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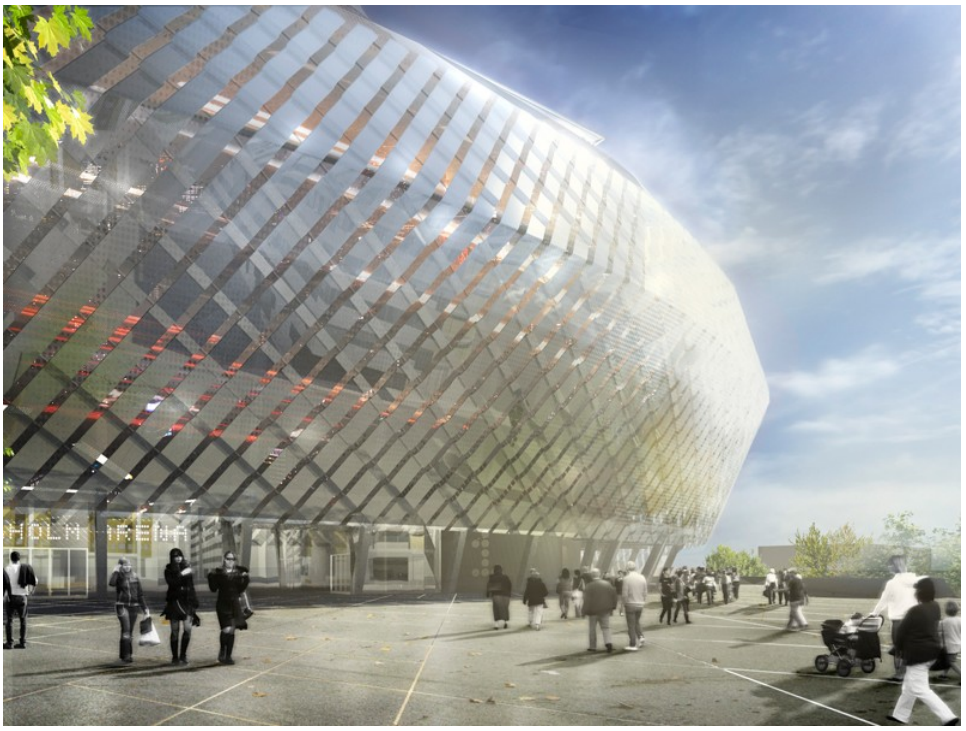

Organizing Robust Logistics Systems in Major Construction Projects

Master of Science Thesis in Master's programme Design and Construction Project Management

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This Master's Thesis contains one article and a summary of that article written in Swedish.

ORGANIZING ROBUST LOGISTICS SYSTEMS IN MAJOR CONSTRUCTION PROJECTS

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Abstract: The construction industry is continuously being accused of being inefficient and not willing to innovate. The process of innovation in terms of new material and new solutions in combining materials is moving forward but the actual construction process has more or less been the same since we started to build. In increasing efficiency in the construction process lies a big potential to cut costs in the construction industry which would result in projects being on time and on budget and hence lowering the cost for the end user. Historically in the construction industry there has been lack of feedback learning and the evaluation of project success or failure is often neglected which further complicates the possibility of increasing the efficiency. The construction industry is process driven and hence there are difficulties to implement traditional quality improvement models of total quality. This article concerns a study at a complex arena project with a high number of parties involved that has implemented an on-site logistics organization in order to increase the efficiency and to coordinate the different processes. Due to the complexity of the project the coordination of activities is crucial for project success. The article presents a study that investigates a limited number of critical incidents that has had an impact on the logistics system at the project Stockholm arena. The article aims to analyze these critical incidents and their contribution to the complexity in order to use the analysis as feedback material in order to be able to build robust logistics systems in the future. This article concludes that in order to build robust logistics systems construction projects should implement a thorough stakeholder/impact analysis in order to map the different stakeholders and their possible contribution to the complexity of the project, moreover the report concludes that every project in the construction industry should have an on-site logistics organization of some sort that should be implemented at an early stage in order to take in to account the complexity of the project from a logistics point of view.

Keywords: coordination, construction industry, critical incidents, logistics, stakeholder/impact analysis.

INTRODUCTION

Organizing construction projects is complex due to the temporary nature of projects, the high level of parties involved and the fact that every project is unique according to De Saram, et al. (2004). Nevertheless, the importance of organizing and coordinating in construction is ever more important because of the increasing demand for lower costs and higher resource efficiency as confirmed in the report by The Swedish Agency for Public Management (2009).

In the report ordered by the Swedish government written by The Swedish Agency for Public Management (2009), the construction industry is being accused of being inefficient and unwilling to innovate. According to Klakegg (2009) the process of feedback learning in project based organizations is limited, due to the fact that the focus of the parties involved is limited to the completion of the project. After completion the organization is resolved and moves on to another project which limits the temporary organizations goals and visions.

The apprehension that the construction industry suffers from change inertia can be an effect of the lack of feedback learning according to The Swedish Agency for Public Management (2009). Gahn & Salter (2000) claims that the construction industry is large and the number of construction projects completed every year is high, hence the conditions for learning from other projects are good still the feedback learning is not satisfactory due to broken learning and feedback loops emerged from the discontinuous nature of project based production.

Klakegg (2009) desribes that in a project oriented industry like construction a temporary organization is assembled to perform a one of a kind product, and when the product is complete the organization dissolves and the involved parties moves on to the next project without thourougly analyzing the past project hence not giving future projects the possibility to learn from earlier misstakes made. Further problems with this is that temporary organizations incentives are limited to the duration of the project and the project goals.

One commonly used explanation of why the feedback learning process often is neglected is that the lessons learned from one project cannot be applied on the next. That is in some sense true but only when the focus is on the actual solution, may it be a technical solution or a way of producing. As elaborated by De Saram, et al. (2004) the process of solving the problem arisen is often not included in the evaluation. Or the other way around, what is the source of the need for problem solving.

That kind of question formulation is a powerful tool to identify sources of either a good way of handling a problem or to identify what the source are for the problem arisen. Identifying solutions or sources for an incident in accordance with above is called the critical incident technique which De Saram, et al. (2004) confirms as a useful tool in measuring the quality of coordination.

The focus on coordinating the logistics in construction projects is of increasing importance for every project. This is especially true for major and complex projects where there can be up to 100 000 and even more material deliveries planned. It is easy to understand that in projects like this the risk of a situation to arise that will complicate or even delay the project is high. Both the studies made by Agapiou, et al. (1998) and Bertelsen and Nielsen (1997) claims that if a project implements a system designed to plan, organize and manage all matters regarding the logistics the outcome will be control over the flow of materials and processes, eased information exchange and increased customer and stakeholder satisfaction. This is why the coordination and planning process is very important and why every project should implement a logistics organization which is elaborated by Karlsson (2009). The European Construction Institute Total Productivity Management Report (ECI 1994 cited in Agapiou, et al., 1998) further claims that it is crucial for project success to implement sound and stable logistics systems designed to handle the logistics in construction projects.

This article presents a study that identifies a number of different critical incidents that arose during a limited period of time at the studied case, Stockholm arena. The article aims to analyze these incidents and to map their contribution to the complexity and the effects for the logistics system. The purpose of the article is to produce a sound feedback material using the lessons learned from these incidents from the studied case as prejudice, in order to build future robust logistics systems.

LOGISTICS SYSTEMS

Logistics were initially developed by the army in order to move and quarter the troops as efficient as possible. Today logistics is according to studies by Bertelsen & Nielsen (1997) and Agapiou et al. (1998) well known and adapted in the manufacturing industry and is an important tool to increase productivity. Originally logistics main focus was to improve the internal conditions but with the increasing globalization and implementation of jointly supply chains between organizations the focus has shifted on synchronizing external logistics.

Johnsson and Matsson (2008) states that logistics is planning and controlling of the forward and reverse flow and storage of goods, services and the flow of information through the whole supply chain which is done in order to meet the requirements from the customers. As Agapiou et al. (1998) establishes, the term logistics in business context has mainly involved movement and storage of materials, transportation and distribution in order to have the desired object of flow at the right time at the right place.

In the book written by Johnsson and Matsson, (2008) the positive effects of applying logistics systems is said to be not only the increased control of the supply chain and flow of materials but also economical winnings in terms of lower costs for insufficient material handling. But also in addition to economical winnings one of the upsides with logistics if performed properly is increased customer satisfaction. By creating sound and distinct information exchange the effect will be lower planning uncertainty for all involved parties thus creating good will and increased cooperativeness.

Moreover the upsides with applying logistics systems is elaborated by Björnland et al. (2008), who claims that the main purpose with implementing logistics systems is to improve the efficiency by reducing the costs but also increased income by improved delivery service. Furthermore applying a robust logistics system will have the effect that the organizations invested capital is used more efficient.

Applying logistics systems is a mean to work towards total quality, but it is not enough to implement just a logistics system, as stated in Johnsson and Matsson (2008) there is no reason to excel in something that is not requested by the customers.
In order for the logistics system to work against total quality the focus has to be holistic and as stated by Goetsch and Davis (1994) the focus must be on continuous improvements of products, services, people, processes and the environment.

Tenner and DeToro (1992) elaborate that every process generates by-products for other customers than the end users, such as the stakeholders, that is why quality improvement work has to focus on four parties concerned: the end users/customers, owners/shareholders, employees, community/stakeholders.

For a logistics system to be focused on total quality and continuously improvement there has to be an evaluation of stakeholders and their needs and concerned which is further elaborated by Olander (2007). He suggests that during the different stages of a construction project a vast number of stakeholders will affect the project may it be positive or negatively, moreover he elaborates that without a proper stakeholder/impact analysis it is highly unlikely that their interest and expectations will be met.

Logistics systems in construction

Applying logistics systems and seeking control over the deliveries to the construction site is critical for the construction industry, as elaborated by The European Construction Institute Total Productivity Management Report (ECI 1994 cited in Agapiou, et al. (1998).

According to Josephson and Saukkoriipi (2005) a large part of the total cost of construction is hidden in form of waste. Waste is an activity that doesn't add any value to the end user. Waste occurs when there is lack of coordination of the logistics and when the material is insufficiently handled or when resources are used insufficient.

Studies made by Larsson (1983 cited in Agapiou et al. 1998) suggest that low productivity is an effect of poor planning and logistics and that common factors between projects with low productivity are delays on-site, wastage and breakage of materials. When applying a robust logistics system, Bertelsen and Nielsen (1997) claims that an increased productivity is to be expected.

Agapiou et al. (1998) claims that when designing a robust logistics system there should be a focus on developing partnering relationship between the participants in the logistics organization this in order to improve the communication and coordination between project participants.

According to Agapiou, et al. (1998) the main focus of logistics should be the interface between parties involved focusing on information exchange. As there are many different participants in a construction project the communication can be complex but is eased by applying a logistics system.

Karlsson (2009) elaborates that effective material handling, planning and coordination of the logistics in construction industry in form of an on-site logistics organization, expert in logistics or Logistics Manager should be used on every project just as the projects uses experts in fields such as engineering. Moreover this expert should be hired at an early stage in order to maximize the possibility to influence the project outcome.

METHOD

Critical incidents technique

Flanagan (1954) claims that the critical incidents technique consists of a number of procedures for collecting observations of human behavior in a way that will make them useful in problem solving. The description of the critical incidents technique is further elaborated in the study made by Stauss et al. (1993) in which it is described as a way of gathering, classifying and analyzing stories or incidents. Moreover Flanagan (1954) offers a definition of a critical incident:

> *"A critical incident is any observable human activity that is sufficiently complete in itself to permit inferences and predictions to be made about the person performing the act and is critical if it makes a significant contribution, either positively or negatively, to the general aim of the activity".*

Both Flanagan (1954) and De Saram et al. (2004) describes the advantages with the critical incidents technique and it is described as a simple tool for the observer to use because it requires little preparation. Moreover Stauss et al. (1993) establishes that the critical incidents technique is suitable for quality improvement because the involved parties will always keep the incidents that have occurred in mind that has had a significant influence on their work. The critical incidents technique also offers an evaluation tool that enables the involved parties to present their opinion in their own words and familiar way of expressions which gives this application an advantage.

The study made by Flanagan (1954) offers an outline for interviews when adapting the critical incident technique. This consists of three questions or directives

1. *Introductory statement:* We are making a study of (specific activity). We believe you are especially well qualified to tell us about (specific activity)
2. *Request for general aim:* What would you say is the primary purpose of (specific activity)?
3. *Request for summary:* In a few words, how would you summarize the general aim of (specific activity)

The critical incidents discussed in the study presented in this article were chosen in consultation with the on-site Logistics Manager. Due to the fact that this report is a case study from the Stockholm arena and reflects a limited range of time of the production, the possible critical incidents to analyze were limited. Originally, ten critical incidents were listed. But due to lack of relevant information and the confidentiality in some of the chosen incidents a number of four critical incidents were finally chosen. The four incidents have all disturbed the logistics system and the production organization significantly.

The critical incidents chosen are as follows:

1. Arenavägen – A public road crossing the production area which has been open for traffic during most of the time of production.
2. Nynäsvägen – A public road which is located just alongside the east side of the production area, which cannot be closed due to the very high level of traffic passing into Stockholm on this road.
3. SL railway tracks – A railway crossing the production area which has been open for traffic during most of the time of production.
4. Stakeholders – Adjacently organizations which has ongoing operations during the production.

Interviews with the logistics organization

Interviews were held with three representatives from Svensk Bygglogistik: the Logistics Manager, the Delivery Planning Manager and the Material Delivery Managers. All of these interviews were semi-structured with open ended questions and the location of the interviews were chosen by the interviewees. This approach was chosen in order to get the most out of the interviews. These interviews were complemented by the interviewer observing the interviewees performing their work. The duration of these observations varied and lasted from 1 hour to 3 hours. The length of the interviews varied from 15 minutes to 1 hour. When needed for further questions, telephone or e-mail were used. The purpose of these interviews were to get a clear view of the organization and coordination system that is used in the studied project.

Interviews with stakeholders and managers
A total of 10 open ended and semi-structured interviews were held with representatives from different organizations involved in the project or from organizations that are affected by the production of the Stockholm arena.
The interviewees where chosen in accordance with their participation and their importance for the different critical incidents described in the article. All interviews were structured alike, but were differentiated due to the fact that they cycled around different critical incidents. These interviews were held at two different dates. All interviews were semi-structured in order to get the interviewees honest opinions and floating answers. Moreover the duration of these interviews varied from 20 to 45 minutes. The interviewee choose to have a lower number of questions in the interviews in order to get a more dialogue or conversation feeling to the interviews. One interview was forced due to the limitation of the interviewees' time to be held via telephone. A dictaphone were used at all interviews except at one, were the interviewee didn't want to be recorded. When needed complementation to the interviews, questions were asked by email or by telephone.

The author structured the interviews in accordance with the interviewees' involvement to a specific critical incident. Representatives for the critical incidents of stakeholders and Arenavägen where one person responsible for data communication and real estate from the organization Kakelspecialisten, one plant manager from the organization Grönsakshallen and one facility manager from the organization Nordic Pm, responsible for the organizations renting spaces in the Globen business area. Furthermore five persons were interviewed representing the critical incident Arenavägen. These five persons where, a foreman from Peab, Bygglogistiks Logistics Manager and a foreman from the organization Berg och Väg responsible for the ground work. The two remaining interviewees representing the critical incident of Arenavägen were, the assembly manager representing the organization responsible for the cranes, and one project manager representing the organization responsible for the prefab materials, this person were also interviewed for his participation in the critical incident Nynäsvägen. Additionally one person where interviewed for her participation in the critical incident Nynäsvägen, this person were a team leader from Peab representing the production of facade materials.

Finally a production coordinator from the organization responsible for the railways of Stockholm was interviewed, due to his participation in the critical incident of the railway crossing the production area.
The purpose of these interviews were to penetrate the critical incidents and to find good solutions and maybe bad decisions made, in order to be able to generate a sound feedback material when implementing logistics systems in future projects.
The interviewees were then chosen in accordance with the research made by Flanagan (1954), which says that only qualified persons for the specific activity should be interviewed. The persons to interview were also chosen in collaboration with the Logistics Manager. The questions asked during the interviews took inspiration from the directions of the research made by Flanagan (1954) and hence the interview and the questions were structured as follows.

- Introduction to why this person is chosen
- What is your responsibility regarding this critical incident?
- What is the main purpose with this critical incident?

- Has complexity regarding this critical incident changed from the original plans?
    - How?
    - Why?
- What effects has this had on your work?
- Can you think of any action regarding this critical incident that has been either positive or negative and describe it with your own words?
- Why do you think this happened?
- What effects did this have on your work?
- What should be done in order to avoid this in the future?

CASE DESCRIPTION

In this part of the article the arena project and the on-site logistics organization that is responsible for the coordination of logistics in the project will be described more thorough.

The Stockholm arena

The Stockholm arena will be a sport and event arena with a capacity of 30,000 spectators and is owned by the city of Stockholm. The first event that will be hosted on the arena will take place in the spring of 2013 which also is the aspired finish year for the project. The arena should contribute in making Stockholm a world-class event city and also contribute to attracting big events to Sweden and more specifically Stockholm.

The production cost of the project is estimated to 2.7 billion Swedish kronor and the contractor is Peab with a form of a design-build contract. The goal of the arena is to create an accessible arena for everyone. This is a vision set up by the city of Stockholm. This vision is supposed to be reached due to the favorable conditions of the arena in form of geographic location, infrastructure and the public transportation which could contribute in making this a modern arena with a vision that every visitor of the arena should choose an environment friendly traveling via the public transportation, by foot or by bicycle.

Early in the planning phase the formerly production manager, today he has due to various reasons reassigned and has been replaced, decided that he wanted to take the logistics in this project to a new level. He had past good experiences from cooperation with Svensk Bygglogistik. Hence he took contact with Svensk Bygglogistik in order to develop a jointly structured plan for the logistics and to develop a sound coordination system for the Stockholm arena. One of the first actions that took place was that an analysis of the logistics was made. This analysis investigates what the different problem areas in terms of logistics might be in this project and offers solutions in questions like lift and crane placements, disposition of areas and it also offers a plan for how transportation of materials should be dealt with.

The logistics

During the planning of the coordination and logistics system, the conclusion was drawn that this is a very complex project which requires an on-site organization which main duties is logistics. This resulted in implementation of an on-site logistics

organization consisting of personnel both from Svensk Bygglogistik and Peab which consists of a total of 9 persons, more specifically:

- 1 Logistics Manager, Svensk Bygglogistik
- 1 Delivery Planning Manager, Svensk Bygglogistik
- 1 Team Leader, Peab
- 3 Material Delivery Supervisors, Svensk Bygglogistik
- 2 Traffic supervisors, Svensk Bygglogistik
- 1 Wicket-keeper, Svensk Bygglogistik

During the production of the Stockholm arena there will be around 100 000 deliveries of various materials. Therefore the coordination and planning of deliveries is of vital importance and hence both Peab and Svensk Bygglogistik have established this on-site organization which will work as the logistics system. When structuring all of the matters concerning logistics trough this on-site organization the management and coordination of processes will be eased. This is achieved by implementing clear structure in both the logistics organizations work roles but also by informing all involved parties which areas to confront the on-site logistics organization with. The aim is to create a safe, clean and efficient workplace and to give sound conditions for all the parties involved in the production.

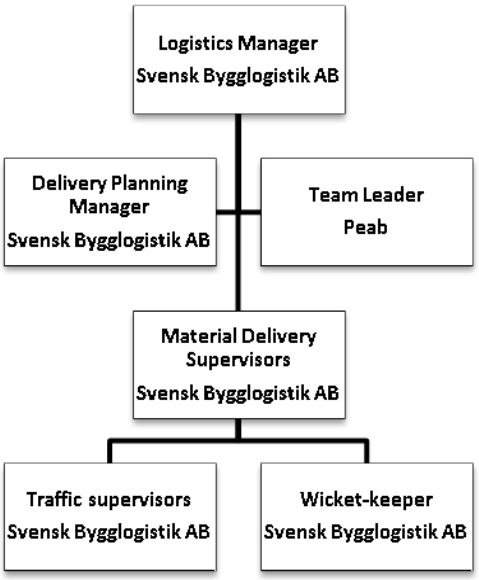

Figure 1: Organization chart of the on-site logistics organization at the Stockholm arena

The delicate parts in this project are the high number of involved parties, which complicates the coordination and information exchange. Furthermore, the actual location of the construction site which increases the complexity of the processes of construction. In this on-site organization there is one person responsible for the overall coordination of the logistics. This person is Svensk Bygglogistiks representative and works as the leader for the on-site organization.

Furthermore they have one person which is responsible for coordination of all deliveries to the construction-site. In order to help the Delivery Planning Manager, Svensk Bygglogistik has implemented a digital delivery coordination system called LogNet. LogNet is a product developed to both ease the administration of coordinating the deliveries planned to the construction site, and it is also a powerful visualization

tool which gives all of the involved parties a graphic visualization of the booked deliveries. LogNet is an interactive tool which gives the parties involved in the project an opportunity to book their deliveries via LogNet and as soon as the administrator has accepted the booking it will be posted on the LogNet visual schedule available for all parties involved. This tools aim is to visualize the planning for both the Delivery Planning Manager but also for all involved parties so that the coordination of processes and deliveries will be eased. It is also at tool in order to ease the communication with all the involved parties and the logistics organization. LogNet has a built in direct communication system using both email and text messages to cellphones. This enables direct distribution of information between the logistics organization and the involved parties.

Additionally the logistics organization has a Team Leader which is employed by Peab. His main duties are traffic-plans, coverage of ID06 and billing. He was not included in the original plans for the logistics organization but was implemented when the work load were shown to be too much. The Team Leader spends much time out on the site which enables him to give directions and taking in information directly from the contractors which increases the partnership relation between the logistics organization and the parties involved.

Moreover the logistics organization consists of three Material Delivery Supervisors. Their main duties are to control the inflow of deliveries and to be a contact person for the organization that delivers the goods. They are also responsible for giving information about the deliveries to the Logistics Manager, Delivery Planning Manager and the Team Leader. Their duties also consist of ensuring that all the delivered goods match up with the delivery order.
The organization also has two Traffic Supervisors that have the responsibility of making sure that the actual unloading of the goods is done in a way that is in correlation with the traffic laws of Stockholm city.
A Wicket-Keeper is also included in the organization. He is responsible for making sure that noone enters the construction site without being booked in accordance with the current logistics system.

This organization works closely together alongside the management organization from Peab. And on the weekly construction meetings logistics has a standing point. On these meetings it is only the Logistics Manager that is present from the on-site logistics organization. These weekly meetings are being held with surrounding organizations or with other words stakeholders or neighbors in order to inform them about the production and take in their point of view on how they are being affected of the production. Furthermore, weekly information meetings are being held with both the client and the management organization of Peab where logistics has a standing point. The on-site logistics organization also has weekly internal meetings. These meetings are being held to ensure that everyone in the organization feels that they have the information they want and to make sure that their way of working is improving. Usually on these meetings all representatives from the on-site logistics organization are present and everyone is asked to present three positive and three negative aspects of their organization.

The logistics organization has the hierarchy and the organizational structuring due to both the complexity of the project, thus forcing the logistics organization to have a

several positions but also this organizational structure is a result of experience from Svensk Bygglogistik. They are active in projects all around Sweden and their main and only focus is logistics. The logistics organization also has clear distinctive roles in order for the information exchange process to be eased. This together with Svensk Bygglogistiks long experience of coordinating and managing logistics resulted in the formation of this logistics organization.

The Logistics Manager was the first person to be implemented in this logistics organization and was implemented between the phases procurement and production. The logistics organization was at first only consisting of personnel from Svensk Bygglogistik but the complexity of this project forced the organization to implement a Team Leader from Peab due to the fact that the workload on the already existing organization was too heavy.

CRITICAL INCIDENTS AT THE STOCKHOLM ARENA

In this part of the article a number of chosen critical incidents for the Stockholm arena will be analyzed and discussed. The amount of data collected for the different critical incident is not equivalent hence the length differentiation between the different critical incidents. Furthermore, the analysis of the critical incidents will merge due to the fact that the different critical incidents affect one another and they are linked together.

Critical incident 1: Arenavägen

Arenavägen is a public road that has approximately 14000 passing cars per day. This road has been open for traffic during most of the time of production which has complicated the production due to the fact that the road, as Figure 2 illustrates, crosses the production area.

The foreman for the organization responsible for the ground work has been involved since the beginning of the project Stockholm arena. His responsibility is to coordinate and manage the process of ground work, rock blasting and pile work. He has clearly seen difficulties in having the road open for traffic. Having the road crossing the construction site has led to complications in structuring their work. This is due to the fact that his team had to establish different small work places instead of establishing two big workplaces as the plans were from the beginning. This has led to restructuring of their work which is not optimized. From the start of their work on 22nd of April 2010 they were given the directives from Peab that they had to redirect the Arenavägen through the construction site, this because they had to be able to close the original Arenavägen in order to bulldoze, conduct pile work and cast the pole foundations that were supposed to be located on the same location as the original road.

The rock blasting, which also is a responsibility of his team has also encountered difficulties in form of conflicts with a nearby organization. This nearby organization or stakeholder has its parking lot and warehouse in direct connection to the construction site. When blasting rocks, the measurement for chocking and shakes values has been in the accepted limits according to the interviewee. On the other hand, the representative from the nearby organization claims that even though the measurements has been in the accepted limits it is a risk for his stock of tile in his warehouse to fall down. This representative is responsible for data communication and real estate for the nearby organization. He is also affected by the fact that the Arenavägen is open, but not for the same reasons as the production. The Arenavägen

is used as a passage for all the deliveries made to the construction site. This fact has led to an increasing amount of heavy traffic getting stuck on the road which in return has led to that deliveries to his organization has been stalled or even cancelled.

The fact that the construction is ongoing close to his organization leads to redirecting of pedestrian's trough the nearby industrial area, which he claims causes his organization to lose customers. According to the current agreement this stakeholder's organization is not to be disturbed by the production of the arena. This is not the case according to the interviewee. Instead he claims that his organization is suffering from big losses in sales which threaten the existence of the organization.

From the start the city of Stockholm was supposed to offer the organization a replacement location to conduct the business, but this has not been the case. According to the interviewee the city of Stockholm has not performed what were initially agreed upon, which has had the effect that the organization had to stay close to the production much longer than wanted.

Furthermore, there are two more stakeholders or neighbors that have been affected of the Arenavägen being open during the construction process. The first one is a large greengrocer which has its stock and warehouse in direct connection with the construction site, if not to say almost in the middle of the construction site. The closeness to the construction site has had an impact on the greengrocer. This is due to the fact that the arenas stand on the west side is overlapping the loading dock of the green grocer. This has had the effect that trailers with deliveries to or from the greengrocer has to share space with the carpenters of the arena project. The drivers working for the greengrocer has also changed how they dock when loading or unloading their trailer due to the fact that one of the pillars from the arena unable them to drive like they always has. The representative from the greengrocer, a plant manager says that this has been an ongoing problem but the greengrocer and the organization from Peab with a lot of contribution from Bygglogistiks Logistics Manager had worked it out. But it has been a problem which could have easily been solved if an analysis of the space needed for the trailers would have been made at an early stage.

The second stakeholder mentioned above is a facility manager from the organization Nordic Pm which is responsible for the organizations renting spaces in the Globen area. The Globen area is located in direct connection to the construction site in the North direction. The main concern for the organizations that has their business in the Globen area is that when the construction process is ongoing the access to the Globen area is very limited which leads to losses in sales which in turn results in cut downs in personnel according to the interviewee. This problem is a direct effect of lack of obedience and understanding for the nearby organizations businesses. Peab has not put up signs and redirected the traffic as they were supposed to according to the interviewee.

Analysis of the incident enables observations of at least some of the reasons that led to the impression of increasing complexity for the logistics organization and the production.

- *The fact that the Arenavägen was open at all during the production*

- *The fact that there seems to be lack of planning of how this road were supposed to be handled with in practice*

After analyzing the interviews the fact that this road has added a lot of complexity to the production of the Stockholm arena is clear. As clearly is illustrated by a quote by a foreman from Peab.

> *"The road should not have been open at all, it should have been closed from the start of production"*

The increased complexity from having the Arenavägen open for traffic is further illustrated from another quote by one of the production managers.

> *"It is always a danger in having third person inside a construction site"*

The fact that the Arenavägen has been open for traffic and even at one stage of the project redirected trough the construction site has led to increasing amount of work for the logistics organization. As it looks today the logistics organization has to work on a daily basis with questions that concerns signs, redirecting of traffic or even upset stakeholders. This is all an effect of the Arenavägen being open for traffic. A much more detailed plan for how the infrastructure around the project is supposed to be dealt with had easily erased all the problems with this road. This analysis should not only include how the traffic is supposed to be redirected but should also contain a deeper analysis of the effects of redirecting the traffic and then including the stakeholder aspect.

Critical incident 2: Nynäsvägen

The Nynäsvägen is a public road which is one of the arteries of traffic into the central parts of Stockholm thus it has a significant amount of daily traffic. The location of the road is in direct connection to the construction site on the east side. The complexity that this brings is that, just as the case is on the west side of the arena, the stand of the arena will overlap the road. This adds a lot of complexity to the actual assembling of the facade materials as the interviewee, the team leader for the production of facade materials stated. When lifting material with a crane, there are clear restrictions regarding lifting materials over third persons. When assembling the facade materials it is impossible not lifting over third person due the location of the road and the overlapping of the stands of the arena. Adding to that complexity is the fact that the city of Stockholm has forbidden the onsite organization to stop the traffic on this road. As understood from the interview, there is no clear plan for how this complexity is supposed to be handled but discussions is being held although there are a lot of different wills and opinions in this question. But one can draw the conclusion that due to the fact that the interviewee and the logistics organization is aware of the problem and that the topic is discussed which is a sign that the logistics system used on the Stockholm arena is having a valid function.

The interviewee also stated that the architect had been informed about the situation thus taking that into consideration when the design the facade and the prefab materials thus making them possible to assemble from the inside.

Another problem that has arose due to the fact that the Nynäsvägen is so close to the arena is that the assembly of prefab materials had to be adjusted in a way that is not optimal. For instance the project manager for the organization responsible for the prefab materials stated.

> *"The road is located where we would like the crane to be, but we solved that problem by assembling the materials from the inside instead. It is not optimal but it will do"*

Analysis of the incident enables observations of possible reasons that have led to the increasing complexity for the logistics organization and the production.

- *The fact that there is not a valid and clear plan for how the incident is supposed to be dealt with from the start of the production.*
- *The fact that the road has made the crane placement more difficult thus even changing the way the assembling of materials is done.*

The fact that the road is located so close to the arena raises difficulties in the crane placements. The optimal location of the crane is not possible due to the road which is clearly illustrated by the quote above. The logistics organization has struggled with different solutions on crane placements, and has even considered placing the crane on the opposite side of the road, in the middle of a housing area.

The interviewees is fairly convinced that the solution to the complexity regarding the Nynäsvägen will be one where the road is being built in just to secure that third party will be under a temporary roof when traveling under the crane. This solution offers new complexity which the logistics organization will have to deal with due to the fact that the Nynäsvägen is used to transport material in to the construction site. Analysis of this incident also offers an indicator that the work of the logistics organization hence the logistics system is working but also indicates that the complexity of the incident offers additional work for the logistics organization which could have been dealt with at an earlier phase.

Critical incident 3: SL railway track

Stockholm has a large and complex railway system, which is highly occupied every day. In direct connection to the construction site of the Stockholm arena lies a railway track belonging to the city of Stockholm. This track is occupied with a lot of goods trains supporting both the nearby organizations and the organizations south of Stockholm. This together with the fact that a nearby railway junction point for the whole railway system is being refurbished during the time of construction and therefore closed, forced the city of Stockholm to have this railway track open for traffic during the construction process. This of course has led to increasing complexity for the whole project.

As illustrated in Figure 2, the railway track is running through and under the construction of the stands for the arena. Just by studying the picture one can clearly understand the different complications that arise as a direct effect of having the railway tracks open for traffic.

Figure 2: Illustrates both the Arenavägen and the railway tracks on the West side of the construction site, that both have been open for traffic during the construction process.

The complications arisen from the fact that the railway track had to be open has mainly concerned the time of production for the organization responsible for prefab materials and the organization responsible for groundwork. The effect of having the Arenavägen open is that no lifting with cranes is allowed when the road is used thus forcing the organization to work nightshift. Hence resulting in contractors having to work at the hours when the traffic on the railway tracks is at its highest. During the night the contractors gets a warning signal meaning that in 15 minutes a train will have to pass the railway, which interrupts the workflow and planning processes. Furthermore, it is not an optimal solution to work with construction at night due to the possible risks that can occur, according to the project leader for the organization responsible for the prefab materials.

Analysis of the incident enables observations of some of the reasons that led to increasing complexity for the logistics organization and the production.

- *The fact that redirection and coordination of the railway tracks traffic seems to be lacking.*
- *The fact that it seems that the consequences of having the railway track open during the construction process haven't been thoroughly analyzed.*

The fact that the city of Stockholm has to keep the railway track open for traffic is a fact that no construction organization can change. But with that in mind it is clear from the analysis of the incident that the preparation and logistics regarding how the commute traffic and goods trains were supposed to be redirected during the construction process is something that should have been highlighted at an earlier phase. Instead the logistics organization alongside with the production team has to "put out fire" instead of preventing them from occurring, which is illustrated in forced actions such as nightshifts. This is clearly an effect of the logistics organization not being implemented at the appropriate phase.

Critical incident 4: Stakeholders

As mentioned earlier there are several nearby organizations conducting business located in direct connection to the construction site. These stakeholders having

business ongoing during the construction process increases the complexity for both the production and the logistics organization. The stakeholders have daily deliveries both to and from their premises, customers visiting their premises. Both these are factors that complicate the logistics concerning both the deliveries to the construction site as well as the redirection of third person. The complication of redirecting third person and the limitations of the Arenavägen is concerned in the earlier critical incident analysis. There is another level of complications concerning the stakeholders, the stakeholders are occupying the logistics organizations with their complaints and their standpoints. This is clearly illustrated due to the fact that there are ongoing meetings, telephone and email contact with these stakeholders on a weekly basis.

From the interviews it is clear that the stakeholders feel that their issues and concerns has been looked upon and not dealt with thoroughly. This has the effect that the logistics organizations has to, on a weekly basis, deal with these issues. It takes up time, which could have been spent on other important planning and coordination. Analysis of the incident enables observations of one of the reasons that led to increasing complexity for the logistics organization and the production.

- *The fact that it seems that a thorough stakeholder/impact analysis has not been performed*

As illustrated by the research made by Olander (2007) a thorough stakeholder/impact analysis can ease the construction process. In the case of the Stockholm arena it seems to be that the surrounding stakeholders and their concerns has been overlooked or not looked into as thorough as it should have been. Furthermore, there are several levels of stakeholders which has different amount of eager to raise their voice and their concerns, this is where a stakeholder/impact analysis is a powerful tool. Moreover, these issues and concerns could have been detected at an earlier stage, which would have led to a greater possibility to meet and even exceed the expectations of the stakeholders. The on-site logistics organization continuously deals with the stakeholders concerns which is time consuming thus hinders them from focusing in their initial aim which is structuring, coordination and organizing of the logistics.

DISCUSSION AND CONCLUSION

The case project is very complex and has a lot of different variables of coordination. It is clear that implementing a logistics organization has helped this project in terms of coordinating and managing the process of construction. This is illustrated by a quote from one of the interviewees.

> *"After the Logistics Manager came in to the picture at least I have gotten the impression that the situation has improved and that my concerns have been taking into account".*

Moreover, it is clear that without personnel dedicated only to coordinating the logistics this project would have suffered from even more complexity and resistance from stakeholders than it already has. As the quote above describes, the implementation of a logistics organization and more specifically a Logistics Manager has increased the customer satisfaction which is in correlation with the studies made by (Tenner & DeToro, 1992; Olander, 2006; Johnsson & Matsson, 2008).

As described the studied project is large and has a lot of different organizations active, this fact complicates the information exchange. But implementing the logistics organization structures and limits the information exchange regarding all matters of logistics trough the logistics organization. This leads to an overall eased information exchange process which coincides with the study made by Agapiou, et al. (1998). Even though this project has implemented a logistics organization on-site, which main focus is logistics, there have been some complications regarding some incidents during the project. This is a result of the logistics organization not having the possibility to plan these incidents ahead which is a direct effect of the implementation time of the organization. This is in accordance with the studies made by Agapiou et al. (1998) and Karlsson (2009), who says that a logistics system should be implemented as early as possible in the process.

This article reflects a limited period of time during the production of the Stockholm arena, which infer that the suggestions for improvements for future robust logistics systems is not complete due to the additional incidents that may or may not occur during the remaining life cycle of the project. The results from this article are produced in a qualitative manner via interviews, which infer that interpretations occur.

Incident	**Logistics system**	**Logistics organization**
Arenavägen	The location of the road, directly through the construction site has render in increased amount of work, complexity and risk. The consequences of redirecting traffic must be thoroughly analyzed, and no traffic should be directed through the construction site.	The incident has increased the workload for the on-site logistics organization. This can be avoided by implementing the organization at an earlier phase of the construction project.
Nynäsvägen	The location of the road has affected the coordination of work processes and the assembling of materials. Analysis of the conditions surrounding the construction site needs to be analyzed thoroughly.	The location of the road has increased the complexity regarding assembling and transportation of materials. The logistics organization should possess the right experience of logistics.
SL railway track	The location of the railway track directly through the construction site has render in increased amount of work, risk and complexity. Coordination of the city's plans for local traffic should be analyzed at an early stage. Furthermore if necessary, the	The complexity regarding this incident has increased the complexity for the logistics organization thus rendering in that they have to focus on "putting out fire" instead of focusing on their main task. This should be avoided by implementing the logistics

	consequences of having traffic through the construction site, needs to be analyzed thoroughly.	organization earlier thus enabling the opportunity to analyze these matters in collaboration with city.
Stakeholders	The nearby organizations complaints and concerns render in increased amount of work and complexity. A stakeholder/impact analysis should be implemented to avoid this.	The logistics organization needs to be good at handle the contact with stakeholders, and the stakeholder/impact analysis should be done early in the project.

Figure 3: Illustrates conclusions and summary of the consequences and arrangements for future logistics systems and recommendations for logistics organizations.

Analysis of the critical incidents summarized above indicates some potential improvements that can be implemented in future projects in order to build even more robust logistics systems.

- A thorough stakeholder/impact analysis should be performed at an early stage in order to proactively ease the interaction with the surrounding stakeholders.
- The implementation time of the Logistics organization should be moved to an earlier stage in the project in order to get a more holistic view and to be able to take in to account the logistic viewpoints.
- Implementation of the logistics organization already in the design phase of the construction process will lower the amount of work and time the logistics organization has to put on matters that are outside their core aim.

Recommendations for future studies are to further analyze the advantages and effects that implementation of the logistics organization at an earlier stage brings to future projects in terms of eased coordination of activities and logistics. Possible data to analyze in such research could be economical winnings, health and safety aspects and eased production flow in both terms of stakeholder's influence and project activities being on time.

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Utvecklande av robusta logistiksystem i komplexa projekt

Byggbranschen har länge förknippats med att vara ovillig att implementera förändringsarbete samt att vara ineffektiv. Ett grepp för att hantera ineffektivitet är att fokusera på logistik. Byggbranschen har mycket att lära av tillverkningsindustrin där logistik sedan länge är ett huvudfokus. Logistik innebär att effektivisera och kontrollera materialflöden och till detta kopplade resurs, informations- och monetära flöden. Att fokusera på logistik och förbättringsarbete har visat sig öka effektiviteten och det värdeskapande arbetet, vilket har lett till att allt fler projekt och organisationer inom byggbranschen numera fokuserar på att arbetar med att implementera logistiska system för att hantera koordination och strukturering av processerna. Detta är ett steg i att söka effektivisering i byggbranschen.

I ett byggprojekt är det många inblandade parter vilket försvårar arbetet med att organisera och koordinera arbetet. För att underlätta detta arbete bör varje större byggprojekt upprätta ett logistiskt system i form av en logistikorganisation vars huvudfokus är att organisera och koordinera både flödet av material samt de olika processerna.

Byggbranschen är av en projektnatur vilket innebär att en temporär organisation tillsätts för att utföra en unik produkt under en begränsad tidsperiod. När projektet är utfört så upplöses projektorganisationen och de medverkande parterna går vidare till nästa projekt. Detta har traditionellt sett utförts utan att en genomarbetad återföring av erfarenheter och kunskaper återförs till nästa projekt. Byggbranschen är stor och antalet projekt som utförs årligen är många vilket innebär att möjligheterna för att återföra kunskap och erfarenheter till nästa projekt är goda. Ändå så återupprepas många av de misstagen om och om igen som redan har stötts på i tidigare projekt.

Varje byggnadsprojekt är unikt men det finns en rad olika händelser som är återkommande som försvårar arbetet med logistik. Denna artikel bygger på en fallstudie på det komplexa projektet Stockholms Arenan där ett logistiksystem har implementerats i form av en logistikorganisation bestående av personal från Svensk Bygglogistik AB. Utgångspunkten tillika syftet för studien är att analysera ett antal incidenter vars effekter har skakat om eller påverkat det logistiska systemet, även kallade ”kritiska incidenter”. Analysen strävar efter att hitta ursprunget till den inträffade incidenten. Detta för att kunna synliggöra potentiella utvecklingspunkter för upprättande av framtida robusta logistiksystem.

Arbetet med datainsamlingen genomfördes via intervjuer med representanter från den implementerade logistiska organisationen, entreprenörer och intressenter utanför projektorganisationen. Dessa valdes ut med hänsyn till deras inblandande i de valda kritiska incidenterna som var:

1. Arenavägen
2. Nynäsvägen
3. SL:s-järnvägsspår
4. Intressenter utanför projektorganisationen

Arenavägen

Arenavägen är en allmän väg som har varit öppen för trafik under stora delar av projektet. Detta har haft till följd att tredjepart har färdats i direkt anslutning och under vissa tidsperioder även igenom arbetsplatsen. Detta har lett till att de olika entreprenörerna har fått anpassa sin produktion och även arbetat nattskift under vissa delar av projektet. Då detta inte har fokuserats på i ett tidigare skede beroende på implementeringstiden av den logistiska organisationen så har resultatet blivit att fokus har lagts på säkerhetsfrågor rörande lyft över vägen, koordination av processer under nattetid samt omdirigering av trafik vilket borde ha fokuserats på i ett tidigare skede för att möjliggöra fokusering på den logistiska organisationens huvudsyfte.

Nynäsvägen

Nynäsvägen är en av de artärer som försörjer Stockholmstrafiken. Trafiken som belamrar denna väg är betydande och får inte i enlighet med direktiv från Stockholms stad inte stoppas under produktionen. Detta har försvårat arbetet med produktionen dels i form av kranplacering men även i form av planering av montage av fasadmaterial. Resultatet av att denna väg har varit och skall vara öppen under produktion är att försvåringar för den logistiska organisationen har uppstått i form av att anpassningar och kompromisser har fåtts göras gällande kranplacering och montage av fasadmaterial. Gällande denna kritiska incident så har även de positiva resultaten av arbeta med en logistisk organisation visats då produktionsteamet och den logistiska organisationen samarbetar nära med varandra och har kontinuerliga diskussioner om lösningar kring dessa komplikationer.

SL:s järnvägsspår

Stockholm har ett stort och omfattande järnvägsspår-system som är belamrat med mycket trafik. Under tiden då denna fallstudie genomfördes så rekonstruerades en av knytpunkterna som försörjer den södra delen av Stockholm med trafik på järnvägsspåren, vilket hade till följd att ett spår som passerar i direkt anslutning till byggarbetsplatsen var tvunget att vara öppet för trafik. Detta har givetvis försvårat struktureringen av själva produktionen vilket även har försvårat arbetet för den logistiska organisationen i form av planering av nattskift men även omdirigering av trafik och säkerhetsfrågor.

Intressenter utanför projektorganisationen

I direkt anslutning till byggarbetsplatsen finns en rad olika organisationer som bedriven sin verksamhet under tiden då produktionen av arenan fortlöper. Dessa organisationer har påverkats av produktionen då omdirigering av vägar har lett till minskad framkomlighet till deras verksamhet vilket i deras mening har lett till minskad försäljning. Intressenterna har även påverkats av att den ökade trafiken som uppstår då det är nästan 100000 leveranser planerade till produktionen av Stockholms Arenan, detta försvårar framkomligheten för intressenternas egna leveranser. Komplikationerna med närliggande intressenter har ökat arbetsbördan för

logistikorganisationen och de arbetar på en kontinuerlig basis med att tillgodose intressenternas synpunkter.

Det är tydligt vid analysering av resultatet från genomförda intervjuer i denna fallstudie att implementeringen av en logistisk organisation har underlättat arbetet väldigt mycket för produktionen av Stockholms Arenan. Samtliga intervjuade poängterade att arbetet med logistik har fungerat väldigt bra och att utan ett logistiskt system upprättat för koordination och samordning hade konsekvenserna från de kritiska incidenterna varit ytterligare försvårade. Dock finns några potentiella utvecklingsområden att belysa.

Dessa kritiska incidenter har haft en påverkan på det logistiska systemet och dess arbete och haft till följd att organisationen har fått arbeta med att kontinuerligt lösa problem som uppstått kring dessa. Bakgrunden till att dessa händelser har påverkat den logistiska organisationen tycks vara att det inte har funnits någon tydlig plan i ursprungsskedet eller projekteringen för hur dessa händelser skall hanteras. Detta kan grunda sig i att den logistiska organisationen inte har implementerats i det skede som är önskvärt. Samt att en ”stakeholder/impact” analys inte tycks ha genomförts, denna analys syftar till att i ett tidigt skede kartlägga de olika intressenternas synpunkter och önskemål för att kunna tillgodose och även överträffa dem för att undvika konfrontationer.

Slutsatsen från denna fallstudie är att ett av svaren på att effektivisera byggbranschen ligger i att utveckla robusta logistiksystem som tar i beaktande både koordination och organisation av processerna inom produktionen men även tar i beaktande de intressenter som påverkas av projektet som inte är i en del av projektorganisationen. För att säkerställa kontinuerlig utveckling av byggbranschen bör även fokus läggas på att återföra kunskap och erfarenheter från tidigare projekt. Artikeln fastställer även att för att möjliggöra att ett logistiskt system skall kunna belysa de logistiska synpunkterna skall systemet eller organisationen implementeras i ett tidigt skede av projektet, gärna redan i projekteringsfasen. Detta för att om implementeringstiden skjuts till ett senare skede så är möjligheten att påverka och effektivisera redan minskad och försvårad samt att arbetet med att hantera situationer som kunde ha motverkats tar upp mycket av den logistiska organisationens tid.

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