





Effects of a repetitive approach when planning and constructing railway in Sweden

Master's Thesis in the Master's Programme Infrastructure and environmental engineering

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Department of Civil and Environmental Engineering Division of GeoEngineering Research group Road and Traffic CHALMERS UNIVERSITY OF TECHNOLOGY Gothenburg, Sweden 2016 Master's Thesis BOMX02-16-19

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Cover:

The crossing station in Daglösen under construction, the first part of the project Kil-Ställdalen described in chapter 10.2. The picture was taken by the author.

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ABSTRACT

The Swedish government is aiming for sustainability in which development of the railway network plays an important part. Already today the railway network runs on a high utilization capacity which makes large investments a necessity. This creates a need for efficient production strategies and this study will evaluate if more repetitive designing and production processes of railway in Sweden could be an option by stating possible effects of a repetitive approach.

Researchers agree that there is a significant learning rate for activities in the construction industry but that complete repetitions are hard to achieve because of the project based work with always new conditions. Some approaches to increase the amount of repetitions are already used in the industry, for example product platforms or standardization using prefabricated products. This could give shortened lead times and enable the workers to get familiar with a certain product family making the production more efficient. To fully take advantage of the learning outcomes it is important to have a well-working system for experience feedback but earlier made studies show the systems often are experienced as insufficient.

Interviews were held with ten persons at three different cases. One case was Trafikverkets initiative of making the production process more repetitive by coordinating all switch replacements in Sweden nationally. The others are two large projects including for example capacity improvements and construction of crossing stations. The interview results indicate that a more repetitive approach could give increased efficiency and the administrative work seems to be one of the main obstacles for a more efficient working process today.

Both the study of literature and the interview sessions speaks for a more repetitive approach. This could be done by for example standardization or larger procurements. It is also important to develop more standardized processes for the administrative work as well as improved systems for experience feedback.

Key words: Railway construction process, efficiency improvements, repetitions, experience feedback

Effekter av ett mer repetitivt arbetssätt vid projektering och byggnation av järnväg I Sverige

Examensarbete inom masterprogrammet Infrastructure and environmental engineering

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SAMMANFATTNING

Sveriges regering satsar mycket för ett hållbart samhälle och en viktig del i det är utveckling av järnvägsnätet. I dagsläget drivs det på en hög kapacitet och de kommande åren väntar flera stora investeringar. Därför vill man hitta effektivare produktionsstrategier och denna studie kommer att undersöka om en mer repetitiv process för projektering och produktion av järnväg kan vara ett alternativ genom att studera effekterna av en mer repetitiv järnvägsproduktion.

Tidigare utförda studier tyder på en betydande inlärningshastighet för flertalet processer i byggbranschen, men projektformen med sina ofta unika förutsättningar försvårar för en hög grad av repetition. Vissa metoder för att öka det repetitiva används redan i byggindustrin, exempel på det är produktplattformar och standalisering genom prefabricerade produkter. Detta kan korta ner ledtiden och gör arbetarna välbekanta med sina produkter. För att fullt kunna dra nytta av det repetitiva krävs ett välfungerande system för erfarenhetsåterföring, men tidigare studier tyder att de ofta upplevs som som onödiga eller bristfälliga.

Intervjuer genomfördes med totalt tio personer från tre olika projekt. Ett var Trafikverkets satsning på att nationellt koordinera alla spårväxelbyten för en ökad repetition och högre effektivitet. De andra var två stora projekt som inkluderade bland annat kapacitetshöjningar och byggnation av mötesstationer. Intervjuresultaten tyder på att ett mer repetitivt arbete kan leda till ökad effektivitet och att de största förbättringsområdena för ökad effektivitet finns i de administrativa delarna.

Både litteraturstudien och intervjuerna talar för en mer repetitiv process. Detta kan möjliggöras till exempel genom standardisering eller större upphandlingar. Det är också viktigt att utveckla en mer standardiserad process för det administrativa arbetet samt förbättrade system för erfarenhetsåterföring.

Nyckelord: Järnvägsproduktion, effiktivitetsökning, repetitioner, erfarenhetsåterföring

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Preface

This study was made from January 2016 to June 2016 and is a master thesis of the master's programme Infrastructure and environmental engineering at Chalmers University of Technology, Gothenburg. The aim is to contribute to a development and increased efficiency of the construction process of railway in Sweden by studying possible effects of a more repetitive approach.

Ten interviews were held to get an insight in opinions and possible effects, big thanks should be addressed to all participants that have contributed with valuable experience and thoughts. Big thanks are also addressed to the people at Tyréns which have been providing guidance and support throughout the process as well as providing a workplace in their nice premises. Also my supervisor at Chalmers University of Technology, Anders Markstedt, have been an appreciated support by discussing big and small concerns that emerged during the process.

Gothenburg, June 2016

Sara Edman

1 Introduction

A common issue on the political agenda in Sweden is how to achieve sustainable living, which includes safe, efficient and environmentally friendly transports. (Trafikverket, 2012a) Compared to other major transport modes, rail transportation is environmentally friendly and energy efficient and a modal shift to train traffic could play a part of achieving sustainability. However, the utilization capacity of the railway network is almost reached which is one of the main reasons for rail not taking a greater share of the total amount of transports. (Roso et al., 2014) Therefore, the Swedish rail network is now facing large refurbishments and modernizations. (Trafikverket, 2012a)

The construction industry has during the latest years to a large extent been focusing on achieving increased efficiency and productivity which are extra important when there is a large and increasing demand for investments. A common issue for a more industrialized construction process is the unique conditions presented by each project. Construction projects are almost always at new locations which make it dependent on site specific conditions like geology, local issues and available space. The open environment also makes the project dependent on unpredictable environmental factors such as weather and the equipment and material have to be transported because of the different locations. (Mohamed, 2001) The mentioned construction characteristics are one of the main obstacles for the serial approach and promote designing and planning from scratch.

However, many advantages can be seen with a more serial/repetitive approach. In other industries it have resulted in significant time and cost savings and an implementation in the construction industry can be possible. Studies have shown that knowledge-based improvement by for example experience feedback is a great tool for development in many industries and plays an important part of the repetitive approach. (Lee et al., 2015)

Since the construction industry is aiming at increased production efficiency it is of interest to see if a more repetitive approach in railway construction projects give any significant effects. It is also relevant to study how the companies are working with experience feedback since many of the benefits from the serial production will be lost if the learning outcome is not shared between the coworkers.

1.1 Aim

The aim is to contribute to the goal of finding more efficient ways to design and construct railway in Sweden by studying the effects of repetitive work, especially concerning required time and total cost. In addition, systems used for experience feedback at different companies will be studied since experience feedback could be an important tool to receive all the advantages with a more repetitive approach.

1.2 Research questions

To fulfil the aim of this research answer is given to the main question which is: What effects can come from a more repetitive approach when planning and constructing railway in Sweden and could it give increased efficiency? In order to get answers five sub-questions were stated which are:

- Do the companies have systems for experience feedback today? In that case how does it work?
- What difference can be seen when comparing similar activities conducted early in a project with later ones, particularly concerning time and cost? Also, have the process somehow changed along the way as a result of gathered experience?
- Are there any certain obstacles for a more repetitive approach?
- Has any initiatives been taken to achieve more repetitive work in Sweden? In that case, are there any noticeable effects?
- What advantages and disadvantages do the theoretical framework states about a repetitive approach in the construction process for railway?

2 Methodology

The research questions were answered by a qualitative research based on literature and semi-structured interviews. In addition to earlier made studies and information given at internet three cases were studied deeper. The chosen cases were located at different places and all including/included processes that are/were somehow repetitive.

To receive background information an extensive study of literature was done using internet databases and the Chalmers library. The study of literature gave information about for example the Swedish railway network, the construction process, possible effects of repetitive work and also some information about the cases.

Interviews with people involved in the different cases/projects were conducted to get a deeper knowledge about the projects. One part of the study was to gather their opinions and experience of a repetitive approach and a relatively unstructured approach was assumed to be the most suitable. In chapter 9 different interview techniques are described and in this project the semistructured approach was chosen. The most valuable information was expected to be given by using prepared questions with additional discussion objects and questions that rose during the conversation. The result from the interview sessions gave information about the possible effects on time and costs which is an important part of the evaluation of the repetitive effects. Furthermore, it was necessary to understand how the companies are working with experience feedback since it can play an important part of a more repetitive approach and also this was explained during the interview sessions. Both the design phase and the construction phase were studied and therefore the interviews were conducted with clients, project designers and contracted entrepreneurs. A template for the interview sessions can be found in Appendix but the questions were adjusted some depending on the response and given answers. Since the interviewees were stationed in different cities telephone contact was the best option for conducting most of the interviews and in some cases follow-up questions were answered by email. When there was a possibility of meeting in person this was preferred since it simplified the dialogue. To enable some preparation the interview questions were sent to the interviewees a few days ahead.

The three cases of study are (1) an initiative taken at Trafikverket to nationally coordinate all replacements of railway switches in Sweden, (2) the ongoing project of upgrading the 140 km long railway stretch between Kil and Ställdalen and (3) an investment in the southeastern parts of the Swedish railway network finished in 2013. After studying information given on internet the interview session started with a representative from the client which was Trafikverket in all three cases. The interviews with the clients gave a deeper knowledge about the projects and also contact details to representatives from contractors and project planners for further interviews.

While the interview sessions where conducted a smaller additional study of literature was done as a complement to the already found information. To answer the research questions the interview results were summarized and analyzed together with the results from the study of literature. Conclusions about possible effects were then taken based on the received results. During the whole process the consultancy firm Tyréns and supervisor at Chalmers University of Technology was providing guidance. A schematic picture showing the methodology can be seen in Figure 1.



Figure 1: Schematic illustration of the used methodology

3 Limitations

The study is limited to railway projects in Sweden consisting of some activities with similarities. The analysis will compare early parts of the projects with late parts mainly in terms of used time and cost both for designing and construction. Interviews were conducted with project managers at Trafikverket, a project designer and a contractor of three different initiatives/projects that are under construction or that has been finished during the past years.

This project was conducted during the spring 2016 and the number of cases of the study was limited because of time. However the projects had a geographic spread, involved several companies and where relatively recently conducted which makes them a good base for the study. It was hard to find comparable figures and therefore a qualitative approach was chosen. All interview participants were very helpful and gave great inputs to the work. The fact that the interviews were conducted in a relatively unstructured way could give a risk for somehow influenced answers.

4 **Construction process**

The construction process involves designing and construction as well as operation and maintenance and throughout the whole process many different actors are involved. To begin with an idea of the final product is specified including some needs and demands. Step two is the main design phase where construction documents are created; these are later used as a ground for the process of procuring contractors. Next part is the actual production which is based on the results from the design phase. The fourth and last step is usage which includes operation and maintenance. (Hultqvist & Jansson, 2013) A schematic picture showing the four major steps in the construction process can be seen in Figure 2.



Figure 2: Schematic illustration of the most common construction process.

The design phase itself includes several parts and starts with predesigning which includes a project programme with scope and budget that is discussed and evaluated by interested parties and professionals. In the next step different alternative concepts are brought up and environmental documents are completed. Further designing happens in the phase of design development which includes for example making plans of the construction and delivering some details about things as space accommodations, colours and specifications of serving systems. The final part of the design phase is creating the contract documents including for example drawings and specifications with information such as required quality and design. (University of California, 2013)

The result from the design phase is used in the following construction phase where the actual production takes place. Throughout the construction process check-ups are done to make sure that all requirements are fulfilled. Also followups and tunings are done after certain activities since some conditions that could impact the production are hard to predict or affect. (Hultqvist & Jansson, 2013)

4.1 Involved parties

There are many different actors involved in a construction process that all need to cooperate. The client is the one who orders the project and request building permit as well as make sure that legal laws are followed and it can be either an individual person or a company/organisation. The client needs to have a construction project manager who is responsible for coordinating the process, cost controlling and the procurement process. In some projects the project manager also has help from specialists of certain critical areas. To create the specifications and contract documents project planners are used and for the actual construction process there are also contracted suppliers which deliver material to the construction site. In addition to client, specialists, manager, project planners and contracted entrepreneurs there could also be separate companies hired for tasks like guarding, transportation or cleaning. (Söderberg, 2011)

4.2 Engineer-to-order

The construction industry with its engineered parts and specific projects mainly uses a production approach named engineer-to-order which mean that the customer/client is involved in the design and manufacturing processes enabling the final product to be highly customized. An engineer-to-order approach put high demands on the information flows between customer and suppliers and also requires a very clear and detailed contract. The process of an engineer-toorder production gives an opportunity to achieve a high level of customization but is also complex, involves several actors and demands more time than other production approaches. (Jonsson, 2008)

Another production strategy that also allows a relatively high degree of customization is the make-to-order approach. The product is then created when the order is received which give some flexibility to the process. The major difference from the engineer-to-order strategy is that the customers are less involved in design and manufacturing processes. (Jonsson, 2008)

4.3 Construction contract forms

8

There are several different ways to procure contractors. One way is by performance contract which means that consultancy firms are contracted for the earlier parts including investigations and project planning and based on the results from that the contractors are procured also by the client to handle the actual production. An example of a performance organization can be seen in Figure 3, note that three different consultancy firms are hired separately for tasks connected to different areas which can be for example electricity, ventilation and sanitation. (Nordstrand, 2008)

This way of procurement constricts the contractors to work according to the delivered documents and it could be either one contracted firm for all production work or many different that are responsible for different parts. (Nordstrand, 2008) The main contractors can however still hire subcontractors as well as suppliers. Procuring performance contracts brings an opportunity to invite the best tenders for each area but also lead to relatively high administration costs. A

benefit with this type of organization is that it allows the project planning to partly be done after starting the actual construction process, hence giving an opportunity to start the construction process earlier. However, a great responsible lies on the client which could have increased risks such as compensation of faults, coordination failures and hardness to point out the responsible actor if something goes wrong. (Söderberg, 2011) One way to decrease the administration costs is by contracting only one company for all jobs at the construction site thereby making the client less responsible for coordinating the construction processes as in the example seen in Figure 3. All other contractors are than hired as subcontractors by the first contracted entrepreneur with potential exceptions from some companies like machine firms that can be hired separately. (Söderberg, 2011)



Figure 3: A schematic illustration of an organization based on a performance contract.

Another commonly used contract form in Sweden is the design-build procurement where only one contract is given and the contractor is then responsible for both project designing and production, an illustration of how the organisation could look like can be seen in Figure 4. This can give higher costs for the client in the earlier parts of the project but also means less time and lower costs in the early design phase since the documents do not have to be as complete as if complete construction specifications were required. (Söderberg, 2011) Design-build contracts could encourage innovative and smart solutions from the contractors since they are responsible for the whole process and Trafikverket has during the latest years aimed for a greater share of design/build contracts. One of the major risks with this type of entrepreneurship is that the result might not be the best in a long-term perspective since the contractors of course always strive for as profitable solutions as possible for them. Therefore this approach put high demands on well formulated specification documents including quality requirements. Since the contractor is responsible for the whole process it means minimal risks for the client in terms of increased costs from faults or passed time limits. (Söderberg, 2011)



Figure 4: A schematic illustration of an organization based on a design/build contract.

One approach to organize the cooperation between the involved actors is by the partnering concept which means that the involved actors work together to reach a common goal. By early contracting of both consultants and builders the usual design-bid-build process with late involvement of builders is avoided and it is easier to cooperate between companies. The idea is to encourage engagement and creativity as well as trust and respect for each other's work. (Byggherrarna, 2016)

5 Railway in Sweden

The Swedish railway network, which is illustrated in Figure 5, consists of approximately 16 500 km of rail tracks covering large parts of Sweden and plays an important part in both passenger and freight transportation. (Trafikverket, 2015a)



Figure 5: The Swedish railway network. Picture from <u>www.trafikverket.se/resa-och-trafik/jarnvag</u>.

In the year of 2014 the amount of freight transported by rail in Sweden was about 22 billion tonnes km which represents about 22 % of the total share. Figure 6 shows the split for all main freight transport modes except from aviation in Sweden 2014. (Trafikanalys, 2015a) One important stretch for the freight transport is in Figure 5 marked with a green line in northern Sweden going through Kiruna. It is called Malmbanan (eng. Ore line) and allows an axle load of 30 tons which is the largest allowance in Sweden. (Trafikverket, 2014a) 2014 this stretch transported 42 % of the total amount of freight transported by train in Sweden. (Trafikanalys, 2014)



Figure 6: The modal split for freight transport in Sweden 2014. (Trafikanalys, 2015a).

The passenger transports on the Swedish rail network were in 2014 estimated to approximately 12 120 million passenger-km which can be compared to the amount of vehicle-km by road the same year which were 66 155 not considering the Lorries since they are assumed to mainly transport freight. (Trafikanalys, 2014) (Trafikanalys, 2015b) Note that the amount of transports by road are given in vehicle-km and not passenger-km and to receive a completely comparable value the number has to be multiplied with a factor representing the average amount of passenger in a vehicle. One important railway stretch for the passenger traffic is going between the two largest cities in Sweden, Stockholm and Gothenburg (Sw. Göteborg) and is marked with pink in Figure 5. It is called Västra Stambanan (Eng. Western trunk line) and has double tracks allowing both freight- and passenger transports. This stretch is highly trafficked and runs on a very high capacity. (Trafikverket, 2015b)

5.1 Further development

Trafikverket, the national road administration in Sweden, made a ground for how to develop the transport network towards cost efficiency and sustainability for the time period 2018-2029. Among other things, the report highlighted the importance of using rail for mid-distance transports. Forecasts indicate that the demand for transports will increase and also that a shifting of demand will occur as a result of globalization and urbanization. Without further political measures the total amount of freight transports are expected to grow with about 55 % between the years of 2010 and 2030 and the freight transported by rail is during the same time period expected to grow with 37 %. (Trafikverket, 2015c) An illustration of Trafikverkets prognoses for rail transports can be seen as blue dotted lines in Figure 7 where the red one shows earlier measured values. (Trafikanalys, 2015a) Trafikverket states that also the total amount of passenger transports are increasing as well as the railway transport share. (Banverket, 2004) However, the demand for railway transportations has increased for several years without equivalent investments and maintenance which have resulted in an already high utilization and disruption sensitivity in the railway network. (Trafikverket, 2015c) In addition, an EU policy to achieve modal shift goals states that 30 % of the total road freight transport over 300 km should shift to rail transports or shipping before 2030 and 50 % before 2050. (European commission, 2011)



Figure 7: An illustration of the estimated amount freight transport by rail in Sweden given in billion tones km. The blue dotted lines represent prognoses and the red one shows earlier measured values. Figure taken from the report *Bantrafik 2014* made by Trafikverket.

ERTMS stands for European Railway Traffic Management system and is an important part of the development of the Swedish rail network. The ERTMS project was developed to simplify train transports across European countries which are now controlled by more than a total of 20 different train control systems. The system includes an automatic train protection system and a radio system which makes communication between trains and tracks possible. Compared to the system used today this will significantly increase the capacity and also makes the timetable more reliable. Gradually the ERTMS system will be replacing the earlier system in Sweden as well as the other former systems in Europe. (ERTMS, 2013)

5.2 Productivity improvements

Trafikverket has a goal to increase both productivity and innovation in the industry and is continuously working to reach this goal. It is stated that the productivity should increase by 2-3 % each year at least until 2025. One measure to reach the goal is that Trafikverket since the start in 2010 only should take the role of client and thereby give more responsibility to the suppliers. Another example is that a greater share of the consultancy jobs should be contracted to a set price thereby encourage them to be more innovative and productive. Another part of giving the contractors more responsibility is to procure a greater share of the projects as design/build contracts. This change puts new demands on the contractors, like more expertise in areas like planning, controlling and regulatory requirements. Also the consultancy firms now need more expertise in areas like technical issues, function descriptions already at early stages and project managing. (Trafikverket, 2014b)

6 Learning curve theory

One way to increase the production efficiency is by learning development. If a person performs similar tasks many times he/she gets familiar with the particular process and thereby works faster. This means that when a process is performed by the same staff many times the efficiency improves over time. (Ammar & Samy, 2015)

Learning-curve theory is a way of describing learning by experience graphically and is traditionally used to describe learning in the manufacturer industry. Some researchers believe that it can be adapted to the construction industry while other studies show a too big gap between reality and theory. There are different mathematical models describing learning-curves and the one that fits the construction industry best is the straight-line model, which means that the learning rate remains constant over the production time, see Figure 8. Learning rate is the percentage reduction in the unit input (e.g., cost or time). Note that the original curve actually is exponential but that the logarithmic curve is straight which gave the name of straight-line model. (Lee et al., 2015) However, Lee et al. among other researches believes that the traditional learning-curve is not fully applicable to the construction industry, but still states that repetitions give increased learning. Hijazi, Abourizk & Halpin (1992) brings up the construction project characteristics (weather, noise, equipment, accessibility etc.) as a major issue when determining the learning rate. The conditions for each project vary too much to predict the learning rate, which will most likely be random and not constant. (Hijazi, Abourizk, & Halpin, 1992)



Figure 8: Graphs describing learning curve - straight line

Although the effect of learning by experience is commonly known in the construction industry it is often not accounted for when designing and producing constructions. Ammar et al. highlights that this brings a risk of wrong decisions being taken about for example needed amount of staff or machines. (Ammar & Samy, 2015)

7 **Experience feedback**

A tool to improve the quality and efficiency of coming projects is experience feedback; it is a knowledge-based improvement and means that information sharing is used for development. The construction industry relies heavily on the knowledge of the participants of a project and experience feedback is often seen as a key issue for progresses in a long-term perspective. (Forcada et al., 2013)

However, it can be difficult to achieve a high level of learning from experience in the construction industry since the work is project-based with various teams between projects and subjects which put high demands on a well-developed system. (Jabrouni et al., 2011) The very project-based production is something that differ the construction industry from many other industries and could complicate the process. Temporary teams are created to fit each project which could give a relatively unstable organisation compared to more fixed traditional strategies. (Engwall, 1995) Furthermore, a tight schedule and a tight budget are common for construction projects which make it harder to add extra work like sharing knowledge. (Kamsu-Foguem & Abanda, 2015)

Interviews with different parties in the Swedish construction industry were handed out by Hultqvist & Jansson (2013) and it showed that many find the experience feedback insufficient. Also, the industry is now facing a generation renewal which without proper feedback results in much experience getting lost. The consequence of this could be that similar errors are made several times during both designing and construction resulting in unnecessary use of resources. (Hultqvist & Jansson, 2013) Also a report handed out by Boverket states that there is insufficient experience feedback in the construction industry. Many companies actually have systems for experience feedback but it is very seldom used by the employers and Boverket ends the report by stating that *"the most common error in the construction industry is repeating the same errors over and over again".* (Boverket, 1992)

Organizational learning is a concept meaning that experiences are shared between co-workers within the same organization. The idea is that individual learning from experiences should give learning also for other employees and thereby improve the working process within the entire organization. Organizational learning is relatively easy to achieve at smaller companies with a low amount of staff but can be very complex at large organizations where a welldeveloped and systemized system is needed. Achieving a high degree of organizational learning requires engagement from the employees who need to keep the system up-to-date to get the possible benefits. (Mellander & Nystedt, 2005)

Lean production is a concept first developed for the automotive industry and is now commonly used in many industries aiming at reducing waste, limiting errors and receiving a more efficient production by reducing the amount of nonvalue activities. The earlier mentioned construction industry characteristics make it hard to apply the exact methodology and adjustments have therefore been done to the Lean production approach to fit the industry resulting in the concept Lean Construction. Lean construction is also aiming at increased efficiency and two things that play important parts of the approach are systems for experience feedback and standardized products. (Mellander & Nystedt, 2005)

8 **Repetitive work in the construction industry**

There are some construction projects with a relatively large amount of repetitive tasks and these could be called repetitive construction projects. Examples of such projects are high-rise buildings, highways and pipelines and these could be divided into (1) typical projects where major tasks are almost identical with same expected duration or (2) non-typical projects where some parts differ between sections. (Baqerin, Shafasi, & Kashani, 2015) Repetitive work is not only beneficial considering the learning rate but also allows some processes to be reused in coming projects and thereby save time for the project planners.

Nguyen, L.D. & Nguyen H.T. are two researchers that have studied the labor productivity of two activities involved in construction of high-rise buildings. The activities were conducted similar on each floor which gave repetitive tasks for the skilled workers. The study showed a significant learning rate that declined over time which means that a larger difference was seen between the bottom floors than the top ones. The learning rate differed also between the two activities, one of them were more modular which resulted in productivity improvement declining earlier. (Nguyen & Nguyen, 2012)

Larsson et al. (2012) made a study of how to industrialize the construction process and in particular infrastructure projects. Exceeded budgets and overran schedules are common for infrastructure projects and the productivity is increasing slowly. Achieving increased industrialization has proven difficult for the project-based production and companies struggle with finding a good balance between uniformity and variation. Many researchers mention process platforms (see chapter 8.2) as a possible solution to the problem of achieving both high production volumes and flexibility. The design-bid-build approach with early involvement of the project planners but late involvement of builders could hinder the contractors' ability to work repetitive since they cannot impact the construction during construction which could hold back development. But not only the contract form is an obstacle for the more standardized process, also the fact that the industry is relatively conservative causes problems and attitudinal changes are needed. (Larsson et al., 2012)

The project based way of working can be problematic in a long-term perspective since temporary teams most often are used. The study of Larsson et al. indicates that repetitive work and experience feedback are two of the most important elements to reach a more industrialized approach. Furthermore, the report highlights that the client is highly responsible in the work of achieving a greater efficiency since they manages many of the barriers. (Larsson et al., 2012)

8.1 Prefabricating

Prefabrication means that manufacturing takes place at a location other than where final installation is planned. This could be in factories or at temporary places closer to the construction site. Pillars/beams and surface elements are relatively often prefabricated while it is more uncommon for volumetric elements. The basic idea with prefabrication is to protect the production process from unpredictable weather conditions and to shorten the manufacturing time at site. (NE, 2016) Prefabrication is often used when constructing parts for small buildings like houses. Commonly elements for roof, walls and tier of logs are prefabricated to later be put together at site. This significantly decreases the required manufacture time at site and also has a possibility of decreasing the total amount of waste. (Eriksson & Mellbert, 2007) Since about 2000s the approach has played an important role in the efficiency development process also for railway constructions in Sweden and as an example the railway switches are today most often prefabricated.¹

8.2 **Product platforms**

Product platforms are used to develop products in a quick and efficient way. The researchers Robertsson & Ulrich define product platforms as "a collection of assets that are shared by a set of products" where assets can be components, processes, knowledge or people and relationship. The platforms are an important part of mass production since it enables productions in high volumes. The products are then often somehow tailored in the end of the process to meet the customers' individual demands. A schematic illustration of a platform model can be seen in Figure 9 where all products are based on three different platforms all characterized by different assets. All products developed from the same platform and thereby with the same processes create a product family with tiered prices. (Robertsson & Ulrich, 1998) Tiered price setting means that the product or service is provided at different price levels to gain the best possible profit, if a product cost 10 \$ but there are customers willing to pay for example 40 \$ there could be different varieties of the product available also with a higher price setting. (Perhac, 2016) Some of the benefits with shared assets are that (1) fewer investments are needed since machines etc. can be used for higher production volumes, (2) decreased risk in terms of investment since each new product is developed from a platform and (3) higher service level since less stock is needed if components are shared among several products. Furthermore, production is cheaper per unit if it is done in large volumes and also development processes cost less since fewer tests are needed. An example of a successfully developed product platform is the one for the Kodak camera where four product types where developed from the same base model. The cheaper and faster production gave an opportunity to come up with new products more often than competing companies and thereby they increased their market share. However, it is important to keep some distinctiveness, if too much assets are shared among the products they will be too alike and then not sell. (Robertsson & Ulrich, 1998)

¹ Anders Boëthius, 2016-02-18 email and telephone contact



Figure 9: The Power Tower model of a platform (Meyer & Lehnerd, 1997)

In the construction industry cost and duration of many activities are hard to predict partly because of a relatively unstable supply chain. The idea of product platforms is to standardize technologies and increase the degree of repetitive work which could result in a more predictable supply chain. However, the platform approach was initially developed in industries producing products according to the make-to-order strategy (e.g. automotive industry) and the construction industry is seen as one of the largest engineer-to-order industries. Clients in the construction industry often strive for unique products and standardization is avoided which makes the implementation of product platforms a bit difficult. If the approach should be used it is important to get the benefits without limiting the distinctiveness of the final product. Usually the product families are formed for products sharing communal and some distinctive assets before order, which some researchers do not find applicable to the construction industry where the distinctive parts should be possible to affect as the client. Instead of the usual platform design the commonalities could be combined with the distinctiveness by different support methods. The support methods will adapt the standardized product platforms to the unique conditions at the specific project. As an example a company can use timber-framed modules in a building construction that are standardized but yet engineering is needed to make them match the site conditions. (Jansson, Johnsson, & Engström, 2013)

Platforms can be seen as a way of storing the experience and knowledge gathered from designing and manufacturing that could give value in future projects. Storing knowledge is extra important in processes with an engineering-to-stock approach but today the industry share knowledge mostly through local networks and oral communication. An example of a successfully used platform in the construction industry is a housing platform used at a German company which resulted in a reduction in total cost by approximately 30 % and also improved quality and gave shortened lead times. (Jansson, Johnsson, & Engström, 2013)
9 **Interview techniques**

Interviewing is a commonly used method to collect data and it can be done in different ways. In structured interviewing the same questions are asked in the same order to each person and without any further explanations or follow-up questions. This survey approach can be seen as a questionnaire and the result is often relatively easy to compile and compare in an efficient way. A more flexible approach is unstructured interviewing which is more like a conversation without prepared questions. This allows for questions to develop during the interview depending on the response from the interviewee. The third interview technique, semi-structured approach, is neither as strict as the structural one nor as flexible as the unstructured one and it is often used in qualitative research. Usually the main topics are stated and some questions are prepared in advance. However, the questions can change, be asked in different orders and in different ways depending on the interviewee and given response. (Edwards & Holland, 2013)

10 Case studies

This chapter is based on the study of literature and received interview results. General information about the projects was found mainly during the internet searches while more specific information about procurement, design phase, construction phase, times and costs were gathered during the semi-structured interviews. A list of all persons that participated in the conducted interviews can be found in Appendix and in Figure 10 below. The overall view of a more repetitive approach can be seen in chapter 10.4. All results are summarized in chapter 10.5.



Figure 10: The interview participants divided by project and role.

10.1 National coordination of railway switch replacements

As a part of Trafikverkets' goal to increase their productivity and to be more innovative all railway switch replacements in Sweden should be coordinated nationally and prefabricated switches that are placed using a certain railmounted crane should be used whenever it is possible. (Trafikverket, 2012b) The supplier of the crane as well as the prefabricated switches is a German company named Vossloh² and the crane, named Kirow crane, can be seen in Figure 11. Practicing this method can result in cost savings and also valuable time savings which mean less disruption on the network. (Trafikverket, 2012b)



Figure 11: The Kirow crane which is used in Sweden. Picture from Trafikverket.se.

Anders Boëthius at Trafikverket who is responsible for the crane contract and highly involved in the initiative says that the basic idea was to work more serial with similar projects across the country and to use the same staff as much as possible. This approach allows things such as specifications, base documents for procurement and management proceedings to be reused and thereby increases the efficiency. To handle this across country projects a certain department at Trafikverket was created which is called national projects (Swe. Nationella Projekt).³ This department is supposed to find packaging possibilities for activities and makes the production more efficient by using a serial approach.⁴

Replacement of railway switches was seen as a repetitive task usually performed in about the same way and was therefore considered suitable for national coordination. However, all parties did not agree, some clients believed that the preconditions usually are too unique for the serial approach and also that other activities (like earthmoving or moving poles for overhead wires) often made at the same time as the actual switch replacement should be considered when deciding on method.⁵

By planning the crane route depending on season the crane usage can be optimized, during the summer months the crane is in northern Sweden and then it moves south as the climate gets colder. (Trafikverket, 2012b) The hardness of cutting the traffic flow at many locations lowers the utilization rate by forcing the replacement to be done mainly during weekends. In addition, there are some

² Anders Boëthius, 2016-02-18 email contact

³ Anders Boëthius, 2016-02-18 email contact

⁴ Anders Cinthio, 2016-02-25, telephone contact

⁵ Anders Boëthius, 2016-02-18 email contact

risks connected to the fact that there is only one Kirow crane in Sweden since detailed scheduling has to be done several months ahead. 6

10.1.1 Response from the industry

Boëthius at Trafikverket experiences a quick adaption to this new approach in an otherwise fairly conservative industry. The resistance has decreased a lot since the start date in 2013 and this season the crane is already almost booked up. He estimates that about 70 % of all switch replacements were done with the crane last year, which can be compared to about 20 % the first year in use. One of the main disadvantages is the cost, which is higher than for other switch replacement methods. The high cost is of course partly connected to the fact that it generally must run during weekends. Boëthius states that the greatest benefits are that the method demands much less time and often has much better access to tricky spaces.⁷

Anders Cinthio is working as a project manager at Trafikverket and has been managing many switch replacement projects and he sees a lot of the possible benefits with the initiative even though he thinks that it works better in theory than in actual production. The national coordination means that the project managers at Trafikverket often has to work remotely, which Cinthio sees as one of the major disadvantages with the initiative. It makes it a lot harder to manage the project and you have to put a lot of faith in that the contractors work as they should and delivers the agreed quality. Anders Cinthio thinks that it is important that at least one representative from Trafikverket is present at site and if it is not the project manager it could be another employee at Trafikverket or a hired consultant. However, if there are not too many replacements grouped together and enough time is given for establishment he does not believe that a geographically widespread procurement causes any problems for the contractors. During the past years of implementing the initiative Cinthio has experienced some issues connected to lack of preparation in the industry.⁸

Fredrik Nilsson is working as site manager at the firm Strukton Rail and has been managing several switch replacement projects. He thinks that the basic idea of national coordination of switch replacements is good and that it theoretically works well but that the implementation could have been done better. He experienced that the development of the initiative was based on a lot of assumptions rather than on a dialogue with of all affected parties like contractors, switch suppliers and consultancy firms. The approach as it is now limits the options for the contractors since Trafikverket is providing material and also schedules the replacement. This limitation creates a situation where better optional solutions based on earlier experience might be excluded already from start. Another negative aspect with the procurement design is that many time-consuming discussions about responsibility occur as a result of the contractor being in charge of everything but the actual switch. Nilsson thinks that it could have been preferable to make the contractor in charge also of the switch even if there will be a restriction to use Vossloh as supplier. The contractor is already now the one that has to cooperate with Vossloh and do a lot

⁶ Anders Boëthius, 2016-02-18 email

⁷ Anders Boëthius, 2016-02-18 email

⁸ Anders Cinthio, 2016-02-25, telephone contact

of the work connected to switch replacements even if Trafikverket has the actual responsibility.⁹

A consultant that has been involved in many switch replacement projects during the past years is Thomas Axelsson, technical manager at the consultancy firm ÅF and also he sees some possible improvements with the new initiative. Like Fredrik Nilsson he likes the basic idea and sees a possibility of achieving a more efficient process, especially since the Kirow crane is a very time efficient option for replacing switches. However, this new initiative demands a lot of administrative work with coordination etc. and also limits the possibilities, it is practically an exception that something but prefabricated switches placed by the Kirow crane are used. The fact that the companies are controlled to use the crane and prefabricated switches decreases the competition, especially for design/build contracts. If Trafikverket aims for increased productivity and innovation in the industry Axelsson thinks that more freedom of action has to be given to the consultants and contractors.¹⁰

10.1.2 Time and cost

Trafikverket has not yet evaluated the effects on time and cost from the initiative. Cinthio who works as a project manager describes that when repetitions are made – as with this approach - all parties gets a mindset that fits that working approach and that the gathered experience can simplify for coming projects by decreasing the risk for mistakes. Some economic savings for Trafikverket can also come from quantity discount when several tasks are procured together. The effects resulting only from the repetitive approach are however hard to state. The total cost, which varies between about 3 and 6 million SEK, as well as the used time, are almost impossible to compare between the different switch replacements since the projects all are too complex and different from each other.¹¹ The use of the Kirow crane makes the replacements a bit more alike but there are still many other influencing parts. Some things are even impossible for the project participants to control since the final outcome could be dependent on external planners or projects. Cinthio brings up the importance of getting the whole picture before planning and that there often is a lack of sufficient coordination between all parties. As earlier mentioned, it could also be problematic that the replacements are being scheduled during evenings and weekends which gives a higher cost.¹²

Fredrik Nilsson at Strukton Rail does not think that the approach gives any noticeable economic effects for the contractors. However, there could be benefits in terms of time savings since there are parts and processes of the administrative work that can be reused. It was more uncertainties about coming activities during the earlier conducted projects that made the process more time consuming. When everyone are familiar with the replacement method, they know what to expect and when to expect it which simplifies the daily work and give an opportunity to always be one step ahead. Regarding the technical parts there are not much of the earlier conducted work that can be reused and the

⁹ Fredrik Nilsson, 2016-03-07, telephone contact

 $^{^{\}rm 10}$ Thomas Axelsson, 2016-03-07, meeting

¹¹ Anders Cinthio, 2016-02-25, telephone contact

¹² Anders Cinthio, 2016-02-25, telephone contact

execution has not changed as a result of the initiative. Nilsson highlights that switch replacements are often very complex and highly dependent on site conditions which makes it hard to use an industrial approach. In addition, Nilsson sees a trend towards less time with cut tracks for the replacement work which leads to higher costs for construction. This put demand on 24-hour work when the train traffic is cut which means that more staff is needed for each machine since they need to have substitutes. Less time to work with the tracks cut also makes it harder to make preparations in an optimal way.¹³

Concerning the time required for replacement, Nilsson sees great benefits with the Kirow crane and states that it can give a significant time reduction. However, he questions the procurement between Trafikverket and Vossloh. Since about all switch replacements should be performed with the crane it unables other possible and perhaps better solutions. For example in projects where there is much time with cut tracks it could be cheaper to construct the switch at site. In addition, the technical competence of constructing railway switches at site will eventually be lost if about all switches are prefabricated.¹⁴

Axelsson at ÅF thinks that the repetitive approach most likely would result in cost and time savings, but Trafikverket is adding new requirements each year which make it hard to fully achieve repetitions and to evaluate the effect. Much more information than earlier are required by Trafikverket which give more administrative work for involved parties and thereby increases the cost. This is seen as a problem and Axelsson believes that Trafikverket could be focusing more on increasing the efficiency rather than gathering – sometimes un-useful – information.¹⁵

Like Cinthio and Nilsson, Axelsson brings up that each switch replacement is unique including too many details for achieving a more complete repetitive approach with earlier made solutions being reused to a higher degree. It is not possible to just replace an old switch by a new one with the same method each time partly because of the problem with adjusting a new switch to older tracks. However, routines given from repetitions could simplify the work with coming ones and it is possible to reuse things such as document templates and computer settings with only few adjustments. Learning comes from each project and Axelsson stated that if coming projects has similarities with already completed projects it is easier to know the requirements and what parts that is important to keep extra track on. The fact that the switch replacements are almost always done during weekends with a relatively short amount of time with cut tracks has negative impact on the costs.¹⁶

10.1.3 Experience feedback

For the initiative of nationally coordinating switch replacements there is no central system for experience feedback other than what is orally shared between coworkers. Trafikverket has decided that the client and involved consultancy firms as well as the contractors should meet after each finished project to discuss possible learning outcomes that could give benefits in coming projects. However

¹³ Fredrik Nilsson, 2016-03-07, telephone contact

¹⁴ Fredrik Nilsson, 2016-03-07, telephone contact

¹⁵ Thomas Axelsson, 2016-03-07, meeting

¹⁶ Thomas Axelsson, 2016-03-07, meeting

this is not always done and when it is done the experience is shared only between the participants and not handed to other co-workers. Anders Cinthio thinks that relatively much specific learning outcomes could be listed after each finished project and that a better feedback system has the possibility to decrease the risk of losing valuable experiences.¹⁷

A department at Trafikverket has actually developed a system for experience feedback where the project managers are supposed to write down some specific information after each finished project. However, Cinthio explains that this is not used much at all and that he does not use it in his daily work. The construction firm Strukton Rail just lanced a new system for sharing experiences including meetings and filling out documents. The system is however not yet used by the employers which make it hard to evaluate any possible effects.¹⁸

The rail department at ÅF has its own system for experience feedback. Everyone within the same technical area builds a network which share gathered experience. Meetings are held every other week where interesting ideas, knowledge and newly gathered experience are shared and discussed. Also, one seminar is held every year where everyone brings up interesting experience from the past year. These gatherings make the coworkers know each other better and thereby simplify for communication. In addition to the orally shared experience ÅF has a database including earlier successfully conducted projects. This database is systemized and has photographs and descriptions of good solutions for the employees to learn from. Axelsson thinks that the experience feedback at the rail department of ÅF works well and he benefit greatly from the network in his daily work.¹⁹

¹⁷ Anders Cinthio, 2016-02-25, telephone contact

¹⁸ Anders Cinthio, 2016-02-25, telephone contact

¹⁹ Thomas Axelsson, 2016-03-07, meeting

10.2 Project: Kil – Ställdalen

The capacity of the railway stretch between Kil in Värmland and Ställdalen in Västmanland is now upgraded. The total stretch of 140 km is divided into three parts where the first was constructed in 2014 and the last will be completed 2018. In places where there were existing passing tracks (Daglösen and Hällefors) adjustments will be done and at four destinations (Sandmon, Geijersdal, Herrhult and Kejsarbäcken) new passing tracks are constructed. The whole stretch including crossing stations can be seen in Figure 12 below, note that Kejsarbäcken crossing station is named Bredsjö in the picture which was the name proposed at start. The upgraded stretch will be controlled by the ERTMS management system which was described in chapter 5.1. The main goal is to increase the capacity and thereby also relieve the pressure on Västra Stambanan. Since there are going to be an increased number of passing trains, and possibly higher speeds, the project also includes looking over as well as adjusting, replacing or remove level crossings. (Trafikverket, 2016)



Figure 12: Map over the railway stretch between Kil and Ställdalen which will be upgraded within the project. Picture from Trafikverket.se.

The whole project was divided into three different production parts starting with reconstruction of the station in Daglösen, E1, at the middle part of the stretch. Today the second part of the stretch, E2, is under construction and goes from Ställdalen to Daglösen. It includes 70 km of rail, two new crossing stations (Herrhult and Kejsarbäcken) and reconstruction of the station in Hällefors. Construction of the operation stations in Kejsarbäcken and Hällefors are now finished as well as the tracks between Ställdalen and Hällefors.²⁰ The third and last part, E3, is the stretch southwest from Daglösen including the crossing stations Rådom and Geijersdal. All three parts of the stretch have about the same basic issues including a centralized train control system, construction of crossing stations and increasing capacity.²¹

²⁰ Joakim Svensson, email 2016-03-15

²¹ Lovisa Björkner, 2016-03-23 meeting

10.2.1 Procurement

All work connected to the project planning was contracted by the consultancy firm Tyréns which is responsible for delivering documents such as plans, construction documents and operation information. The construction contracts were given separately for the three different parts and all as performance contracts. For part one the contracted entrepreneur was SJT (Svensk Järnvägsteknik AB) and for the second part it was PEAB.²² The third part which is not yet under production has recently been contracted by NCC.²³ The project planning phase before the procurement process took about 4 months and the production will take 5 months for each part.²⁴

The main reason for choosing this way of procurement was time savings. It takes time to finish the railway plan (Swe. Järnvägsplan) which is needed before the actual construction process and by dividing the project several actors could work with different tasks continuously. This allowed the construction process of earlier parts to start while they were working with the procurement process and designing of following ones.²⁵

10.2.2 Time and cost

Martina Rydberg, project manager at Trafikverket, thinks that the working process has improved throughout the project and that development can be seen when comparing an early part with a later one. Some of the prepared documents and templates could be reused for the planning process and for the construction phase the working procedures has been adjusted and continuously improved. The fact that about the same team from Trafikverket and Tyréns was working with all parts of the project made it easier to learn from earlier experience.²⁶

Since several crossing stations were procured together possible time and cost savings from the repetitive approach do not show for the client as the contractor has accounted for potential savings before the procurement process. However, it can be assumed that the total cost for the client is lower when the stations are procured as a package compared to if they were contracted separately.²⁷ Joakim Svensson, working at PEAB, states that the advantages from a serial approach definitely are accounted for in the tender and most of the savings come from organizational benefits. If they are contracted for much work at a certain stretch the total cost for establishing can be decreased in comparison to a scenario were all crossing stations are produced separately. However, the serial approach does not impact the actual production as much. PEAB was responsible for the grounding issues while they had subcontractors for the other technique areas. Svensson brings up that even if the basic procedures are similar the geology at each location differs which makes it hard with a repetitive approach for the earthwork. However, he thinks that there is a possibility that a repetitive

²² Martina Rydberg, 2016-02-26 telephone contact

²³ Lovisa Björkner, 2016-03-23 meeting

²⁴ Martina Rydberg, 2016-02-26 telephone contact

²⁵ Martina Rydberg, 2016-02-26 telephone contact

²⁶ Martina Rydberg, 2016-02-26 telephone contact

²⁷ Martina Rydberg, 2016-02-26 telephone contact

approach works better for the other technique areas and the extent of the effects depends a lot on given preconditions.²⁸

An estimation of potential savings by comparing complete separate costs for the three stations contracted by PEAB will require too much information. Also, the conditions for the three stations differed relatively much which limits the possibilities to work repetitive and makes it hard to achieve a fair comparison. As an example of the different conditions one station were built in a forest without connected roads while another were built in a smaller community.²⁹

Tyréns was contracted with current account which makes it possible to estimate the cost savings from the serial approach also for the client. When looking at the time and cost used for designing a pattern can be seen with a lower cost for the later crossing stations than for the earlier ones and the reduction can also to some extent be seen for the electrical-, signal- and telecommunication issues. For the earthwork it is more difficult to work repetitive since it is important to make tests and plan for the actual location.³⁰

Lovisa Björkner has been managing the project at the consultancy firm Tyréns and she sees positive effects with packaging smaller projects into bigger ones. Even if it is hard to achieve complete repetitions for the technical parts much value comes from organizational benefits and in this project the organization has been as good as unchanged throughout the whole process both at Tyréns and Trafikverket.³¹ Also Björkner states that many of the crossing stations differ too much to make a fair comparison of just the total costs as an evaluation of the possible effects of a repetitive approach, mainly because of the different preconditions and also because of the hardness with finding fully comparable and clear quantities. Two of the crossing stations included in the project is very much alike, Sandmon in E3 and Kejsarbäcken in E2 and the aim was to make the specifications for Kejsarbäcken as complete as possible before starting the work with Sandmon and thereby enabling as much documents and solutions as possible to be reused. Björkner states that a lot of their work could be reused and a comparison of the two stations shows a great reduction of used time and also of total cost. It can also be seen that the overall additional costs were less in the production of E2 than in E1 probably as a result of a great reduction of significant errors in the contract specifications. ³²

Björkner thinks that it was good to procure Daglösen separately and as the first part since it included almost all technical areas needed throughout the project. By starting with a relatively small part that required many technical areas the organization developed and working approaches could be set together with Trafikverket. Proper arrangements were done and issues concerning things such as documentations, deliveries, communication and schedules were solved. This resulted in extra costs for E1 but lead to a more efficient organization for the other parts since much of the planning process could be repeated with only some

 $^{^{\}rm 28}$ Joakim Svensson, 2016-03-17 telephone contact

²⁹ Joakim Svensson, 2016-03-17 telephone contact

³⁰ Martina Rydberg, 2016-02-26 telephone contact

³¹ Lovisa Björkner, 2016-03-23 meeting

³² Lovisa Björkner, 2016-03-23 meeting

adjustments. If more than one crossing station had been included in part one also those would most likely have been more expensive.³³

Tyréns do not have any direct economic gain from making the work as efficient as possible since they are paid for each invoiced working hour meaning that their income increases with used time. However, Björkner brings up the importance of being engaged in the project and always perform since Trafikverket is their largest customer, this is extra important in projects of this size where the project process stretches over a longer period of time. Therefore Tyréns as well as Trafikverket wanted to take advantage of the possible effects from repetitions and a continuous and close dialogue with Trafikverket has really simplified Tyréns work throughout the whole project process.³⁴

10.2.3 Experience feedback

In the Kil-Ställdalen project they have been working systematically with increased cooperation which has simplified for dialogues and experience sharing. To achieve this they have continuous contact, arrange meetings and give feedback to the project planners throughout the whole construction process. A continuous work with taking advantage of the gathered experience decreases the risk of making a mistake more than once and in this project the experience from the earlier parts made them change and develop better solutions and processes for coming ones. A good team work also gives the involved parties a chance to understand the other people's work which is valuable by for example allowing the project planners to know how their documents are received and read.³⁵

Svensson at PEAB also finds experience feedback as an important part of development and explains that most of the given feedback is shared orally between the coworkers both at site and between locations and projects. PEAB has a policy for experience feedback including meetings with the participants after each finished project, but other than that there are no certain systems. One obstacle for increased experience feedback for them as a construction company is that they often go directly from one project to another without much time for knowledge sharing. However, Svensson explains that the fact that many coworkers are living together at site simplifies greatly for good communication and thereby also experience sharing. They get to know each other very well which makes the communication channels a lot shorter also after the project has ended and you need to call for advices from any of your previous contacts. In addition to the orally shared experience feedback and well-working daily communication Svensson thinks that it could be useful to develop also a more systemized system for experience feedback.³⁶

Considering the Kil-Ställdalen project in particular Svensson experiences a wellworking cooperation between all actors with short communication channels and good discussions. The fact that they are working as a team with the same goal and with understanding of the other actors work simplifies for experience sharing. PEAB was contracted for E2 when E1 was completed and Svensson explains that the learning outcomes from the first part in Daglösen have given

³³ Lovisa Björkner, 2016-03-23 meeting

³⁴ Lovisa Björkner, 2016-03-23 meeting

³⁵ Martina Rydberg, 2016-02-26 telephone contact

³⁶ Joakim Svensson, 2016-03-17 telephone contact

some advantages for them. He also thinks that there are more changes then they know about since a lot of the gathered experienced probably have resulted in improved specification documents.³⁷

Björkner at Tyréns also thinks that there has been a knit team and close connection between all participants which have simplified the work with improving the contract specifications. In addition to the experience shared between different actors through continuous contact and meetings Tyréns is also sharing experience within the company. There is no specific system or database available but Björkner finds the experience feedback well-working and it definitely benefits her in her daily work. Tyréns has nationally a close internal network which gives a good connection between co-workers and thereby simplifies information sharing. She sees the close network as a big strength not only considering the experience feedback but also by decreasing the risk for lack of resources since they are shared between the different offices of Tyréns. She also brings up the importance of always gathering valuable experience and explains that she encourage the client to pass forward all issues discovered during production that somehow could have been prevented by improved specifications. The people managing the project at the involved organizations/companies are all highly influencing the outcome of the project including the level of experience feedback.³⁸

³⁷ Joakim Svensson, 2016-03-17 telephone contact

³⁸ Lovisa Björkner, 2016-03-23 meeting

10.3 Project: Järnväg Sydost (Eng. Railway Southeast)

A big investment to increase the capacity for both freight and passenger transports of the railway in southeastern Sweden was finished in 2014. The project was divided into several subprojects each including different parts of the stretch. (Trafikverket, 2014c) A map showing the southeastern railway network can be seen in Figure 13 where the different conducted project parts are marked with white boxes with red texts. Starting at the northwestern corner the travel center in Alvesta was rebuilt 2012 and a footbridge is now crossing the tracks. In Växjö the railway yard was rebuilt with new tracks, platforms and railway switches and in Åryd, close to Växjö, passing tracks were constructed. Passing tracks were also constructed in Örsjö in east and close to Karlshamn in the southern part and the three crossing stations were all relatively similar to each other. The stretch between Emmaboda and Karlskrona has been upgraded through several investments and also Verköbanan in Karlskrona has been upgraded and electrified. (Trafikverket, 2014d)



Figure 13: Map showing the southeastern parts of the Swedish railway network. Picture from Trafikverket.se.

10.3.1 Procurement

To begin with only the stretch between Emmaboda and Karlskrona was procured while the other parts were included as options which mean that there was a possibility but not a necessity that these tasks would be included in the contract. This contract included a total of seven different options and they all were not priced in the original tender. Parts of the whole project were procured with a set price while others were procured with current account. A performance contract without detailed project specifications was given to PEAB which together with InfraNord conducted the work as a partnering project. They were contracted for the original stretch Emmaboda-Karlskrona as well as all seven options. The contracted consultancy firm was Vectura which in cooperation with Sweco were managing project planning as well as delivering operational data. Also the consultants were procured for the stretch Emmaboda - Karlskrona with all additional options. The decision of procurement approach was based on experience from earlier conducted projects where it had proven successful.³⁹ Note that Sweco and Vectura today is only one company since Sweco bought Vectura in 2013. (Ny Teknik, 2013)

10.3.2 Time and cost

One of the main benefits with having one larger project instead of several smaller ones Källberg thinks was a more efficient organisation. About the same organisation and team were involved throughout the whole process with only smaller adjustments. The relatively unchanged organisation gave a possibility for the actors to get familiar with each other which simplified the work and made it easier to optimize the organization and the distribution of resources.⁴⁰

The repetitive work with the three relatively similar crossing stations had greatest impact on the planning process since much of the work were about the same for each of the stations. Current account were used and the cost decreased for each of the crossing stations, the first crossing station cost about 5 000 000 SEK while the last cost slightly above 4 000 000 SEK. Considering the cost for production a smaller decrease can be seen when comparing the first crossing station with the later ones. However, the costs cannot be directly compared since the conditions differed between locations, for example the time with cut tracks differed and not all construction sites had connected roads. Källberg finds it hard to state any specific procedures that they have changed during the process as a result of the repetitions.⁴¹

Stefan Olsson at PEAB was the site manager and he states that concerning the earthwork the three sites differed largely but that some similarities could be found for the other technique areas. The greatest benefits from the repetitive approach for PEAB were concerning the administrative parts. As an example they learnt the process of requiring lowered speed limits during production of the first crossing station which simplified the work with coming one. One of the stations was built without any train traffic at all which really simplified the production by allowing them to work as efficient as possible during day time. The station built with cut traffic flow was the most efficient one and a comparison of the other two shows improvements and savings especially concerning used time. ⁴²

Olsson explains that the potential savings from a repetitive approach has to be considered by the contractor already in the bidding process if the conditions seem to be alike. They know that there will be a degree of learning throughout the process and that it will be simpler to conduct the later parts than the earlier ones.⁴³

³⁹ Stefan Källberg, 2016-03-16 telephone contact

 $^{^{\}rm 40}$ Stefan Källberg, 2016-03-16 telephone contact

⁴¹ Stefan Källberg, 2016-03-16 telephone contact

⁴² Stefan Olsson, 2016-04-08 telephone contact

⁴³ Stefan Olsson, 2016-04-08 telephone contact

Lena Andersson at Sweco was in charge of the operational data and she sees that the efficiency has increased throughout the project time. With exception from some differences depending on the specific conditions given at each location the processes included similar steps and required about the same documentation. This made it possible to reuse the routines set during the first part also for the remaining parts and reduced the amount of time needed for things such as sorting out requirements with Trafikverket. A part of the learning outcome from part 1 was that clearer guidelines were developed to help them deliver the exact amount of quality and quantity specified in the procurement documents. Work made in previous projects was hard to reuse and take advantage of since the demands concerning the operational data has changes a lot during the past years.⁴⁴

When comparing the consultants early work in the project with the later Andersson can see a significant decrease in used time. However, a relatively extensive part of the total costs were connected to administrative parts that were hard to cut. These parts, like sending information to different locations, reduce the overall efficiency even if the planning work itself gets more efficient. In addition, there are some administrational parts that are hard or impossible to predict and plan for, as an example a few of the set requirements changed during the project process making a repetitive approach hard to fulfil. These administrative issues decreases the improvement possibilities but it can be seen that the budget was easier held for some parts even if the costs remained the same level or increased a bit for other.⁴⁵

10.3.3 Experience feedback

The system for experience feedback within the project consisted mainly of oral exchange after each finished subproject. Important learning outcomes were also documented at meetings with all actors and during group discussions concerning each technical field. This gave all participants an opportunity to learn from each other and to better understand what to keep in the process and also what to change. Stefan Källberg, who is the project manager, sees some advantages with experience feedback and states that it can be useful for coming subprojects by largely decreasing the risk of making the same mistakes over again.⁴⁶ Also Stefan Olsson at PEAB thinks that the experience feedback gave advantages, especially by stating improvement possibilities. He also thinks that meeting all involved actors in person gives shortened communication channels.⁴⁷

At Trafikverket there have been initiatives to create an internal system for experience feedback, but Stefan Källberg who is the project manager does not know how it works and it is not something that he uses in his daily work.⁴⁸ Nor does PEAB have a unified system that they use within their organization; it is up to each manager to handle their own routines for feedback. However, they do have a database with reference projects for the employers to learn from. Stefan Olsson at PEAB thinks that the partnering concept used in the project gave a

⁴⁴ Lena Andersson, 2016-04-14 telephone contact

⁴⁵ Lena Andersson, 2016-04-14 telephone contact

⁴⁶ Stefan Källberg, 2016-03-16 telephone contact

⁴⁷ Stefan Olsson, 2016-04-08 telephone contact

⁴⁸ Stefan Källberg, 2016-03-16 telephone contact

better cooperation between client, contracted entrepreneurs and consultants which also simplified for the experience feedback within the project.⁴⁹

Lena Andersson explains that Sweco mainly share experiences orally between co-workers for example by arranging meetings addressed to experience feedback after completed missions. In addition, they have meetings within the group of people involved in the project at Sweco where they have a chance to discuss what they should keep and what to improve for coming parts. In this project they had about eight deliveries which gave them some possibilities to develop their process and make it more efficient. Information and experience feedback are also shared at their local office on a weekly basis where different parts of Sweco show some of their on-going work, this gives the different departments an insight in each other's missions and thereby simplifies for the employees when they need to ask for support. Also their open-plan office encourages experience sharing since you can overhear some information that could be important in your future work and you learn who you should ask your questions. As a part of making their work as efficient as possible Sweco strives for reusing as much as possible of their earlier conducted work.

The internal network at Sweco is by Andersson seen as a great strength. Asking a more experienced colleague within an area for support is often a lot more efficient than for example searching in databases trying to find the useful information. Andersson highlights that the orally shared experience is the best one and it benefits her greatly in her daily work. However, she thinks that databases could be a good complement to a close network and explains that Sweco has been discussing it as a possible tool for several years but has not yet prioritized to develop one. She highlights the importance of making an eventual database very user-friendly with easy access to the information that you are searching for which requires a lot from the developer. Today, Sweco has a digital archive which can work as some kind of database where you can put some of the gathered experience as attributes.⁵⁰

⁴⁹ Stefan Olsson, 2016-04-08 telephone contact

⁵⁰ Lena Andersson, 2016-04-14 telephone contact

10.4 Opinions about further development of a repetitive approach

During the interview sessions the interviewees were questioned about their attitude towards a more repetitive approach for the railway construction process in general. Overall they were positive to the basic idea of a serial approach but questioned the implementation. Some quotes from the interviews are presented with green speech bubbles; these have been freely translated from Swedish to English by the author.

10.4.1 Opinions of clients

Boëthius at Trafikverket believes in the idea of a more repetitive construction process. As earlier mentioned, the Swedish railway network has had insufficient maintenance for a longer time period which puts high demands on the future maintenance and Boëthius explains that the efforts done today is not sufficient to fulfill the future demands. It is important with quick and efficient production and maintenance and the national coordination of switch replacements could play an important part. Trafikverket does for the moment not have any specific ideas for additional serial concepts but they often discuss the topic and possible initiatives. One possibility could be to procure contractors for a longer period of time thereby allowing them to do similar work for several years and increase the efficiency.⁵¹

Also Cinthio at Trafikverket thinks that it could be many benefits from the repetitive approach if it is achieved in a good and well developed way. Considering national projects he highlights the importance of really thinking through the packaging of activities and sees things in a broader perspective. It could be preferable to not only group similar tasks to achieve as much repetitions as possible but to create packages including different tasks if they can be handed out at the same time and by one contractor. As an example, it could be good to include the switch replacement in the procurement of track replacement and thereby save some costs by only having to establish contractors once and minimize the need for cut train traffic.⁵²

"There are other approaches for packaging that could be better than just packing projects with the exact same tasks" Anders Cinthio

Considering a more repetitive approach in the railway production process overall, Cinthio sees some good possible affects but also highlights the importance of taking a projects unique conditions into consideration when planning. Selected parts can be used again but very often the projects preconditions make it impossible to directly reuse the processes from earlier

⁵¹ Anders Boëthius, 2016-02-18 email and telephone contact

⁵² Anders Cinthio, 2016-02-25, telephone contact

projects. For example, the techniques at crossing stations could differ largely in modernity. $^{\rm 53}$

Also Martina Rydberg thinks that a more repetitive approach could give benefits in terms of increased efficiency if it is developed in a structured and wellplanned way. She states that packing projects together do not automatically lead to increased efficiency and cost savings if there is not any developed system for taking advantage of the positive effects. If the system for experience feedback is badly structured it could hinder a well-working repetitive and more efficient approach. There are also external influencing parts that could hinder a complete repetitive approach since they sometimes are hard or impossible to originally predict and affect. The many level crossings in the Kil-Ställdalen project is a clear example of when a somehow serial approach could have been beneficial but because of external influencing parts like cadastral procedures or landowners it was hard to achieve. The non-predictable parts could also give repercussions or new obstacles which finally results in a completely different solution for the section than the originally planned. Different regulations could also be a hindering the most efficient production by for example not allowing startup of a task before another is finished. 54

"Packaging does not automatically give increased efficiency if there is no clear system to take advantage of it" Martina Rydberg

Stefan Källberg, manager at the railway project in southeastern Sweden, agrees that further development of a repetitive approach can result in increased efficiency. He thinks that many of the tasks included in the railway construction process have similarities and that a serial approach is applicable despite the often somehow unique conditions. If the serial approach should be further developed, Källberg highlights the importance of finding suitable activities. The three similar crossing tracks in the project Railway Southeast are good examples of when a repetitive approach can be beneficial.⁵⁵

10.4.2 Opinions of consultants

Axelsson at ÅF has been working with many switch replacement projects and sees potential benefits with a repetitive approach mainly since everyone gets familiar with the expectations and requirements. There is no actual hinder for a more repetitive and efficient process but he thinks that Trafikverket themselves has created obstacles. The required administrative work and non-value activities needed from all involved parties makes the processes less efficient and are not always necessary. As an example the process of requesting access to all databases could be simplified a lot by for instance making the license valid for a longer time-period. In addition, it is common that new requirements add up over time which decreases the level of repetitive work. More clear and developed

⁵³ Anders Cinthio, 2016-02-25, telephone contact

⁵⁴ Martina Rydberg, 2016-02-26 telephone contact

⁵⁵ Stefan Källberg, 2016-03-16 telephone contact

routines as well as greater competence at Trafikverket would improve the possibility of getting increased efficiency. Packaging of for example more than one switch replacement into each project is by Axelsson seen as a good option to get to the more repetitive approach.⁵⁶

"Trafikverket continuously adds new requirements which hinder a repetitive approach" Thomas Axelsson

Lovisa Björkner at the Kil-Ställdalen project definitely sees benefits with a more repetitive approach in the industry. She thinks that packaging of several parts into larger projects rather than conducting many smaller projects separately is a good approach to achieve repetitions. The total cost of the Kil-Ställdalen project is definitely much lower than if all crossing stations had been procured separately. If about the same organization is used for similar tasks a systematic and efficient working approach will develop throughout the process. The employees will be working with similar tasks and about the same colleagues which enables greater learning and increased efficiency. In addition it will reduce activities that do not add any value to the final product by requiring fewer meetings, administration, questions etc. since fewer parties are involved. Larger projects mean that the staff will be working continuously with fewer projects which make them very familiar with the issues connected to these and it also has the potential to increase the overall commitment. Björkner thinks that it is important to plan a relatively tight but feasible schedule in projects of this large size. If the work load is continuous and relatively high the organization can be kept throughout the process which reduces activities like re-establishing people in the project. This also simplifies when questions should be answered since the involved parties are all updated with the latest information and experiences. Projects of the size of the Kil-Ställdalen project also get priority at the consultancy firms. Björkner thinks that it would be interesting to investigate the economy of scale contra the extra costs to see if larger projects are more profitable. If a greater share of the projects should be procured as packages Trafikverket has to take the initiative since they manages the procurement process. It also has to be remembered that larger projects require more tied up capital for the client which could be problematic. Using design/build contract forms to achieve a higher degree of repetition is not seen as a good option by Björkner who does not finds it suitable for these kinds of projects. 57

"We are able to do about three times as much within the same time frame if the organization could be kept throughout the whole process" Lovisa Björkner

As earlier mentioned, Björkner experienced that starting with the subproject Daglösen resulted in great benefits since it included almost all technique areas.

⁵⁶ Thomas Axelsson, 2016-03-07, meeting

⁵⁷ Lovisa Björkner, 2016-03-23 meeting

After this start-up the organization was as good as fixed and the different working approaches, communications and expectations were known. This simplified for following work and reduced the risk for exceeded schedules.⁵⁸

Lena Andersson at Sweco also states that she sees potential benefits with a more repetitive approach in the industry. A great improvement she thinks is to develop more efficient routines for the administrative work by for example creating templates that can be used regardless of the preconditions. However, she sees some problems with a repetitive approach for railway constructions in particular since it more often have unique conditions and are a lot more dependent of the site-specific conditions then for example construction of smaller houses.⁵⁹

"We gained a lot of benefits from the set routines" Lena Andersson

> "The repetitions is not further developed only because they don't want to, but also because of the unique conditions presented by each project." Lena Andersson

Andersson was managing the operational data in project Railway Southeast and sees some problems connected to their late involvement in the project. Very often the contractor has already completed their part and left the project which makes it hard for Sweco to get an optimal basis for the operational data. In the project Railway Southeast they found some errors in the received documents and it is hard for the contractor to deliver the correct information several months after the project ending. Therefore Andersson sees an earlier involvement of them as consultants handling the operational data as a good way of increasing the efficiency concerning their work. However, this might automatically be achieved when procuring design-build contracts.⁶⁰

10.4.3 Opinions of contractors

Fredrik Nilsson at Strukton Rail states that the idea of a more repetitive approach generally is good and sees benefits with procuring many switch replacements on the same stretch together in bigger projects. This will allow increased efficiency and also a significant decrease in cost especially for the client. Nilsson thinks that there are possible improvements for all parties and believes that more clear and well worked specification documents, especially for design/build contracts, is an important part of making the industry more efficient. More competence at Trafikverket as a client could also improve the

⁵⁸ Lovisa Björkner, 2016-03-23 meeting

⁵⁹ Lena Andersson, 2016-04-14 telephone contact

⁶⁰ Lena Andersson, 2016-04-14 telephone contact

efficiency by reducing the amount of errors and thereby preventing many time consuming discussions about the specification documents.⁶¹

"There is a possibility to make the process much more efficient and save a lot of money." Fredrik Nilsson

The three crossing stations contracted by PEAB in the Kil-Ställdalen project were as earlier mentioned all relatively different from each other which make it hard for the contractor to work repetitive. Even if two of the stations had similarities the ground conditions and surroundings differed which makes a higher level of repetitions hard to achieve. A solution to this could perhaps be to plan for a repetitive approach already in the design phase by locating the construction at places with as similar conditions as possible. Of course there are many aspects to consider when deciding on location and it is not something that PEAB as the contractor can impact, especially not if the procurement is done as a performance contract. Joakim Svensson at PEAB definitely sees some potential benefits with a further developed repetitive approach and states that achieving repetitions are important for the contractors since their experience and knowledge gathered during earlier projects are important resources to get contracts. Furthermore, he think it is a good approach to group similar tasks into larger projects since it reduces costs for establishing, organizing and administrating. However, much of the decisions have been taken already before the involvement of construction companies who often receives about complete construction documents. This makes it harder for them to affect the construction plans and Svensson experiences that the freedom of action for them as contractors has been reduced during the past years.⁶²

Stefan Olsson who was involved in the project Järnväg Sydost also thinks that a more repetitive approach has the potential to result in increased efficiency. He is positive to procurement of larger projects rather than several smaller ones as a way of achieving repetitions. It allows the same organization to work together for a longer period of time which gives shortened communication channels and simplified working processes. Olsson states that the projects characteristics highly impact the possibilities to achieve repetitions and explains that it would have been easier to work more repetitive and effective if the traffic flow was cut totally during production. The available time with cut train traffic also impacts the level of creativity and innovation for the contractors.

"A lot of possible efficiency improvements are hindered by the low access to cut tracks" Stefan Olsson

⁶¹ Fredrik Nilsson, 2016-03-07, telephone contact

⁶² Joakim Svensson, 2016-03-17 telephone contact

10.5 Summary Case Study Results

All the interviewees have a positive attitude towards a more repetitive approach for the construction process of railway projects. The representatives from Trafikverket highlight the importance of finding activities suitable for serial production and also the importance of having a system developed to take advantage of the benefits. The results show that many of the participants see a lot of organisational benefits with these bigger projects since about the same team can be involved throughout the whole process shortening the communication paths. Some of the consultants as well as contractors bring up the large amount of required administrative work from Trafikverket as an obstacle to a further developed repetitive approach. Also the unique conditions presented at each location are brought up as a major obstacle.

The initiative of coordinating all switch replacements at a national level was started to achieve a higher productivity. The switch replacement process was seen as relatively repetitive and therefore a good activity for the serial approach. However, all concerned parties bring up the complexity of switch replacements and says that a fully repetitive approach cannot be fulfilled. The greatest savings seem to be concerning the administrative parts, where the organizations that have been involved in similar projects know the process and what to expect. All interviewees see potential benefits from the initiative but more consideration could have been taken to the opinions of all effected actors. Concerning experience feedback, the companies seem to have some kind of internal systems but there are no central systems to gather valuable experience from the conducted switch replacements.

Kil-Ställdalen is an ongoing project aiming at upgrading a stretch of 140 km. The interviewed actors in the Kil-Ställdalen project all found the cooperation between involved actors well-working which have given many advantages, for example by simplifying a lot for experience sharing. All of them also think that positive development can be seen throughout the project process partly as a result of repetitions. Overall, greater effects were noticed at Tyréns as consultant than at PEAB as contractor and a great decrease of time and costs could be seen when comparing the planning of Kejsarbäcken and Sandmon. They had a lot of similarities which made it possible to reuse lot of the conducted work from the first station to the other. The interview results also shows that the procurement of one larger project instead of many smaller gives a lower total cost since many non-value adding activities like administration, establishment and discussions could be reduced.

Many subprojects were involved in the investment named Railway Southeast (swe. Järnväg Sydost) and the procurement started with the stretch Emmaboda-Karlskrona including 8 option which were all included. Three relatively similar crossing stations were included in the project which allowed some repetitions. The results show that the cost for planning decreased significantly throughout the project process but the effect were not as big for the actual construction. The site manager at PEAB states that repetitions are especially hard to achieve for the earthwork and easiest concerning the administrative parts. Lena Andersson at Sweco states that they experienced an increased efficiency throughout the project but that a more repetitive approach was partly hindered by upcoming new requirements from Trafikverket. The experience feedback in the project mainly consisted of meetings after each finished subproject.

11 Analysis/Discussion

The aim of the study was to investigate if more repetitive ways of planning and constructing parts of the Swedish railway network could give increased efficiency. To fulfill the aim the given results from the theoretical framework as well as the case studies are analyzed in this chapter to answer the five research questions given in chapter 1.2 which also can be seen in the orange boxes below (Figure 14).

1. Do the companies have systems for experience feedback today? In that case how does it work?

2. What difference can be seen when comparing similar activities conducted early in a project with later ones, particularly concerning time and cost? Also, have the process somehow changed along the way as a result of gathered experience?

3. Are there any certain obstacles for a more repetitive approach?

4. Has any initiatives been taken to achieve more repetitive work in Sweden? In that case, are there any noticeable effects?

5. What advantages and disadvantages do the theoretical framework states about a repetitive approach in the construction process for railway?

Figure 14: The five research questions of the study

All interviewees state that they believe that increased efficiency can come from a more repetitive working approach if it is implemented in a good way. In each of the three cases of study several subprojects were procured together allowing a somehow repetitive approach. Most of the benefits for all actors is a result of more efficient work with the administrative parts and the repetitions had a greater impact on the planning process than the production process, which is probably partly because the administrative parts stands for a greater share of the total cost in the planning process. Also, if two identical tasks are conducted at different locations some of the drawings and documents created by the consultants could be about copy-pasted while the production process has of course to be done twice independently of the similarities. It was hard to find fully comparable quantities to clearly show the actual effects on time and cost but the three cases of study all showed some positive effects. As an example a significant decrease in cost could be seen for the planning process of two similar crossing stations in the Kil-Ställdalen project and also for the planning process of the stations in the project Railway Southeast. As earlier mentioned it was harder to notice any significant effects on the costs for the construction phase but the total cost for establishing and also some administrational costs were reduced. The interviewees state that they have experienced increased efficiency over time as a result of repetitions and that this is something that they consider in their tender. The technical area that challenges the repetitive approach the most is the earthwork which is very dependent on the conditions at the specific location. One idea is to package subprojects with as similar conditions as possible, especially ground conditions, instead of the ones that are geographically close to each other to encourage a more repetitive work. The more alike the activities are the faster will the increased productivity from repetitions be achieved as can be seen in the study of Nguyen et al. described in chapter 8. The learning rate for a modular activity declined a lot faster than other which means that a high productivity where achieved after fewer repetitions. However, it has to be remembered that there are many parts influencing the procurement design that can be higher prioritized than getting repetitions and increased efficiency.

The mentioned characteristics of the construction industry make it hard to apply a fully industrial or serial approach and adjustment is therefore necessary to fit the industry. The repetitive production is already used for construction projects such as high-rise buildings and pipelines and to fit the railway production parts feasible for the serial production has to be identified. The national coordination of railway switch replacements is an attempt to take advantage of the gain from one relatively repetitive task. However, the interviews showed that it could have been better to group not only the activity of replacing the switch itself but also include other parts often connected, like for example rebuilding the connected tracks. This would mean that only one contractor has to be established to do all work at the same time instead of involving different contractors or having to cut the tracks more than once.

The study also indicates that it is beneficial in terms of increased efficiency to procure larger projects over a longer period of time rather than several smaller projects. This reduces the resources needed for activities of establishing relationships and working processes and has the potential to give a knit team with shortened communication paths. Kil-Ställdalen is an example of a larger project with about the same team involved throughout the whole project process. The interviewees participating in the Kil-Ställdalen project all experienced an unusual team spirit which significantly simplified the communication between involved actors and thereby also the experience sharing. Tyréns and Trafikverket work continuously with improving the specifications for coming parts as experience were gained during the project planning process has been improved throughout the project resulting in lower costs and it can be assumed that the close communication and continuous work with improvements contributed to the decrease. Results were also seen in the

production process were the additional cost because of significant errors in the specification documents were largely reduced. Because of the longer time period the participants also have a chance to get familiar with the requirements and processes making them more efficient over time, which can be connected to the learning-curve-theory described in chapter 6. Even if it could be hard to estimate the learning rate for construction processes the literature indicates that a significant reduction in the unit input (e.g. cost or time) can be seen over time also in the construction industry. This speaks for a more developed repetitive approach since repeated tasks allow a greater learning. It can be assumed that the similarities within the three cases of study where too few to experience as significant learning rate as for the high-rise building projects studied by Nguyen et al. The construction process is highly dependent on site-specific grounding conditions and since infrastructure projects stretch over longer distances and many locations the level of repetitions is limited. For the contractors a decrease of cost is connected to the establishing process since the need for reestablish is lower in bigger projects than if all parts have been procured separately.

Something else that was proven successful in the Kil-Ställdalen project that can be applied also in other projects is to start with a subproject including many of the technical fields. In the Kil-Ställdalen project it was E1 in Daglösen and by starting with this part including about all technical fields almost every process was tested at an early stage and the processes were set. During E1 the organisation was established which demands extra effort and increases the costs, if more than one subproject are starting simultaneously also those will get the extra costs for establishing. Therefore it could be suggested to have a smaller subproject including many technical fields as start-up thereby avoiding unnecessary extra costs for establishing the organisation and working processes.

In addition to the repetitive effects that follow larger procurements repetitions can also be achieved by standardized solutions as described in chapter 8. It is not used as much in the construction industry with its engineer-to-order approach but is common for other product lines with for example a make-to-order strategy. Changing some of the production parts to a make-to-order approach would allow a higher degree of standardization and thereby enable more repetitions since all parties know the product and its requirements. The idea of achieving a higher level of standardization is used in the concept of product platforms described in chapter 8.2. Developing product platforms for parts of the railway construction could result in some of the possible advantages with a repetitive approach but is partly hindered by the often unique conditions. The initiative of national coordination of all switch replacements in Sweden has to some degree adapted the idea of product platforms. By using only one supplier the industry gets familiar with the product specifications and can then work in a more repetitive way. If they are working repetitive the learning rate will result in increased efficiency and thereby time and cost savings. It could also have the possibility of decreasing the need for resources since the utilization rate of the Kirow crane could be optimized. Considering this initiative in particular, all interviewees have experienced great time savings as a result of using the Kirow crane but they also have a general opinion that too many options have been taken away. The limitation to only use a certain methodology could decrease the competition in the industry and thereby also innovation. Therefore it is

important that the contractors develop platforms themselves rather than Trafikverket as the client and it has to be done in a way that fits the engineer-toorder approach. As described by Jansson et al. (2013) this adjustment could be to add support methods where engineering could give a standardized product distinctiveness to fit the specific site. The major benefit with platforms developed by Trafikverket as the client is that also the maintenance gets standardized since all products are alike. In addition, restrictions set by Trafikverket allow them to make larger procurements, like the one with Vossloh, since a high utilization capacity could be ensured.

Another aspect of the national coordination of railway switch replacements is that the replacements are packed together regardless of geographic spread. The industry seems to be positive to achieving repetitions by packaging but that there are some things to consider. For example Cinthio as a project manager at Trafikverket sees some difficulties with managing projects remotely and Nilsson as a site manager at Strukton Rail thinks that the aspects considered when packing are not optimal. This highlights the importance of inviting opinions from all affected parties before taking decisions that impact their work.

The three cases of study all points out some of the administrative requirements as time consuming and sometimes not really necessary making it an obstacle for a more efficient process. Also, new requirements add to the administration over time which makes it hard to reuse the same templates and processes to achieve repetitions. The interviewees that have been working with railway for a longer period of time explain that they have experienced an increased amount of required administrative work and also a decreased freedom of action for them as contractors/consultants. To achieve a more repetitive and efficient process it is therefore important to make the administration more standardized. The requirements need to be valid for a longer period of time and it is suggested to develop templates that give a more standardized process and work for many different projects. As earlier mentioned, knowledge about the requirements and processes were seen as one of the main benefits with larger projects and with a more standardized process they would always be known.

The fact that the interviewees brought up the requirements from Trafikverket as something that limits their freedom of action does not fit with Trafikverkets' goal to encourage innovation and increased efficiency. It can be assumed that the industry will achieve the greatest efficiency if Trafikverket takes initiatives that allow a more repetitive production but at the same time allow creativity and innovation. Trafikverket is the main client and manage the projects and procurements and therefore it is important that the initiatives are taken by them, a more repetitive approach at Trafikverket would most likely result in a repetitive approach in the industry overall, which is also brought up in the study by Larsson et al. mentioned in chapter 8.

An important part of taking advantage of the repetitions has shown to be a wellworking system for experience feedback. As mentioned in chapter 7 the construction industry relies heavily on the experience of the workers and the industry is now facing a generation renewal, thereby risking much experience getting lost. The project based production makes it harder to take advantage of the gained experiences since there often are new conditions and different teams. This speaks for a well-working experience feedback system where gained experiences give advantages also for those that were not directly involved in the project.

Many of the interviews as well as earlier made studies point out the importance of a well-developed system for experience feedback. All interviewed actors stated that experiences were mainly shared orally between the co-workers during meetings and through daily contact rather than by developed computer systems. If the learning coming from a repetitive approach should lead to improvements in the process also when a different team is involved a wellworking system for experience feedback is needed where the sharing is not only done within the current team but to others in the same organization. The concept of organisational learning described in chapter 7 is one approach to achieve learning for the organisation overall rather than just for the involved participants.

Björkner at Tyréns thinks that their internal experience feedback system works very well and that a computer system is not needed while Svensson at PEAB states that their experience sharing works very well but that it could have been beneficial with a more systemized feedback system. Also Axelsson at ÅF thinks that it is good to have any kind of database for experience sharing. This is probably partly because of the larger sizes of PEAB and ÅF which makes it hard to continuously share experience orally between all within the same technical field. The fact that much of the information is only shared orally means that much valuable experience gets lost, especially since the industry is facing a generational renewal. A solution could be to use any kind of database which is already somehow used at for example ÅF. Databases could be a good tool that could allow the users to search at a specific activity or project specifications and thereby find documents or good solutions that have been used in earlier conducted projects. It is then important that the database is user-friendly and continuously updated. Since some companies actually already have databases that are not used, partly because of the lack of time, it could also be a good option to schedule some time for providing experience feedback by updating the database. But a database where the information is only shared within the company is neither optimal since sharing experience is needed also between the different actors working at different organizations. As an example, like in the Kil-Ställdalen project, it could be valuable for the consultancy firms making the planning to know how their work is read and received by the contractors and thereby learn possible improvements for coming projects.

To take fully advantage of a further developed repetitive approach the systems for experience feedback would most likely have to be improved or at least more specified. The fact that the work is project based could be problematic in a long term perspective if the learning outcome is not shared also with those who were not participating in the particular project.

Note that the interviewees stated that the experience feedback shared orally between co-workers gains them greatly in the daily work and that this is probably the most important type of feedback. However, a computer system could be a good complement allowing the information to be shared also with those that you do not meet at a daily basis, especially at larger companies.

12 **Recommendations/Further studies**

This study shows that an increased level of repetitive work could give benefits for the industry in terms of increased efficiency for all involved actors. The increased efficiency could be of major importance since the Swedish railway network is facing many larger investments.

How to achieve these increased repetitions is not specified but the results show improvement possibilities concerning the administration requirements, which were pointed out as one of the main obstacles by requiring a lot of information and also adding requirements over time. Therefore it would be interesting to develop more standardized administration processes including standard processes and templates that work for a longer period of time and for different projects. It is also interesting to investigate how much of the information/administration gathered during already completed projects that have given any help or have resulted in any additional value. Perhaps some of the administration requirements are found unnecessary and can be removed. An initiative like this probably has to be taken at Trafikverket since they are the main client and sets the requirements. It could be assumed that if the client strives for increased repetitions the other actors will also be impacted.

An increased amount of standardized products by for example developing product platforms could also be one way to achieve repetitions. This approach is successfully used in other industries and with some adjustments it could be applied also to the construction industry and more specifically the production of railway. Railway switches was pointed out as a part that could fit for standardization and it would be interesting to investigate if there are other parts that also could be produced in a more serial way.

The initiative of coordinating switch replacements nationally started at Trafikverket with the aim to increase productivity and innovation but the interviews indicates that there is a risk of limiting innovation rather than encourage it. Therefore it is suggested to investigate the advantages contra disadvantages as an evaluation of the initiative.

The study also showed some benefits connected to larger contracts, where the organisation with communication paths and processes could be set for a longer period of time. An investigation of the possibilities to have a greater share of larger projects is therefore suggested as well as studies of the economy of scale for bigger projects contra the disadvantages.

If a more repetitive approach is developed as a part of increasing the productivity it is important to develop a system for taking advantage of the benefits. A part of this is to make it possible for the entire organization to learn from earlier conducted projects by using experience feedback, especially since the industry is now facing a generation renewal. The conducted interviews showed a great variety of how to gather experience and it would be interesting to further investigate different kinds of feedback systems.

To summarize the suggested further studies a list was made which are presented with bullet points below.

- How to develop standard processes and templates for administrative requirements.
- How much of the information/administration gathered during already completed projects that have given any help or have resulted in any additional value.
- Identify parts that could be suitable for a more serial/repetitive production.
- Evaluate the initiative of coordinating switch replacements nationally.
- Study the economy of scale for bigger projects contra the disadvantages.
- Further investigate different kinds of feedback systems.

13 **Conclusions**

Based on the studied literature and the conducted semi-structured interviews it can be stated that many positive effects including increased efficiency can come from a more repetitive approach for planning and constructing railway. The literature indicates a significant learning rate for the construction industry and the studied projects showed a decrease in costs over project duration especially for the planning process. The study indicates that the area with the greatest possible improvements is concerning administrative parts and since Trafikverket is the client and manage much of the administration they have to be in charge of new initiatives to achieve repetitions. However, the interview results point on the importance if inviting opinions from all actors before taking major decisions.

A higher level of repetitions could be seen in larger projects were the same team is involved throughout the whole process which speaks for fewer larger projects rather than many smaller. Also product platforms and standardization of products could give a more repetitive approach and thereby increase the efficiency. To take full advantage of the repetitive approach it is important to develop a clear and useful system for experience feedback.

To face the coming challenges and to meet the demand of great investments in the railway network it is important to increase the production efficiency, and this study indicates that a part of it definitely could be to increase the level of repetitions.
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Appendix

Interview participants

- 1. National coordination of switch replacements: Anders Boëthius, project manager at Trafikverket Underhåll Upphandling (Eng. Department of Maintenance Procurement) Responsible for the Kirow crane contracts
- 2. National coordination of switch replacements: Anders Cinthio, Project manager at Trafikverket Nationella Projekt (Eng. Department of nationally coordinated projects).
- 3. National coordination of switch replacements: Fredrik Nilsson, Site manager at Strukton Rail.
- 4. National coordination of switch replacements: Thomas Axelsson, Technical manager at ÅF.
- 5. Kil-Ställdalen: Martina Rydberg, Project manager at Trafikverket Investering (Eng. Department of investments).
- 6. Kil-Ställdalen: Joakim Svensson, constructional engineer at PEAB.
- 7. Kil-Ställdalen: Lovisa Björkner, Project manager at Tyréns.
- 8. Järnväg Sydost (Eng. Railway Southeast): Stefan Källberg, project manager at Trafikverket Invesering (Eng. Department of investments).
- 9. Järnväg Sydost (Eng. Railway Southeast): Stefan Olsson, site manager at PEAB.
- 10. Järnväg Sydost (Eng. Railway Southeast): Lena Andersson, project manager at Sweco.

Interview questions

The interview questions differed slightly depending on project and some adjustments were done during the interview sessions depending on given answers.

Case: National coordination of railway switch replacements

This chapter shows templates for the interview sessions of the initiative of coordinating all switch replacements on a national level.

<u>Client 1 - General questions</u>

- 1. Briefly, how did the idea of the national coordination develop and what does it mean?
- 2. How is the Kirow crane contracted? Is it rented from a German company?
 - a. Do Trafikverket rent it in first place and then provide or sublease it to the contractors or how does it work?
 - b. Do you think that the market for the crane will be big enough for a Swedish organisation to own a crane in the future?
 - c. Approximately, what is the total cost for a switch replacement?
 - i. Are there any significant differences in cost or required time for replacements with the Kirow crane compared to other methods?
- 3. How has the response from the projects managers been?
 - a. Do they find it hard to plan the replacements such a long time ahead because of the fixed route for the crane?
- 4. Do you know the approximate share of the total amount of replacements that are done using the Kirow crane?
- 5. Are you pleased by the investment results so far?
- 6. Do you think that a more repetitive work in the construction process for railway can result in increased efficiency and decreased use of resources?
- 7. Do you know if Trafikverket is working with or planning any similar investments?

Client 2 - Project manager

- 1. Briefly describe how you as project manager has experienced the initiative of coordinating all switch replacements nationally.
 - a. What do you see as the major advantages and disadvantages?
- 2. Is there any noticeable difference in cost for replacement when comparing an early replacement process with one of the later ones? (Preferably with the same contractor and where the Kirow crane has been used)
 - a. How big is the difference?
- 3. Did you experience the first replacements as more tricky and time consuming then the later ones? (Perhaps some documents/processes/templates etc. could be reused?)
- 4. Have you change anything in the later projects because of experience given from the earlier?
- 5. Did you have any system for experience feedback?
 - a. How does it work?
 - b. Do you find it useful in your daily work?

- 6. Do you think that a more repetitive work in the construction process for railway can result in increased efficiency and decreased use of resources?
- 7. Do you have contact details to a representative from a contracted company (preferably site manager) and a project planner who has performed many replacements?

Consultant/Contractor

- 1. Briefly describe how you as consultant/contractor has experienced the initiative of coordinating all switch replacements nationally.
 - a. What do you see as the major advantages and disadvantages?
- 2. Has it been possible to reuse something from your work with earlier replacements in the planning of coming ones? (For example technical solutions, documents or templates)
 - a. Can you give an example?
- 3. Did you change anything in your work with later replacements due to experience gathered during the work with previous ones?
- 4. Did you have any system for experience feedback?
 - a. How does it work?
 - b. Does it benefit you in your daily work?
- 5. What was the cost and required time for planning/construct each station? These figures could be an interesting evaluation of the effects of a somehow repetitive approach.
 - a. If it is not possible to find comparable figures, do you think that benefits have come from the more serial approach?
 - b. Do you consider potential repetitive benefits when bidding on a project?
- 6. Were there any certain obstacles for a more efficient/repetitive work? For example if you wanted to do something in one way but the different preconditions hindered it.
- 7. Do you think that a more repetitive work in the construction process for railway can result in increased efficiency and decreased use of resources?

Cases: Kil-Ställdalen and Railway Southeast

This chapter shows templates for the interview sessions of the two studied railway projects.

<u>Clients</u>

- 1. Can you briefly describe the investment?
- 2. How has the project been procured:
 - a. In general, what was included in each contract specification?
 - b. Was the same consultant(s) involved in the designing process for all parts or did it differ?
 - i. Contact details to the consultant(s) involved?
 - c. Contract form?
 - d. Which contractors were involved in which parts?
 - i. Where any responsible for several similar tasks and in that case what are their contact details?
 - e. Fixed price or current account?
 - f. What were the main reasons for this type of procurement?

- g. How much time did the actual procurement process take?
- 3. Did you experience that the first parts required more time and effort than following? (Perhaps some documents or templates could be reused)
- 4. Did you change anything in the working process along the project duration due to gained experience?
- 5. Do you find any parts similar enough to make a fair comparison of the amount of used time and cost? This is interesting for estimation of repetitive effects concerning the planning process as well as construction process.
- 6. Do/Did you have a system for experience feedback within the project or within your organization?
 - a. How does it work?
 - b. Does it benefit you in your daily work?
- 7. Were there any certain obstacles for a more efficient/repetitive work? For example if you wanted to do something in one way but the different preconditions hindered it.
- 8. Do you think that a more repetitive work in the construction process for railway can result in increased efficiency and decreased use of resources?

Consultants/Contractors

- 1. Briefly describe your responsibility in the project.
- 2. Did you experience that some of the work conducted for the earlier crossing stations could be reused in your work with later ones? (For example documents, technical solutions or templates)
 - a. In that case, can you give an example?
- 3. Did you/Are you going to change anything in your working process due to the experience gained throughout the project time?
- 4. What was the cost and required time for planning/construct each station? These figures could be an interesting evaluation of the effects of a somehow repetitive approach.
 - a. If it is not possible to find comparable figures, do you think that benefits have come from the more serial approach?
 - b. Do you consider potential repetitive benefits when bidding on a project?
- 5. Did you have any system for experience feedback?
 - a. How does it work?
 - b. Does it benefit you in your daily work?
 - c. Only contractor in Kil-Ställdalen: How was the experience feedback from E1 (Daglösen)? Do you see any benefits with the fact that part one already were completed?
- 6. Were there any certain obstacles for a more efficient/repetitive work? For example if you wanted to do something in one way but the different preconditions hindered it.
 - a. Do you think that the procurement design effect the possibilities of achieving repetitions?
- 7. Do you think that a more repetitive work in the construction process for railway can result in increased efficiency and decreased use of resources?