the As-Sold, the sum of negative variance is even higher. This figure is driven up by a project with a variance of 18,493 hours, but even without its impact, it is still notable. Spreading the hours among the 14 projects results in an average negative variance of 28% of the As Sold.

Figure 4. Distribution of Ongoing and Completed Projects

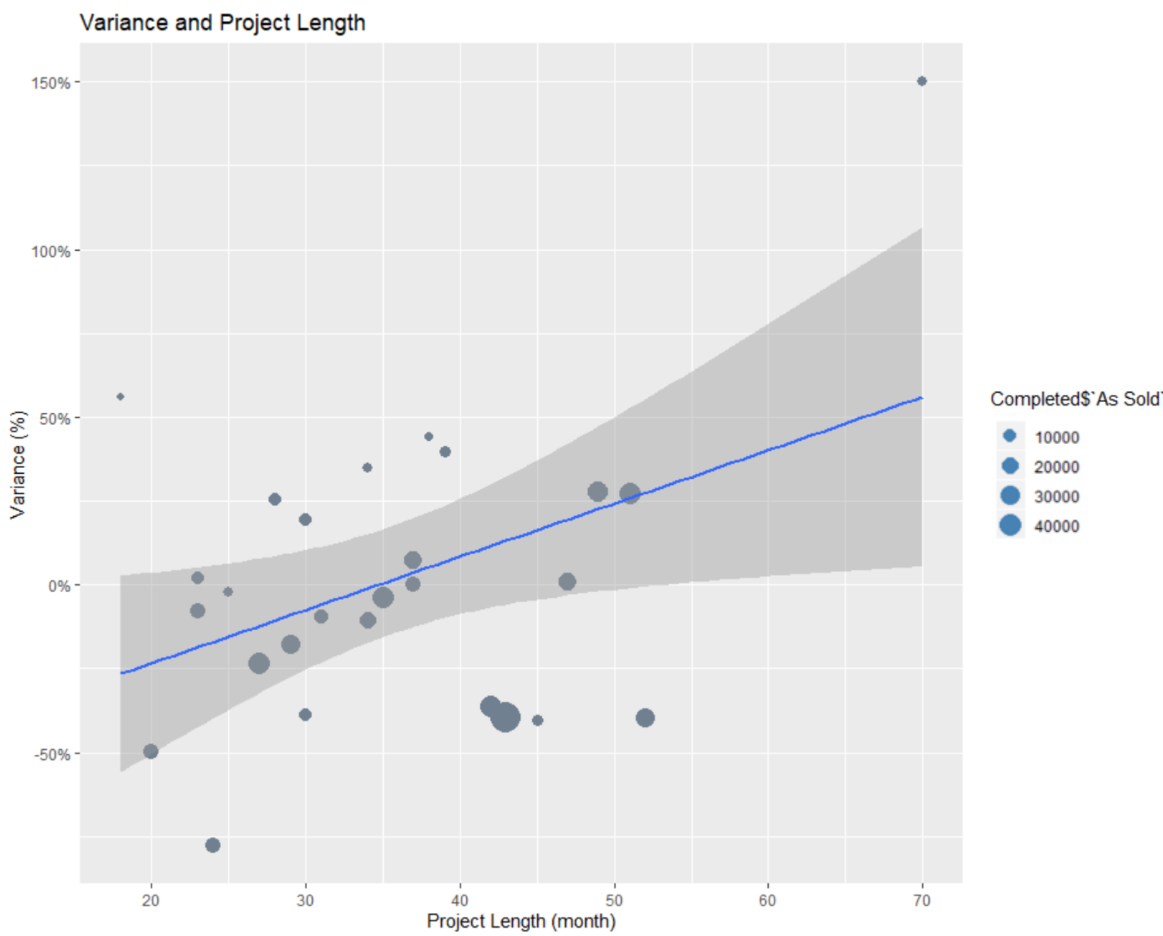


Source: Own analysis based on data from BT

Interestingly, as Figure 4 shows, the distribution of completed projects shows the opposite pattern of that of the ongoing projects. Unlike most (53.1%) ongoing projects having small variances within the range between -10% and 10%, 59.3% of completed projects either have variances higher than 20% or lower than -20%, which proved our observation above that the relatively extreme cases are more likely to occur in completed projects.

Figure 6 below illustrates how a project's variance might change depending on how long this project has lasted. Due to the concern about self-selection issues with ongoing projects that these projects are still running because they are delayed, only completed projects are used for this analysis. The trend line displays a positive relationship between the length of a project and the variance as a percentage of As Sold, meaning that the longer a project has lasted, the higher variance it is likely to have. The t-test (1) result shown in Table 5 is in line with the observation. A possible explanation is that long projects are more challenging to control and manage. It's easier to predict what will happen in two years than four years and members within the project team are more likely to change if the project lasts very long. Another explanation is that as a project progresses, it will receive more VOs, which are not included in the baseline of this comparison.

Figure 6. Relationship Between the Length of a Project and the Variance



Source: Own analysis based on data from BT

Furthermore, I noticed that for some projects the variance is very high from the beginning. According to Lind and Brunes (2015), most cost overruns happen during the initiation stages of a project. To test this theory, I analyzed EAC figures produced after a project just started and explored the relationship between the estimated variance and the actual variance in completed projects. Estimated variance is defined as the EAC estimated two or three months after a project starts minus As Sold, which measures the difference between As-Sold figures produced by the bidding team and the EAC estimated by the project team. Since there is a short time interval between when these two figures are produced, the impact of VOs is minimized. If the estimated variance is high, it indicates that the bidding team and the project team are not aligned with their estimates. Among the 27 projects, 14 have positive estimated variances while the remaining 13 have negative estimated variances. However, for projects with negative estimated variances, the variances as a percentage of As Sold are high and range from -17% to -78%. Positive variances are lower with 10 projects having variances less than 20%. As Figure 7 shows, most projects with positive estimated variance are small in size while projects with negative estimated variances are bigger. This may indicate that As-Sold figures for bigger projects tend to be overestimated, which is consistent with expectations as it is mandatory for Project Managers of big projects to be involved in the bidding phase when these figures are produced.

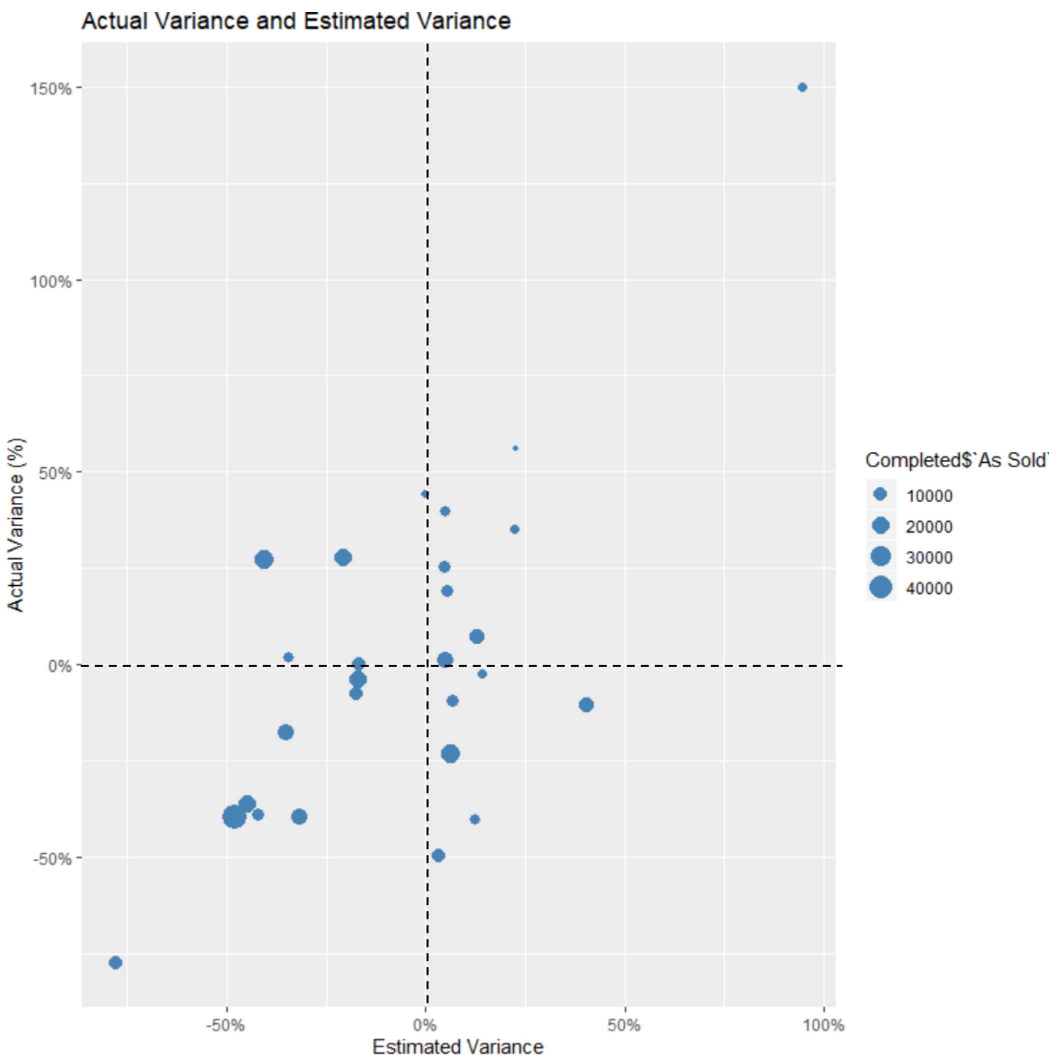
Table 5. t-test Results

		Coefficient	t-value	p-value
t-test (1) Relationship between the project length and the variance				
	(Intercept)	-0.5512	-2.176	0.0392 *
	Project length	0.01588	2.346	0.0272 *
t-test (2) Relationship between the estimated variance and the actual variance				
	(Intercept)	0.0723	1.159	0.257
	Estimated variance (%)	0.91404	4.952	4.22e-05 ***
t-test (3) Relationship between the rest of the variance and the actual variance				
	(Intercept)	-1.57E-02	-0.189	0.852
	The rest of the variance (%)	3.18E-05	1.741	0.094

*Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1*
Source: Own analysis based on data from BT

The result of t-test (2) shows that there is a positive relationship between the estimated variance and the actual variance, which means the higher the variance is between As-Sold and EAC at the beginning of a project, the higher the actual variance this project will have when completed. A possible explanation is that the As-Sold is not accurate from the beginning, and therefore, differs both from the EAC at early phases and from the actual EAC. Additionally, I tested whether the rest of the variance, which is the difference between the EAC estimated two or three months after a project starts and the actual EAC, has a significant impact on the actual variance. As shown in Table 5, there is zero or insignificant correlation between these two variables. Combined with the result of t-test (2), it indicates that the actual variance is mainly driven by the variance at the beginning of a project and that the project team realizes the initial estimates are not accurate immediately after a project gets started. It supports the claim in two Swedish papers that most of the cost overruns occur during the early phases of a project (Lundman, 2011; Lind and Brunes, 2015).

Figure 7. Relationship Between the Estimated Variance and the Actual Variance



Source: Own analysis based on data from BT

6.3 Limitations of the Quantitative Analysis

Ideally when comparing the initial estimates and the actual results, scope changes should be taken into consideration because in some cases, variances were caused by VOs. Therefore, a positive variance does not necessarily mean the project is not performing well. However, as the information regarding VOs was held privately by each project manager and not in a central database, it was not feasible to contact all of them and collect the figures. As a result, it is not possible to analyse the impact of VOs on the total variance. Secondly, the sample is too small to perform linear regression and explore the statistical correlations between different variables. An inclusion of more projects may suggest different results. In spite of these limitations, the available data coupled with the interviews should suffice to form a clear picture of the performance of completed and ongoing projects.

7 Qualitative Analysis

In order to get insights of the causes for deviations in man-hours, eight ongoing projects were selected for an in-depth investigation. The causes frequently mentioned by interviewees were grouped under internal and external categories and explained in detail.

7.1 The Selection Criteria and Studied Cases

Based on the results of Section 6, eight ongoing Trackside signalling projects were selected for further analysis because their variance as a percentage of As-Sold were higher than 10%. As Table 6 shows, the start data that was spanned by these cases ranged from November 2015 to September 2019. The biggest project has an As-Sold of 27,173 hours while the smallest one only encompasses 6,073 hours. Thus, projects with different sizes and durations are included in this sample. The rationale behind choosing ongoing projects instead of completed projects is that interviewees have clearer memories about what happened and WIPR reports containing complete information of ongoing projects are accessible. Also, it’s easier to find the responsible members as sometimes people move to different roles. Though WIPR reports give thorough information about each of the studied projects, such as details about the project budget and project timeline, this study focused only on identifying the causes of deviations in man-hours of the examined projects.

Table 6. Selection of Eight Projects

#	Project	Project Start Date	AS SOLD	Variance (%)
1	A	12-Nov-15	27,173	19%
2	B	20-Jan-17	20,485	18%
3	C	17-Nov-17	12,412	17%
4	D	16-Oct-18	24,483	22%
5	E	13-Dec-18	7,253	12%
6	F	31-Jul-19	11,580	12%
7	G	22-Aug-19	6,073	39%
8	H	20-Sep-19	16,414	19%

Source: Own analysis based on interviews with stakeholders within BT

7.2 Identified Causes for Deviation

Using the causes for project delay and cost overrun that are addressed by the literature, all selected projects are reviewed and selected individuals who were closely involved in these projects were interviewed to determine the causes for deviation in each project. In addition to causes collected from the literature, a few new causes were identified by interviewees which were not previously described. Because most cases have more than one cause that explains the deviation, the number of causes identified is higher than the number of projects examined. As Table 2 shows, 14 external causes and 26 internal causes identified by previous researches were considered for this study. Only 20 factors appeared in the 8 projects investigated and were mentioned by the interviewees. They directly led to cost overruns and were categorized under internal and external categories, which can be found in Table 7.

Other than the 20 factors listed in Table 9, there are 2 internal causes that do not directly lead to deviation in man-hours but have negatively affected project control, which are management focus at high levels and poor data management. Management focus at high levels refers to the fact that senior management is focused on the result of a cluster of projects rather than that of each individual project, which affects behaviors of organizational members and how projects are managed at lower levels. This has two consequences. Firstly, project managers only focus on delivering the “bottom line”. When hours of one activity exceed its initial estimate, project managers will see if other activities within this project have spare hours that can be used. Secondly, hours of projects under the same contract can be moved around if agreed by the head of Project Management and Finance. Poor data management refers to the fact that data is not reliable due to substandard actions and human errors and that there is no up-to-date, single data set in place, which will be further discussed in Section 8.

Table 7. Identified Causes for Deviation

Category	**External Factors**	**Frequency**	**Position**
Social & Political	Social and cultural impacts		
	Obstacles from local government		
	Regulatory change	1	1 LM
	Increase in manpower cost due to environment restriction, insurance premiums and other social expenses of the workforce.		
Financial	High Inflationary pressure		
	High interest rates charged by banks on loans		
Contractor/ Supplier	Increment of materials prices.		
	Poor performance of subcontractor	1	1 LM
Client	Client's over influence/interference on the construction process		
	Scope changes (VO)	7	7 PMs
	Unstable, incomplete, or incorrect input from clients	8	2 Sales, 2 PMs, 5 LMs
	Slow and delayed deliveries	2	1 PM, 1 LM
	Slow and delayed payment of completed work		
Others	Effect of weather conditions		
	Litigation		

Category	**Internal Factors**	**Frequency**	**Position**
Financial	Cash Flow and Financial difficulties		
Organizational	Poor organizational structure		
	Poor project management practices	4	4 PMO
	Delays in decisions making and work approval		
	Hours moved from other projects	4	1 Finance, 1 PMO, 2 PMs
	Lack of coordination/communication	4	2 Sales, 2 LMs
Technical	Inadequate project preparation and planning	1	1 LM
	Technical complexity	1	1 LM
	Unrealistic/Inaccurate cost and time estimates	3	2 PMs, 1 LM
	Lack of cost planning, monitoring and controlling during pre- and post-contract stages		
	Poor cost advice, inadequate contingency allowance or assessment of risks	1	1 PM
	Scope creep	1	1 PMO
	Leftover issues	2	1 PM, 1 LM
	Slow and delayed deliveries from the product team	2	2 LMs

	Insufficient information/investigation about ground conditions		
	Mistakes during execution due to inadequate execution methods		
	Re-works	1	1 LM
Resources	Shortage of available labour	3	1 PMO, 2 LMs
	Members with different management cultures	2	1 PM, 1 PMO
	Change of people	2	1 PM, 1 LM
	Poor resource planning	1	1 PM
	Lack of accountability	2	2 PMO
	Mistakes	2	2 PMs
	Lack of experience	6	3 PMs, 3 LMs
Psychological	Over-optimism biases	2	2 PMs
	Deception	1	1 PM

Source: Own analysis based on interviews with stakeholders within BT

Factors listed in Table 7 with support from more than 2 interviewees were further explained in the following paragraphs.

7.2.1 External Causes

- Scope changes: This happens when the original scope of work is changed. For example, the client wants to add one more station in addition to what is sold in the contract, so he/she place a VO and pay for the extra hours.
- Unstable, incomplete, or incorrect inputs from clients: The problem refers to design/functional changes made by the owner or the subcontractor during the execution phase. Changes to customer requirements and design changes due to errors are also included in this cause.

7.2.2 Internal Causes

- Poor project management practices: This cause encompasses bad practices or mistakes that appear in project planning and management in general, such as the improper use of a standard Work Breakdown Structure (WBS) and a lack of a consistent project management process.
- Hours moved from other projects: As mentioned before, this cause refers to situations where hours from one project are moved to another project, for example, from project A to project

B. As a result, hours in project B contains not only hours spent on this project but also hours used to support project A.

- Shortage of available labor: This cause is also known as resource constraint, which refers to the limitation of people available to complete certain work. Without enough resources, a person has to work at several projects in parallel and is often loaded with work.
- Lack of coordination/communication: The absence of communication exists between different stakeholders within or outside the company. Specifically, there is limited feedback from the resources who execute the work to the professionals who produce the estimates. Additionally, knowledge and experience is not actively shared between Project Managers. Moreover, communication and cooperation with clients and subcontractors requires attention from higher management as there are often errors found in documents provided by them which negatively impacts the work of the whole branch.
- Unrealistic/inaccurate estimates: This cause typically occurs when the Project Manager is not involved in the bids. As a result, the As-Sold hours tend to be very low from the beginning, which leads to overrun in the end.
- Lack of experience: This cause refers to situations in which new employees without much experience are assigned to a project. New hires usually spend their first few weeks on a learning curve with their first projects and getting used to the company tools and systems. Consequently, they won't be productive at the beginning and can sometimes make mistakes, which is a huge opportunity cost for the company.
- Change of people: Since a Trackside signalling project can last from 2 to 6 years, members within a project team may change due to sickness, vacation, new positions or other personal reasons. This causes extra work as a new person needs to pick up where the previous member left off, examining what has been done and getting familiar with the project.

8 Discussion

In the following section I discussed the causes for cost overrun identified in this paper and compared them against the results of similar studies in Sweden and worldwide. Though this paper only focuses on man-hours, the factors discussed in this study are very similar to those mentioned in prior researches. Furthermore, as said before, an increase in man-hours will directly cause higher costs and if not controlled properly, a delay to the project. Thus, it is believed that the findings of similar studies and this paper are comparable. Additionally, based on theory and practice, the research limitations were covered at the end of this section.

8.1 The Identified Causes

As Table 7 shows, the identified causes were grouped under internal and external clusters and further divided into client, organizational, technical, resources and psychological subclassifications. The figure beside each cause represents the frequency that the cause has been mentioned during interviews and the position column explains the roles of these interviewees. Clearly, the most frequent cause of deviation in man hours is "unstable, incomplete, or incorrect input from clients," followed by "scope changes" and "lack of experience."

Only five external causes were identified by the interviewees and three of them were related to clients. Clients are the key drivers of change and the progress of project team is highly dependent on the inputs from client, including drawings and requirements. It is very common that clients place additional orders and change the scope of the project after signing a contract with Bombardier Transportation. Out of the eight projects investigated in this study, only one (Project E) does not have any scope change.

As described in Section 6.3, one limitation of the quantitative analysis is that the impact of VOs not being separated from the total variance. Therefore, to accurately measure the performance of the eight projects, I analysed the As Sold figures for VOs and subtracted them from the total variance. The new variance can accurately serve as a metric for project performance evaluation. As Table 8 shows, after subtracting the As Sold hours of variation order from the variance, only Project G now has a negative variance. The other 7 projects still have notably positive variances. Thus, scope change is not the excuse for deviations of these projects. In effect, VO commonly increases the margin of the original contract. One project manager explained:

> *"VO often improves EAC. If EAC hours are underestimated in the original contract, VO will be used to compensate the loss."*
>
> *--Project Manager 1*

Table 8. Variances of Eight Investigated Projects Excluding the Impact of VOs

Project	Original variance	VOs	Variances after subtracting As Sold of VOs	Variance as a percentage of As Sold (%)
A	2,367	427	1,940	32%
B	5,366	2484	2,882	12%
C	5,282	Unkown	Unkown	Unkown
D	3,115	800	2,315	14%
E	3,695	-	3,695	18%
F	2,159	606	1,553	13%
G	876	1002	(126)	-2%
H	1,356	284	1,072	9%

Source: Own analysis based on data from BT

When it comes to internal causes, organizational factors are the most frequently mentioned. These include “poor project management practices”, “hours moved from other projects”, and “lack of coordination/communication”. In addition to organizational problems, many issues concerning resources are brought up by interviewees such as “lack of experience”, “shortage of available labor” and “change of people”.

8.2 Comparison with Similar Studies in Sweden

Most Project Managers, Line Managers and Sales Managers interviewed have pointed out that unstable, incomplete, or incorrect input from clients was a main reason for deviations, which leads to frequent design changes and, ultimately, extra work. This is in line with Lind and Brunes’ (2015) finding that most cost overruns are related to design changes during the early planning phases. Design changes can be caused by either errors in the original design or changes in customer requirements. The basic design is always produced by a third party selected by the client and approved by Bombardier Transportation. However, it’s common that there are errors in the drawing which are not visible at the beginning when signing the contract. As a result, the basic design will be sent back to the third party and revised. When a project team receives a new design, the team may have to restart the whole process. Another case is that client requests for changed features can result in increased complexity and uncertainty (Jackson, 2002) and adjustments must be made to design already executed. One sales manager described the problem as follows:

"Because we do not get the right drawing/sufficient data from the beginning, it's hard to have a clear understanding of the project scope and a lot of changes can happen during a project lifetime and cause extra work. This is something we have been talking with the client and trying to improve."

- *Sales Manager 1*

A line manager further commented:

"When a project starts, we only have preliminary requirements to work with, meaning there will be a lot of changes in the requirements in later phases. It takes additional hours to make corrections and update the system. However, to be able to meet the commissioning date, we have to start early even without complete inputs."

- *Line Manager 1*

Additionally, the interviewees identified "lack of experience" as an important explanation for the deviation, which is similar to the factor "lack of competence" discussed by Lind and Brunes (2015). This may indicate that infrastructure projects in Sweden are suffering from a lack of competent and experienced resources in general, especially considering that these projects tend become increasingly complicated. According to Line Managers, there is no standard onboarding process in place in each line organization, but they always make sure new employees have a mentor and receive sufficient support. Generally new employees are not very productive at the beginning. In one project, a new Software Engineer caused nearly two thousand hours higher than As-Sold and had a negative impact on the total EAC. As the project manager said:

"New employees have to build hands-on experience and learn. This is unavoidable. However, we should provide them with mentorship and better support."

- *Project Manager 2*

While some line managers are able to decide which member will work on a project early during the bidding phase, and therefore, include additional hours in their estimates if it is a new hire, most line managers are uncertain about their members' availability. One line manager explained:

"When estimations are made, we don't know who will do the work because resource planning is not finalized. If it is a new person, 10-20% more hours should be added to As Sold figures. Since there is no learning account, the additional hours have to be added to each project."

- *Line Manager 1*

Moreover, as discussed in Section 2.1, an efficient and effective planning process requires good management of data (Neely et al., 2001). Riksrevisionen, the Swedish National Audit Office, has found that although cost overrun remains an issue in the Swedish infrastructure sector, data is not registered in such a way that makes it easy to investigate what really happened during the project lifetime cycle and to identify the causes for overspending. Bombardier Transportation is facing the similar problem. The company doesn't have an up-to-date, single data set. People save data on their hard drives, SharePoint, Microsoft teams, and etc., which makes it impossible to have a single view of the data. One consequence is that sometimes people don't have access to data they need because data is saved in local spreadsheets. This was the case when As-Sold figures were collected for the purpose of this study. The data was stored in Microsoft Excel '2.1 calculation' sheets together with company confidential information and therefore had to be extracted manually by a Sales Manager. The Sales Manager explained:

"As you can see, data is not in a downloadable format and has to be gathered manually from different sources, so no one evaluates the performance of previous projects."

- *Sales Manager 2*

Another consequence is that data obtained from different sources is inconsistent. For example, the As Sold figures in WIPR reports are not the same as those from '2.1 calculation', which might be caused by mistakes or different components included. This issue with data quality requires additional manual cleaning of the data.

This study also determined that two causes, "hours moved from other projects" and "members with different management cultures", are specific to Bombardier Transportation. As mentioned in Section 5.2.1, hours may be moved among different projects under the same contract or used to support tool development and training. In two out of the eight projects examined, hours were moved to fund other projects which led to higher EACs. Such practices to some extent imply management's focus at high levels and show the internal project control defects at the company. Also, working with members from other countries is tricky due to different management cultures. In the Swedish business unit, most people are open and transparent. They are comfortable escalating problems to higher levels of management without fear of censure. Therefore, communication is efficient and issues are often discovered early. In contrast, people from some other countries tend to hide their uncertainty because it is perceived as unprofessional by their Line Managers. As a result, issues are not identified until it's too late. One Swedish project manager gave an example about working with an engineer from Ukraine:

> *"That person was assigned to Configuration Management which had an As-Sold figure of 200 hours. After 2 months, I found he had already spent 200 hours on it. I felt his work should be complete and no more hours would be needed. I asked him 'can you fix the rest of the work within 20 hours?' He said "yes" but I knew it was not true given the remaining workload. I added another 100 hours to the forecast and reported this issue to my manager without causing his problem with his Line Manager."*
>
> - *Project Manager 3*

In Lind and Brunes' paper (2015), technical problems are an important explanation for cost overruns, resulting in the need for additional material or work hours. In this study, however, only a few interviewees raised technical issues. Though many technical causes such as "unrealistic/Inaccurate cost and time estimates", "poor cost advice, inadequate contingency allowance or assessment of risks" and "scope creep" were brought up during interviews, the frequency of each factor was low. The dissimilarity might be explained by different definitions of technical factors in these two papers – Lind and Brunes (2015) used a broader scope and included some organizational factors, for example, inadequate organizational structures and processes as technical issues. Another possible explanation is that a Trackside signalling system is a very standard product and activities across different projects are very alike. As a result, its technical complexity is relatively low.

8.3 Comparison with Global Studies

Table 9 presents a comparison between the results of this study and the causes identified by similar studies conducted in other countries that were discussed in Section 2. The numbers in the table represent the ranking of factors in each paper.

Table 9. Comparison Results With Global Similar Studies

Source	**This study (2021)**	Lind and Brunes (2015)	Garry et al. (2010)	Jackson, S. (2002)	Hamed et al. (2016)	Long et al. (2007)	Jyh-Bin et al. (2013)	Sambasivan (2007)	Memon et al. (2011)	Aljohani et al. (2017)
Country	**Sweden**	Sweden	Austria	UK	Iran	Vietnam	China	Malaysia	Malaysia	Global
Scope changes	**2**		2	1	5		2			
Unstable, incomplete, or incorrect input fron	**1**	1	1	2	3	2	1		1	2
Hours moved from other projects	**4**									
Poor project management practices	**4**			4		1	6			
Lack of coordination/communication	**4**				4					
Lack of experience	**3**	2		6	3	3		3	3	3
Shortage of available labour	**5**									
Unrealistic/Inaccurate estimates	**5**			3					2	1
Financial difficulty						5	5	4		4
Weather							3			
Poor site management				5			4	2	5	
Social and government impact						4				

Note: Sweden, Austria and UK are classified as developed countries while Iran, Vietnam, China and Malaysia are classified as developing countries.

"Scope changes", a cause considered to be equivalent to "changed orders", "unstable, incomplete, or incorrect input from client" and "lack of experience" are the most frequent and highly ranked causes for cost overruns identified by these general studies of infrastructure projects. As Table 11 shows, most of the causes that resulted in more hours spent in Swedish projects can also be applied to other contexts around the world.

However, this study determined that projects in developing countries are more affected by financial capability and site management, given the frequencies with which these causes were identified. Furthermore, there are certain factors specific to this study, including hours moved from other projects and shortage of available labor. In other words, these issues have caused deviation in hours in the projects investigated at Bombardier Transportation in Sweden, but they were not commonly mentioned by studies conducted in other regions.

8.4 Limitation of Qualitative Analysis

Firstly, as discussed above, the case study methodology has inherent limitations such as the quality of research being largely determined by the skill of the researchers. Moreover, there are limitations when generalizing the explanation for cost overruns for the whole population of projects in Sweden. The research scope is limited to only one type of project in a specific company. Therefore, it's likely that the causes identified are related to the unique feature of Trackside signalling projects and are influenced by the culture of Bombardier Transportation. To improve the quality of this research, the results have been combined with the observations of rich literature.

Secondly, this paper classified all identified causes into internal and external categories and further divided them into different groups for the purpose of comparison and explanation. However, the classification might be subjective and biased.

Thirdly, since the causes were ranked based on their frequency mentioned by the interviewees, the importance of each cause is influenced by the roles of the respondents, which may give a biased result. To make answers more convincing, many competent and experienced managers were selected for the interview, most of whom have worked in this industry for more than 10 years. With this level of experience, it's assumed that the interviewees would give fair and objective views.

Finally, this paper focuses only on man-hours. Consideration of other cost components such as material costs and indirect costs may yield different results.

9 Conclusions

This thesis aims to contribute to the literature with respect to causes for cost overrun in infrastructure projects. Two sets of information, namely empirical data and interview studies were used for quantitative and qualitative analysis. The results of the quantitative part show that the majority of projects have used more hours than initially estimated and that the longer a project has lasted, the higher variance it is likely to have. Moreover, I found that most hour overruns happen in the initial phase of the project, which is consistent with findings in prior research.

The qualitative part focuses on which factors caused cost overrun in relation to man-hours. To investigate reasons for hour increases, I selected eight real projects for the case study and interviews were conducted with twenty-five stakeholders including Project Managers, Line Managers, and Sales Managers. In order to achieve the purpose of this thesis, the focus was on repetitive patterns and mutual factors drawn from information on these eight projects and opinions from interviewees. The results were split between external and internal categories and compared with similar studies. It is found that:

- The main issue that caused hour increases is the unstable, inaccurate and incomplete inputs from clients, which is a common problem found in similar studies. Even with little information available or information of low quality, projects have to start to be able to meet the commissioning date.
- Scope change is very common during the project execution phase, but it is not an excuse for hour increase.
- Training new hires results in a huge opportunity cost for the company. As new employees get experience through learning-by-doing, having an inexperienced member in a project usually results in higher costs and more hours.
- Poor data management and knowledge sharing impedes the potential for improvement. A major problem identified during this research is that the available information on projects that have been finished is not recorded centrally in a standard way.

Although hour increases and hour variations can never be entirely eliminated, the company should take proactive actions to improve the current situation in both categories. To manage the causes in the external category, the company should invest more time in the early stages to review documents more carefully and build a structured way to communicate and coordinate with clients and subcontractors. Also, the company should educate these external stakeholders by conducting statistical analyses and share its experience to help them improve.

To solve the internal issues, the company needs to create an integrated database that contains estimates and actuals which can be used for future estimation, comparison and risk assessment. Moreover, it should improve its knowledge sharing – information and experience should be forwarded from old projects into new ones, as well as from one phase to another phase.

Although this paper focused on a specific type of projects executed by a particular company in Sweden, the employed approach in this paper can be applied to other countries after careful consideration of the assumptions and limitations associated with cost overruns in infrastructure projects. The result of this paper provides the following directions for further research.

- In total eight projects were analysed and twenty-five insiders were interviewed to generate ideas for causes for hour increase. The size of the sample could be extended to include more data and get more representative results. Additionally, viewpoints of people outside the company such as subcontracts, clients and consultants might provide different perspectives as regard to the causes of hour increase in projects.
- This study has summarized the causes mentioned by the interviewees and ranked them by the frequency. However, the impact of these causes was not quantified. If possible, it would be interesting to know how many additional hours are caused by each specific cause and therefore, evaluate the amount of attention which should be given to each factor.
- Future research should also consider investigating how risks concerning the identified causes are controlled and managed through risk management tools and processes. New integrated models may be needed to help Estimators and Project Managers systematically manage risk during project lifecycle.

References

Literature

Abderisak A., Per-Erik B.J. and Göran L. (2017) Aggregation of factors causing cost overruns and time delays in large public construction projects. Engineering, Construction and Architectural Management, Vol. 24, No. 3, pp. 393-406

Alemu M.B. and Olav T. (2017) Do Longer Projects Have Larger Cost Deviation Than Shorter Construction Projects? Procedia Engineering, pp. 262 – 269

Aljohani, A., Ahiaga-Dagbui, D., and Moore, D. (2017) Construction Projects Cost Overrun: What Does the Literature Tell Us? International Journal of Innovation, Management and Technology, Vol. 8, No. 2, pp. 138-143.

Anastasopoulos, P., Labi, S., Bhargava, A. and Mannering, F. (2012) Empirical Assessment of the Likelihood and Duration of Highway Project Time Delays. Journal of Construction Engineering Management., 138(3), pp. 390-398.

Argyris, C. (1952) The Impact of Budgets on People. New York: Controllership Foundation

Baldwin, J. R., Manthei, J. M., Rothbart, H., Harris, R.B. (1971) Causes of Delay in the Construction Industry. Journal of the Construction Division, Vol. 97, Issue 2, pp. 177-187

Brownell, P. (1983) The Motivational Impact of Management-By-Exception in a Budgetary Context. Journal of Accounting Research, Vol. 21, No. 2, pp. 456-472

Christopher K. Bart (1988) Budgeting Gamesmanship. The Academy of Management Executive, Vol. 2, No. 4. pp. 285-294

Dubois, Anna, and Lars-Erik Gadde. (2002) Systematic Combining: An Abductive Approach to Case Research. Journal of Business Research, Vol. 55, No. 7, pp. 553-560.

Erik W. L. and Clifford F. G. (2018) Project Management: The Managerial Process.

Flyvbjerg, B., Bruzelius, N., and Rothengatter, W. (2003) Megaprojects and Risk: An Anatomy of ambition, Cambridge: Cambridge University Press

Garry D. C, Martin S, and Johnny K.W.W (2010) Evaluation of Risk Factors Leading to Cost Overrun in Delivery of Highway Construction Projects. Journal of Construction Engineering and Management. DOI: 10.1061/_ASCE_CO.1943-7862.0000160 pp. 528-537

Hamed S., Seyed M.M.T, Pouria T., Ahmad M.H. and Keith W. (2016) Studying the Reasons for Delay and Cost Overrun in Construction Projects: The Case of Iran. Journal of Construction in Developing Countries, 21(1), pp. 51–84.

Himansu B. (2011) Avoid cost overrun for megaprojects. Project and Technology Management Foundation News Letter, DLF City, India, pp. 2.

Jackson, S. (2002) Project cost overruns and risk management. Proc. Association of Researchers in Construction Management 18th Annual ARCOM Conference, Newcastle, Northumber University, UK

Joaquim M.S. and Luc R. (2017) Cost Overruns in Public Sector Investment Projects. Public Works Management & Policy, Vol. 22(2), pp. 140-164

Joseph Fusco (1997) Better Policies Provide the Key to Implementing Project Management. Project Management Journal, Vol. 28, pp. 38.

Jyh-Bin.Y., Mei Y.C., and Kuei M.H., An Empirical Study of Schedule Delay Causes Based on Taiwan's Litigation Cases. Project Management Journal, Vol. 44, No. 3, pp. 21–31

Long L., Young D.L., and Jun Y.L. (2008) Delay and Cost Overruns in Vietnam Large Construction Projects: A Comparison with Other Selected Countries. Korean Society of Civil Engineers, 12(6), pp. 367-377.

Lund, H. and Brunes, F. (2015) Explaining cost overruns in infrastructure projects: a new framework with applications to Sweden. Construction Management and Economics, Vol. 33, No. 7, pp. 554–568.

Lundman, P. (2011) Cost management for underground infrastructure projects: A case study on cost increase and its causes. Doctoral thesis, Lulea˚ University of Technology.

Memon, A., Abdul Rahman, I., and Abdul Aziz, A.(2011) Preliminary Study on Causative Factors Leading to Construction Cost Overrun. International Journal of Sustainable Construction Engineering & Technology, Vol 2, Issue 1, pp. 57-71.

Michael C. Jensen (2003) Paying People to Lie: the Truth about the Budgeting Process. European Financial Management, Vol. 9, No. 3, pp. 379–406

Morris, S. (1990) Cost and time overruns in public sector projects. Economic and Political Weekly, Vol. 25, No. 47, pp. 154-168

Neely, A., M. R. Sutcliff, and H. R. Heyns (2001) Driving Value through Strategic Planning and Budgeting. New York, NY: Accenture.

Paul M. Collier and Anthony J. Berry (2002) Risk in the process of budgeting. Management Accounting Research, 13, pp. 273–297

Riksrevisionen. (2010) Kostnadskontroll i stora väginvesteringar? [Cost control in large road investment projects?] Rapport 2010:25, The Swedish National Audit Office, Stockholm

Sambasivan, M. and Soon, Y.W. (2007). Causes and effects of delays in Malaysian construction industry. Int. J. Project Management, Vol. 25, pp. 517-526.

Wight, O. (1988) ABCD Checklist – Definitive Performance Measures, Oliver Wight Inc.

Yin, R. K. (2009) Case study research: Design and methods. Thousand Oaks, CA: Sage Publications.

Public sources

Bombardier, 2020, General company information, Available: https://en.wikipedia.org/wiki/Bombardier_Transportation

Bombardier, 2020, Annual Report 2020, Available: https://bombardier.com/system/files/financial-reports/2021-02/Bombardier-Financial-Report-2020-en.pdf

Alstom, 2021, Corporate press releases, Available: https://rail.bombardier.com/en/about-us/worldwide-presence/germany/de.html/bombardier/news/2021/bt-20210129_transformational-step-alstom-completion-acquisition-bombardier/en

Garrett Butt, 2015, What is a Variation Order?, Available: https://www.quora.com/What-is-Variation-order

Private company sources

Bombardier, 2018, RCS Region North Monthly Control Process

Appendix

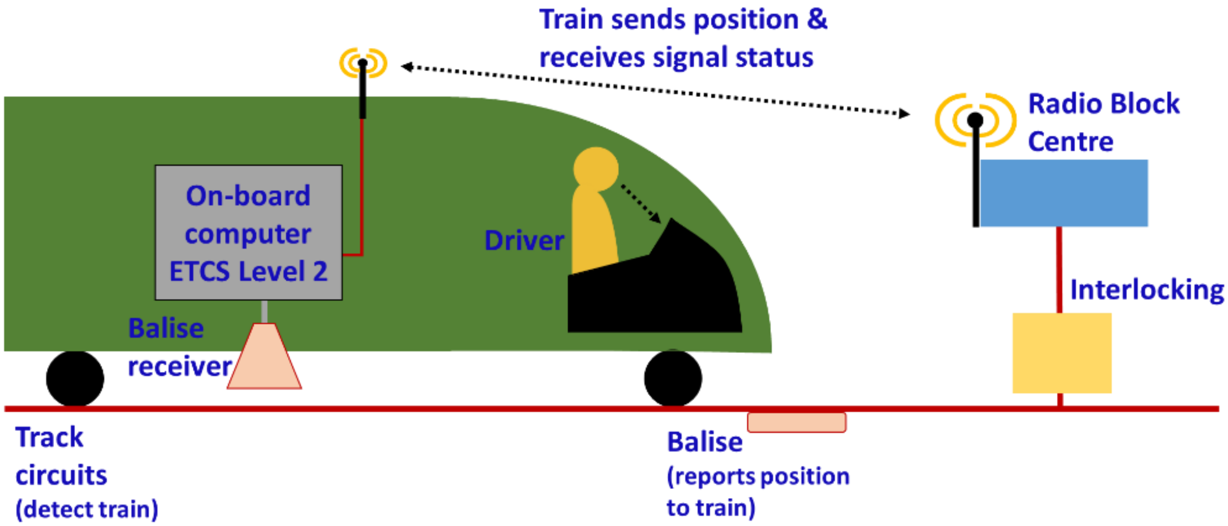
Appendix 1: Interview Questionnaire

Questions for Project Managers
What can explain the variances in your project?
How is the As-Sold figure decided? Is the number finalized only when you are satisfied with it?
Do you evaluate the performance of projects?
Do you have responsibility of project performance? Profits?
How do you control and manage your project?
Are you required to trace the cause of variances to individuals within your team?
How do you interact with project members and other stakeholders? Do you provide feedback to them?
Do you think planning at a lower level is a good idea?
Is there any area you think can be improved?

Questions for Bid and Sales Managers
How do you estimate the hours for prospects? Do you think it's possible to increase its forecasting accuracy?
Do you keep As-Sold figures? What about As-Sold figures for VOs?
How are As-Sold figures produced?
Is there any area you think can be improved?

Questions for Line Managers
Could you please tell me a bit about your position?
How do you estimate As-Sold figures during the bidding phase? What parameters are used? Is there any template?
Do you communicate with other functions when producing estimates?
Do you get feedback from the project team over the accuracy of these estimates? From the Sales Manager?
Who is accountable for the accuracy of estimates?
Do you think your estimates are accurate in general?
How do you onboard new employees? Is there any standard process?
How do you provide members within your team with feedback?
What may explain the hour increase in work done by your function?

Appendix 2: Example of Trackside Signaling System



Source: Bombardier

Note: The on-board computer radiates energy waves to activate the ground equipment on the track, and then the ground equipment sends signals back to each train, which are ultimately received by the control center. Through these two processes, the control center is able to determine the precise location of trains running on these tracks and their real-time speed and thus provide feedback to trains with instructions on how to operate.

Appendix 3: Extract from an example Project WBS

	C	D	E	F	G	H	I	J	K	V	Y
1	WBS Code									RCS STANDARD WBS	PROJECT WBS
2											
226	T2	40								APPLICATION DESIGN	.
253	**T2**	**40**	**35**	**35**	**30**					**AD WSS Construction Documents Area A1**	.
254	**T2**	**40**	**35**	**35**	**30**	**05**				**Signalling System Configuration**	x
255	T2	40	35	35	30	05	05			Design	
256	T2	40	35	35	30	05	05	05		WSS Requirements	
257	T2	40	35	35	30	05	05	10		Geography	
258	T2	40	35	35	30	05	05	15		Signalling	
259	T2	40	35	35	30	05	10			Verification	
260	T2	40	35	35	30	05	15			Release and Internal Delivery	
261	**T2**	**40**	**35**	**35**	**30**	**10**				**Hardware Configuration**	x
262	T2	40	35	35	30	10	05			Design	
263	T2	40	35	35	30	10	05	05		Station Sx/Signal Equipment Room N	
264	T2	40	35	35	30	10	05	05	05	Object Controller Cabinets	
265	T2	40	35	35	30	10	05	05	10	Track Circuits	
266	T2	40	35	35	30	10	05	05	15	ELC	
267	T2	40	35	35	30	10	05	05	20	Relay Interface	
268	T2	40	35	35	30	10	05	10		Station and Signal Equipment Room N+1	
269	T2	40	35	35	30	10	10			Verification	
270	T2	40	35	35	30	10	15			Release and Internal Delivery	
275	**T2**	**40**	**35**	**35**	**30**	**20**				**CD Validation**	x
276	**T2**	**40**	**35**	**35**	**30**	**25**				**CD Release and Delivery**	x
277	**T2**	**40**	**35**	**35**	**35**					**AD WSS SW Configuration (Area A1)**	.
278	**T2**	**40**	**35**	**35**	**35**	**05**				**Design**	.
279	T2	40	35	35	35	05	05			Geography (INFRA)	x
280	T2	40	35	35	35	05	10			Interlocking (ILS)	x
281	T2	40	35	35	35	05	15			Radio block (RBS)	x
282	T2	40	35	35	35	05	20			LEU and Balise data (AWS)	x
283	T2	40	35	35	35	05	25			Local Manoeuvre Sytem (LMS)	x
284	T2	40	35	35	35	05	30			MDC	x
285	T2	40	35	35	35	05	35			Level Crossing	x
286	T2	40	35	35	35	05	30			TCC system (TCC)	
287	T2	40	35	35	35	05	35			Special object (logic) (SSO)	x
288	**T2**	**40**	**35**	**35**	**35**	**10**				**Quality Test (´Pre-FAT´)**	x
289	**T2**	**40**	**35**	**35**	**35**	**15**				**Verification**	
290	**T2**	**40**	**35**	**35**	**35**	**20**				**FAT3**	x
291	**T2**	**40**	**35**	**35**	**35**	**25**				**SWC Validation**	
292	**T2**	**40**	**35**	**35**	**35**	**30**				**SWC Release and Internal Delivery**	
293	**T2**	**40**	**35**	**35**	**40**					**AD WSS System Integration(FAT4)**	
294	**T2**	**40**	**35**	**35**	**45**					**AD WSS Validation**	
295	**T2**	**40**	**35**	**35**	**50**					**AD WSS Release and Delivery**	X

Source: Bombardier

Note: A Work Breakdown Structure (WBS) is a "deliverable oriented hierarchical decomposition of the work to be executed by the project team". A standard WBS is considered a 'pick list' for defining the Project WBS at Bid stage (so that estimates can be tracked from Bid phase through to Project Completion using the same control structure).When defined, the Project WBS should be made available and used by all members of the project core team for their use in managing scope

Appendix 4: Example of Hours Booking in Monthly Control Process

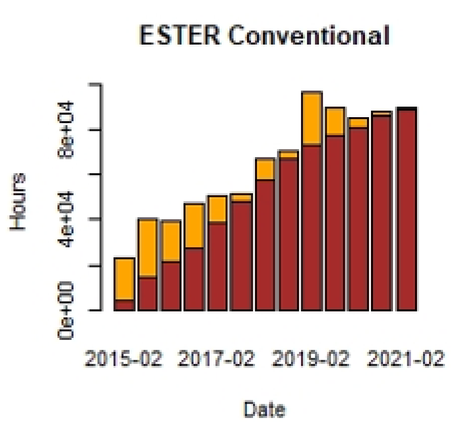
FILTER ON YOUR WORKPACKAGE

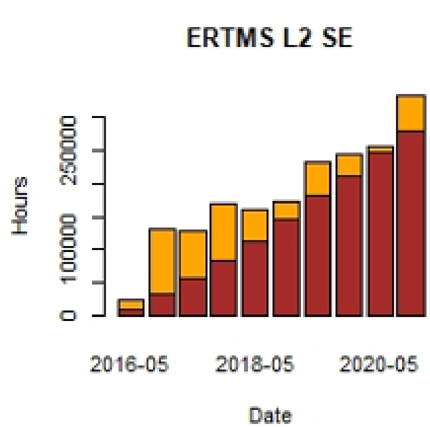
RELEASE	WORKPACKAGE			Resource Name	Role	Start	Finish	Spreadsheet Field	20-Feb-17	27-Feb-17	6-Mar-17	13-Mar-17	20-Mar-17	27-Mar-17	3-Apr-17	10-Apr-17	17-Apr-17	24-Apr-17	01-May-17	08-May-17	15-May-17
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Andreas Jakobsson	Ada	18-Jul-16 A	18/Aug/17	Remaining Units							16	12	12	16	12	16	16
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Ove Nielsen	Ada	18-Jul-16 A	18/Aug/17	Actual Units					8	5							
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Ove Nielsen	Ada	18-Jul-16 A	18/Aug/17	Remaining Units							15	12	12	15	12	15	15
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Justin Pati-2017040111	Ada	18-Jul-16 A	18/Aug/17	Actual Units	36	36	36	36	32	36							
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Justin Pati-2017040111	Ada	18-Jul-16 A	18/Aug/17	Remaining Units							5	4	4	5	4	5	5
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Kurt Erbil	Ada	18-Jul-16 A	18/Aug/17	Actual Units	39	40	40	42	12								
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Kurt Erbil	Ada	18-Jul-16 A	18/Aug/17	Remaining Units							18	15	15	18	15	18	18
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Ake Berglund	Ada	18-Jul-16 A	18/Aug/17	Actual Units	7	14	13	9		17	0						
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Ake Berglund	Ada	18-Jul-16 A	18/Aug/17	Remaining Units							7	6	6	7	6	7	7
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Bjorn Eriksson	Ada	18-Jul-16 A	18/Aug/17	Actual Units	40		40	40	40	40							
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Bjorn Eriksson	Ada	18-Jul-16 A	18/Aug/17	Remaining Units							17	13	13	17	13	17	17
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Mikael Larsen	App	18-Jul-16 A	18/Aug/17	Actual Units													
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Mikael Larsen	App	18-Jul-16 A	18/Aug/17	**Remaining Units**							4	3	3	4	3	4	4
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Elin Hallander	Ada	18-Jul-16 A	18/Aug/17	**Actual Units**	40	40	41	22		43							
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Elin Hallander	Ada	18-Jul-16 A	18/Aug/17	Remaining Units							22	17	17	22	17	22	22
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Anders Wiren		18-Jul-16 A	18/Aug/17	Actual Units													
SR7.3	CBI	SR7.3-CBI-1010	SR7.3 ERTMS L2: CBI I	Anders Wiren		18-Jul-16 A	18/Aug/17	Remaining Units							28	22	22	28	22	28	28
Activity ID: SR7.3-CBI-1020						08-Aug-16 A	18/Aug/17	Actual Units													
Activity ID: SR7.3-CBI-1020						08-Aug-16 A	18/Aug/17	Remaining Units													
SR7.3	CBI	SR7.3-CBI-1020	SR7.3 ERTMS L2: CBI S	Fernoush Salehian	GA	08-Aug-16 A	18/Aug/17	Actual Units	32	40	21	42	40								
SR7.3	CBI	SR7.3-CBI-1020	SR7.3 ERTMS L2: CBI S	Fernoush Salehian	GA	08-Aug-16 A	18/Aug/17	Remaining Units							25	20	20	25	20	25	25

Source: Bombardier

Note: Every month, project members report their actual work hours and make forecasts under their work package.

Appendix 5: EAC Changes of the Two Projects





Note: EAC of these two projects increases considerably during the project lifecycle as their scope keeps changing.

Appendix 6: Definitions

Trackside Signaling System	Trackside signalling system is a complex system that combines hardware and software to enable communications between trains and the rail control center. By equipping tracks with transponders, the control center is able to determine the precise location of trains running on these tracks and provide them with instructions on how to operate, ensuring the trains are spaced at safe distances
2.1 Calculation	An excel template used to calculate the value and margin of a project. A Sales Representative input the cost and price information into the template and it will automatically generate the margin. It contains confidential information, and therefore, is only accessible to a few people.
Work Breakdown Structure	An exhaustive, hierarchical (from general to specific) tree structure of deliverables and tasks that need to be performed to complete a project. For example, a Trackside signaling project is usually broken down into software and hardware parts, which can be split into basic design, procurement, install, test and commission stages and further subdivided into pre-planning, system engineering and other work packages. WBS helps the project team better monitor and manage the project throughout its lifecycle and review the project performance at certain milestones.
Work package	A unit of work that is clearly distinguishable from other such units while being integrated with the schedules of related units. It has an assigned budget and a defined time span subdivided to facilitate measurement and control of scope, cost and time. A work package is usually controlled by one person or group within the project Core
As-Sold figure	As-Sold is the estimate and schedule produced by line organization at the WBS level. It's made by the bidding team at the beginning of a project and verified internally. In this paper, As-Sold serves as the baseline for comparison against the actual results. One exception is when a variation order is placed by a client, As-Sold will be updated as the scope of the contract changes and serve as the new baseline.

Line Organization	In line organizations, a supervisor exercises direct supervision over a subordinate. Also, authority flows from the top-most person in the organization to the person in the lowest rung. At Bombardier Transportation, the line organization is made up of three burden centers: Project Management, Engineering and ITC (Installation, Test and Commission), among which Engineering is the biggest center consisting of various cost centers including Software, Hardware, Safety, Validation etc.