Potential improvements of the reinforcement process by implementation of BIM

Master of Science Thesis in the Master's Programme Structural Engineering and Building Performance Design

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Department of Civil and Environmental Engineering
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Structural Concrete
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ABSTRACT

During the last years there has been a growing interest in making the construction process more efficient. Great potential has been found in the flow of information and the use of more accurate data early in the process. A way of handling this is building information modelling, BIM. BIM is a mode of operation that ensures the flow of information between participants through the process without any data loss.

This study investigates the potential improvements in the reinforcement process, from the client to delivery at site. Actors throughout the process has been interviewed in order to establish in what way BIM is used in infrastructure industry today and in what way BIM can improve the reinforcement process in the future. Some critical areas where data is lost or redesigned in the reinforcement process has been identified and explained. Finally, the author's views of how these critical areas can be improved and in what way BIM is able to catalyse these improvements are described.

The study concludes that the use of BIM in infrastructure today is still at an early stage. In the current reinforcement process data and information is lost and redesigned several times. By further implementation of BIM the flow of information could be ensured throughout the process leading to fewer errors and therefore a more efficient overall process.

Key words: BIM, Building information modelling, reinforcement process, information flow, reinforcement design, reinforcement supply.

Potentiella förbättringar av armeringsprocessen genom att implementera BIM

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SAMMANFATTNING

Under de senaste åren har det blivit ett växande intresse för att göra byggprocessen effektivare. En stor potential för detta finns i flödet av information mellan parter och i användandet av mer exakta data tidigt i processen. Ett sätt att hantera detta är Building Information Modelling, BIM. BIM är ett arbetssätt som säkerställer informationsflödet genom byggprocessen mellan de olika aktörerna utan förlust av data.

Denna studie undersöker de potentiella förbättringar i armeringsprocessen, från beställare till leverans på arbetsplatsen, genom implementering av BIM. Alla aktörer under hela processen har intervjuats för att fastställa på vilket sätt BIM används i infrastrukturbranschen idag och på vilket sätt BIM kan förbättra armeringsprocessen i framtiden. Kritiska områden i armeringsprocessen där data går förlorad eller får göras om identifieras och förklaras. Därefter presenteras författarnas tankar om hur dessa kritiska områden kan förbättras genom att implementera BIM.

Studien visar att användningen av BIM inom infrastrukturbranschen i dag fortfarande är i ett tidigt skede. I armeringsprocess går data och information förlorad och blir flera gånger manuellt återskapad. Genom att implementera BIM skulle flödet av information kunna garanteras. På så sätt skulle fel och missförstånd kunna undvikas och därmed leda till en effektivare process.

Nyckelord: BIM, Building information modelling, armeringsprocessen, informationsflöde, armeringsprojektering, armeringstillverkning.

Contents

Preface

This master's thesis was initiated by the authors and Skanska Teknik in Gothenburg. The study was carried out from January 2011 to June 2011. The study was carried out at Chalmers University of Technology at the division of Structural Engineering under the great supervision of Rasmus Rempling and the examiner Kent Gylltoft.

The study is mainly based on interviews with actors in connection with Skanska´s reinforcement process. Therefore we would like to thank participation from WSP, Trafikverket, Lars Hildebrandsson AB, Skanska Production and VMS Steel for their great support. We would also like to thank Jörgen Johansson and Rune Møller at Skanska NPU for their participation and for making the visit to the suppliers in Latvia possible.

Last but not least we would like to give our gratitude to Henrik Ljungberg and Per-Ola Svahn at Skanska Teknik for making this master thesis possible. Not only by supervision and support, but also by providing us with a place of work at Skanska´s office in Gothenburg.

Göteborg May 2011

Magnus Johansson & Emil Jonasson

1 Introduction

1.1 Background

During the last years there has been a growing interest in making the construction process more efficient. It has been found that one way of reaching this is to put more time and money into the early stage of the projects. By doing an accurate planning and design the overall process is likely to be more effective since the risk of making mistakes due to uncertainties further in the process will decrease. BIM (Building Information Modelling) is a way to, in 3D, gather and manage all data and information in the different stage of the construction process. In Sweden BIM has been used for some years in the building industry. However, the purpose of using BIM in the infrastructure industry has been uncertain so far. Skanska Sweden highlights in their business plan that by year 2015 BIM shall be implemented in every infrastructure project. To make this possible it is important to have good knowledge concerning the nature of the concept BIM but also the needs of BIM in the infrastructure industry. The expectations that BIM will play a significant part in the future construction process makes BIM a potential source of competitive advantage for the major firms within the industry, including Skanska.

According to the above, it’s relevant to consider how to implement BIM into Skanska´s Infrastructure department. The great scope of the area suggests a valuation of which questions to deal with first in order to achieve a practical usage of BIM. One of the questions that Skanska Sweden has identified as crucial is the usage of BIM in combination with design and purchasing of reinforcement. The entire chain of activities from the clients prerequisite to the final erection on site, the so-called reinforcement process, has several shortcomings in terms of communication between the participants and overall effectiveness. The data is in the first stage submitted from the client to the design department. Their design drawings and complementary documents are then sent further to external reinforcement consultants who specifies all reinforcement into reinforcement schedules. When the procurement department and the project organisation on site achieves these schedules they collectively correct some deviations before they send it forward to the supplier of reinforcement. During this flow of information data is changed and sometimes even lost due to different file formats, miss communication between the participants etc. The resource demand and economical disadvantage related to the current situation motivates an investigation of how to develop the process in to a more effective one.

1.2 Aims

The aim of this study is to identify critical areas of development and corresponding improvements in the reinforcement process described above. The study will investigate how an extended implementation of BIM can catalyse the development and lead to a more effective overall process. Due to this, the following questions will be treated:

In what extent considering reinforced concrete is BIM used in infrastructure industry today?

Which are the most important aspects to consider in order to reach a more effective reinforcement process?

Based on the previous question, in what extent can BIM influence the different stages in order to reach a more effective overall process?

1.3 Research Approach

Literature and reports have been studied in order to understand in what way BIM is used in infrastructure industry today. Interviews has been executed in order to identify the need of information and input data in every stage of the process, from the client all the way to the final erection on site. The participants have shared their view of BIM in infrastructure industry today and their needs related to the reinforcement process. Documentation of what information each participant produces in their individual processes has been studied in order to see differences in data and how this is sent further.

The nature of this specific subject advocates an approach like the one adopted in this study. The aim of the study is to develop an existing process into a more effective one. The participating actor’s needs are very crucial in such analysis why interviews are a good tool. Moreover, the fact that BIM is a concept under development leads to an overall lack of relevant literature. The edge knowledge regarding BIM can only be extracted by interviewing informed individuals within the industry.

Another important aspect to consider is that the analysis is executed on initiative of the authors and Skanska Teknik. The interviews have covered other actors within the industry, but a significant part of the information has been achieved through contacts within Skanska.

1.4 Limitations

The research is based on a case study of Skanska Sweden´s reinforcement process. Processes accompanied by other contactors may differ from Skanska Sweden´s why this study shall be seen as an example in where the processes and flow of information can get more effective. The study deals with the reinforcement process, from the client to the erection on site. The service life and design of other materials will not be considered in this study.

1.5 Report outline

Chapter 2 is divided into four subchapters starting with a presentation of the concept building information modelling (BIM). Some definitions of BIM are presented before the authors finally states their own interpretation of the concept. Chapter 2.2 contains general information about the usage of BIM in the infrastructure industry today. There are some commonly used software’s to handle data in the infrastructure industry which are presented briefly in chapter 2.3. Finally chapter 2.4 describes the current usage of BIM at Skanska Infrastructure department.

Chapter 3 reviews the current reinforcement process. First the general process is presented briefly. This is followed by a separate subchapter for each main activity in the process; the client, the design process, the procurement process, the supplier and the erection on site. In each subchapter the participants view of the current process and their thoughts about potential areas of improvement is described. Finally, in Chapter 3.6, two successful attempts to reach a more effective process by the implementation of BIM are described.

Chapter 4 is divided into two main parts. In Chapter 4.1 the authors view of the most critical areas of improvement are described briefly. These areas has been identified based on the analysis of the current situation in Chapter 3. Thereafter the author's view of how these improvements can be executed through the process is presented in Chapter 4.2.

2 BIM as a resource in the infrastructure industry

The aim of this chapter is to describe the concept BIM and its potential in the infrastructure industry. The final part of the chapter describes the implementation of BIM at Skanskas Infrastructure department specifically.

2.1 What is building information modelling?

Traditionally the information flow between design and erection in the construction process has been accompanied by 2D-drawings and construction documents. This way of working has been accepted and deeply rooted in all project-participants minds. Over time this conservative approach has resulted in a barrier for innovation in the construction industry.

However, the need of a more efficient way of handling the construction process has lately become a significant part of the major construction companies' agenda. Building information modelling, BIM is a method to gather and handle information and data of a project throughout its lifecycle. Advanced software and technology is used to store information in and around a three-dimensional model. Used in the right way, BIM optimises the use of resources and the flow of information in the construction process.

There is no single definition of BIM that has been accepted on an industry level. Instead there are a lot of different definitions and interpretations of the concept BIM among companies and other stakeholders within the industry. The Swedish organisation Byggindustrin describes BIM in the following way:

BIM is an acronym for Building Information Model and Building Information Modelling. There is today a broad term that means different things depending on who uses it. For most people it means computerised systems for information management and visualisation during construction projects, from conception and throughout the entire building life cycle. BIM is not the same as 3D, although the visualisation represents a significant part of the concept. The computer models of BIM differs in terms of reliance on databases. (Köhler, N. 2008)

Rogier Jongeling, technical project manager for the Swedish development program OpenBIM, gives further explanation to the concept through the report `BIM istället för 2D-CAD i byggprojekt`.

BIM is all information which is generated and administered during a buildings life cycle, structured and represented by means of (3D) objects. The objects may be construction elements as well as more abstract objects such as spaces. BIM modelling is the process in which this information is generated and used. BIM tools are the IT applications needed in order to create and manage the information. Thus, BIM is not a technique but rather a generic term over how information is created, stored and used in a systematic and quality insured way. (Jongeling, R., 2008)

An international approach to the concept BIM is given from Chuck Eastman, Ph.D at Georgia Tech College. He defines BIM in the following way:

"BIM integrates all of the geometric model information, the functional requirements and capabilities, and piece behaviour information into a single interrelated description of a building project over its life cycle. It also includes process information dealing with construction schedules and fabrication processes".
(Eastman, C. Teicholz, P., Sacks, R. & Liston, K. 2008)

Based on these definitions and interpretations of BIM the authors would like to describe BIM in the following way:

BIM is a mode of operation when creating and administrating data concerning a project. To ease this process the data and information is often stored in an intelligent model containing 3D objects. BIM is often used in order to minimise misunderstandings and errors with the goal of having a more effective construction process. Technique and software should not be seen as BIM itself but rather a tool to simplify the administration.

2.2 Experiences of BIM in infrastructure industry today

The use of BIM in the Infrastructure industry is not as widely spread as in the building industry. (Ljungberg, H. Appendix 8.1) This is often due to differences in areas of focus. In the building industry the primary focus has been on the 3D modelling and on the collision avoidance between different actors in the erection process. The 3D modelling represents a significant part of the BIM usage in the infrastructure industry as well but the collision control is not relevant to the same extent. In addition there are well developed standards regarding file formats etc. in the building industry which is not the case in the infrastructure industry. (Bengtsson, P. Appendix 8.2) Thus, there are unclear opinions regarding the potential of BIM in the infrastructure industry today. (OpenBIM, 2010e)

Despite the above mentioned uncertainty there are some real life examples that show the advantage with BIM in the infrastructure industry. Foundation works in urban areas is one example where BIM models are favourable. By modelling the area in 3D before the construction work starts results in a visual understanding of the present conditions which reduce risks in the later erection process. (Bengtsson, P. Appendix 8.2) This was done in the project Örtedalen in Uppsala where the 3D model clearly showed present pipes in the ground. (OpenBIM, 2010a)

Another important area in which BIM can make a significant improvement is for terrain models for excavators. Today the surveyors on site has to translate the traditional 2D drawings into terrain models for the excavators. By developing a BIM model where the output data is directly comprehensible with the excavators staking will be less time consuming and avoid errors. The fact that there often is high volumes of mass that shall be excavated demonstrate the economic importance of this improvement. (OpenBIM, 2010b)

The above text indicates that there are economic incentives connected to BIM in the infrastructure industry already today. Nevertheless, it's important to remember that

BIM still is under development and therefore not capable to generate its full potential in practice yet. Projects using BIM is often expected to give a payback directly connected to the BIM applications. This is of course not relevant due to the low maturity of the concept. BIM, as well as any greater development project, needs a trial period in terms of development projects in order to achieve necessary experience regarding the function in practice. Due to these circumstances it is important that BIM, within the organisations, is controlled from a central point of view apart from the different departments. The departments will then feel confident using BIM without jeopardising the economical result to any greater extent. In a broader perspective there is a risk that the current organisations may take a reserved position in the BIM discussion and wait for other companies to carry out the costly development process. The latter demonstrates the importance of agreements on an industry level in order to govern and in some extent force organisations to use BIM. (Bengtsson, P. Appendix 8.2)

One of the main problems with BIM in the infrastructure industry is the absence of regulations of responsibilities concerning the flow of digital information. Without such regulations it's hard to distinguish who is responsible when problems occur. Moreover, this may cause disagreements when it comes to pricing of the digital deliveries in the end of a project. In the Swedish building industry an agreement template `Avtal för digitala leveranser` has been developed in order to cover most of the above complications. However, any such template in the infrastructure industry has not been arranged yet. (OpenBIM, 2010c)

Another complication with BIM in the infrastructure industry is to make every actor in the project to work as a team rather than thinking of their individual needs. The 3D drawings created in the design process need to be in a detail level that is favourable for the consultants and contractors if the process shall work without complications. The consultants and latter contractors have certain requirements regarding accuracy and tolerance which need to be fulfilled. If the detail level between the different actors is not synchronised, a lot of the benefits with the model oriented way of working will be lost. Therefore the extent of BIM usage in each separate project must be defined and mediated to the participants in an early stage of the process. In addition there is a hope and belief among many actors in the industry that `Bygghandlingar 90 del 7` will become a natural platform for such disagreements in the future. (OpenBIM, 2010e)

In order to deal with the above mentioned problems some advocate that the involved actors need to change their focus. Today most stakeholders almost exclusively highlight the technical aspects as the primary source to a successful BIM implementation. Instead more qualitative aspects such as individual characteristics and attitudes should be considered. The industry can achieve minor development by exclusively focus on technical aspects but the great increase in efficiency, which BIM has the potential to generate, can only be achieved if the participating actors has a shared view of the project process. (Bengtsson, P. Appendix 8.2) A common goal is crucial for a well working organisation within the project and this can only be achieved if the participants understand and respect each other. (OpenBIM, 2010d)

Moreover, not only consensus between the actors is of major importance, but also understanding for the concept BIM. The BIM concept must not be interpreted as a separate process besides the ordinary design process, but rather a development of the already existing process into a more efficient one. The former approach may be destructive for the implementation in terms of easiness to skip something that is not understood as a part of the original process. Even the need of significant amount of money in the development phase will be easier to legitimate if the concept is interpreted as an innovative breakthrough for the entire industry. (Ljungberg, H. Appendix 8.1)

2.3 Common BIM software in infrastructure industry

In order to be able to handle the great amount of information and data that is created in the BIM process intelligent software is often used. By using intelligent software data can be stored in a single model making it available for all with access to the model. Some of the more common software used in infrastructure will be presented in the following sections.

AutoCAD Civil 3D

The AutoCAD Civil 3D is a software developed with the purpose to fulfil the needs in BIM for civil engineering. In practice it´s mainly used in large civil projects to modelling roads and landscape in 3D, see Figure 1. The software is based on a non-parametric coordinate system and, in order to model a structure, all the dimensions have to be changed individually. The latter is a disadvantage when it comes to modelling a bridge or larger concrete structure since every model created will be unique. One of the purposes with BIM is to make the design process more effective. The current software's inability to reuse or modify old models to create new ones is thus a drawback with AutoCAD Civil 3D. (Autodesk, 2009)

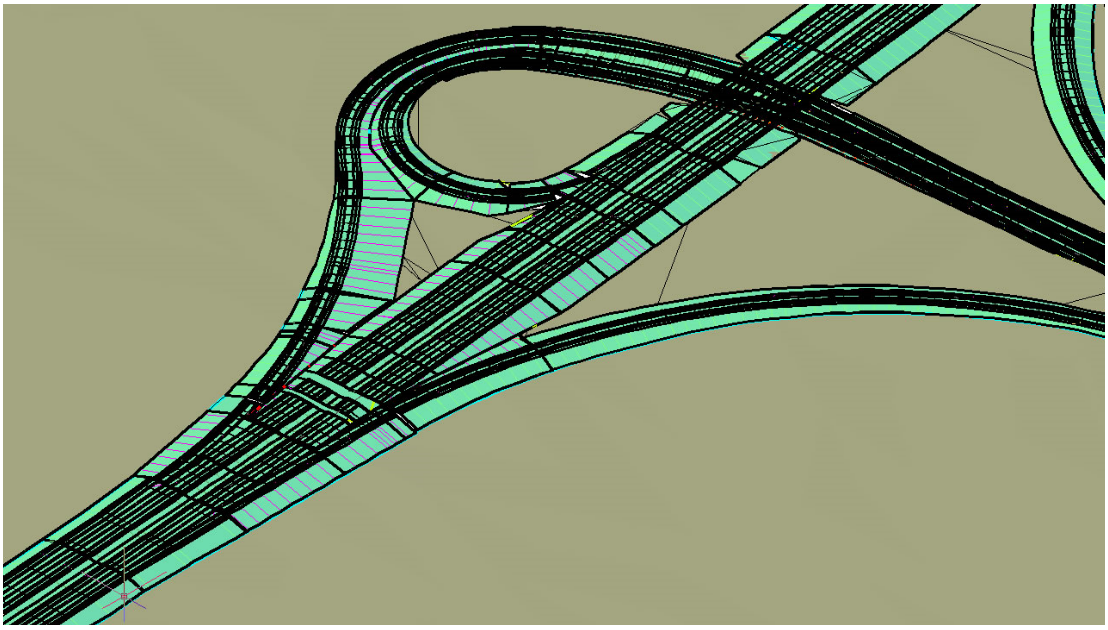


Figure 1 - AutoCad Civil 3D (Autodesk, 2009)

Autodesk Revit Structure

The Autodesk Revit Structure software supports the BIM process primarily concerning structural engineering. The ability of Revit Structure to coordinate design and documentation of structures makes it an useful equipment in BIM design. One of the main advantages with the software is the favourable properties concerning detailed design such as reinforcement placement etc. In addition the software is able to generate schedules of materials and components which make the design and erection process more effective.

The coordinate system used by Revit Structure is parametric i.e. the software enables the reuse of models from previous projects but with different dimension. However, the software does not cope with curvature in both x-y direction and x-z direction simultaneously. Thus, for simple geometries such as straight elements or elements with curvature in one plane only the software works well. In more complex design situations, with curvature in more than one plane, the use of Revit Structure is more problematic. Due to these features Revit Structure is mostly used in design of standard elements or structures such as simple bridge supports, see Figure 2. (Autodesk, 2010)

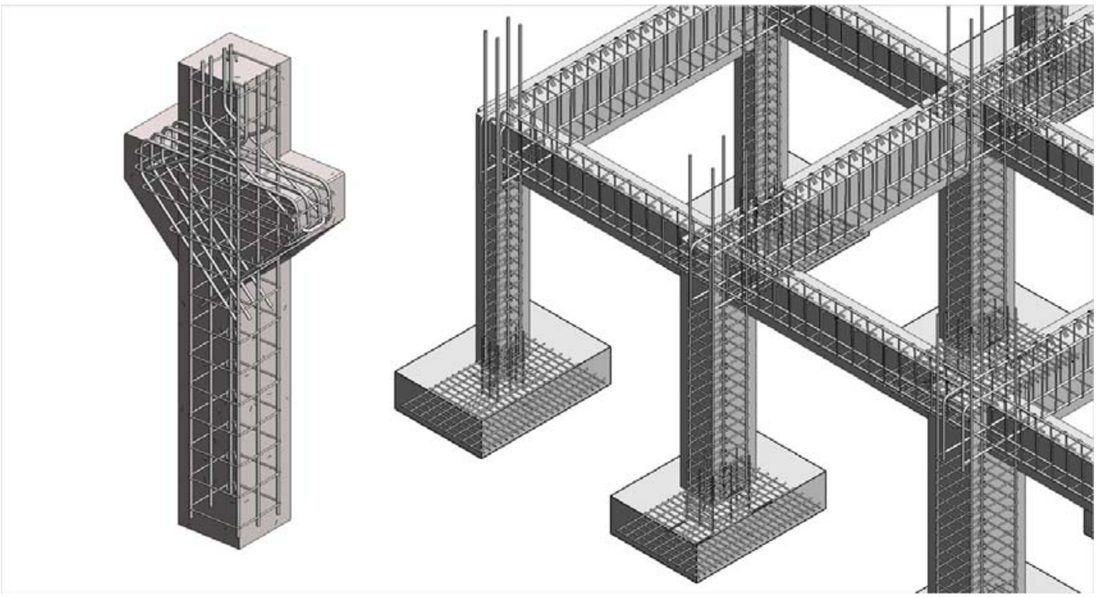


Figure 2 - Autodesk Revit Structure (Autodesk, 2010)

Tekla Structures

Tekla structures is a software developed for structural engineering. The software integrates detailed reinforcement and is able to create schedules that can be used throughout the construction process, see Figure 3. This makes the software a powerful tool for all participants in the construction process. Models created in Tekla Structares are fully parametric. When changing the dimensions of structual elements, details such as reinforcement spacing and number of bars are correctred automatically. The fact that Tekla Structure uses a parametric coordinate system by standard creates potential for reuse of models and data. (Tekla, 2011)

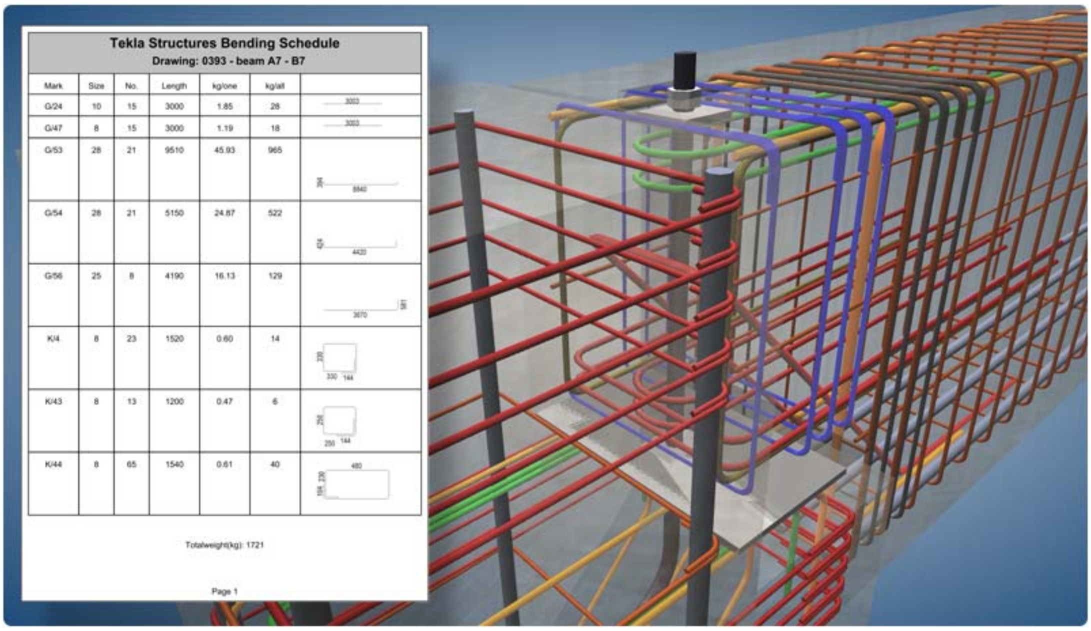


Figure 3 - Tekla Structures (Tekla, 2011)

Impact Reinforcement

Impact Reinforcement (IR) is an application for AutoCAD software which generates intelligent reinforcement drawings and schedules. By using IR you can draw reinforcement in traditional 2D but include detailed information such as dimensions and bending radius. The reinforcement can be specified in several ways, including predefined reinforcement solutions or completely manual schedule. Later complete reinforcement schedules can be created and used further on in the process. A process which normally is done by hand. IR can also generate 3D drawings of the specified reinforcement making the understanding easier for participants later in the process, see Figure 4. (StruSoft, 2011)

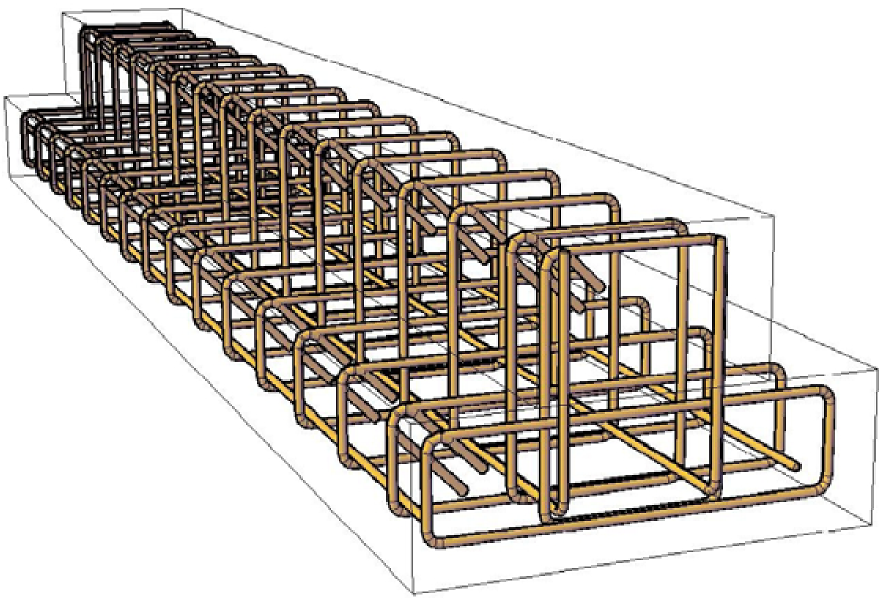


Figure 4 - Impact Reinforcement (StruSoft, 2011)

2.4 Implementation of BIM at Skanska Infrastructure department

According to Skanska's business plan for year 2011 – 2015 every infrastructure project with a contract sum exceeding 50 million sek, shall use some BIM applications. Skanska has identified some applications that can support the present project entirely and some less proven applications in which Skanska views great potential. Among the former 3D design is an important contribution while the latter may house applications such as safety planning, use of digital models on the construction site etc.

The infrastructure department at Skanska works with the BIM implementation in different stages. In order to evaluate the priority of implementation between different BIM applications Skanska tries to estimate the demand of resources in relation to present or potential requirements in the organisation for each application respectively. A rule of thumb is that an application with low resource demand in relation to organisational needs shall be implemented in an early stage. Thus, high complexity and/or lack of need in the organisation are/is primary reasons for omission of specific applications. Moreover, working in this way will simplify the anchoring of the BIM applications in the erection process. The latter is due to the focus on organisational needs which is likely to generate value adding applications for the present project. (Ljungberg, H. Appendix 8.1)

However, the extent of BIM usage is also dependent on the type of procurement. In traditional design and build contracts, Skanska execute the detail design in accordance with the project brief. This means that the design of constructions is broadly predetermined. In operations contracts, on the other hand, the potential benefits from BIM are clearer. This is due to the shifted focus to function/operation instead of detailed constructions. The function/operation approach enables use of BIM-applications such as parametric standard bridges etc.

The 3D model and the development of more comprehensible terrain models for excavators can be distinguished areas in which Skanskas infrastructure department has put considerable efforts so far. Another area that has not been treated in any greater extent yet, but in which Skanska views significant potential, is reinforcement schedules generated directly by the BIM-model. By develop models with comprehensible output-data i.e. schedules suited for each step in the chain from design to erection, Skanska infrastructure believe that they could save considerable amount of money. Without the today necessary translation of the schedules at each step in the chain, i.e. at the procurement department, supplier, etc., valuable time will be saved in the process. (Ljungberg, H. Appendix 8.1)

3 Current reinforcement process

The information flow in today's reinforcement process for construction of reinforced concrete structures is characterised of a few main activities. Once the client has submitted the necessary input documents to the design department, the detailed work with drawings and schedules will start. When the design work is completed, or almost completed, the documents are submitted to the contractors' procurement departments. The procurement departments will in turn start to purchase the necessary amount of reinforcement. Commonly, framework agreements are set up with a few suppliers in order to avoid time consuming and resource demanding negotiation work in every separate purchase activity. The final call is then usually made by the on-site organisation for each individual project. When the supplier achieves the schedules and drawings the production of the physical reinforcement product starts. Finally the requested quantity of reinforcement is delivered to the construction site (Johansson, J. & Møller, R. Appendix 8.4) Figure 5 illustrates this process

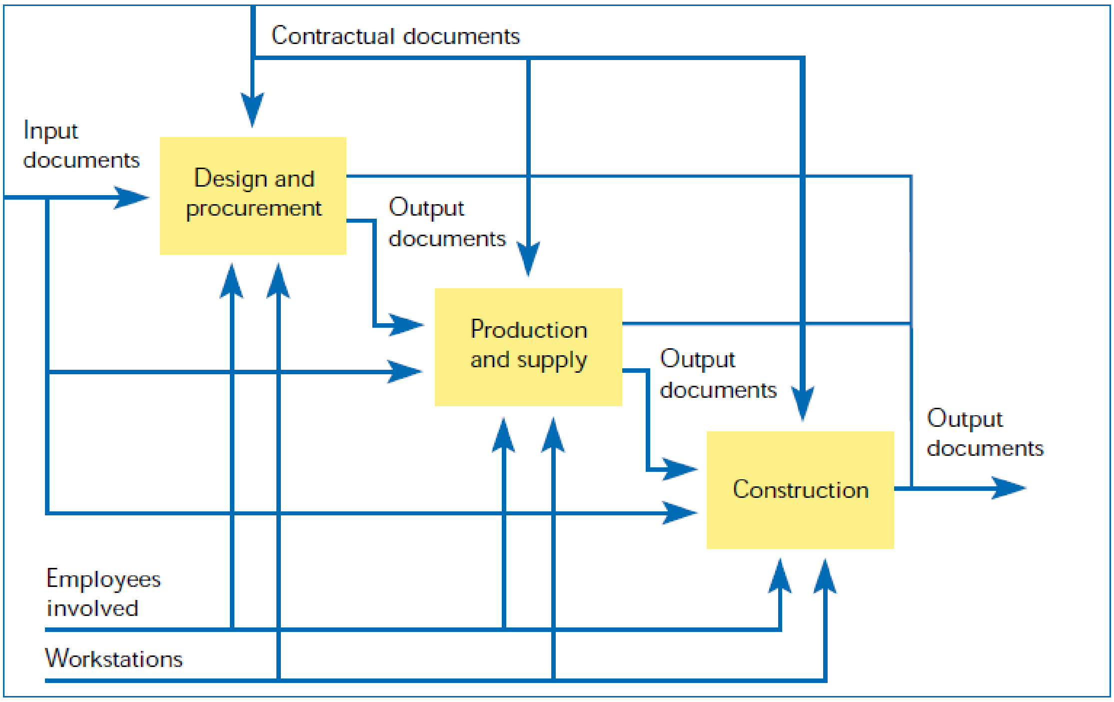


Figure 5 - A flow chart showing reinforcement process information flow (British Cement Association, 2000)

The following sections will describe each one of the main activities in the process illustrated in Figure 5. First the clients' role and needs concerning this process will be described. Corresponding analysis will then be executed for the design department. The procurement department and suppliers are strongly connected to each other and represents a central part of this process. Thus, these two functions will stand for a major part of this chapter. The needs from the on-site organisation will also be covered in minor extent. Finally two successful attempts, in which two companies in different ways contributed to a more effective process, are studied in order to highlight potential areas of improvement in the current reinforcement process.

An important aspect to consider is that the information flow between the above mentioned functions in the process is of great importance for this study. Nevertheless, the breakdown of this chapter into the separate activities still feels natural due to the fact that the aim of the chapter is to introduce the present conditions. The thoughts about the information flow between the functions will still be covered within each subchapter.

3.1 The Client

One of the main buyers of infrastructure services in Sweden is Trafikverket. Trafikverket is an authority with the purpose of expanding and maintaining the Swedish road and railway system. (Trafikverket, 2011)

The data that Trafikverket requires from their hired contractors today, is the traditional 2D drawings. Trafikverket state the importance of that they as a company does not require specific software since this would limit the freedom of competition. In today´s enquires the requirement is set to the file format dwg. However, today AutoCAD as a software is considered to be a standard in the industry. Trafikverket's internal documents and manuals that state how to achieve the correct data are also based on AutoCAD which indicate that Trafikverket after all is not completely neutral. The data such as road lines created by Trafikverket, which is later given to contractors and other cooperation partners, is not required to be in a specific format. This is due to the fact that Trafikverket hire external consultants for the creation of data. Thus, by demanding a specific format Trafikverket would exclude some consultants which cannot fulfil the format requirements. Common formats for this type of data is XML and Novapoint with Novapoint as the most common. (Franzén, H. Appendix 8.3)

Trafikverket is at an early stage in the usage of BIM. They have started a development program within the organisation containing the introduction of BIM. The purpose is to inform and educate the employees in the subject of BIM. At Trafikverket there are currently no demands in using BIM within the organisation. However, specific projects are encouraged to use BIM to some extent. This is however strongly dependent on the people assigned to each project. (Franzén, H. Appendix 8.3) During the last year Trafikverket has shown more interest in BIM by using this in some enquiries. (Bengtsson, P. Appendix 8.2) However since BIM is under development Trafikverket chooses to monitor the market to observe, what software and processes are being used. As with previous enquires Trafikverket is careful not to set any standards considering file formats and software due to the risk of preventing the freedom of competition. (Franzén, H. Appendix 8.3)

Trafikverket has some development projects where the enquires contains requirements concerning how the data should be able to interact with BIM. The BIM requirements are in these cases complement to the traditional 2D requirements. The models created in development projects should be able to deliver data such as visualisation, quantities etc. see Figure 6. The specific format is however up to the contractors to choose individually. (Franzén, H. Appendix 8.3)

- ✓ Collision control
- ✓ Drawing production
- ✓ Information flow
- ✓ Time planning
- ✓ Survey at site
- ✓ Machine control
- ✓ Amount regulation
- ✓ Project follow-up
- ✓ Schedule model
- ✓ Visualization

Figure 6 - Requirements set by Trafikverket in a development project. (Appendix 8.13)

According to Trafikverket there are two main ways of implementing BIM in the process. First, the participants in each project can be forced to use BIM. The consequence of this could be lack of interest since the initiative does not come from the participants themselves. Thus, there is a risk that the outcome will not be as good as it could have been and the probability of using BIM in following projects will decrease. Another way to implement BIM would be to create incentives for the participating actors. An example could be economic compensation for the usage of BIM which is likely to increase the interest for the concept. Today Trafikverket has their own budget to stimulate the usage of BIM in their organisation.

Of great importance in Trafikverket further work is to set the procedure to insure quality in the data delivered to other participants. (Franzén, H. Appendix 8.3) Contractors and other cooperation partners have signalled for a long time that in order for their work to be more efficient they must be able to rely on the data that is given to them. Often the data is incorrect or in the incompatible format. Thus, the data has to be transformed into other formats in order to be comprehensible, which may lead to data losses. (Ljungberg, H. Appendix 8.1) An important aspect for Trafikverket is to determine in which extent their data is correct. This is in order to ensure the contractors about in what extent they can rely on the data achieved. Therefore this is one of the main areas of focus at Trafikverket today. (Franzén, H. Appendix 8.3)

In the today's 2D data and drawings the participants are familiar in dealing with errors. In new type of models however there is an uncertainty in who has the main responsibility for the model and therefore the responsibility for possible errors. (Bengtsson, P. Appendix 8.2) In the case with BIM models Trafikverket views their ability to define in which extent the model is correct which would facilitate the allocation of responsibility. (Franzén, H. Appendix 8.3)

3.2 Design process

The design process is of great importance when it comes to influence the information flow in the reinforcement process. The drawings and schedules are created in this stage which in great extent will influence the use of BIM in the overall process. Thus, this stage will set up a framework in which the remaining activities in the process will take place. (Ljungberg, H. Appendix 8.1)

3.2.1 Reinforcement detail design

As described in Chapter 2.3 there are some common design programs within the Swedish infrastructure industry today. The choice of program differs between the companies and is often based on a weighted assessment of technical features as well as overall costs. The latter includes costs for licenses etc. (Johansson, J. & Møller, R. Appendix 8.4)

The major part of Skanskas infrastructure design is still done in 2D. A widely used software for this propose at Skanska, as well as at many other actors within the industry, is AutoCAD. However, once the drawings are created there is no standardised application available within the organisation for reinforcement schedule. Thus, the principal process today is that drawings are created in AutoCAD and then submitted to an external consultant for the creation of reinforcement schedules. These consultants are specialists within the current area and specify every single reinforcement bar according to the clients' needs. Except for this schedule work the consultants also are able to identify shortcomings in the drawings and, based on that, come up with suggestions of improvement. The fact that this job in some way is done by hand indicates great potential of improvement in this stage in order to streamline the entire process. (Ljungberg, H. Appendix 8.1)

In order to develop the above mentioned reinforcement design process Skanska infrastructure today increasingly uses the AutoCAD application Impact Reinforcement. By extracting 2D sections from the 3D model the reinforcement lines can be drawn using this application. Moreover, the program also include functions for creating complete reinforcement schedules. This way of working saves significant amount of time and resources compared to the traditional working method described above. (Ljungberg, H. Appendix 8.1)

In order to utilise the full potential of Impact Reinforcement, extensive knowledge and experience regarding both the software and reinforcement design is essential. As a result of this Skanska infrastructure has not been able to exploit the function for creating complete reinforcement schedules so far. An important step in this development process is to preserve the knowledge from the external schedule consultants. This knowledge is mainly due to experience in practical usage of reinforcement on site and corresponding adjustments according to the erection method. By preserving this knowledge Skanska will be aware of their own shortcomings in the initial design and thus be able to implement the modifications earlier in the process. (Ljungberg, H. Appendix 8.1)

However, the design software described in Chapter 2.3 are also widely used abroad. One of Skanska's steel suppliers, UPB Holding, uses Tekla in order to execute their design commitments. UPB Holding is one of the leading Latvian construction and building material manufacturer. Their detailed steel design is commonly based on 2D-drawings achieved from their customers. When UPB have finished their design in Tekla they are able to extract schedules etc. directly from the 3D-model. The schedules need some manual intervention afterwards but otherwise the process is automated in large extent.[1]

3.2.2 Current reinforcement drawings and models

As mentioned earlier Skanska infrastructure uses AutoCAD Civil 3D in many of their projects. A drawing generated from the AutoCAD Civil 3D model is exemplified in Figure 7.

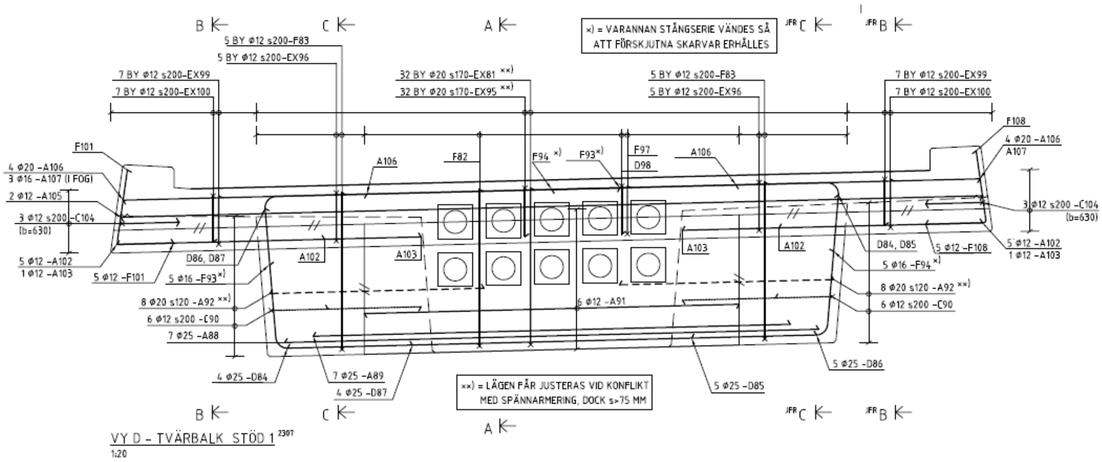


Figure 7 - Example of a drawing generated by AutoCAD Civil 3D

Drawings, such as the one in Figure 7, are submitted to external schedule consultants for creation of reinforcement schedules.

Impact reinforcement is, as mentioned earlier in the report, used in some extent by Skanska infrastructure design department. In contrast to the process with the external consultant, Skanska here execute the entire reinforcement design on their own. Models created with Impact Reinforcement can generate complete reinforcement drawings without any manual intervention. An example of such drawing is shown in Figure 8.

[1] Edgars Tooms, Project leader UPB, interview 2011-04-15

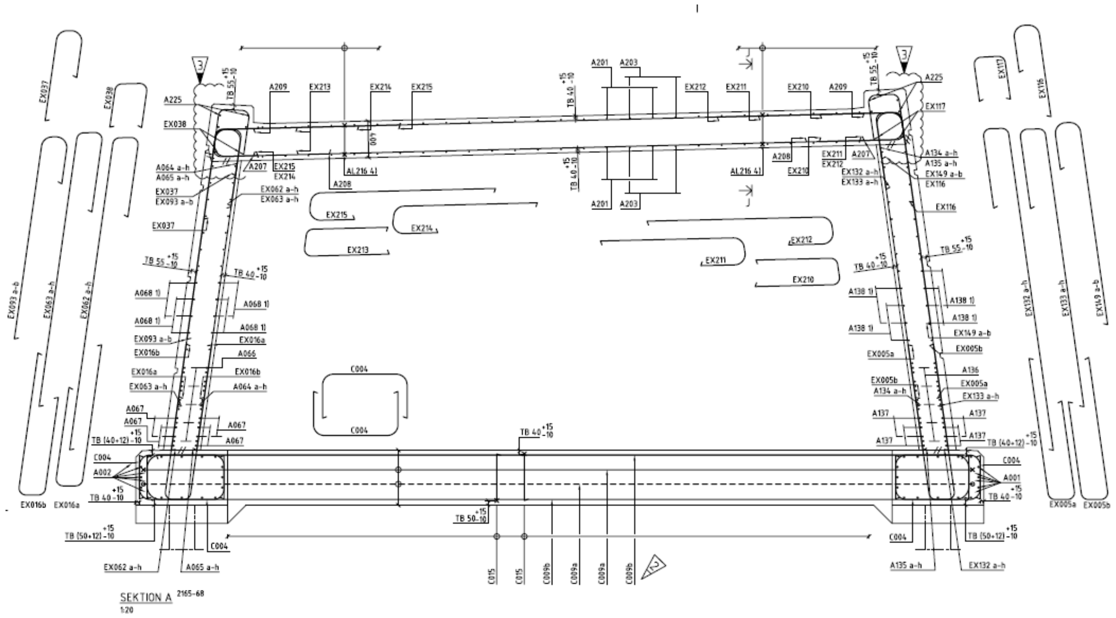


Figure 8 - Example of a drawing generated by Impact Reinforcement

Although Skanska use the above mentioned software's in order to execute their reinforcement design there are, as mentioned earlier, other widely used software's within the industry. The consultancy firm WSP uses Tekla Structures in many of their design commitments. Models and drawings generated by Tekla Structures are exemplified in Figure 9.

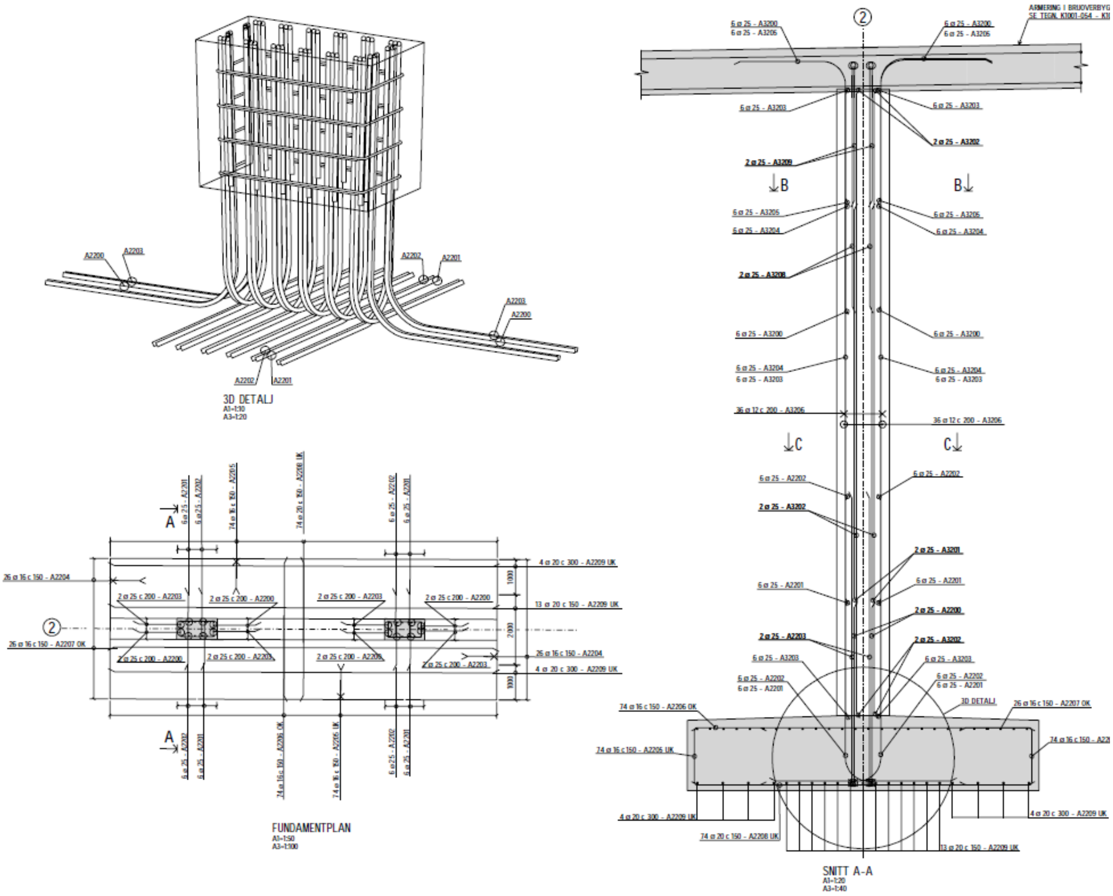


Figure 9 - Example of models and drawings generated by Tekla Structures

An interesting aspect to consider regarding the Tekla Structures software is that the above models and drawings are generated directly from the program without any larger manual intervention from the designers. Thus, WSP has no need for additional software such as Impact reinforcement.

3.2.3 Current reinforcement schedules

As already mentioned most of Skanska's reinforcement schedules are made by an external consultant. Once the consultants achieve the drawings exemplified in Figure 7, he/she starts to translate the information into comprehensible schedules. This is usually done with Celsa Steel`s software Q-armering. Q-armering saves the data in XML-format which is compatible with software such as AutoCAD. An example of schedule generated by Q-armering is shown in Figure 10.

	TYP	NUMMER	STÅL SORT	ANTAL GRP	ANTAL ST/GR	ANTAL TOTALT	Ø mm	KLIPP LÄNGD	DELMÅTT:mm, VINKLAR:grader Å	a	b	c	d	e	f	g	Å	x	y	v	s	t	u	R	KONSTRUKTIONSDEL ANMÄRKNINGAR	ÄNDR
1																									Ramp Etapp 1	
2	EX	81	B500BT			32	20	3470		1350	872	1350							875	87			93	64	Tvärbalk stöd 1	
3	A	82	B500BT			16	12	2100																		
4	F	83	B500BT			10	12	2110		1350	800									93				64		
5	D	84	B500BT			4	25	5870		1250	4700									84				160		
6	D	85	B500BT			5	25	2370		1250	1200									84				160		
7	D	86	B500BT			5	25	5860		1250	4700									86				160		
8	D	87	B500BT			4	25	2360		1250	1200									86				160		
9	A	88	B500BT			7	25	4700																		
10	A	89	B500BT			7	25	4200																		
11	C	90	B500BT			12	12	2640		550	830	1350												64		
12	A	91	B500BT			6	12	3250																		
13	A	92	B500BT			16	20	1900																		
14	F	93	B500BT			5	16	3690		650	3100									95				100		
15	F	94	B500BT			5	16	3090		650	2500									95				100		
16	EX	95	B500BT			32	20	1870		550	872	550							875	87			93	64		
17	EX	96	B500BT			10	12	2140		800	416	1000							420	87			93	64		
18	A	97	B500BT			16	12	1200																		
19	A	98	B500BT			16	12	1400																		
20																										

SAMMANDRAG

STÅLSORT	Ø	TOT m	TOT kg	KLIPPT kg	BOCKAT kg
B500BT	12	169	150	150	66
B500BT	16	34	54	54	54
B500BT	20	201	497	497	422
B500BT	25	136	525	525	285
STANDARDPRODUKTER		0			1226

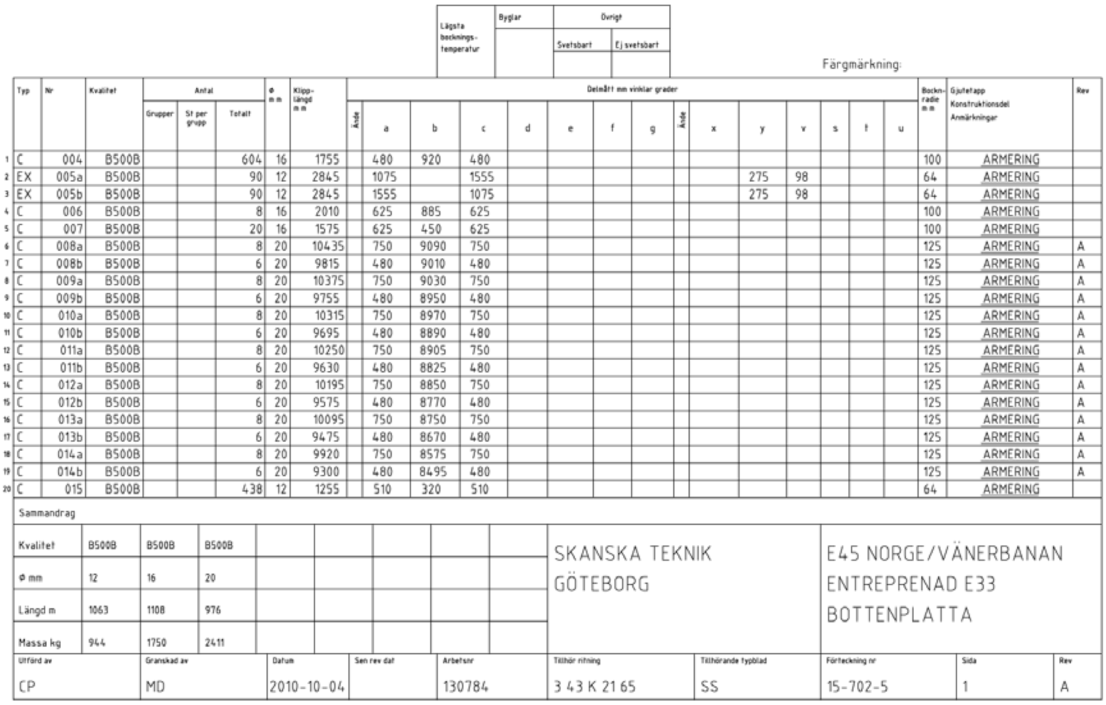
ARMERINGSFÖRTECKNING

PROJEKT Bro 15-702-4 SV Rampen	DATUM 2010-11-03	ÄNDRINGSDATUM		
Etapp 1	UPPDRAG NR 0159			
Tvärbalk Stöd 1	FÄRG 1 Vit			
	FÄRG 2			
UTFÖRD AV C-J B	GRANSKAD AV	TILLHÖR RITNING 343 K2312A	TYPBLAD	FORT.NR L-03	ÄNDRING

Figure 10 - Reinforcement schedule made by external consultant in Q-armering

In addition to the schedules of the type shown in Figure 10 the external consultant also summarise the total amount of the different reinforcement types for the current project, see appendix 8.9. The latter is done in order to simplify the subsequent purchasing process for Skanska.

The schedule generated directly by Impact Reinforcement differs in some aspects from the ones created by the external consultants. A significant shortcoming with Impact reinforcement is the absence of any function for summarising the total amount of the different reinforcement types. Another difference concerns the colour coding of the different bars. The external consultant codes the bar types with different colours which Impact Reinforcement does not. The principle of colour coding is that bars with a specific colour shall be placed in a specific part of the construction, e.g. red colour in the foundation. This will simplify the reinforcement work on site. (Liewendahl, M. Appendix 8.8) An example of reinforcement schedule generated from Impact Reinforcement is shown in Figure 11.



Lägsta bocknings-temperatur	Byglar	Övrigt	
		Svetsbart	Ej svetsbart

Färgmärkning:

	Typ	Nr	Kvalitet	Antal: Grupper	St per grupp	Totalt	ø mm	Klipp-längd mm	Ände	a	b	c	d	e	f	g	Ände	x	y	v	s	t	u	Bockn-radie mm	Gjutetapp Konstruktionsdel Anmärkningar	Rev
1	C	004	B500B			604	16	1755		480	920	480												100	ARMERING	
2	EX	005a	B500B			90	12	2845		1075		1555							275	98				64	ARMERING	
3	EX	005b	B500B			90	12	2845		1555		1075							275	98				64	ARMERING	
4	C	006	B500B			8	16	2010		625	885	625												100	ARMERING	
5	C	007	B500B			20	16	1575		625	450	625												100	ARMERING	
6	C	008a	B500B			8	20	10435		750	9090	750												125	ARMERING	A
7	C	008b	B500B			6	20	9815		480	9010	480												125	ARMERING	A
8	C	009a	B500B			8	20	10375		750	9030	750												125	ARMERING	A
9	C	009b	B500B			6	20	9755		480	8950	480												125	ARMERING	A
10	C	010a	B500B			8	20	10315		750	8970	750												125	ARMERING	A
11	C	010b	B500B			6	20	9695		480	8890	480												125	ARMERING	A
12	C	011a	B500B			8	20	10250		750	8905	750												125	ARMERING	A
13	C	011b	B500B			6	20	9630		480	8825	480												125	ARMERING	A
14	C	012a	B500B			8	20	10195		750	8850	750												125	ARMERING	A
15	C	012b	B500B			6	20	9575		480	8770	480												125	ARMERING	A
16	C	013a	B500B			8	20	10095		750	8750	750												125	ARMERING	A
17	C	013b	B500B			6	20	9475		480	8670	480												125	ARMERING	A
18	C	014a	B500B			8	20	9920		750	8575	750												125	ARMERING	A
19	C	014b	B500B			6	20	9300		480	8495	480												125	ARMERING	A
20	C	015	B500B			438	12	1255		510	320	510												64	ARMERING	

Sammandrag

Kvalitet	B500B	B500B	B500B
ø mm	12	16	20
Längd m	1063	1108	976
Massa kg	944	1750	2411

SKANSKA TEKNIK
GÖTEBORG

E45 NORGE/VÄNERBANAN
ENTREPRENAD E33
BOTTENPLATTA

Utförd av	Granskad av	Datum	Sen rev dat	Arbetsnr	Tillhör ritning	Tillhörande typblad	Förteckning nr	Sida	Rev
CP	MD	2010-10-04		130784	3 43 K 21 65	SS	15-702-5	1	A

Figure 11 - Reinforcement schedule generated by Impact Reinforcement

An interesting comparison to Skanska's reinforcement schedule can be achieved by studying corresponding schedules for WSP. As mentioned in Chapter 3.2.2 WSP works in great extent with the design program Tekla Structures. In this particular project WSP generated reinforcement schedules directly from drawings in Tekla Structures, see Figure 12. The file format is .csv and contains all the information necessary for the present contractor. Due to well rooted routines regarding format for reporting, the file in this particular project were extracted to a Microsoft Excel file. However, the later transformation didn't contribute with any additional information regarding the reinforcement.

Tekla Structures böyeliste
Prosjekt: E18 GULLI - Dato: 2010-12-10
Prosjektnr: 119727

Pos.	Var	Antall	Kval.	Dia.	Lengde	Vekt/stk.	Vekt	Form	Krok	Krok	a	b	c	d	e	R
A1100	1	32	B500NC	20	10490	25.9	827.8	0	0	0	10490					0
A1100	2				10490	25.9					10490					
A1101	1	31	B500NC	12	1605	1.4	44.2	21	0	0	600	450	600			16
A1102	1	24	B500NC	12	685	0.6	14.6	21	0	0	120	490	120			16
A1103	1	71	B500NC	16	2625	4.1	294.1	21	0	0	1100	490	1100			25
A1104	1	142	B500NC	16	2155	3.4	482.9	0	0	0	2155					0
A1104	2				2155	3.4					2155					
A1400	1	36	B500NC	20	10490	25.9	931.3	0	0	0	10490					0
A1400	2				10490	25.9					10490					
A1401	1	24	B500NC	12	685	0.6	14.6	21	0	0	120	490	120			16
A1402	1	142	B500NC	16	2290	3.6	513.1	0	0	0	2290					0
A1402	2				2290	3.6					2290					
A1403	1	71	B500NC	16	2625	4.1	294.1	21	0	0	1100	490	1100			25
A1405	1	36	B500NC	12	1605	1.4	51.3	21	0	0	600	450	600			16
A2100	1	32	B500NC	16	11890	18.8	600.4	0	0	0	11890					0
A2101	1	80	B500NC	20	3285	8.1	648.1	21	0	0	490	2390	490			40
A2102	1	32	B500NC	16	1985	3.1	100.2	21	0	0	800	450	800			25
A2103	1	71	B500NC	16	3325	5.2	372.5	21	0	0	1450	490	1450			25
A2104	1	80	B500NC	16	3305	5.2	417.2	21	0	0	490	2390	490			25
A2200	1	8	B500NC	25	3160	12.2	97.4	99	0	0						250
A2201	1	24	B500NC	25	3155	12.2	291.7	12	0	0	2040	1250				250
A2201	2				3155	12.2					2045	1250				
A2202	1	24	B500NC	25	4365	16.8	403.6	12	0	0	3250	1250				250
A2202	2				4400	17.0					3290	1250				
A2203	1	8	B500NC	25	4410	17.0	135.9	99	0	0						250
A2204	1	52	B500NC	16	2170	3.4	178.1	21	0	0	800	635	800			25
A2205	1	148	B500NC	16	2205	3.5	515	21	0	0	800	670	800			25

Figure 12 - Reinforcement schedule generated by Tekla Structures

3.3 Procurement process

Skanska Nordic Procurement Unit (NPU) is a cooperation between the procurement units in each of the Nordic countries. The purpose is to create common agreements and in that way get better deals with the producers. NPU also share ideas and methods of how to make the procurement process effective. (Johansson, J. & Møller, R. Appendix 8.4)

One of NPU´s main responsibility area is the creation and support of different kinds of framework agreements. The purpose of these agreements is to keep the total costs down, insure an overall satisfying quality over time and save time in the procurement processes. The latter is due to the fact that negotiations concerning price, quality etc. already are included in the framework agreements and thus can be neglected in the separate procurement processes within the projects. (Johansson, J. & Møller, R. Appendix 8.4) Except the above mentioned aspects the framework agreements also is favourable from an environmental point of view. The possibility to develop smart logistic solutions for large quantity purchases will reduce the total transportation needs and thus support a sustainable development.

Except developing the different types of framework agreements, NPU also work in large extent with the implementation of the agreements in the line organisation. This is a crucial factor in order to benefit from the favourable features generated from these agreements. The departments and project organisations need to get enough information about the present framework agreements in order to use them. Thus, local info newsletters are send out bi-weekly or when necessary to the concerned parties.

Concerning purchasing of reinforcement NPU are strongly collaborated with suppliers based in Latvia and Poland. The reason for this is the beneficial economic conditions which are present in these parts of Europe today. The primarily source for these conditions is the low cost for labour in relation to the Nordic countries but also the ability to decrease productions cost as a result of high quantity production. Thus, it is a strategic decision from Skanska's point of view to establish supplier relations in these countries. (Johansson, J. & Møller, R. Appendix 8.4)

However, NPU have noted that the information i.e. the reinforcement schedules sent to their suppliers today are inadequate in many aspects. To begin with they are converted into .pdf format before submission. This format is in general inappropriate when it comes to transmission of complex data. Secondly the schedules submitted are often incomplete and contains defects or unclear details which is a source to a poor quality process. (Johansson, J. & Møller, R. Appendix 8.4)

The final call for the reinforcement is done directly from the on-site organisation in the current project. When the project organisation achieves the schedules from the design department they in some cases have to adjust them in some extent. (Liewendahl, M. Appendix 8.8) The latter is a consequence of the uncertainty that is present in every planning and design phase. Thus, there will be some manually intervention in almost every project of this kind. This will in turn lead to an inconsistent structure of the final schedules due to the fact that the different project organisations have their own way of interpret and do these adjustments. (Johansson, J. & Møller, R. Appendix 8.4)

3.4 The supplier

To date, the process within many reinforcement suppliers organisations is based on manually work methods. Once the schedule is obtained from the current contractor, it has to be translated into an understandable and compatible format for the suppliers bending machines. This work is today done by hand and is a significant source of deviations from the intended schedule. The latter is due to human errors in the replication and transmission of data on paper. (British Cement Association, 2000)

In order to deal with the above mentioned problems it has to be a strong correlation between the contractor/designers file format and the capabilities of the suppliers bending machine. The latter is a quite common problem due to the relatively high cost related to the investments in new state-of-the-art machineries. Except the high costs in terms of capital, the supplier also has to train the workforce in order to make us of the new machineries full potential. Regarding the contractors/designers file format the absence of any industry standards seems to be the main problem. If the exchange of data shall work without any manually intervention a common standard within the industry is significant. (British Cement Association, 2000)

The following subchapters aim to describe the above mentioned problems in terms of case studies of Skanska's reinforcement suppliers. The first subchapter focuses on Skanska's abroad supplier VMS Group while the later gives a brief description of the domestic supplier Celsa Steel Service.

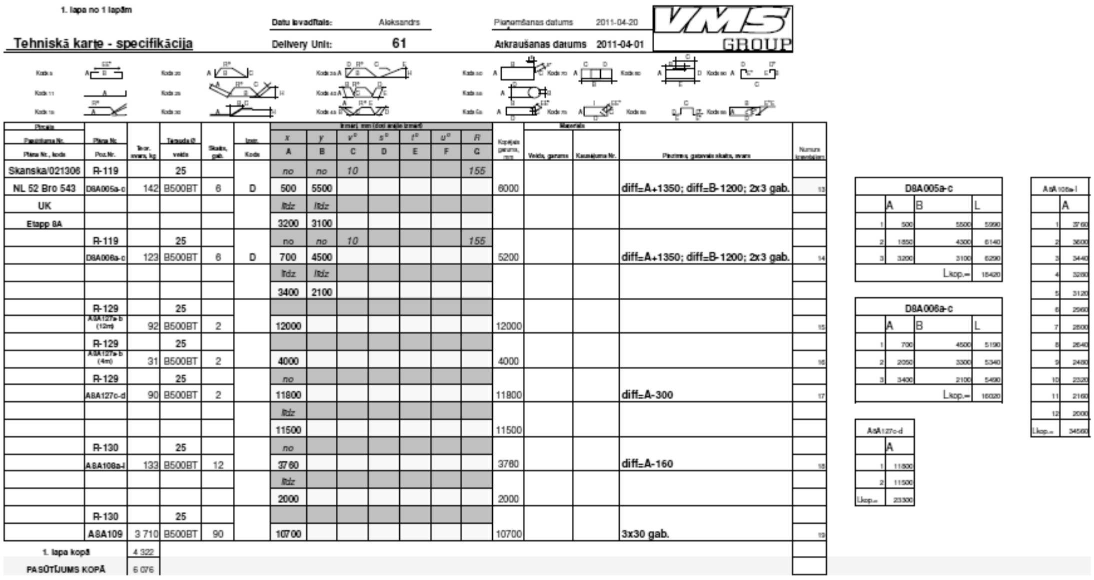
3.4.1 VMS Group

One of Skanska’s main suppliers of reinforcement is VMS Group based in Riga, Latvia. Example of products and services which VMS Group offers are ordinary loose reinforcement, reinforcement meshes and roll mesh. These products are cut and bended in accordance with the current project schedule. In addition to this VMS also offers design services which enables their customers to, instead of complete reinforcement schedules, only submit design drawings and thus hand over the work with schedule creation to VMS group. Moreover, VSM Group also executes steel fixing works on site, even though this only represents a minor part of their business today. (Svarinskis, E. Appendix 8.7)

The purchasing process of reinforcement between Skanska and VSM Group is today characterised by manual intervention in the interface between the two companies. The reinforcement schedule send to VSM Group are as mentioned earlier often in the format .pdf. This is usually the case irrespective of the schedule is made by an external consultant or with the software impact reinforcement, see Chapter 3.2.1. This means that the designers at VSM Group have to convert the information by hand in order to make it compatible with their software and in the end their bending machines.

Moreover, for more complex reinforcement products such as armature carcasses VMS group has experienced that the information submitted from the client often is insufficient. The 2D drawings VMS group achieves lack in the description of geometric aspects e.g. angles between the bars etc. which forces them to execute necessary calculations on their own. This is quite time consuming work which may have drastic consequences due to the tight delivery schedules. (Svarinskis, E. Appendix 8.7)

VMS Group today type in the information obtained from the schedules into an Microsoft Excel document, see Figure 13. When the information is structured in this Microsoft excel document it has to be manually typed in the bending machines. Thus, manual intervention is needed two times within VSM Groups internal organisation.


1. lapa no 1 lapām

Tehniskā karte - specifikācija | Datu ievadītais: Aleksandrs | Plānošanas datums 2011-04-20
Delivery Unit: 61 | Atkraušanas datums 2011-04-01

Pircējs / Pasūtījuma Nr. / Plāna Nr., kods	Plāna Nr. / Poz.Nr.	Teor. svars, kg	Tērauda Ø / veids	Skaits, gab.	Izm. Kods	x / A	y / B	v° / C	s° / D	t° / E	u° / F	R / G	Kopējais garums, mm	Veids, garums	Kausējuma Nr.	Piezīmes, gatavais skaits, svars	Numura [illegible]
Skanska/021306	R-119		25			no	no	10				155					
NL 52 Bro 543	D8A005a-c	142	B500BT	6	D	500	5500						6000			diff=A+1350; diff=B-1200; 2x3 gab.	13
UK						līdz	līdz										
Etapp 8A						3200	3100										
	R-119		25			no	no	10				155					
	D8A006a-c	123	B500BT	6	D	700	4500						5200			diff=A+1350; diff=B-1200; 2x3 gab.	14
						līdz	līdz										
						3400	2100										
	R-129		25														
	A8A127a-b (12m)	92	B500BT	2		12000							12000				15
	R-129		25														
	A8A127a-b (4m)	31	B500BT	2		4000							4000				16
	R-129		25			no											
	A8A127c-d	90	B500BT	2		11800							11800			diff=A-300	17
						līdz											
						11500							11500				
	R-130		25			no											
	A8A108a-l	133	B500BT	12		3760							3760			diff=A-160	18
						līdz											
						2000							2000				
	R-130		25														
	A8A109	3 710	B500BT	90		10700							10700			3x30 gab.	19
1. lapa kopā		4 322															
PASŪTĪJUMS KOPĀ		6 076															

D8A005a-c	A	B	L
1	500	5500	5990
2	1850	4300	6140
3	3200	3100	6290
		Lkop.=	18420

D8A006a-c	A	B	L
1	700	4500	5190
2	2050	3300	5340
3	3400	2100	5490
		Lkop.=	16020

A8A127c-d	A
1	11800
2	11500
Lkop.=	23300

A8A108a-l	A
1	3760
2	3600
3	3440
4	3280
5	3120
6	2960
7	2800
8	2640
9	2480
10	2320
11	2160
12	2000
Lkop.=	34560

Figure 13 - Supplier´s reinforcement schedule in Microsoft Excel

However, Recently VMS Group has started to use Lennerts & Partner software LPSYSTEM in order to create their reinforcement schedules. LPSYSTEM house an application for generating bar bending schedules, mesh cutting lists, labels, truck load reports, delivery notes, invoices etc. Example of such documents can be found in appendix 8.10. LPSYSTEM is also programmed to simplify connection with production machines. This application is however not fully exploit in VMS Groups processes yet due to the rather recent implementation of the programme. Furthermore is LPSYSTEM compatible with the file format .BVBS, which can be extracted from programs such as Impact reinforcement and Tekla. Thus, if information is submitted to VMS Group in this format, they will be able to transfer it into LPSYSTEM without any manually intervention. (Svarinskis, E. Appendix 8.7)

3.4.2 Celsa Steel Service AB

Celsa Steel Service AB is another supplier which Skanska collaborates with in many projects. Celsa Steel Service AB is a part of the larger Spanish organisation Celsa Group. Celsa Steel produces and sells reinforcement products such as roll mesh and welded cages.

Most of the external consultants that Skanska hire to do their reinforcement schedules uses Celsa Steel´s own developed software, Q-armering, for schedules. Due to this fact the file format submitted to Celsa Steel from Skanska is compatible with Celsa Steel´s production process. This means that no additional resources has to be put on converting the data to fit Celsa Steel´s machines, which saves both time and money. In addition the file format, which is XML, also is compatible with AutoCAD. The later indicates a potential to, already in the design phase, make use of the benefits related to a common file format. (Hildebrandsson, L. Appendix 8.6)

3.5 Erection process

The final step in the reinforcement process is the arrival of material and construction on site. The way the truck is loaded is important from the contractor's point of view. At Swedish construction sites there are restrictions regarding maximum carrying capacity for cranes etc. which may not be considered during loading at the supplier. This may result in an obstructed handling on site. If the supplier, in addition, is based abroad the problem may be even more likely to occur due to different restrictions in different countries. (Liewendahl, M. Appendix 8.8)

The lifting device to the reinforcement has to be adequate for the current purpose. The devices shall be approved for the current weight and arranged in order to simplify the handling on site. Finlay the supplier shall strive to achieve deliveries that are as consistent as possible concerning location to be used on site. The latter is very important for large project with high amounts of reinforcement but may be hard to achieve in smaller projects. (Liewendahl, M. Appendix 8.8)

Concerning defects and deviations from the intended schedule the extent and type of problem differs between different projects. According to Liewendahl there have not been any larger repeated problems at the major infrastructure project Partihallsförbindelsen. The deviations that do occur include missing parts, inaccurate angles on the bars etc. This has been solved by small purchases from suppliers nearby and by their own bending stations on site. However, the extent of this problem has almost been negligible at Partihallsförbindelsen. (Liewendahl, M. Appendix 8.8)

Moreover, Liewendahl emphasise the importance of accurate reinforcement schedules. If the schedules submitted to the project needs to be corrected there will be delays in an already tight delivery schedule. To overcome this problem in the project Partihallsförbindelsen, co-workers with extensive erection experience were involved already in the design phase. By contributing with their practical knowledge in this early stage, the schedules were more accurate and suited to the actual erection process. In the following erection phase the responsible design manager were situated at the construction site a few days per week. In this way the ordinary project organisation with simplicity could ask and sort out their questions and uncertainties regarding drawings, schedules etc. (Liewendahl, M. Appendix 8.8)

A similar interaction has been executed at Veidekke Gothenburg's projects. The employee assigned to be leader of structure design in the design process is later transferred to the actual construction on site as a team leader. By doing this Veidekke transfers design knowledge to the on site organisation which ensures a `smoother` erection process. (Åhlmans, A. Appendix 8.5)

3.6 Successful attempts to reach a more effective process

The following subchapters will describe how the two companies, E. Pihl & Søn A.S and Celsa group UK, succeeded in their attempts to reach a more effective reinforcement process. Their work is in great extent in line with the BIM concept which shows the potential with such a concept.

3.6.1 E. Pihl & Søn A.S

In the year 2009-2010 the Danish contractor E. Pihl & Søn A.S (Pihl) built an in situ concrete railway bridge in Sweden, Gothenburg. At an early stage Phil in cooperation with the Danish organisation "Det Digitale Byggeri" decided to implement BIM throughout the project reinforcement process. The goal was to add extra value to the erection on site by a 3D model containing information about the project. By doing so they hoped to see if an optimisation of the reinforcement process was possible. (E. Pihl & Søn A.S, 2010)

The development project was ordered by Trafikverket who at an early stage had done all the pre design in traditional 2D drawings. When choosing the software that would be used aspects such as the possibility to export reinforcement schedules, collision control and compatibility with other software were taken into account. The software chosen were Tekla Structures – precast Concrete Detailing. Pihl also saw the importance of having a project manager with the responsibility of the model itself which included tasks such as integration of the model at the suppliers manufacturing process and the integration at the construction site. (E. Pihl & Søn A.S, 2010)

One of the critical factors in the information flow where to identify the delivery time for data and drawings from each process. By setting a clear time schedule defining each participants available time for their processes the case with delayed deliveries due to late documentation could be minimised. For example the supplier, Celsa Steel, needed the documentation at least 14 days before delivery at site. This made it clear that in order to complete, and review the reinforcement design in time Pihl needed to start their design at least three weeks before delivery at site. (E. Pihl & Søn A.S, 2010)

By designing the reinforcement in 3D based on the traditional 2D drawings received from Trafikverket errors were detected which weren't visible in 2D. This was mainly errors such as collision and bending errors. In a ordanary project based on 2D drawings these errors probably would be detected as late as in the erection phase and thus would have to be corrected manually. However by doing the design in 3D Pihl could not only detect but also design and present solutions in the 3D model minimising the errors at site. (E. Pihl & Søn A.S, 2010)

When constructing a bridge in 2D Phil normally has 20-25% errors in the reinforcement that has to be adjusted manually at site. However in the case with the design in 3D the errors could be minimised to 0-2%. The time of erection the reinforcement was reduced from 26 days per bridge section to only 8-9 days per bridge section. Further into the project Pihl could see a trend in less used hours for erection when designing in 3D, see Figure 14. (Det Digitale Byggeri, 2010)

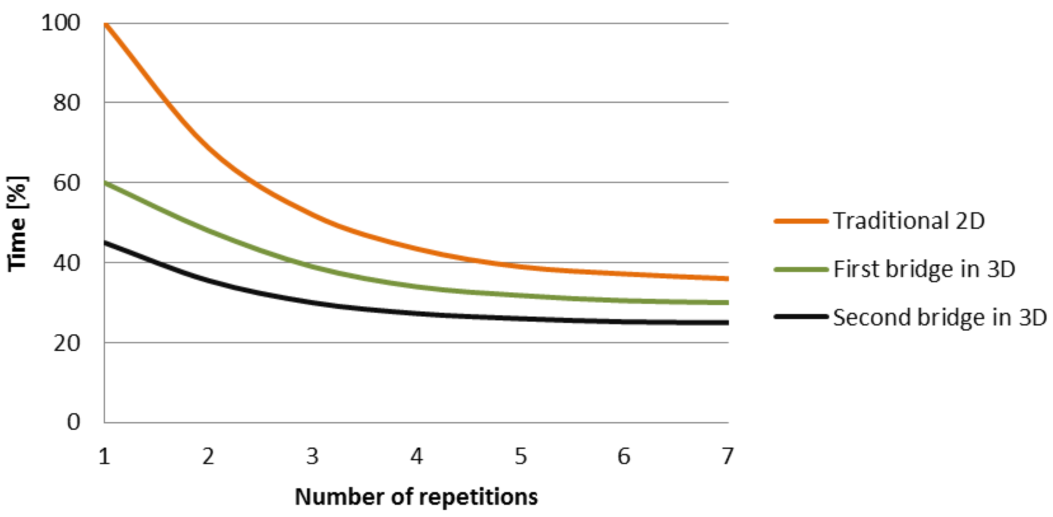


Figure 14 - Time for erection of bridge deck in Pihl study (Appendix 8.12)

The reduction of time was not only due to fewer errors but also the use of the model in erection. The employees at site were educated in how the reinforcement process would work and in what way the model could be used as a tool to demonstrate the method of erection. By educating the employees their practical knowledge could be integrated to the design and the reinforcement solutions. (E. Pihl & Søn A.S, 2010)

Phil also knew that one source of error where the delivery of documents to the manufacturing of reinforcement. By developing an application making Tekla Structures directly compatible with Celsa Steel´s production software Q-armering they could ensure that the reinforcement designed in Tekla Structures really where the reinforcement produced. With the application it was simple to mark the current reinforcement in the 3D model and send it directly into Celsa Steel´s manufacturing system. (E. Pihl & Søn A.S, 2010)

3.6.2 Celsa group UK

As mentioned in Chapter 3.4.2 Celsa Steel is a considerable supplier of reinforcement in Sweden. However, in UK Celsa group has developed well working processes in order to satisfy their clients' needs. The process from Celsa group UK point of view is illustrated in Figure 15. (CSSTG, 2010)

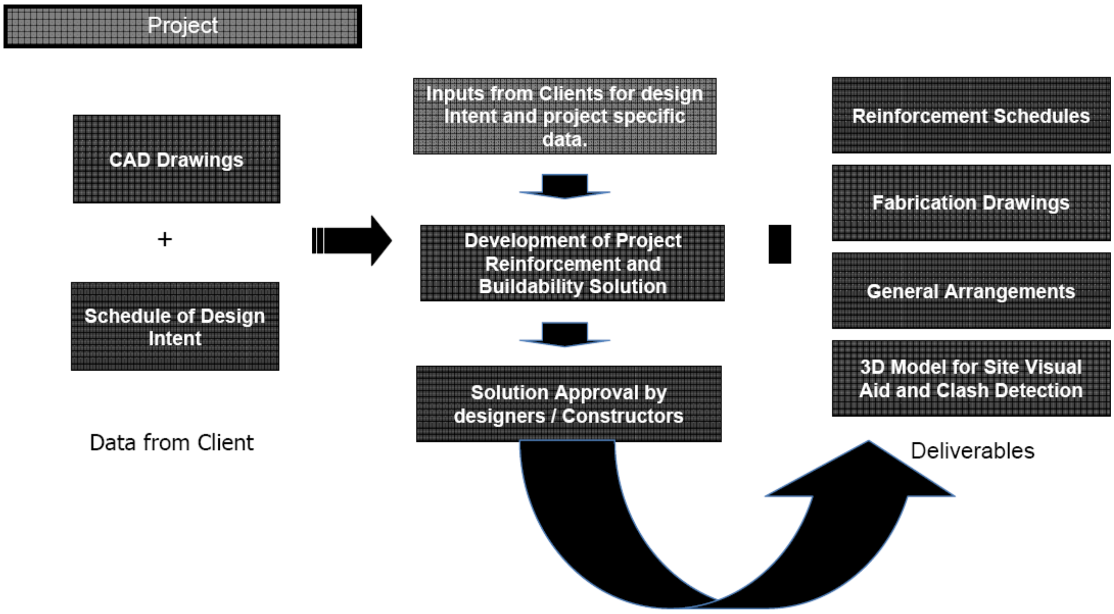


Figure 15 - Flow of information during the reinforcement process. (CSSTG, 2010)

According to own admission, Celsa group put substantial resources to develop the above illustrated process. By taking part in the detailing process they can use their broad reinforcement knowledge in order to improve the clients' solutions. As a consequence the steel fixing process during their own production is optimised and thus the later steel fixing process on site is reduced. In addition Celsa Group UK has strong belief in a parametric approach to speed up the detailing process. This will in the long term lead to an extensive library containing many different standardised reinforcement parts. (CSSTG, 2010)

Moreover, Celsa group tries to interface with both consultancies and contractors in order to identify a method of detailing that suits all i.e. is favourable for the total value stream. Their main focus is to reduce work on site by using value adding products like roll mesh, prefabrication and the utilisation of stock lengths. In order to avoid clashes they create their own 3D models of both concrete and reinforcement. These models are then brought together to create a BIM-model where the interaction between the concrete outline, the prefabricated reinforcement cages, roll mesh and loose reinforcement is shown. Finally construction sequences and delivery schedules are provided in order to optimise transportation and suit site requirements. The latter enables the site to receive just in time deliveries and will accelerate the unloading and placement of reinforcement. Figure 16 shows an example of a delivery schedule from Celsa group UK. (CSSTG, 2010)

DELIVERY ORDER	PRODUCTION WEEK	DEPOT	POUR	DATE REQUIRED	ROLLMAT TONNEAGE	MODEX TONNEAGE	LOOSE TONNEAGE	No. OF TRAILERS	POUR TONNEAGE	NOTES
1	N/A	NEATH	POUR 1 & 3	N/A	49.695	56.781	52.59	1	159.066	
2	N/A	NEATH	POUR 2	N/A	0	80.286	132.572	1	212.858	
3	N/A	NEATH	POUR 4	N/A	22.863	19.045	45.494	1	87.402	
4	N/A	NEATH	POUR 5a	N/A	15.38	18.049	18.82	1	52.249	
4B	N/A	NEATH	POUR 4b	N/A	0	9.083	0	1	9.083	
5	N/A	NEATH	POUR 5b	N/A	21.235	65.378	27.052	1	113.665	
6	N/A	NEATH	POUR 6	N/A	37.639	32.477	24.432	1	94.548	
7	N/A	NEATH	POUR 6A	N/A	0	0	12.13	1	12.13	
8	N/A	NEATH	POUR 7	N/A	29.466	19.033	25.207	1	73.706	
9	N/A	NEATH	POUR 8	N/A	37.552	37.745	29.669	1	104.966	
10	N/A	NEATH	POUR 9	N/A	31.913	22.492	21.34	1	75.745	
11	N/A	NEATH	POUR 10	N/A	49.105	35.182	30.497	1	114.784	
12	N/A	NEATH	POUR 11	N/A	29.012	65.752	48.839	1	143.603	
13	N/A	NEATH	POUR 12	N/A	23.66	183.675	42.85614	1	250.19114	
14	N/A	NEATH	POUR 13	N/A	19.532	71.956	25.10557	1	116.59357	
15	N/A	NEATH	POUR 14	N/A	6.973	49.151	67.33622	1	123.46022	
					374.025	766.085	603.93993	16	1744.04993	TOTAL TONNEAGE

Figure 16 - Delivery schedule of reinforcement created by Celsa group UK. (CSSTG, 2010)

Celsa group UK has identified early involvement of and understanding between all the actors as a crucial factor for a successful process. In order to work in line with this ambition Celsa group UK has developed detailed project check sheets, see appendix 8.11. By providing the client with such check sheet in an early stage, Celsa group UK will achieve important information regarding the present conditions and limitations on site, and therefore be able to adjust and plan their own manufacturing process. Moreover, in order to achieve this consensus and understanding between the actors in the process, BIM will play an important and significant role according to Celsa group UK. If the design team works in the same model and shares the same information the process will be accelerated and contain less defects. The latter is due to the visual understanding related to a BIM model in contrast to un-coordinated or poorly detailed drawings. Moreover, documents and presentations will be clear and complete which will minimise risks and simplify quality control. (CSSTG, 2010)

4 Future reinforcement process

By studying the reinforcement process described in Chapter 3 a flow chart illustrating the entire process can be created, Figure 17. It is clear that several times during the information flow from client to the final erection, data is either lost or recreated due to shortcomings in communication and administration. These shortcomings are all potentials in saving time and money by developing the current reinforcement process. By developing a way that eases the creation and administration of data errors will be minimised which ensures that data created in the early stages is not lost during the process.

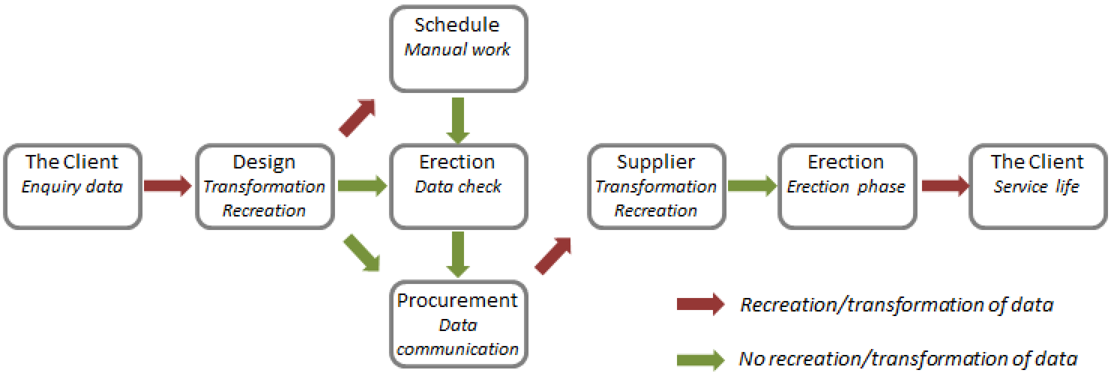


Figure 17 - Flow chart of current reinforcement process

Chapter 4 is divided into two main parts. First the most important improvement areas are listed and described, according to our interpretation of the situation. After that we try to come up with suggestions of how these areas shall be developed in order to reach a more effective reinforcement process.

4.1 Critical areas of improvement

Due to the current situation in the reinforcement process some critical areas of improvement has been identified. The following sections will summarise the most important steps in order to develop the current process.

1. Clear needs from the client:

The overall requirements for the entire process have to be given in an early stage. The frames, within which the actors are allowed to act, shall be specified with sufficient accuracy in order to develop the flow of information. The client is of significant importance concerning this, due to its great possibility to influence the other actors within the process.

2. Accurate/complete data submitted from the client:

In the next stage the data submitted further in the information chain has to be complete an accurate. Inadequate data is a source of errors which is likely to influence the entire process in terms of delays and overall uncertainty. The client has an important function here as well, due to the role as initial submitter of data.

3. **Compatible file format in the entire process:**

The compatibility in terms of file format is another important aspect to consider. Today this compatibility issue generates time consuming work in the interface between the actors. The absence of any industry standard is of course one of the reasons to this. However, any such standard is not likely to be set up within a reasonable time frame, which forces the participating actors to solve this on their own.

4. **Integrate erection knowledge in the design process:**

A key factor in the design process is knowledge regarding work practice on site. To make drawings and other document comprehensible for the project organisation on site, is crucial for a successful overall process. Thus, integrating persons with extensive erection experience as early as in the design phase may generate an increase in quality as well as decrease in time consuming extra work.

5. **Integrate design knowledge in the erection process:**

As mentioned in the previous section, integration of erection knowledge in the design process may be crucial for the end result. However, integration of design knowledge in the erection process may be beneficial as well. If the project organisation on site has the possibility to gain design knowledge in a simple and comprehensible way, the time needed for interpretation of drawings etc. will be minimised.

6. **Listen to and meet supplier's needs:**

In order to streamline the entire process the supplier's needs and wishes shall be considered. By developing the suppliers, i.e. help them to improve their process in accordance with the contractor's needs, the process will work in a better way. A two way communication between the contractor's procurement department and the supplier is crucial and may lead to benefits such as more accurate deliveries and innovative manufacturing and loading solutions that simplifies the final work on site.

4.2 Possible improvement approaches

The process described in Chapter 3 almost exclusively concerns information flow and information carriers which are creating this flow. Furthermore, a reconnection to Chapter 2.1 reminds us about the BIM concept. After consideration of different definitions and interpretations of the concept we came up with our own view of what BIM is:

BIM is a mode of operation when creating and administrating data concerning a project. To ease this process the data is often stored in an intelligent model containing 3D objects. BIM is often used in order to minimise misunderstandings and errors with the goal of having a more effective construction process. Technique and software should not be seen as BIM itself but rather a tool to simplify the administration.

By studying this interpretation it becomes clear that information flow and information carrier is two corner stones in the BIM concept. By making data delivery and communication possible without any loss of information the future reinforcement process can get more effective. A flow chart of this more effective process is illustrated in Figure 18.

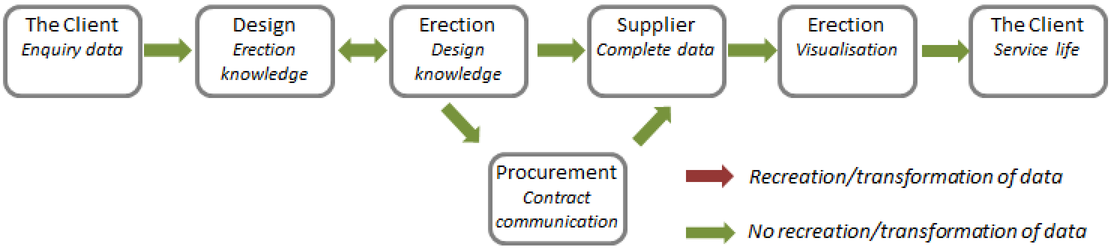


Figure 18 - Flow chart of future reinforcement process

Thus, from our point of view BIM will be very fundamental in the development of the current reinforcement process. How this can be done more specific within the critical areas stated in Chapter 4.1 will be discussed in the following sections.

1. **Clear needs from the client:**

As mentioned in previous section, we think that the development of the current reinforcement process shall be accompanied by BIM. However, BIM in turn has to be accepted in every stage of the process in order to reach its full potential. The fact that every development project needs a trial period in order to work well creates a situation with divided views regarding who is going to lead this resource demanding trial period. Thus, we think that the client shall work more actively and set up clear requirements regarding BIM usage in the entire process. A reconnection can be done to Figure 18 where this is illustrated by the green arrows between all the participating actors.

In the case with Trafikverket they argue that too many requirements will be destructive for the industry in terms of limiting innovation. However, we think that some requirements or standards are needed in order to initiate an implementation of any dignity. There is also symbolic value in such requirements. When the actors further in the information flow becomes aware of that the client will require BIM in greater extent, it`s easier for them to legitimate BIM efforts within their own organisations. As described in Figure 6, Chapter 3.1, there isn’t a complete absence of BIM related requirements today. From our point of view this is an important step which shows that Trafikverket are willing to work to develop the process. Nevertheless, more requirements of this type are needed in order to reach a complete impact in the process.

It’s also important that the client consider the entire lifecycle of the process. By setting up requirements regarding BIM in an early stage they will also submit complete data in the end when the construction is finished. Thus, possible renovation or rebuilding of the construction during the lifecycle will be based on complete data which will simplify any such execution. The green arrow between `Erection` and `The Client` to the right in Figure 18 illustrates this improvement.

2. **Accurate/complete data submitted from the client:**

The advantage of complete and accurate data in an early stage of the process can be illustrated as in Figure 19.

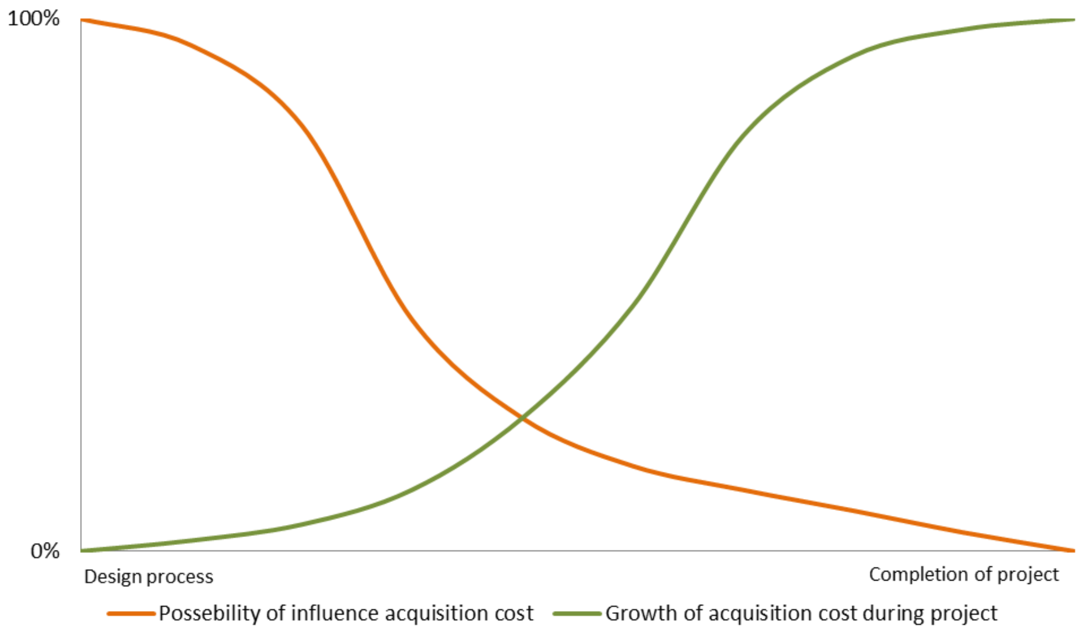


Figure 19 - Possibilities to influence cost of a project during the construction process. (Based on Söderberg, J. 1980)

As the figure shows the possibility to impact the entire project to a low cost is high in the beginning of the process. By putting in some extra resources in the enquire-stage and formulate complete and accurate output data, the risk for mistakes and misunderstandings will decrease. The actors downstream the information flow will be more certain about the accuracy in the data they achieve and thus able to make better decisions. This is also illustrated in Figure 18 with the green arrow between the client and the design. An additional effect of high accuracy and completeness of data submitted from the client is that the design department has more favourable conditions for creation of the reinforcement schedules on their own. This will eliminate the need for any external consultant for this purpose which explains the absence of this activity in Figure 18 compared to the current process illustrated in figure 17.

One of the main characteristics of BIM is to create more information in an early stage. Thus, an increased usage of BIM in the reinforcement process would catalyse the procedure described in previous section. In the other end, more accurate data would in turn result in a more effective process i.e. a process in line with the BIM concept. Thus, BIM would be favourable for early creation of data which in turn would gain the implementation of BIM in the later stage of the process.

3. **Compatible file format in the entire process:**

In order to deal with problem concerning file format we think that consensus between the participating actors is of great importance. Two-way-communication and experience feedback shall be made continuously in order to highlight advantages and drawbacks with the current format.

In the particular case with Skanska Infrastructure's procurement of reinforcement from VMS Group in Latvia the file format .BVBS would be suitable. VMS Group is just about to implement the software LPSYSTEM in their internal manufacturing process and this software is compatible with the format .BVBS. In addition Tekla Structures, one of the most common design software in the industry, is able to extract files in this format today. This indicates the potential to reach improvements in this area without any greater resources demand. As in the case with improvement area 1 `Clear needs from the client` this is illustrated in Figure 18 by means of the green arrows between all the participating actors.

However, we think that the BIM implementation in the long run will lead to design software that are compatible with many different file formats. In a longer perspective the focus shall be on how to develop the process to suite outputs from different software instead of standardise one specific file format. Since this is the case, the discussion regarding this issue should be neutral when it comes to file format.

4. **Integrate erection knowledge in the design process:**

The work done in the design phase has to be done with current erection practice in mind. Integration of experienced erection managers etc. has already been done in several projects in order to provide the design team with such knowledge. The overall opinion is that this is favourable for the end result and we think that this has to be done in greater extent. We also think that guidelines shall be set up regarding how this information shall be utilised. It's important that the current erection manager gets involved in the right time where he/she has the possibility to influence. If the timing isn't right e.g. if the involvement takes place too late, it's likely that the knowledge contribution will be lost. Figure 18 illustrates this integration with the two-way green arrow between `Design` and `Erection`.

Extended implementation of BIM in the design phase would catalyse the extraction of information in this stage. Information structured in an intelligent 3D model would favour the utilisation of knowledge from the erection manager and other participating stakeholders. Moreover, the creation of a common database available for the different actors would ensure the information access in every step of the process.

One positive side effect of the early involvement of erection knowledge is that the participating co-worker would achieve insight in how the designers thinks and reasons in different situations. In the upcoming construction phase this knowledge would support the on-site organisation in terms of understanding and interpretation of drawings etc.

5. **Integrate design knowledge in the construction process:**

Due to the fact that misunderstandings and misinterpretations of the drawings is a significant source of delays in the construction phase, design knowledge with advantage shall be integrated during erection. We think that one of the design managers for the current project shall continue to work as a project support during the construction phase. The current person shall be physical attendant on-site in varying extension depending on size of and phase in the project. As in the case with the previous improvement area `Integrate erection knowledge in the design process` this is illustrated by the two-way green arrow between `Design` and `Erection` in Figure 18.

A successful example of such design involvement in the construction phase is Skanska's major infrastructure project, Partihallsförbindelsen. Skanska's were responsible for the design work as well as the construction. By letting the design manager work in close collaboration with the on-site organisation during the entire construction phase, valuable time was saved in many stages of the project.

6. Listen to and meet supplier's needs:

By developing the suppliers, i.e. help them to improve their internal process in accordance with the contractor's needs, the process will work in a better way. A two way communication between the contractor's procurement department and the supplier is crucial and may lead to benefits such as more accurate deliveries and innovative manufacturing and loading solutions that simplifies the final work on site. Moreover, if the data submitted to the client is in a compatible file format no manually intervention is needed. The fact that any translation of data in to other formats is a process that in some extent contains interpretation and assumptions highlights the importance of compatibility. Due to this, the submission of compatible file format to the supplier can be seen as quality insurance from the contractor's point of view. In Figure 18. the green arrows from `Erection` and `Procurement` to `Supplier` illustrates the gains of compatibility in submitted data while the green arrow from `Supplier` to `Erection` illustrates the favourable effect of well working manufacturing processes at the supplier.

The implementation of BIM will facilitate the communication with and understanding of the suppliers. The BIM model will work as a communication tool between the procurement department and the suppliers. If agreements been established regarding accuracy, completeness and compatibility of the data submitted, it's likely that the BIM-model will lead to considerable time savings in the process.

5 Discussion

The critical areas which we identified in this study and the corresponding improvement areas, does in some extent cover the entire reinforcement process. The data created in an early stage needs to be in line with the needs further in the process. Interdisciplinary knowledge shall permeate the process and experiences shall be shared in the interface between the actors. BIM house great potential to be a significant contribution in this development process which highlights the importance of an overall understanding and willingness to implement the concept further.

There isn't one identified path of execute an analysis of this kind. We decided to base our analysis on interviews as described above. Another approach could be to base the analysis on a case study of a specific project. In close collaboration with the project organisation it's likely that important aspects would crystallise, which our approach didn't cover. Another approach would be to compare two or more projects with almost similar initial prerequisite but different working methods. If one of the projects was executed in the traditional way while the other were BIM influenced, interesting differences would appear in the interface between the two.

Nevertheless, as mentioned in chapter 1.3 the nature of this specific subject advocates an approach like the one adopted in this study. A case study approach of a specific project would have some shortcomings compared to the current approach. First it would be hard to cover the entire process from client to supplier. Second, the time frame for such analysis would be too long in order to be covered within the extension of a masters thesis. The time frame would be a problem if the analysis were executed in terms of a comparison between two projects as well. The difficulty to find projects with similar prerequisite would be another complication in the latter approach.

One final important aspect to consider regarding the method is that the analysis is executed on initiative of the authors and Skanska Teknik. The analyse aims to find out areas of improvement which are relevant on an industry level but it is likely to believe that the result would have differed in some extent if the initiative came from another company.

As mentioned in the beginning of this chapter the aim of this study was to identify critical areas of development and corresponding improvements in the reinforcement process. However, the critical areas and improvement suggestions described in Chapter 4 are results of the author's view of the situation and by no means any given best solution. Thus, it's likely to believe that a similar analysis executed by other authors would have ended up with other results even though the overall message would have been the same.

The reliability or relevance in the results is another aspect that is important to consider. Some of the improvement suggestions stated in chapter 4 are in some extent contradictable while some are very essential. Early requirements regarding the rules and frames of the process is from our point of view fundamental in order to reach a more effective process. The client shall work actively in order to reach this and focus on BIM as a powerful concept to catalyse the development work.

The focus on accurate and complete data submitted from the client may be a bit contradictable. Our analysis emphasise the importance of this area as it minimise errors and defects further in the process. However, the resources demand to reach complete data is high and results in a time consuming process. The submitter has to put extensive efforts in the creation of data because the achieving part expects that the data shall be complete. In addition the submitter is responsible for the data submitted and if the expectations of completeness are too high it's likely that there will be a very extended process (Bengtsson, P. Appendix 8.2).

Thus, In order to reach an effective process it's important to state the purpose with the current data. In an early stage of the process the detailed level with favour can be lower than in the construction phase. What's really important is to reach consensus between the participating actors regarding the purpose of the current data (Bengtsson, P. Appendix 8.2).

The compatibility of file format is another of the stated key areas of improvement. The today's situation claims a focus on the file format in order to be effective. However, in a longer perspective the focus shall be on how to develop the process to suite outputs from different software instead of standardise one specific file format.

Integration of production knowledge in the design process and design knowledge in the production process has already been realised with success. The production knowledge integration shall according to our view of the situation be executed in almost exclusively every project. The design knowledge integration on the other hand needs projects of some minimum scale in order to be legitimate. Complex design solutions and/or large scale projects are suitable application areas. In small projects it will be hard to justify the latter integration from an economical point of view.

The efforts from the entrepreneurs to develop the suppliers manufacturing processes may be a bit contradictable as well. There is no guarantee that you will work with the same clients in a few years. The resources needed in order to meet the suppliers demands may in such case be a lost investment for the contractor. In addition the improvements reached in the supplier's internal organisation and production line will not only gain the current contractor, but also other actors which are clients to the supplier. The latter may even be a competitor to the current contractor. Nevertheless, frame agreements with some pin pointed suppliers favour long term collaboration and legitimate development efforts.

6 Conclusions

The aim of this study was to identify critical areas of development and corresponding improvements in the reinforcement process. By analysing the participating actor's view of the today's process and try to find out their needs concerning interaction with each other and the process as a whole, we finally came up with some key development areas and corresponding improvement suggestions.

A reconnection to the questions stated in Chapter 1.2 indicates in what extent the study reached its intended purpose. First, the usage of BIM in the infrastructure industry so far is very limited which results in lack of relevant knowledge and experience regarding the concept as a whole but also regarding the different application within the frames of BIM. In addition the participating actors in the reinforcement process needs to reach consensus regarding how they shall relate themselves to BIM and what they can expect from it. To shift focus from technical aspects and instead consider relations and attitudes to each other is fundamental in order to reach a successful implementation.

The second question concerns which aspects that are of great importance in order to reach a more effective reinforcement process. The overall message that permeates the improvement suggestions is that the reinforcement process needs to be seen as a chain in which information flows in both directions between the participating actors. The design department cannot execute their commitments without consideration of the upcoming erection process. The supplier's needs are of significant importance already in an early stage if the process shall work effectively. In the final erection phase the project organisation views several benefits with close collaboration with the design department. Fundamental for all these aspects is that the client in an early stage creates information and data that is favourable for the process as a whole. BIM has the potential to become an important contribution in this stage as well as in later stage in the process which answers the third and final question in Chapter 1.2.

At the conclusion, communication between the participating actors in the reinforcement process is the key to any significant improvement. The major actors within the industry have to take responsibility and together push the development of the process forward. By doing so, minor actors will follow and the successful development projects will turn in to standardised working methods. The development projects can with favour be driven in collaboration between several actors in order to split both cost and knowledge. In the end, not the strongest actor but the strongest chain of actors will succeed and this chain is likely to be accompanied by BIM.

6.1 Further works

Our study has identified some key improvement areas within the reinforcement process and also some suggestions on how to execute these improvements. However, further works are needed in order to create incentives and motives for organisations to develop the process further. Studies that focus on more quantitative aspects such as economic benefits etc. would be suited for this purpose. If scientific studies showed economic gains with an improved reinforcement process it is likely that the industry would adopt the development suggestions in greater extent.

Another area which is crucial from our point of view is the handling of information within the process. The participating actors need to reach consensus regarding how data and information shall be communicated between them. This area is quite complex why further research is fundamental in order to create an understanding of how information can be transported in an effective way without consideration of any specific software.

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8 Appendices

8.1 Interview: Henrik Ljungberg, Skanska Teknik

So far there has been no projects in Skanska that was designed entirely in BIM. We have done some development projects like Bohus and NL11 but in these cases only parts of the project have been modelled for BIM purposes. Mainly for geometrical difficulties. But from the year 2011 it is set by Skanska that every new project exceeding 50 million sek must include a 3D-model and some sort of BIM application.

BIM was first initiated in Skanska Sweden's in the building industry. At this stage the infrastructure industry only took part in the discussions but where not ready for an implementation of the BIM-process. The potential for BIM might even be greater in the infrastructure industry. The first development projects including BIM were done using 2D drawings. The general idea though is that a BIM needs to include a 3D model.

The 3D model is the core of the project. This is easy to implement since everyone is expecting a 3D model when BIM is used. After implementation of the 3D model the next steps according to Skanska is collision control, 4D simulation and virtual construction. Applications of BIM that will be implemented at later stage is either done so because the lack of need or the high rate of complexity. Examples are "virtual tours" but the need is not that large in the design process. This is more needed for marketing and sales. Also the connection to procurement and calculation is a more complex application of BIM. The usage of BIM might be different in the building industry than in the infrastructure industry but when developments are done in the building industry this is often also used in the infrastructure industry.

It is important to know that BIM is not a separate process besides the ordinary design process but a development of the already existing process into a more efficient one. Often BIM is referred to as a separate process and that is not the case. However it is important that BIM gets a greater focus since the need of money for development is large. If BIM is referred to as a separate process there might be a risk that it is easy to skip BIM in the design process since it is not believed to be a part of the original process. At this stage the design team often needs to create BIM applications on its own beside the original design process to create an interest for BIM in the later processes of the construction.

When using AutoCAD Civil 3D today an application called "Impact reinforcement" is used. This is used to draw 2D reinforcement on sections picked from the 3D model. Traditionally the reinforcement has been drawn line by line but now Impact reinforcement is implemented since the program delivers full reinforcement schedules. These schedules are by Swedish standard and look the same way as if they were done by hand. The process to create the schedules are a lot more efficient though. To this day the schedules has not been done by Skanska themselves but by consultants specialised in reinforcement schedules. The process today is that the design team at Skanska produces 2D drawings which is sent to the consultants. The consultants then by hand specifies by Swedish standard every reinforcement bar individually. The aim of using Impact reinforcement is to be able to create the reinforcement schedules directly from the model without using external consultants.

The schedules though will still be based on the same Swedish system from the 1970´s. As the process is today the design team at Skanska produces 2D drawings including every reinforcement bar. However some simplifications are done which leads to that some parameters such as concrete cover might not be correct. This is then corrected by the external consultants. Besides from correction and simplifications the consultants also makes some modifications so that the production will be smoother. These modifications however are not known by Skanska and therefor todays BIM models always will need some modifications done by hand. Skanska need to get this information from the external consultants to be able to implement the modifications earlier in the process in their BIM model.

When the information has been created during the design process 2D drawings are created and sent to the external consultants and the production team. The information flow hereafter is however unknown to Henrik. If errors are discovered after the 2D drawings has been sent, feedback is given from the consultants and the production team so that the errors can be corrected by the design team. When information and the schedules reaches procurement new modifications are made in order for the schedules to be compatible whit the reinforcement producers. The modifications and how many are however unknown to Henrik at this time.

The actual next step for Skanska when using BIM is a bit uncertain. The goal is to be able to model the reinforcement but this is depending on many separate factors such as software development and knowledge of reinforcement scheduling. Next possible steps could also be a cooperation with cost calculation and 4D simulations. 4D simulations are mainly for the production but there are no actual request for this today. The way of implementing 4D simulations is to create examples and show the production teams what is possible with models and then the request for BIM models gradually increases. You need the find people that have an interest of this kind of technology in the production otherwise the implementation of BIM will be much more difficult.

In projects where external consultants are used during the design process separate demands on BIM implementation is not set from Skanska at this time. As the usage of BIM gradually increases in Skanska the aim is to also demand the usage of BIM at external consultants. When this is to be done it is important that the demands set on the consultants match with the way of programming BIM at Skanska so that you can combine the information to one model. In the building industry this is already used in larger projects where special BIM demands are set on external consultants.

From the clients there are only demands for 2D drawings at this time. No data that is to be delivered to the client are in 3D. Henrik´s impression is that this is very regulated and there are little room for new concepts. Skanska are able to do their design in 3D but the models delivered to the clients however is in 2D. The project information given by the byer is not that complete. Often there are a lot of uncertainties which makes it impossible to use the data delivered by the client but a lot of changes is needed. The data is also often given in 2D which is not compatible with the 3D models used in BIM. Henrik would like the client to deliver more complete data in 3D so that the model created in early stages also can be used throughout the design process. Information such as “road lines” in plan and profile should be delivered in 3D and fully quality assured. Sometimes this is the case but mostly information is delivered in 2D.

In which formats the data is delivered is also important. Today there is no common format that is used but some are used more frequent than others. In the building industry one of these are IFC and this might me a good format even for the infrastructure industry. However the IFC format store a huge amount of data and there are difficulties in getting this complete. A format that might be more easy to implement in the infrastructure industry is LandXML which handles surfaces and data in 3D. Many of the engineers working today are using Novapoint. This format is not directly compatible with AutoCAD Civil 3D. Therefore Skanska manually exports the data from Novapoint and into LandXML to be able to use it in their design. There might be a risk that Novapoint will become a standard for the predesign since so many consultants use it today. One of the reasons that Skanska does not use the Novapoint software are the costs of purchasing licenses. In addition to the basic Novapoint software you need a number of applications in order for the program to be compatible with Civil 3D. Each of these applications are a separate license cost. Therefore Skanska decided to go for Civil 3D as the main software to use for civil design.

8.2 Interview: Pontus Bengtsson, WSP

BIM in WSP today is used as far as it is possible considering technology, file formats etc. This is more difficult to implement in the infrastructure process than in the building process since in the building industry standards considering file formats and objects already exist in contrast to infrastructure. Today at WSP BIM is used in up to half of their projects as a way to mediate information throughout the processes. WSP as a company advocates their employees to use BIM since the long term effects are distinct.

This way of thinking has existed for a long time and this is the way we have been trying to carry out our projects. The difference today which makes it possible to reform our processes is that we have new technology that supports this philosophy. The new technology makes it possible to loop and distribute the information in a much more efficient way. Some outcomes are more direct than others. When using 3D models the understanding of projects increases and time is saved.

The key to make BIM work in a process is to ensure that all participants look at the model with the same expectations. If some participants expect a full scale exact model but some others accept some minor errors the communication can fail. Therefor the importance of defining BIM and the extent of usage in each separate project. In the case with 2D drawings we know how to handle the minor errors that always occur, but when using BIM models there is a hesitation in how the errors is to be handled. Therefor disinclination in sending models further in the process that is not entirely correct.

When discussing BIM focus often lies on the technology and different file formats. However the great problems are human and the relations between people. The industry can achieve minor development by focusing on the technical factors but by turning the focus on to human relations the great increase in effectivity can be achieved. To achieve this there must be a dialog between different actors in the process in how problems are solved. Today however there is a lot of rivalry among the great contractors. This rivalry drag the implementation of BIM in the industry since companies are afraid to share their solutions to problems connected to the usage of BIM. But again all this is depending on that the technology works as expected.

There might also be a problem that BIM is easy to exclude from the overall process since it is often seen as a separate phenomenon rather than a way of carrying out the process itself.

The extent of which BIM is used and the flow of information is based on the actual model instead of 2D drawings differs between the companies who hire WSP. Pontus meaning is that there is higher probability that they do not need to extract 2D drawings when working directly with the contractor. When working with Trafikverket however, in most cases the information is delivered in 2D. This is often regulated by law. In cases where a model is requested this is only as a complement to the mandatory 2D data.

Projects using BIM is often expected to give a payback every time. However there must be some developement projects that does not go as well as planned for the industry to learn from the mistakes. The big question is who wants to pay for this. There is a risk that companies sit tight and expect others to do that first mistake so that they won´t suffer themselves. It is there for of great importance that the industry agrees that BIM is to be used in all processes, starting with Trafikverket.

WSP has set that the company´s goal is to use BIM in their projects. In what extent and how is then up to each project individually. The use of BIM is primarily dependent on which people are assigned to the project and their personal interest in BIM. This I mainly because projects differs from each other and WSP does not know ahead which projects they will get.

In Norway the usage of BIM has come much further. According to Pontus this is because the capital is great. Therefor there is no discussion of money in the projects but a focus on what need to be done.

In the case with Trafikverket Pontus opinion is that they the last year has shown more interest in BIM. Now Trafikverket has stated that BIM is to be implemented into their organisation. BIM however is new also for Trafikverket which means that there will take some time to implement the BIM process into their organisation. Now enquires are starting to appear from Trafikverket including demands on BIM and some sort of 3D data.

When delivering data from BIM to the other participants there must be an acceptance inspection of the data. If data is delivered from the model directly into machines the risk of errors will increase. The drivers of the machines will at some point lose the feeling for what´s right and what´s wrong and completely depend on the data shown by the computer screen. Therefor there must be an inspection of the data to determine possible errors before the data is used in practice. The people in production will always hold knowledge that is not known to the design team and their involvement is there for necessary. A way of saving time is to involve the production team earlier in the process so that the data produced by the design team is more accurate.

8.3 Interview: Henrik Franzén & Niklas Lindberg, Trafikverket

Trafikverket´s function in the process is to create the data that will be the basis for the following enquiry. Such data could be road corridors and landscape geometry. The relation in creating this data and the later design process when creating the reinforcement is not that strong and therefor Trafikverket does not set that high requirement in the coming design process. Therefor the contractors are given full scope in the creation of the design data. Today though, the final requirements are traditional 2D data that is to be delivered to Trafikverket. In today's enquiries Trafikverket say that the data should be delivered in dwg-format. Trafikverket does not require the use of a specific software but today AutoCAD is a standard in the industry. Trafikverket's internal documents that define how you achieve the data correctly are based on manuals concerning AutoCAD. So after all Trafikverket is not entirely format neutral. When considering BIM, Henrik and Niklas see that in the long term a standard is needed, in the same way as AutoCAD in 2D.

At Trafikverket there are currently no demands on the usage of BIM within the organisation but projects are free to use BIM individually. In large projects the use of BIM is recommended by the own organisation. This however is strongly dependent on the people assigned to each project.

Since Trafikverket is at an early stage in the usage of BIM they have started a program containing the introduction of BIM within Trafikverket. This is to inform the organisation and educate in the subject of BIM. The program involves partly the usage of BIM in the design process and also the usage of BIM during the entire life cycle. Trafikverket is careful to not set any standards but to monitor the market to see which techniques and which processes are being used. This is because of the danger in setting requirements that not every contractor can compete with. At this point the requirements are set to that the data should be compatible with different software and formats. The models should be able to deliver data such as visualisation, quantities etc. In what specific format this is done is however up the contractors. With time the participants need to agree on how different software and formats should be used and their ability to interact with each other without losing or rearranging the data.

Henrik and Niklas see the importance that contractors develop their own processes individually as well as interacting with other participants. Today the BIM process is driven by a few enthusiasts at each company but for the process to work globally everyone involved should have knowledge about the process and not only a few people at each company. In large projects with many participants Henrik and Niklas see a growing responsibility for Trafikverket as the contractor to coordinate the group.

According to Trafikverket there are two main ways of implementing BIM in the process. You can demand the participants in each project to use BIM. The consequence of this could be lack interest since the initiative does not come from the participants themselves. There is then a risk that the outcome will not be as good as it could have been and the chance of using BIM in coming projects will decrease. However if you create incentives such as economic compensation the interest might increase. Trafikverket has their own budget for development of BIM in their processes.

One of the next steps at Trafikverket is to set the procedure to insure quality in the data delivered to other participants. Contractors and other cooperation partners have signalled for a long time that in order for their work to be more efficient they must be able to rely on the data that is given to them. The importance for Trafikverket before each project is to set in which extent the data is correct so that contractors know this in their design. Therefor this is now a strong focus at Trafikverket. The 2D data and drawing used today are familiar to the participants and they all know how to deal with errors. In the case with BIM models Trafikverket see their role as client and their ability to set in which extent the model is correct.

8.4 Interview: Jörgen Johansson & Rune Møller, Skanska NPU

Skanska Nordic Procurement Unit (NPU) is a cooperation between the procurement units in each of the Nordic countries. The purpose is to create common agreements and in that way get better deals with the producers. NPU also share ideas and methods of how to create the procurement process effective. Jörgen Johansson and Rune Møller are category managers for reinforcement in Sweden and Norway respectively.

According to Rune Møller, The delivery chain of reinforcement information during a construction process is totally absent in Norway. Individually, each participant in the process creates a great result but the flow of that result and data to other participants is non-existent. Rune sees the potential in implementation of new techniques such as BIM with the purpose of making their process more effective. By using BIM more data is created in the design process and this can be used throughout the rest of the project. The more detailed data created in the design makes it possible in an early stage to decide in which type of reinforcement that should be used. By forecasting this at an early stage producers can be procured at a better price. However the way of making the data available for all participants and in the correct way is partly unknown.

Besides the benefits with forecasting and early procurement, you can achieve a better workflow at the actual construction site. By virtual construction builders get an understanding of the project and the way of construction which cannot be achieved by traditional 2D drawings. Simple 3D models have been used in several projects mainly for marketing. However in these cases there has been no information and data linked to the model except for the purpose of visualisation. When BIM is used the visualisation is generated as a bonus.

In reinforcement design there is a need of schedule of the material in contrast to many other materials. In order to create the schedule, the methodology must be chosen at an early stage. Today however the design process is mainly in regard to structural properties. Thereafter the data and drawings are handed over to the construction team and external consultants with the expertise in reinforcement schedule. When the schedules are made by external consultants there is a risk of errors in terms of too much steel or a methodology that is not comprehensive with the actual project. There is also a risk of errors that were made in the design is undetected by the consultant and therefor sent further on to the producers. There is a lack of quality control in combination with many participants involved in the process. Errors are often detected late, sometimes to late when the reinforcement is mounted at the site. At that late stage the source of error is impossible to detect because of all participants involved. By using one software and one format throughout the process the risk of errors would be smaller. Rune and Skanska NPU has made a research where producers where asked how often it occurs that Skanska/consultants send new redefined drawings. The four producers asked shared the same opinion that 40-50% of the drawings where redefined during the process. The producers were also asked how often the redefined drawings where sent to them after start of production. The shared opinion where that 30% of the drawings where redefined after start of production. This leads to irrational procurement behaviour with many additional purchases. The problem according to Jörgen is not that the system doesn’t work, because it does, but it’s very cost driving.

In some projects the drawings of the reinforcement is not well defined. Only some typical sections are shown which leads to that the consultant that specifies the reinforcement omit some details. These are then solved by the men at site. When not every detail are defined in a drawing extra reinforcement are purchased just in case. There has been finished projects where the leftover reinforcement where estimated to over 15000kr due to safety purchasing. There is also a risk that if changes are made by the constructors and this is not communicated further, the wrong amount of reinforcement is invoiced. If BIM and a 3D model were used from the beginning, the details have to be defined in the design process otherwise the model won't work.

The schedules made today are not made by any standard. A standard for reinforcement schedules does not exist and the schedules even differ between Sweden and Norway despite their close cooperation.

The information that NPU receive from other participants differ between projects. In projects the reinforcement design can be more or less advanced. Partihallsförbindelsen in Gothenburg uses a quite simple design with much reinforcement which is the same.

At first NPU receive 2D drawings created by Skanska Teknik or a hired external consultant. The 2D drawings are also sent to external reinforcement specificatiors. At the time there are as little as three to four consultants in Sweden which specifies reinforcement for the projects. They are all in the upper fifties and have great knowledge in schedules. This makes them fast and therefor cheap for Skanska to hire. The external consultants that specifies the reinforcement uses the software Q-armering made by Celsa Steel Service. This software is designed for the machines and production technique used by Celsa. In Poland and Latvia however there is another system for schedule of the reinforcement. This is often designed by market leading Lennerts & Partner. The potential with BIM and related software is to create the schedules from the model directly. When external consultants are used the responsibility remains at Skanska, despite the fact that the external consultant has made the final schedules of the reinforcement. Some schedule and some detailing made by the consultant are entirely based on the knowledge and feeling fore reinforcement that the consultant possess. This might be difficult or even impossible to implement into an entirely computerised model. Therefor the need of some human correction most certainly will remain.

The actual purchase of reinforcement is often based on decision by the production team. This is due to changes in the time table of the project and also the actual way of construction. Therefor the importance of adapting the purchasing according to the actual construction and not entirely rely on the design drawings. With experience there are almost no projects where changes are not made during the construction which influence with the procurement.

The 2D drawings and additional sketches is sent to the producers in Latvia. It is then up to the producers to interpret the information and translate the data so that the information is comprehensible with their machines. The material sent to the producers is often sent in pdf and the work of translate is then done manually. This is often done under time pressure and uncertainties are often overlooked. After production of the reinforcement the producer prints a delivery document specifying all the reinforcement that has been produced. According to Jörgen, this document includes almost the same information as the early schedules. This is however created by the software used by the producer.

8.5 Interview: Adam Åhlmans, Veidekke

Adam Åhlmans work at Veidekke building department and is involved in developing BIM in some of their building projects.

In building BIM has been used for some time in contrast to infrastructure. Therefore the use of a more common file format, IFC, is more regular in the building industry. In Sweden today there is no demand in using specific IFC but in Norway this has been set as a standard. Problems with IFC are that some data are lost when converted between different software's. Therefor Veidekke in Gothenburg has chosen not to use IFC but Navisworks which is compatible with all AutoCAD products. By using Navisworks no data is lost when converted between AutoCAD's products. However in time IFC will be that developed and advanced that data won´t be lost.

The models created by Veidekke Gothenburg is designed to be able to extract amounts from the model. For this they use the software VICO. In order to use VICO the model needs to be adapted with letters and material properties. By the use of other VICO software´s this amount information can be linked to computing and the total cost for the building can be estimated. This cost estimation and amount data is then sent further on to the procurement unit. The procurement unit does not receive the actual BIM model but rely entirely on the data generated from the model in earlier processes.

The BIM model created by Adam Åhlmans in the design process will later be used by himself as a team leader in the actual construction of the building. By doing this Veidekke secure the flow of information from design to construction. The main purpose for the model in the construction will be visualisation and review the way of production.

Software used in the design process such as Revit and ArchiCAD are much more designed for the building industry than the correspondent software's in infrastructure.

8.6 Interview: Lars Hildebrandsson, Lars Hildebrandsson AB

Lars Hildebrandsson started his career at Göteborgs Industribyggnader. After some years he moved to Fundia Armering AB now called Celsa steel. Here he got the practical experience of cutting and bending rebar. For the last 30 years he and his wife have run their own business specialised in reinforcement schedules and reinforcement production in small extent.

Lars Hildebrandsson is specialised in two main areas, building and infrastructure. The overall opinion is that the documents received from building contractor are much more incomplete than the documents received from infrastructure. In the case with building the 2D drawings received are not complete and the design does not take into account the way of production. The reinforcement is not detailed but only some general reinforcement is specified. The data and 2D drawings received from infrastructure are more detailed and the design is in some extent in regard to the way of production. Almost each reinforcement bar is specified with its own letter and dimensions. When this is not the case the consultant who do the schedule get more work in giving each bar individual letters. These letters might not be known to the production team since the letters are not defined in the drawings but only in the schedules.

During a project Lars Hildebrandsson receive 2D drawings and revisions from the design team, the production team and in some cases external design consultants. The drawings are then reviewed little by little. Lars opinion is that there are no recurring errors that needs to be corrected but the errors differ between each project.

In many cases the data is delivered to Lars Hildebrandsson with short notice with the effect that the reinforcement schedule might not be ready in time for production. Then the production starts without the reinforcement schedules making the actual schedules and the produced reinforcement differ.

The schedule is done in Celsa Steels´s software Q-armering. Q-armering is a software created to be compatible with the machines used by Celsa Steel so that they do not need to convert the data sent to them. Q-armering saves the data in XML-format which is compatible with software such as AutoCAD. The schedule is often sent further on in XML format or in some cases printed into PDF.

Lars Hildebrandsson sees problems in making his job automatically integrated in a BIM model as early as in the design process. The years at Celsa Steel and his practical experience has given him a feeling of the way of production which the design team does not possess. When looking at a 2D drawing, Lars has the ability to see when the design does not work in practice. Since not every section is defined in separate drawings these has to be specified based on experience. This knowledge has to be contributed by people with production experience early in the design process in order to get correct reinforcement schedules from the beginning.

8.7 Interview: Edgars Svarinskis, VMS Steel

Edgars Svarinskis is the export manager at VMS Group in Latvia. VMS Group manufacture reinforcement bars after clients demands and schedules according to cutting and bending. VMS Group is one of Skanska's suppliers of reinforcement hired abroad.

When making an order Skanska send drawings and reinforcement schedules to VMS Group in pdf format. This data is then manually adapted into an excel document similar to the reinforcement schedule made by Skanska. VMS Group uses their own schedule since it is important that it has the same style so that the employees who control the machines are familiar with the document given to them. In some cases angles and radiuses need to be computed manually because of insufficient data from Skanska. If drawings and schedules were delivered in dwg and xml format Edgars point out that their work would be more easy and effective.

VMS Group has as recently as two months ago installed new software making it possible for them to enter data automatically in their design process and by this also control the machines. This software is called LPSystem and is delivered by Lennerts & Partner in Germany. The changeover to the new system will take some time but VMS Group´s goal is to in the near future only use the new system. Drawings and schedules received in pdf will be entered manually as before. However LPSystem has the possibility to import data from the file format BVBS directly, without any manual intervention.

The machines used in production at VMS Group are not older than four years. This makes them fully compatible with the new software, LPSystem. When the system is fully implemented in their process the machines will be able to construct roll mesh and cages automatically. This requires schedules and drawings from Skanska which contain 3D data or at least makes it possible to calculate the required data at VMS Group.

When loading the trucks each bundle is marked with labels stating bundle weight, number of pieces, name of construction site etc. LPSystems will make it possible for VMS Group to better optimise transports and their production. Labels containing all necessary information can be printed directly from the program.

VMS Group have recently started a department specialised in making reinforcement schedules directly from drawings received from their clients. Edgars opinion is that by offering this service the process will be more effective with the actual schedule made at their office. Time consuming correspondence regarding errors in schedules can in that way be eliminated.

8.8 Interview: Mattias Liewendahl, Skanska Production

Mattias Liewendahl work as section chief at Partihallsförbindelsen (PHF), Gothenburg. He has the responsibility for part of the concrete bridge with more than fifty subordinated employees.

At PHF Skanska production has an agreement that all procurement of reinforcement shall be done through Nordic Procurement Unit, NPU. With this agreement Skanska Teknik has the responsibility of creating all drawings, NPU has the responsibility of creating reinforcement schedules and interact with suppliers and Skanska production has the responsibility of making the final call when reinforcement is procured. By doing this Skanska production and Mattias Liewendahl give away some of their supervision but gain more time for ensuring the production flow. The reinforcement schedules are sent to Mattias Liewendahl before the final call. These are sometimes modified by hand in case of last minute changes but most often the schedules are not even reviewed before purchase. This is because the lack of time and the consultants responsible for the reinforcement schedules are considered to be skillful.

The agreement with NPU state that final call must be made at least 2 weeks before delivery date. However often final call is made as late as 3-4 days before delivery date. According to Mattias this is due to late delivery of the drawings and documents from consultants and Skanska Teknik. At PHF it is more the rule than the exception that final call is made based on not yet confirmed documents and drawings. According to Mattias the accuracy of the reinforcement design has been better than expected with regard to these conditions. Nevertheless some errors always occur. Mattias cannot see any recurrent errors but errors that occur are unique in some way. To deal with this, extra stations and employees are used to supplement the reinforcement delivered from abroad.

As an attempt of minimising errors and ease the production method, Mattias has been involved early in the design process. By doing this Mattias can give his view of the production and in what way the design can be simplified in order to ease the fixing works. The simpler and more standardised the reinforcement is the more effective fixing works. Mattias opinion is that this has made the following processes easier however he point out that there are no concrete verification that this is the case.

When the reinforcement is delivered to site it is important that it has been loaded correctly at the supplier. Right amount of toggles in the correct positions is important when unloading. The weight capacity of the cranes at site needs to be considered by the supplier when creating bundles of reinforcement. Unless weight restrictions are made at an early stage unloading at site might be difficult or impossible. When delivered to site the bundles can be marked by colours defining which part of the construction it belongs to. This might ease the separation when unloading reinforcement in narrow placed, however at PHF the colour system has not been used.

For PHB there has been developed a BIM model with the purpose to visualise the construction and amount of space available during construction. Mattias opinion is that BIM fulfils a purpose, but at PHB the model haven't been used. This is because you need someone dedicated to the job of handling the BIM model and passing this information further in the group. This has not been the case at PHB and therefor the model has not been used in the extent it could have been. Mattias mainly see the strength with BIM in visualisation, making the co-workers agree upon production method. Processes such as delivery works well as they do today and Mattias see no great advantages in involving BIM in these processes.

8.9 Summarised reinforcement schedule in Q-armering

	FORT.NR	ILF	NÄT	BYGGNADSDEL		kg/SIDA	TILLHÖR RITNING	DATUM	ÄNDRINGS DATUM	ÄNDR.
1	L-03	X		Etapp 1	Tvärbalk Stöd 1	1226	343 K2312A	2010-11-03		
2	L-04	X		Etapp 1	Tvärbalk Stöd 1	410	343 K2312A	2010-11-03		
3	L-05	X		Etapp 1	Balk UK	4548	343 K2307B	2010-11-03		
4	L-06	X		Etapp 1	Balk ÖK	4609	343 K2307B	2010-11-03		
5	L-07	X		Etapp 1	Brobana UK+kantbalk	6940	343 K2307B	2010-11-03		
6	L-08	X		Etapp 1	Brobana ÖK	4109	343 K2307B	2010-11-03		
7	L-09	X		Etapp 2	Balk UK	4257	343 K2308B	2010-11-03		
8	L-10	X		Etapp 2	Balk ÖK	4210	343 K2308B	2010-11-03		
9	L-11	X		Etapp 2	Brobana UK+kantbalk	2190	343 K2308B	2010-11-03		
10	L-12	X		Etapp 2	Brobana ÖK	3973	343 K2308B	2010-11-03		
11										
12										
13										
14										
15										
16										
17										
18										
19										
20										
21										
22										
23										
24										
25										

INNEHÅLL

SAMMANDRAG

ANSVARIG C-J B	OBJEKT Bro 15-702-4 SV Rampen	
LAND Sverige	-	SENASTE DATUM 2010-11-03	SIDA 1 (2)

8.10Reinforcement schedule generated by LPSystem

Bar Bending Schedule

26.03.2009
Page: 1

LENNERTS & PARTNER GmbH
Mohrenstrasse 12
96450 Coburg

CS: Presentation sample

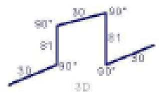
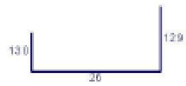
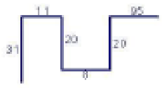
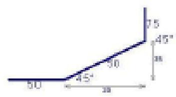
Costumer: 99999

Processor: LP

Project:	**Schedule No.:**	**Delivery Date:**	**Created:**
10001	23 D	01.04.2009	18.03.2009

Order No.:	**Schedule:**	**Colour:**	**Delivery Unit:**
85622	Schedule 1 Presentation	Blue	

Member: 2

Bar Mark	No.Bars	Diam. (mm)	Length (m)	Total Length (m)	Weight (kg)	Steel	Shape	Comment
1.0	1325	20	2,52	3.339,00	8.247,33	4	432	
2.0	1	16	8,00	8,00	12,64	4	1	
3.0	556	10	2,85	1.584,60	977,70	4	208	
4.0	314	12	1,85	580,90	515,84	4	560	
5.0	4	16	2,10	8,40	13,27	4	117	
6.0	40	12	1,75	70,00	62,16	4	229	

Diam.	**Total Length**	**Weight**	**straight**	**bent**
10	**1.584,60 m**	**977,70 kg**	**0,00 kg**	**977,70 kg**
12	**650,90 m**	**578,00 kg**	**0,00 kg**	**578,00 kg**
16	**16,40 m**	**25,91 kg**	**12,64 kg**	**13,27 kg**
20	**3.339,00 m**	**8.247,33 kg**	**0,00 kg**	**8.247,33 kg**

Total Weight: **9.828,94 kg** **Total number of positions:** **6**

Total Weight Schedule: **9.828,94 kg**

8.11 Celsa group UK project check sheets

Concept Requirements

Will There Be A Crane On Site?

No. Of Cranes

Craneage Weight Limit

Craneage Reach Limit

Craneage Limit At Tip

Total Site Crane Coverage ☐ Yes ☐ No ☐ When

Hook Times ☐ Morning ☐ Afternoon

Lifting Requirements ☐ Lifting Strops ☐ Sprayed Lifting Points ☐ Lifting Beam

Coupler Preference ☐ None ☐ Griptec ☐ Lenton

Stop Ends ☐ Hyrib ☐ Timber

Precast Columns ☐ Yes ☐ No

Shear Reinforcement ☐ Yes ☐ No ☐ Type

Preferred Practices

Pull Out Bars ☐ Express Strip

Production Requirements

Unloading Restrictions ☐ Yes ☐ No

Height Accessibility ☐ Yes ☐ No

Stillages ☐ Yes ☐ No

Goal Posts ☐ Yes ☐ No

Airbags ☐ Yes ☐ No

Dog Chains ☐ Yes ☐ No

Site Access Restrictions

☐ Height ☐ Width ☐ Turning

☐ Congestion ☐ Security

Site Access Times ☐ AM ☐ PM

Other Site Restraints ☐ Yes ☐ No

Haulage Type ☐ Road ☐ Rail ☐ Barge

Technical Requirements

Project Stage ☐ Concept ☐ Design ☐ Detailing ☐ Tender ☐ Approval ☐ Construction

Project Start Date

Technical Conversion Time ☐ Days ☐ Weeks ☐ Months ☐ Years

Construction Program ☐ Electronic ☐ Paper ☐ None ☐ When

Pour Start Location ☐ Pour Number ☐ Pour Sequence ☐ None ☐ When

Pour Layout ☐ Electronic ☐ Paper ☐ None ☐ When

Estimated Tonnage ☐ 0-100 ☐ 101-250 ☐ 251-500 ☐ 501-1000 ☐ 1001-2500 ☐ 2501-5000 ☐ 5001-10000 ☐ 10000+

Temporary Works ☐ Sheet Piles ☐ Waler Beams ☐ Steel Props

Concrete Drawings In .Dwg Format

☐ General Arrangements ☐ Sections ☐ Dimensions ☐ Concrete Strength

Rebar Drawings In .Dwg Format

☐ Cover ☐ Lap Lengths ☐ Factored Laps ☐ Staggered Laps

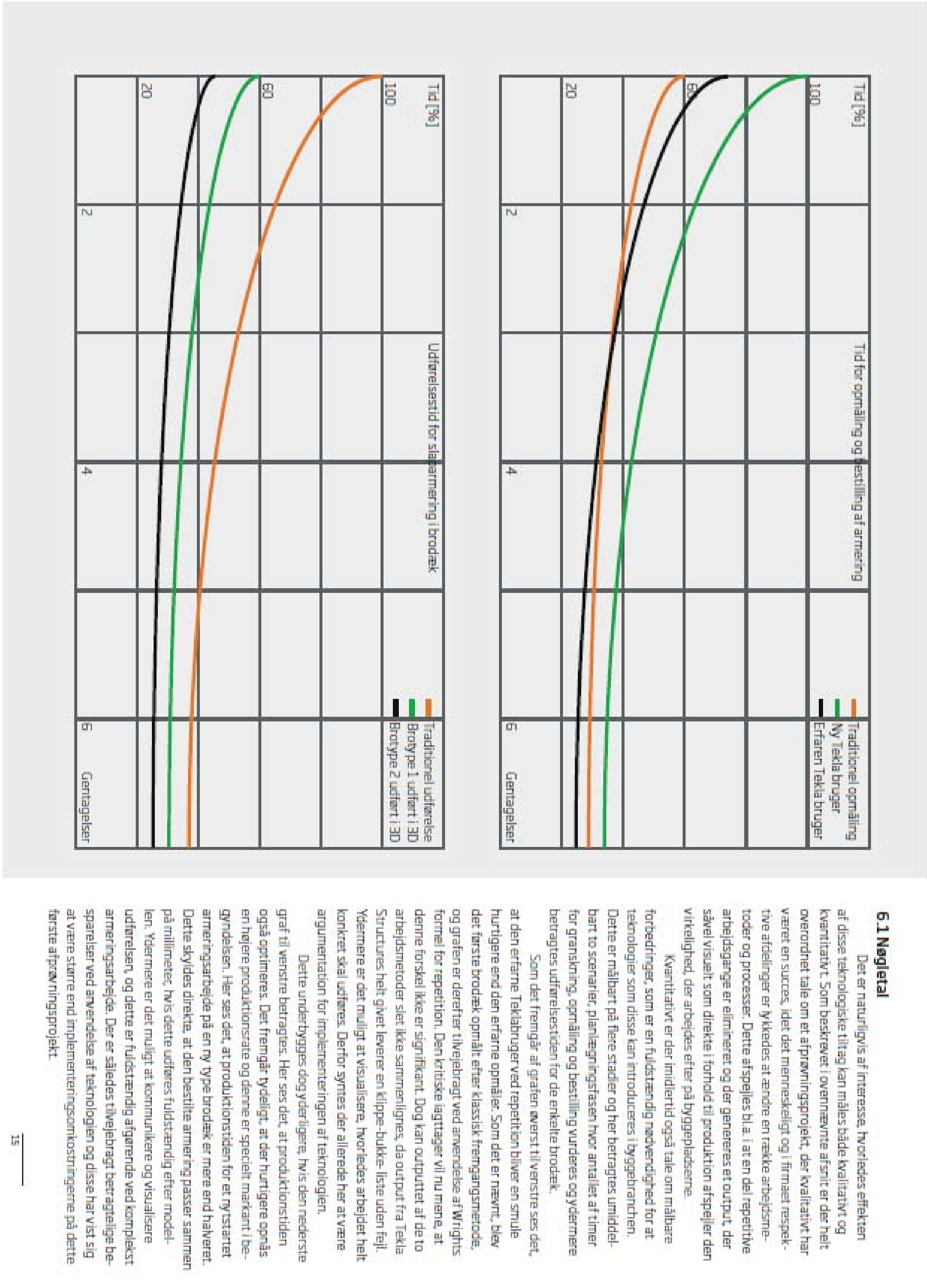
Bar Bending Schedules ☐ Yes ☐ No ☐ When

Drawing Approval ☐ Tender ☐ Preliminary ☐ Construction

Connection Type ☐ Welding ☐ Steel Tied ☐ Stainless Tied

Miscellaneous

8.12E. Pihl & Søn A.S



6.1 Nøgletal

Det er naturligvis af interesse, hvorledes effekten af disse teknologiske tiltag kan måles både kvalitativt og kvantitativt. Som beskrevet i ovennævnte afsnit er der helt overordnet tale om et afprøvningsprojekt, der kvalitativt har været en succes, idet det menneskeligt og i firmaet respektive afdelinger er lykkedes at ændre en række arbejdsmetoder og processer. Dette afspejles bl.a. i at en del repetitive arbejdsgange er elimineret og der genereres et output, der såvel visuelt som direkte i forhold til produktion afspejler den virkelighed, der arbejdes efter på byggepladserne.

Kvantitativt er der imidlertid også tale om målbare forbedringer, som er en fuldstændig nødvendighed for at teknologier som disse kan introduceres i byggebranchen. Dette er målbart på flere stadier og her betragtes umiddelbart to scenarier, planlægningsfasen hvor antallet af timer for granskning, opmåling og bestilling vurderes og ydermere betragtes udførelsestiden for de enkelte brodæk.

Som det fremgår af grafen øverst til venstre ses det, at den erfarne Teklabruger ved repetition bliver en smule hurtigere end den erfarne opmåler. Som det er nævnt, blev det første brodæk opmålt efter klassisk fremgangsmetode, og grafen er derefter tilvejebragt ved anvendelse af Wrights formel for repetition. Den kritiske iagttager vil nu mene, at denne forskel ikke er signifikant. Dog kan outputtet af de to arbejdsmetoder slet ikke sammenlignes, da output fra Tekla Structures helt givet leverer en klippe-bukke- liste uden fejl. Ydermere er det muligt at visualisere, hvorledes arbejdet helt konkret skal udføres. Derfor syntes der allerede her at være argumentation for implementeringen af teknologien.

Dette underbygges dog yderligere, hvis den nederste graf til venstre betragtes. Her ses det, at produktionstiden også optimeres. Det fremgår tydeligt, at der hurtigere opnås en højere produktionsrate og denne er specielt markant i begyndelsen. Her ses det, at produktionstiden for et nystartet armeringsarbejde på en ny type brodæk er mere end halveret. Dette skyldes direkte, at den bestilte armering passer sammen på millimeter, hvis dette udføres fuldstændig efter modellen. Ydermere er det muligt at kommunikere og visualisere udførelsen, og dette er fuldstændig afgørende ved komplekst armeringsarbejde. Der er således tilvejebragt betragtelige besparelser ved anvendelse af teknologien og disse har vist sig at være større end implementeringsomkostningerne på dette første afprøvningsprojekt.

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8.13 Enquiry from Trafikverket with BIM requirements

TRAFIKVERKET

Datum
2010-12-14

Uppdragsbeskrivning

Järnvägsplan & Systemhandling

Inledningsvis kommer beställare och konsult träffas för att bestämma arbetsinriktning och arbetsflöde. Mer information om arbetssättet finns att finna i infoblad från OpenBIM , se länk http://www.openbim.se/sa/node.asp?node=1206

MED ANLÄGGNINGSMODELL AVSES HÄR:
Modell (digital) som i 3D och för vissa specificerade objekt i 2D beskriver projekterade konstruktions- eller anläggningsdelar med ingående byggdelar klassificerade med olika objektstyper t.ex. komponent, yt-, volym- och linjeobjekt.

Anläggningsmodell ska visa anläggningen i sin helhet. Avvikelser från komplett anläggningsmodell ska godkännas av beställaren. Anläggningsmodell ska vara interdisciplinär och så uppbyggd att den kan används för:

- Samgranskning/kollisionskontroll
- Ritningsframställning
- Informationshantering
- Tidsplanering
- Utsättning
- Maskinguidning/styrning
- Mängdförteckning/reglering
- Kontroll och uppföljning
- Relationsmodell/handling
- Visualiseringsunderlag

Kända avvikelser och saknad information i anläggningsmodell ska dokumenteras i "Redogörelse för anläggningsmodell". Dokumentation ska även innehålla typ av avvikelse/saknad information och för vilka områden/sträckor detta gäller.

Anläggningsmodellens ingående byggdelar ska vara korrekta i plan och höjd. Volym- och punktobjekt ska ha korrekta infästningspunkter. Export av båggeometrier från anläggningsmodellen ska ha en noggrannhet (pilhöjd) i plan ≤20 mm och ≤3 mm i höjd.
Anläggningsmodellen ska innehålla 3D- och 2D-information med yt- och materialbeskrivning samt vara komplett med möjlighet att söka ut dessa datatyper i angiven dimension.
Anläggningsmodellens alla ingående byggdelar ska vara informationsbärande och kopplade enligt Trafikverkets kravdokument TK, Tekniska Krav.
Objektstyperna yt- och volymobjekt och komponenter kodas genom att dess aktuella

Diarienummer
TRV 2010/100745

FU2000 utgåva J

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