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School of Engineering and Science

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Successful application of Last Planner System combined with Location Based Management System

Divergences between theory and practice

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Synopsis
As the title insinuates, the research relates an effective guideline on how to apply the Last Planner System (LPS) in combination with Location Based Management System (LBMS) within construction companies and presents the disconnection between theory and practice.

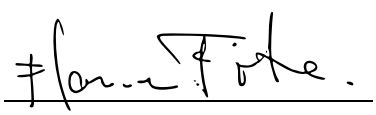
The paper starts by describing the actual deficiencies of the Danish construction industry, this leading to a valid issue presented as a lack of productivity within the last years.

In order to increase the productivity of the construction companies, the research presents a theory based application of the combined system. Following this, two case studies are introduced in order to observe the divergences between theory and practice. In addition, a survey has been developed to ask different staff in the industry about the planning tools that really make the difference and the tools that do not offer satisfaction in practice.

To conclude, the reader is offered an improved system of LPS combined with LBMS. The system's credibility is backed up by recent theory, present field planning and the actual needs of the construction staff.

Signatures

David González



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PREFACE

This research is conducted as a Master thesis of the Management in the Building Industry programme, from the department of Civil Engineering, at the faculty of Engineering and Science of Aalborg University.

The main report contains a detailed description of the research process continued by the contribution to knowledge and its derived results, aiming to provide an improved system for production scheduling and control of construction projects.

The group would like to thank all the contributors to this project. To all the 30 anonymous respondents of the questionnaire, to Søren Munch Lindhard for his first guidance and advice, to Kristine Ann Barnes for allowing us to perform a study of her current project and in special to our supervisor Brigitte Krag Festersen, for her continuous revision and constructive critique of our work.

David González, Florin Firte and Ivan Dimitrov

LIST OF ACRONYMS

- LPS: Last Planner System
- LBMS: Location Based Management System
- LBS: Location Based Schedule
- VDC: Virtual Design and Construction
- BIM: Building Information Modelling
- CPM: Critical Path Method
- WWP: Weekly Work Plan
- MRP: Make Ready Process
- PPC: Percent Plan Complete
- JIT: Just In Time

SUMMARY

This Master thesis has been conducted by a group of three international students, as the 4th semester of the Management in the Building Industry programme, from the department of Civil Engineering at Aalborg University.

The thesis is entitled "*Successful application of Last Planner System combined with Location Based Management System. Divergences between theory and practice.*" As the title suggest, the research topic focuses on scheduling of on-site construction with enhanced attention on improving the traditional methods. This is achieved by applying the Last Planner System (LPS) combined with Location Based Management System (LBMS).

The topic was chosen due to the inadequacy of current production control systems and their incapability to handle the complexity of on-site construction. Since 1966, the productivity in Denmark has increased by a rate of merely 10%, while other industries have increased production rates as high as 100%. This data shows the construction sector's stagnation, the reason being the numerous cost and time overruns and overall inefficiency of the building process. LPS and LBMS are reported to have a positive effect on schedule reliability and control, although there is limited research and guidance about the combination of both systems.

Further, the research observes and scrutinize the disconnection between theory and practice through a number of two case studies (one with the suggested combined system already in practice and the other using the traditional planning methods). The different planning and building methods will show advantages of using the system, but also argues why different theory elements prove not to be useful in practice.

In addition, an online survey has been performed to get an insight of the methods and tools for production and control that are being used on the construction site. This quantitative research method brings the voice of multiple project managers, foremen and other constructions staff into the study.

Based on the collected data, the system was further analysed revealing several weak points, which were thoroughly investigated, the improvements being presented in this dissertation. Among the headlines stand: a more collaborative Make Ready Process (MRP), a simplified Percent Plan Complete (PPC) approach, a more detailed and transparent tracking of variances and the addition of a kick-off meeting.

The reliable and robust system developed by this paper is defended not only by the existing studies and theories, but also the actual behaviour of LPS and LBMS elements in practice. This is a great improvement of the two tools (LPS and LBMS) and the combination of them will bring the Lean methodology to a new level.

REPORT STRUCTURE

The report starts with the project's purpose and the reasons for choosing this topic, followed by "Research Design" to explain how the research is structured and elaborated. The project is written as the final thesis of the Master degree in Management in the Building Industry of Aalborg University (Denmark), thus including the introduction to the Danish Industry and the challenges it faces.

With this project, is intended to elaborate a guideline to successfully apply LPS in combination with LBMS in construction companies. Both tools support Lean Construction principles, therefore it is considered necessary to introduce the reader to the Lean production and its principles, narrowing down to Lean construction and ultimately to logistics in construction.

The questions that the research intends to answer are presented in the Problem Formulation Chapter, together with a short description of the reason to choose this topic.

In the next chapter named Application of the combined system, is intended to answer the first main question presented in the problem formulation; "*How to successfully apply the LPS in conjunction with LBMS in construction companies?*". This is done by describing how each of the tools of LPS should be applied when used together with LBMS.

Since most of the researched literature felt too positive towards the principles of Lean, was decided to elaborate a chapter of Criticisms before proceeding with the case studies, to be as objective as possible in the elaboration of the report. In addition, since every change needs to be implemented through a long process in which many factors are involved, was decided to talk about the Levitt model, a method to analyse the current state of a company before proceeding with a change.

Finally, the case studies are introduced, explaining their similarities and differences of the companies in charge and the projects itself. Right after, each case is presented individually, structured with an introduction to describe the reasons of doing the case study, observation to objectively explain the planning methods used in each of them and concluding with arguments from the theories presented earlier.

With the elaboration of the first case study, since is based in a construction project using the same system suggested in this report, it is intended to answer the second main question from the problem formulation; "*What is the disconnection between theory and practice from the suggested system and why?*".

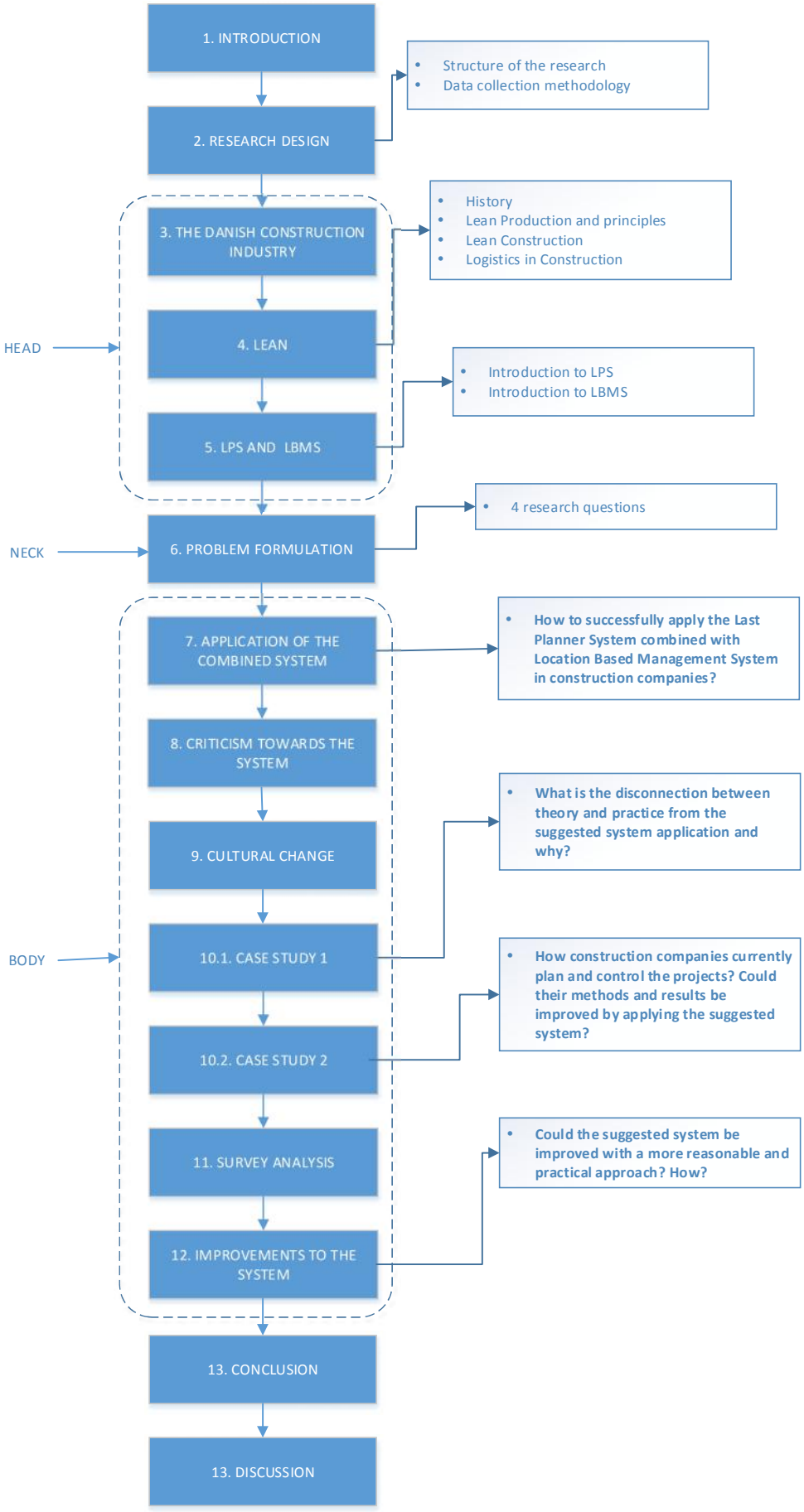
The second case study is analysed due to the traditional construction planning and control of the project, highlighting on possible improvement by applying the system. Hereby, the research aims to answer the third main research question; "*How construction companies currently plan and control the projects? Could their methods and results be improved by applying the suggested system?*".

Following, it is presented analysis of the online Survey, where all the answers from each respondent is screened and analysed to fully understand how the planning is conducted in projects using and not using LPS and the results obtained.

With the ideas gathered after the Case studies and the Survey analysis, improvements are suggested considering the benefits of the theoretical approach and what is reasonably feasible in practice, answering the fourth and last research question; "*Could the suggested system be improved with a more reasonable and practical approach? How?".*

To finalize, there is a conclusion, summarizing the main points discussed in the report and answering the research questions presented in the problem formulation. This is followed by the last chapter of Discussion, to introduce some additional tools that were not considered due to the time limitations and suggestions for further researches.

In the following figure is schematically shown the described structure: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1 INTRODUCTION

It is widely known, that the construction industry is a very unpredictable and complex sector, given its dynamic behaviour and the numerous parties involved in construction projects. However, existing production control tools are unable to fully handle the complexity of the construction processes (Meyer, 2002), resulting in cost and time overruns as a common issue in the construction industry. According to Jesper Kranker (2015) the current averages of construction projects disruptions are:

- Budget overruns up to 28% increase
- Up to 40% time escalations increase
- Failure cost accounting for 15% of total costs
- Only about 51% of the workday is value adding

The presented values highlight the need to reinvent the traditional methods for production planning and control.

Gibson (2006) defends the importance of pre-project planning for the success of the project execution. He argues that the more resources are allocated for pre-project planning the better results are achieved. Gibson performed a study of 56 different construction projects, where he measured the effort expended in pre-project planning (considering 6 weighted variables) and the success of the project execution, (considering a weighted blend of budget, schedule, design capacity and utilization performance versus target). The results were as follows:

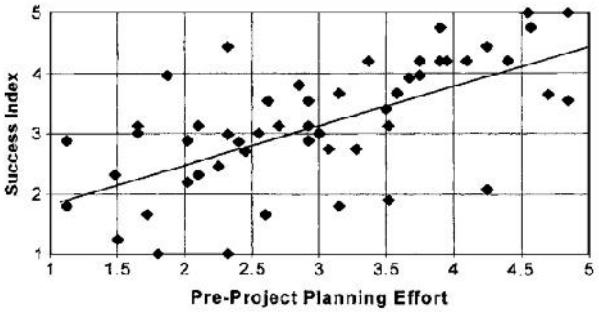


Figure 1: Success index versus pre-project planning effort index, N=53 (Gibson, et al., 2006)

In Figure 1 it is observed how the success ratio of the surveyed projects is proportionally related to the effort expended in project pre-planning, achieving higher success as more resources are put on pre-planning. Of course, the amount of pre-project planning required in large and complex projects, which imply higher risk, is also correspondingly higher.

In addition, great leaders such as Eisenhower, believe that for a successful project execution, is required continuous planning, control and monitoring of the project (Gibson, et al., 2006) .

"*Plans are nothing… Planning is everything*" – Dwight D. Eisenhower

What the above quote refers to is the importance of continuous revision and control of projects plans. However, it is important to define how a successful project is perceived.

According to Hoffman (2007), the success or failure of a project is based on its ability to follow the agreed time, budget and quality of the construction project. Zwikael and Sadeh (2012) suggest that most projects fail to achieve the agreed project specifications; however, if a construction project does not meet its requirements, it can still be considered successful, due to the benefits it has brought to the stakeholders.

The Sydney opera house is taken as an example. The project was scheduled to be finished in 4 years and to cost 7 million AUS, however it ended up taking 10 years and close to 102 million AUS (MARTIN, 2012). Nevertheless, the Opera House is considered a World Heritage by UNESCO and furthermore have become symbol of Sydney and Australia. Thus, Zwikael and Smyrk (2012) state that even though the construction project has not conform its requirements, it is considered to be of great value and success for all the involved parties. It is impossible to say whether the Opera House would have been equally successful if it had been constructed within the set requirements.

According to Walker and Lui (1998), time, cost and quality are simplistic criteria to evaluate the success of a construction project. It is argued that the successful outcome is divided in three categories:

- Project goals
- Satisfaction of parties involved
- Perception and awareness of different stakeholders

In addition, the success of a project depends on the individual perception of failure or success of the project. Hereby, factors like project complexity, commitment, goals, rewards and environment can have a significant impact on the way the construction project is perceived (Walker & Lui, 1998).

Therefore, even if a project is not completed on time within its frame budget, it can still benefit all stakeholders involved. However, the research intends to investigate the current construction processes in regards to planning and management, leading to possible optimization of current planning and control methods, without taking into consideration the merit of success for a construction project.

2 RESEARCH DESIGN

The chapter provides knowledge on how the research design is structured, as well as how the data is obtained, allowing the reader to get a better understanding of the techniques used, not only to collect and analyse the data, but to verify it.

2.1 STRUCTURE OF RESEARCH DESIGN

The master thesis report is structured based on Jørgensen (2000) methodical procedure, which is used to compose either research or development projects within businesses. Jørgensen (2000) divides the methodical procedures in two central system concepts, known as analysis and synthesis (Figure 2). Furthermore, the two system operations can be combined and sequenced.

Jørgensen (2000) argues that a problem solving activity is initially based on observed problem, followed by the analysis of the concept. Based on the analysis of the problem, a diagnose is stated, followed by synthesis. The synthesis part creates the innovation processes, where they are being analysed and verified in order to find specified outcome. Moreover, Jørgensen (2000) argues that some of the elementary operations can be embedded in each other, which is illustrated in Figure 2. The figure also highlights the general methodical structure used in the master thesis.

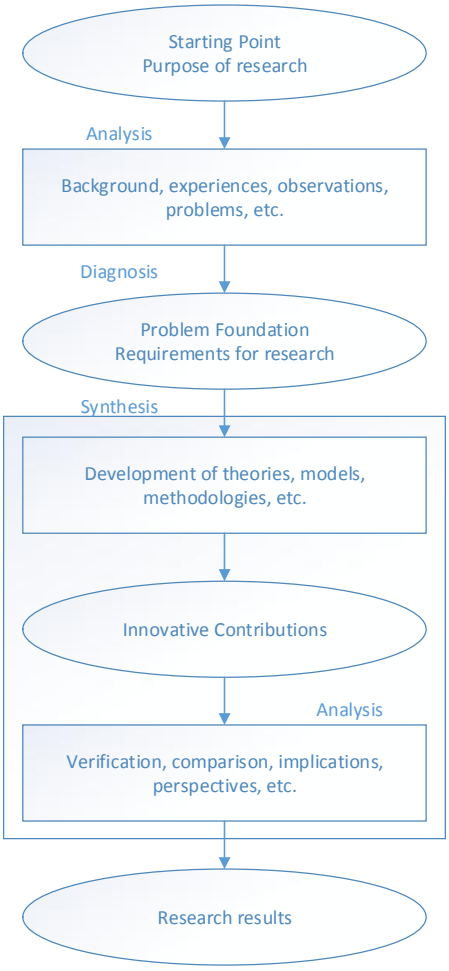


Figure 2: Methodical procedures commonly used as structure of research and development projects (Jørgensen, 2000)

The thesis is composed in six phases, creating a chronological overview of the stages that the research is going through. By following and completing all 6 stages a clear focus is achieved and maintained.

In step one, problems are confirmed related to on-site production and control of activities. This step provides the reader with an understanding of the extent and complexity of problems that are occurring in on-site production. Confirming the occurrence of problems with today's management control on-site, stating that production control can be improved with the use of LPS in conjunction with LBMS.

In order to gain a broad overview of both systems and to create theoretical foundations for future research, a literature review is performed in the next step. The literature review allowed to gain better understanding of the use of both systems, however to improve the construction process, it is necessary to observe the different methods used on site.

The data is collected using qualitative methods represented with both case studies, as well as quantitative methods. Both methods are used in order to gain knowledge, not only about how the different systems are used on-site, but also to gain analytical data representing the most used tools and the reasons behind them.

The analysed data leads to the next step of the 6 stages, where has been presented the new approach to optimization and control of construction processes and scheduling. The last step consist of closing, as well as suggestions for future research.

2.2 DATA COLLECTION METHODOLOGY

The sub-chapter refer to the different techniques that are applied, how the research is conducted and how knowledge is obtained. The thesis research is composed by 4 main research components: literature review of LPS and LBMS, 2 case studies, 2 interviews and an online survey. All four components are used in order to gain better understanding of the theoretical and practical approach of both systems and their application.

During the literature review, essential elements of theory are gathered and studied, giving an understanding of the ideas and functionality of LPS and LBMS, increasing the knowledge of their positive and negative effects on the construction industry.

The survey is conducted in order to gather quantitative data of construction experts at different organizational levels and collect information based on different experiences, knowledge and attitudes towards LBMS and LPS. Normally questionnaires have a low response rate; however, this has been counterbalanced by spreading the survey as much as possible within the set time frame. The gathered answers follow an already predefined structure, allowing an easy analysis and comprehension of data.

The interview and the two case studies are conducted in order to collect qualitative data of LPS and LBMS. By comparing two different construction sites, the level of data is increased, allowing a better understanding of how the systems are applied in practice, as well as the improvement they can make on construction planning and control. Case study 1 is based on an interview and the gathered documentation presented to us, while Case study 2 data is collected from previous semester detailed investigation of the construction site. However, the analysed data has been confirmed throughout an additional interview.

Based on the collected data, theoretically and empirically, different aspects of LPS and LBMS are analysed, highlighting strengths and weakness.

As mentioned before data can be collected by either a qualitative or a quantitative way; e.g. conducting an interview is typically done as qualitative research. The qualitative interviews are usually conducted in an open and simple method; however, the simplicity of the questions leads to complex and rich answers (Jeremiassen, 2010). According to Kvale (2007), there is a qualitative criteria for conducting an interview which consists of:

- The shorter the questions, the longer the answers, the better
- Get to rich, spontaneous and relevant answers from the interviewers
- The interviewers attempt to verify his interpretations during the course of the interview
- The interview is a self-reliant story, that do not require extra explanations

- Degree to which the interviewer clarifies and follows the meaning of interviewee's answers.

(Kvale, 2007)

In the project, it is decided to compare the difference between LPS in theory and the manner LPS is being used in practice. Therefore, qualitative interviews are performed since it is wanted the interviewees' opinion, attitude and daily problems using LPS (Jeremiassen, 2010). Before the interviews were conducted, it was considered the type of information that was necessary to obtain. Furthermore, it was decided to use an online survey approach, to investigate the way construction projects are managed by LPS and non-LPS users and see the differences.

The online survey was prepared the same way as the questions for the interviews, focusing on the simplicity of the questions, but with the possibility for the person filling the survey to give a complex and rich answer, based on their experience. The research team is aware that the amount of responses using an open survey, where people can elaborate on their answers, is lower than a survey using multiple-choice type of answers. However, by providing project managers and site managers with the option to elaborate their answers, it is argued that their detailed answers provide a better understanding of their daily routines using LPS. Ultimately, it was agreed, for the convenience of respondents, to use both open and closed questions.

As mentioned before, the open questions provide the opportunity for more detailed and elaborative answers; however, the closed ones provide a checklist of acceptable answers, thus making the process of filling in the survey easier. Moreover, multiple-choice questions are less time-consuming to analyse and interpret than the responses to open questions (Thayer-Hart, 2008).

Furthermore, the survey questionnaire is developed in order to ask neutral questions, without leading the participants towards a particular answer (Parasuraman, 1991). Thus, focus is placed on the way questions are asked to get objective answers.

In addition, a Likert rating scale was added to measure people's attitudes by asking them a series of statements about a specific topic. The scale uses fixed type responses specifically designed to measure opinions (Bowling, 1997).

Likers scale provides the option of having a five, seven or even nine choices allowing individuals to express themselves on how much they disagree or agree with a particular question or statement (Figure 3). Within the answers, the responders can select neutral, where they neither agree nor disagree with the made statement (Likert, 1932). It has been decided to use the scale, due to the fact that it eliminates the simple yes\no answers with a degree of opinion or no opinion at all (McLead, 2008). Thus, the method allows the acquiring of quantitative data and analyse it with relative ease.

Scale *

	Disagree Strongly	Disagree	Neutral/neither Agree or Disagree	Agree	Agree Strongly
Increased predictability	○	○	○	○	○
Support of value, flow and transformation	○	○	○	○	○
Reduce of waiting, waste and costs	○	○	○	○	○

Figure 3: Part of Likert Scale used in the online survey

Figure 4 highlights the process from developing surveys to collecting and analysing the data (Thayer-Hart, 2008). Furthermore, the survey was tested in order to make sure that the process of answering the survey is smooth and understandable. Essential feedback was gathered from Aalborg University teachers and construction project managers and the necessary changes were made to ensure the reliability of the survey.

Figure 4: Survey sequence

The gathered data can be applied for further investigation of the topic, building on it, clarifying the different construction methods in order to deliver a successful project. Furthermore, the data can be further analysed when 4D and 5D are present, making an impact on the proposed system.

3 THE DANISH CONSTRUCTION INDUSTRY

As already mentioned in the Introduction Chapter, there are common reasons for time and cost overruns on a global scale, however the research is limited only to the Danish construction industry.

The chapter introduces the development of the Danish industry through the years and the projects and initiatives launched by the government in order to increase construction productivity rates, improve the Danish construction image, as well as reduce the accidents on site. The chapter also provides a broad perspective of the construction industry in Denmark and includes information about the Danish version of LPS from MT Højgaard A/S, known as TrimByg, and the beginning of Lean construction in Denmark.

3.1 CONSTRUCTION PRODUCTIVITY

The Danish construction industry is often criticized for not being efficient in regards to labour productivity, even though new technologies have emerged throughout the years, helping other industries to experience productivity gains. The Danish construction industry has been experiencing labour productivity stagnation since the mid-80s, in spite of the technological progress. Figure 5 represents the difference in labour productivity between the construction industry and the general industry (Statistikbanken, 2015)

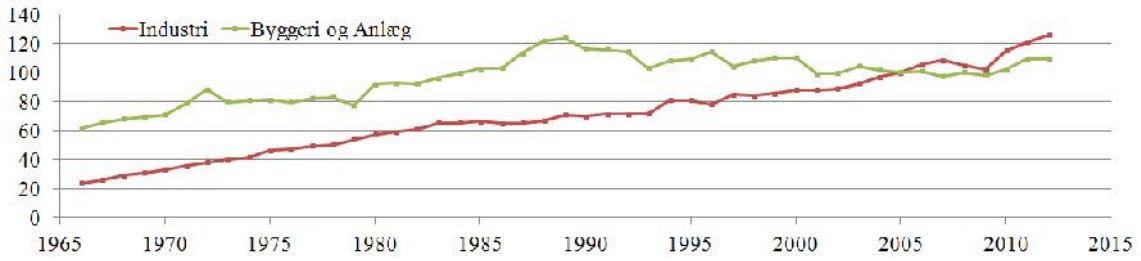


Figure 5: The difference in the development of labour productivity, respectively to general industry (Statistikbanken, 2015)

Even though there has been a lack of labour productivity within the Danish construction industry, the construction sector itself constitutes about 11% of Denmark's GDP and employees more than a 1/5 of total private sector (Tiknuss, 2012). As shown on Figure 6, the number of employees has drastically declined due to the financial crisis of 2008-2009, therefore the employees number in the construction industry has dropped down to 140.000-150.000 people (Statistikbanken, 2015).

Figure 6: Number of employees within the construction industry (Statistikbanken, 2015)

In addition, as shown in Figure 7, the most numerous projects are the detached houses within the residential properties; however, farm buildings are the most numerous facilities at the current construction industry. Furthermore, in the recent years it is observed a decrease within the residential construction activity, which has led to many companies to participate in municipal and state tenders, ultimately leading to a drop of 40% in tender prices. The drastic drop of tender prices brought a new concern in regards to the quality of the projects, especially in some of the low-priced tender applications (Tiknuss, 2012). Hereby, it is important to consider the proper application of Lean principles and methods in order to increase profitability and reduce waste.

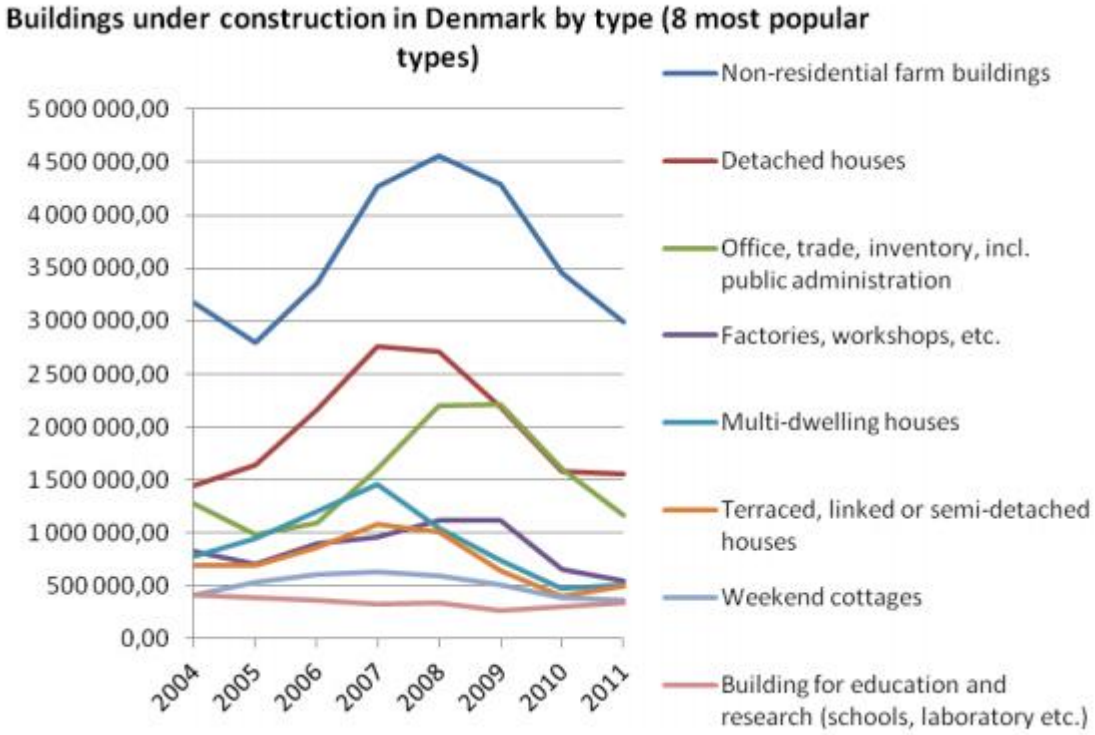


Figure 7: Different type of buildings under construction in Denmark (Tiknuss, 2012)

3.2 PROJECT HOUSE AND TRIMBYG

According to Sven Betelsen (2002), since the 80s the government has initiated procedures to increase productivity and lessen errors, overruns in cost and schedule, bad reputation and high accident rate within the construction industry. In the early 1990'es a series of experiments were conducted, using only the pull logistics on construction sites. The methods developed during that time were similar to the LPS by Glenn Ballard; however, the Danish construction sector became aware of Lean not until 1999, due to the newly introduced government program called Project House (Bertelsen, 2002).

Lauri Koskela (2005) argues that there are similarities between the objectives of Project House and the objectives of Lean Construction, is to maximize value while minimizing waste. Project House challenged the industry by attempting to produce double value for half the cost over the next 10 years (BERTELSEN, 1999).

Moreover, the largest Danish owned contractor company MT-Højgaard (MTH), researched and developed a new concept, which was known by the name "TrimByg". The concept is developed and based on LPS. Eventually, the concept was adopted by the Danish Technological Institute promoting it as "The way" to manage construction projects (Kristiansen, 2005). TrimByg is a process management concept, which reduces waste, focusing on increasing both efficiency and value.

Figure 8: The 5 steps of TrimByg

The concept follows 5 steps (Figure 8) in order to create the most effective building processes for all the parties involved (mth, 2015).

The process begins with defining roles at the construction site early in the process, ensuring clear division of responsibilities between the different key participants. Moving forward to the next step of planning, which is focused on prerequisites. This phase follows the different requirements for completion of tasks. Furthermore, the planning on site is executed for a short planning horizon, in order to increase predictability, ensuring sound and robust activities.

The next step is to ensure the best possible working conditions. Essential part of the step is for the process manager to support collaboration across the different site operators and ensure continuous interdisciplinary coordination of individual activities. As shown on Figure 8, the next step is follow up, where the construction schedule is analysed, thus allowing optimization of activities. Furthermore, if problems are identified, the cause is investigated, ensuring that the error will not occur again. The last step is to compare the project with others, focusing on knowledge sharing. Thus, ensuring that mistakes are not repeated (mth, 2015).

MT-Højgaard used the principle on all the construction jobs where they were the ones executing the project management part. Furthermore, Thomasson (2002) conducted

comparison between the construction sites using TrimByg and the others, taking into consideration the same quarter of 2001 and 2002, where a significant drop of 50% on accident rates is observed on the construction sites using lean principles.

According to Bertelsen (2002), the Danish government was aware of the achieved results and is further investigating and pushing forward the use of process management, as well as Last Planner process control. In addition, the Construction Workers' Union is insisting on the use of lean principles, because it can be used as a tool to increase professional respect to the employees, reduce accidents on site and increase workers' earnings. Moreover, in order to support the implementation of lean principles within the Danish Construction industry, Lean Construction Institute Denmark has been established in close relation to the USA based LCI (Bertelsen, 2002).

4 LEAN

To provide the reader with a foundation for understanding the LPS, it is necessary to introduce Lean principles, as well as how lean techniques are applied to manage and control construction processes. Furthermore, it is required to understand how the lean approach improves the performance of the different processes not only within the construction industry, but also the manufacturing industry, from where the approach originated and was developed over the years (Howell, 1999).

The chapter introduces the different wastes and the loss of resources when the processes are not fully utilized. Moreover, the chapter introduces Logistics in the construction industry, due to its importance and relation to the delivery and quality criteria of the project, highlighting on the traditional stocking of large amounts of materials on site before even requested for use and their negative impact on the construction site.

In addition, the chapter presents Lean origin and principles followed by Lean construction and logistics, in order to provide the reader with a broader perspective of Lean, narrowing it down to its application in the construction field.

4.1 LEAN PRODUCTION AND PRINCIPLES

One of the first companies to deviate from the traditional mass production was Toyota, which introduced numerous manufacturing philosophises in order to increase their productivity. The production philosophises, introduced and implemented by Toyota are known as Toyota Production System, which formed the basis of Lean (see Figure 10) (Howell, 1999). The model is also known as ”Just in Time” (JIT), brought to life and promoted by the engineer Taichii Ohno, who incorporated the Ford production techniques and other methods into their own manufacturing and production of cars (TOYOTA, 2015).

The founder of the Toyota Corporation, Sakichi Toyoda studied Ford’s operations for 3 months, where he observed and saw possibilities for improvements in his own production plant. In collaboration with the chief engineer Ohno, they were able to recognise the waste in Ford’s operations, even though the operations were acknowledged as the world’s most efficient (Lincoln H. Forbes, 2011).

Eliminating waste is the key element in Toyota’s production philosophy. Moreover, the processes of reducing unnecessary resources are termed as **Muda** (Waste), **Muri** (Overburden) and **Mura** (Unevenness). The first term refers to variety of non-value adding activities (Mcmanus, 2013). Simply presented, **Muda** does not add value, which ultimately leads to physical waste of time and resources. The most common **Muda** wastes are connected to unnecessary storage costs, worthless old stock. **Muda** resources that are wasted can be categorized as followed:

- Inventory: The stocks and raw materials that company holds.
- Waiting time: For a process or machine to finish.
- Overproduction: Production beyond what is actually requested by the client;
- Over-processing: Conducting processes beyond what is requested by the client.
- Talent: Not able to utilize the skills and knowledge of employees.
- Defects: Project reworks.

- Resources: Failing to utilize machinery, as well as not able to turn off unused machinery and lights.

(Tools, 2014)

There are even more issues that are being overlooked, known in the Toyota organization as **Muri**. The English translation of **Muri**, as already mentioned, is overburden, which means that there is unnecessary stress to employees or operations. In order to avoid the overburden, it is important to distribute the production processes evenly. However, if the company fails to manage the production processes properly, the possible outcomes could be reduced time to complete the task, while allowing too much time is considered waste of resources (Mcmanus, 2013).

The third type of waste that is recognized within Toyota is known as **Mura** and is one of the main pillars of the Toyota Production System and JIT system (Mcmanus, 2013).

Mura refers to eliminating waste in regards to unevenness or irregularities within the production process. By not managing the demands on processes and people, causes the creation of inventory and other waste. Furthermore, the issues are caused when the manager is evaluated on a monthly output, therefore the department needs to speed up in the final week and uses most of its components, leading to a slow first week, due to shortage of components. Figure 9, highlights the demand and monthly targets drive behaviour, which is also known as the hockey graph of production. Ultimately, it is better to smooth out the production and focus on the demand by the customer (Tools, 2014).

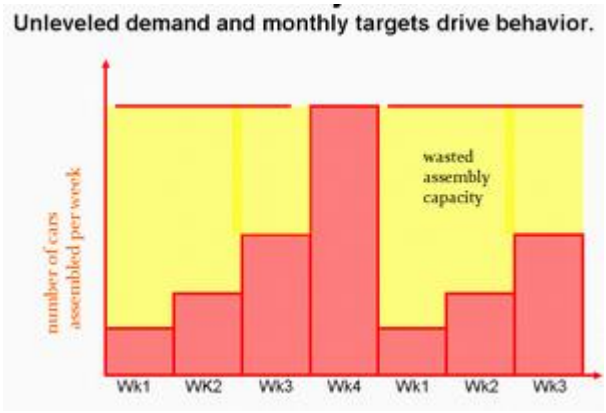


Figure 9: Irregularities within the production process (Tools, 2014)

As mentioned before, Lean manufacturing is about removal of waste and being as value creating as possible, thus by concentrating on solving Mura and Muri leads to the removal of Muda as well (Tools, 2014).

Ohno realized that the above mentioned type of wastes and issues, implied a financial loss for the corporation and continuously worked on the development process of Toyota Production System, which took place between 1945 and 1975 and was spread to other Japanese companies (Just-In-Time, 2007).

Before proceeding with Lean construction, it is important to analyse the traditional conceptualization of construction projects, which is a very old industry where most of the methods have been developed before any scientific proves or analysis.

After the Second World War, the construction industry improved due to the fact that different initiatives tried to understand the industry and address its different problems, in order to develop tools and corresponding solutions for improvements (Koskela, 1992). According to L. Koskela (1992), since the 70's a lot of new approaches to production management have emerged, known as Just In Time, Total Quality Management, Value Based Management and

many more. Moreover, the above-mentioned production philosophies have a common core, although they are viewed differently. The common core is created by "*conceptualization of production or operations in general; the angle is determined by the design and control principles emphasized by any particular approach*" (Koskela, 1992, p. 2). For instance, Total Quality Management (TQM) aims to eliminate errors, while JIT focuses to eliminate waiting time.

Hereby, Koskela (1992) argues that a new production concept (Figure 10) is coming forward throughout the generalization of the previously mentioned philosophies (known as a lean production or world-class manufacturing).

According to Koskela, in the technical report "*Application of the new production philosophy to construction*" the most general concept is "*the understanding of construction as a set of activities aimed to a certain output, conversions*" (Koskela, 1992, p. 30). Therefore, it is suggested that non-value adding flow activities, should be reduced and even eliminated (Koskela, 1992).

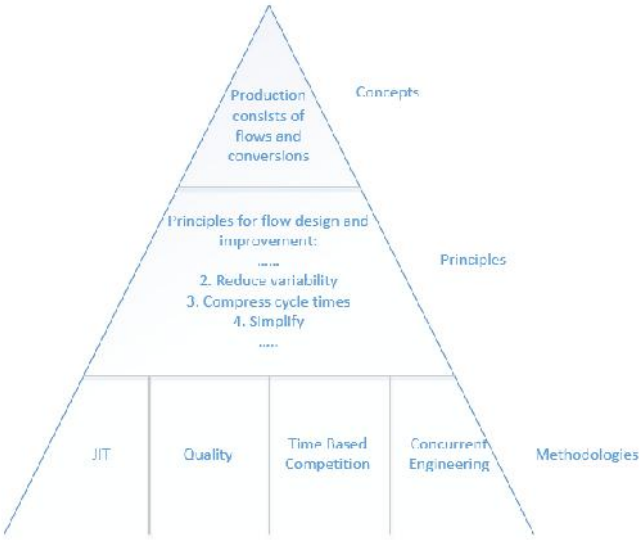


Figure 10 Different levels of new production philosophy

Howell argues that most of the waste in both construction and manufacturing industries, arises from the issue called "*Activity-centred thinking*" (Howell, 1999, p. 4). To be more specific, the production management in the construction industry as well as the mass production have the same aim, which is to optimize the project activity by activity. Moreover, the above-mentioned industries are assuming that the identification of customer value is completed in the design phase. Focusing on the activities, reduces the waste *"generated between continuing activities by the unpredictable release of work and the arrival of needed resources"* (Howell, 1999, p. 5). In addition, by focusing on the activities only, ignoring the flow of the production processes, as well as the value consideration for the client during the duration of the project, diminishes the success rate of the project in progress (Howell, 1999).

In fact, the flow aspect in construction projects is historically neglected, and even nowadays the construction projects would have significant quantities of waste or even loss of value (Koskela, 1992). However, according to Koskela (1992) the new production philosophy (Lean) has principles for flow process design, control and improvement of the project, thus evolving those same processes. Hereby, Koskela argues that through those principles of lean, *"the flow processes in production activities can be considerably and rapidly improved"* (Koskela, 1992, p. 3).

4.2 LEAN CONSTRUCTION

According to the Lean Construction Institute (LCI), the Lean construction approach is a new way to manage construction projects. The approach has been defined as *''the continuous*

process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of constructed project' (Lincoln H. Forbes, 2011, p. 45). Moreover, Lean construction is defined as a production system for minimizing waste of materials, time and money, hereby reaching maximum value and increasing profitability (Lincoln H. Forbes, 2011).

The construction industry has rejected many of Toyota's principles and methods, due to the belief that the construction industry is different. By different it is referred to the fact that projects in design and construction are unique and complex, working in uncertain environment, being tight on time and money. The reason why managing construction under the guidance of Lean is different from the typical practise is due to the fact that the construction projects have a clear set of objectives in order to deliver the process. Another difference is that the construction aims to maximize the performance for the client at the project level. Furthermore, the construction projects are applied with production control trough out the whole life of the project (Howell, 1999).

According to Koskela (Koskela, 1992), the construction projects are seen as "*a set of activities, each of which is controlled and improved as such*" (Koskela, 1992, p. 8). Koskela argues that conventional managerial methods like Critical Path Method (CPM), violate the principles of flow process design and improvement. Therefore, in cases of delays, a considerable amount of management resources is consumed, leading to lack for better planning or room for improvements. By following the lead of manufacturing, the starting point for improving the construction is by changing the activity based thinking, seeking on individual solutions to the different variety of problems that are occurring during the duration of the project. Furthermore, it is important to introduce new tools and methods that focus on the flow rather than on the activity, increasing the percentage of completed tasks on time. That can be done by the implementation of Lean principles like LPS, 5why's and many more (Koskela, 1992).

In addition, Koskela introduces the Transformation-Flow-Value (TFV) theory, which has many common elements with the lean principles of production. However, the difference in the introduced method derives from the fact that TFV theory has different characteristics in the assembly environment and process, while lean "*follows the idea from lean production to optimize production in the pursuit of perfection. T-F-V sees the production as a flow of materials starting from raw materials and ending as the final product. The material flow is undergoing moving, waiting, inspection and conversion before the construction is finished"* (Lindhard, 2014, p. 239)

4.3 LOGISTICS IN CONSTRUCTION

Logistics is the part of a supply chain involved with the forward and reverse flow of goods, services, cash and information in a supply chain and it plays an essential role throughout the construction process. Materials include all of the physical items used in the production process. In addition to raw materials, there are support items such as machinery, fuel, tools, parts, office supplies, etc. Logistics management includes management of inbound and outbound transportation, material handling, warehousing, inventory, order fulfilment and distribution, third-party logistics and reverse logistics (Stevenson, 9th Edition).

Traditionally, the organizations used to stock considerable amounts of material on site before requested in the process. This implies an unnecessary use of financial and space resources,

which increased the use of the JIT concept created by Toyota (Gary Sullivan, 2010). From this concept emerged the application of logistics in construction, originally used for military purposes. Logistics, aims to control the efficiency and risks in production. It is a branch of knowledge that supports the control and management of material, financial services and information resources between suppliers and customers. In construction, the ordering, transport, reception and storage of material, dominates the logistic processes (Anna Sobotika, 2005).

The value in construction is created when the elements are assembled. Value is what the customer wants to receive and is willing to pay for, thereby the objective to reduce time and costs, is to reduce waste or non-value added activities (Mossman, 2008), which as previously explained, is a principle of Lean Construction. It is important to note that logistics does not create value by itself, meaning that it is a cost for the contractor, but still is highly necessary since it provides the required operations for the assembling of the elements on site with minimum waste.

Examples of waste and non-value added activities:

- Long distances for staff to reach the cabins and other facilities
- Moving materials required later so the current operations can proceed
- Damage of stored materials
- Operation delays caused by late delivery of materials, information, equipment or delays of the workforce
- Skilled craftsmen moving materials, information or equipment so their skills are not in use
- Skilled craftsmen waiting for materials, information or equipment
- Accidents caused by hurry and rush or inadequate planning caused by delays
- Sub-optimal construction processes after inadequate consideration of logistics in design
- Traffic congestion caused by inadequate logistics planning and traffic management
- Over-ordering of materials *"just-in-case"*

(Mossman, 2008)

With the use of the mentioned JIT concept, where the materials are ordered and delivered on site, ready to be assembled, whenever are needed and in the right amount, most of the non-value added activities listed above are minimized, thereby the importance of coordination between suppliers and contractors. Being the JIT concept a principle of logistics management, shows the importance of incorporating logistics control into the production planning.

To effectively plan the logistics in a project, a tool to be used by the managers and the logistics coordinator is the so-called Make-Ready checklist, which is used to ensure that the 9 preconditions for ready work are met. From this 9 preconditions, 7 were first mentioned by Koskela (1999) and one of those Søren Lindhard (2012) proposed to split it into 3. Thus, the 6 unchanged preconditions proposed by Koskela are: information, materials, people, equipment, space and prior work. The remaining external conditions was split by Lindhard into weather conditions, safe working conditions and known working conditions. More on the Make-Ready process in explained later in the report (Chapter 7.5).

The logistics planning starts in the preconstruction phase with an outline plan. In this outline plan are represented the perimeters of the site, access points, footprints and vehicle movements, which have to be considered carefully. Elements such as neighbours access, noise control, road network, traffic levels, etc. are also taken into consideration (Gary Sullivan, 2010).

The design of the building and the construction method to be used, has to be understood by the logistics manager in order to consider the impact of the different constraints that can arise.

The logistics coordinator needs to consider the location and type of vehicles, cranes, hoists and manual-handling equipment required for the reception and unloading of deliveries. In addition is important to control the volume and flow of material, the capacity and the time available; and all this without talking about the weather conditions and its unpredictable behaviour, which can severely disrupt the plans (Gary Sullivan, 2010).

This short introduction about logistics management in construction shows how broad, important and at the same time meticulous this topic is and how strongly can influence the progress of the project.

5 LPS AND LBMS

In this chapter, the LPS and LBMS tools supporting Lean Construction principles are briefly explained, to get the reader familiar with both systems and show their benefits and applications to production planning and control.

Further on, in Chapter 7: Application of the combined system, each of the tools from LPS are explained in details, the way they are supposed to be used together with LBMS, setting a guideline for the successful application of the combined system in construction companies.

5.1 INTRODUCTION TO LAST PLANNER SYSTEM (LPS)

This chapter aims to make the reader understand the importance of LPS in production control to increase the predictability of the project plans, hereby increase productivity while reducing variability and extra costs.

LPS is a registered brand from the Lean Construction Institute. It has been in development by the author Herman Glenn Ballard since 1992, with the objective to increase the reliability of the workflow in construction.

For many years, the construction sector has experienced that about 50% of the activities scheduled were not finished on time (Ballard, 2000). This was mainly caused by the traditional push philosophy of construction, where the activities are included in schedule even before of making sure that can be performed, due to bad management decisions. Thus, there is need for a new system that enables the parties involved in the project to predict the ongoing of the construction and commit themselves with the tasks they agreed to perform.

The difficulty of planning and control in construction and design projects, arises by the fact that involves different parties, at different places and at a different time during the duration of the project and these elements need to interact with each other in a proper manner for the successful completion of the project (Ballard, 2000).

The LPS, a tool created by constructors for constructors, more than a structured system is a philosophical approach of the necessary mind-set that the parties involved in a project need to have, which involves collaboration, commitment to the project and a team relationship (Mossman, 2013). This affirmation refers to the way this system is applied all along the planning and control of the construction phase.

LPS promotes conversations and collaboration between the site manager and superintendents from the different trades, to a level of detail that enables both parties to anticipate the issues and constraints.

Besides that, within LPS there is a measure of predictability of the workflow called Percent Plan Complete (PPC) (See Chapter 7.7).This ratio measures the percentage of tasks completed on time versus the total number of tasks scheduled (Mossman, 2013).

LSP also supports logistics planning, to ensure that all the seven flows of construction are “flowing” to the site and the tasks are ready to be scheduled (Mossman, 2013). These 7 flows are: materials, people, information, equipment, external conditions, space and prior work (Koskela, 2000). This procedure is performed in the so-called Make-Ready-Process, where the construction logistics help to ensure availability of the first four, not before the task

starts, nor after, but “Just In Time”. External conditions are beyond the control of anyone, but construction managers and logistic planners can work to reduce space congestion and contribute this way to the predictability of task completions (Mossman, 2008).

Although it was designed to be relevant for projects with more than 3 trades and longer than 8-week duration, there is not a too big or too small project where LPS cannot be used. However, the system has to be adapted to the size of the project; not all the tools from LPS are needed or relevant for small size projects. LPS has been applied from a project of a 15 minutes duration to the biggest project in Europe by the time; the £4,5bn London Heathrow Terminal 5 (Mossman, 2013).

The traditional planning method of push planning, sometimes does not differentiate between the activities that should be done with the activities that can be done (Figure 11), unlike in the LPS where the planning follows a workflow defined by Should-Can-Will-Did (Figure 12). The Make-Ready process is the phase where the activities that “Should” be done are ensured that “Can” be done and all the possible constraints are removed (See Chapter 7.5). Later in the process, in the Weekly Work Plan (WWP) (See Chapter 7.4), the different parties involved in the project, agree on when they “Will” do them. After the planned activities are executed, so the parties in charge consider that they actually “Did” the task, the PPC previously mentioned, is calculated and the delays that may appear are analysed for its future avoidance (Jang, 2008).

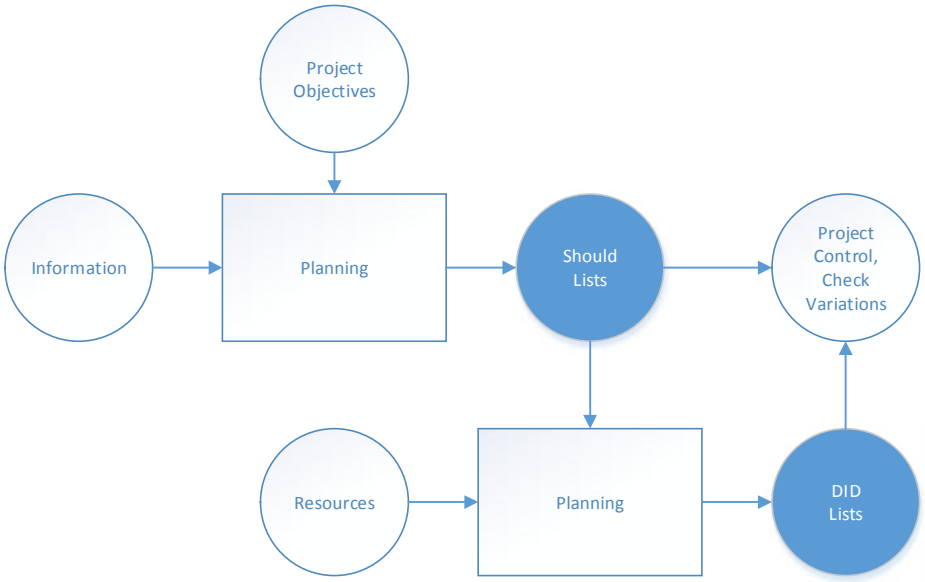


Figure 11: Traditional Construction sequence

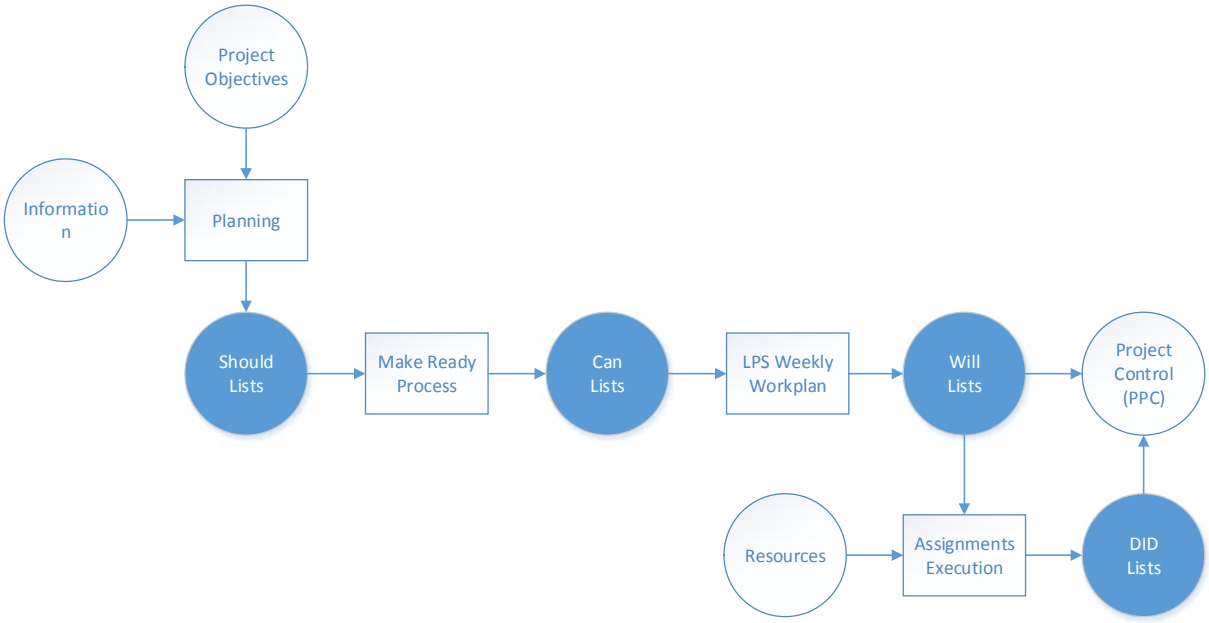


Figure 12: LPS sequence

After comparing the diagrams of the traditional method versus LPS (Figure 11 and Figure 12), it can be concluded that in the traditional construction method there is not any control barrier between the activities that should be performed and the activities that are actually done, to check whether can be done or not. This "check-point" from LPS to ensure that the scheduled activities can be actually done, increases the reliability of the plan and reduces variances, which is one of the main benefits of the system.

The rest of LPS benefits are as follow:

- Increases safety and predictability
- Supports supply chain standards
- Stabilise unique projects production system
- Reduces waiting, waste and costs
- Supports effective relationships
- Can be applied on small & large projects
- Increases quality in projects
- Makes 'control' proactive
- Reduces and helps to manage conflicts
- Decentralises decision making
- Delivers bad news early
- Helps reduce stress on project management staff

(Mossman, 2013)

5.2 INTRODUCTION TO LOCATION BASED MANAGEMENT SYSTEM (LBMS)

LBMS, just like LPS aims to achieve lean goals. LBMS changes the way the construction projects are traditionally planned and managed, aiming to improve efficiency, speed and productivity. It is an upgrade from the traditional CPM, which became insufficient for many project managers. In order to achieve a continuous production, the system considers the locations, thus the activities are planned in regards with the locations hierarchical order, unlike the traditional activity-based planning methods, which base the planning solely in the logical relationship between each task. These locations represent the very core of the system following the same logic of the CPM within each task, considering the sequence between the different locations and not just between the tasks. LBMS emphasizes on managing for productivity by ensuring a continuous flow of work and resources, thus optimizing the production and in turn the schedule (Swinburne, 2006).

The Location Based Planning comprises the following:

- Location Breakdown Structure
- Location-based quantities (to achieve feasibility)
- Location-based tasks – highlighting the area of work
- Duration calculations based on quantities, resources and consumption rates
- Layered CPM logic - there are 5 layer logics: relationships between activities within locations, relationship between activities driven by different levels of accuracy, between activities within tasks, between tasks in related locations and link between tasks.
- Buffers and lags (to minimize the risk of delays)
- A CPM engine with continuity heuristics

(Seppanen, 2009)

In LBMS, the critical path is integrated in the plan. Therefore, logic can automatically be applied as the tasks follow the sequence of locations.

LBMS consist of four different stages. The first stage creates a baseline for the schedule, setting the project's constrains. The second stage called "current", enables the modification of quantities, productivity rate and logic. The third stage "the progress" shows the actual performance of each task and detects the off-course tasks and the final stage of the LBMS, is the forecast where the system assumes how the production will continue following the same productivity rates, thus the system can generate alarms where problems appear. These alarms allow the planner to make the necessary changes in order to avoid the same problems to happen. This stage of controlling requires daily update of the crew size, quantities and suspended tasks, in order for the system to work (Olli Seppanen, 2010).

The better overview of the project schedule achieved by the flow line view of LBMS, improves the interpretation of the schedule among the project participants and effective communication with subcontractors, to facilitate a successful use of the schedule. LBMS also helps to avoid overlapping of work and congestion on site and thus to effectively utilize unused locations (Varghese, 2012).

The LBMS is currently one of the most efficient ways to plan and control a construction project. One of the first software featuring LBMS tools is VICO and because of this fact, the

amount of features and functions that VICO provides can really make the difference. The Empire State Building in New York, was completed in just seventeen months applying location-based management and drawing the productivity of the crew (VICO, 2015). Nowadays many construction companies are training their managers to switch from the traditional activity based view of the CPM; a sign of how well LBMS performs (Martinez, 2013).

Resuming all written above, the goal of the LBMS is to *"achieve feasible schedules with acceptable risk levels, while maximizing continuity and minimizing project duration"* (Seppanen, 2009). By maximizing continuity refers to reducing of waste and promoting JIT production, ensuring that work does not wait for workers and workers do not wait for work or resources. "*LBMS supports improved project control by planning and monitoring each individual location for work and resources at a given time*" (Varghese, 2012, p. 9).

6 PROBLEM FORMULATION

After analysing in details Lean Construction, LPS and LBMS, it is identified that there is no summarised explanation of how the methods are actually applied. Therefore, the decision is to elaborate a structured guide as an application method for all in the construction industry to use, familiar or not with Lean management.

A guideline to apply the LPS in combination with LBMS is suggested because it is believed that the combination can contribute to an even more reliable planning and control over the construction process, ultimately leading to waste reduction. Furthermore, the combined and modified system is considered to be superior to any of these system used alone.

Thus, these intentions lead to the following questions to be answered throughout the report.

- How to successfully apply the LPS combined with LBMS in construction companies?
- What is the disconnection between theory and practice from the suggested system application and why?
- How construction companies currently plan and control the projects? Could their methods and results be improved by applying the suggested system?
- Could the suggested system be improved with a more reasonable and practical approach? How?

The data used for this comparison is gathered through the performance of surveys and interviews to different individuals from the construction industry, involved in planning and control of construction projects and the analysis of two different case studies.

Therefore, the argument behind this report is to gain a clear understanding of LPS, LBMS and how the combination of both systems can help to manage construction projects. In addition, a guide is provided to the readers to understand the suggested systems, its principles and benefits and apply it in a successful manner.

7 APPLICATION OF THE COMBINED SYSTEM

The aim of this chapter is to create a guideline for a successful application of the LPS in conjunction with LBMS, explaining in detail, how each of the LPS tools are supposed to be used together with Location Based Scheduling, finalizing with a summary to provide a broad view of the application process.

As mentioned before, the system has to be adapted to the individual requirements of the project. Not all the tools are specially necessaries for different types of projects. Depending on the project size, the type of collaboration with the participants, the contractual requirements, previous experiences and human factor, it is responsibility of the management to adapt the system as required.

7.1 MASTER SCHEDULE

The Master Schedule is a planning tool developed during the project initiation, usually represented using Flow or Gant charts. It shows the whole length of the project, containing all the major activities or milestones but not going very detail into any of them. It can be done just by the project manager on its own and usually it does not show more information than the name of each major tasks, its duration, start date, finish date and the sequence of milestones.

While the project is progressing, a more detailed phase schedule (see Chapter 7.2) is performed from milestone to milestone and the master schedule is updated to give an overall view of the progression of the project as a whole (John M. Nicholas, 2008).

The master schedule is suggested to be elaborated using CPM logic by the project manager, because in such early stage when the master schedule needs to be elaborated, the subcontractors might not have been selected yet. Therefore, the CPM is only used as a baseline schedule for the latter elaboration of a detailed phase schedule using LBMS in collaboration with the subcontractors.

The actual dates of the master schedule are used only for long lead-time items, and to establish realistic phase milestones. As the project is progressing, the master schedule is gradually replaced by the Location Based Phase Schedules, and it is used as control tool for execution.

7.2 PHASE SCHEDULING

The phase scheduling consists of two planning meetings: The pull planning and the optimization meeting. The first thing to do, is to notify all the participants in the meetings at least one week in advance, providing them with the required information regarding the meeting (which areas will be covered, what is expected from them, how are the meetings going to be performed, any information relevant for the performance of theirs tasks, etc.) and of course they are required to come prepared. For the first pull-planning meeting, the subcontractors need to come with an estimation of quantities of work and labour consumption (man-hours / unit) for each task in each location that they need to perform. If there is any activity that the project manager observes that has unreasonable low/high labour

consumption or quantity estimation, needs to be further analysed asking the responsible trade the reasons for that.

It is recommended to provide the participants, especially the newcomers, with general information about Lean Construction, LPS, LBMS and how the pull-planning meeting is performed, so they can read up on it if they choose to.

All the parties involved in the planning of a specific phase of the project, need to be present in the meetings, from the architects and owners to the superintendents from the different trades. This is necessary in order to gain their collaboration and involvement, to have a clear understanding of all the tasks to be performed and its requirements and ultimately elaborate a reliable schedule that suits everyone.

The first of the two meeting or pull planning meeting, is where the Location Breakdown Structure is determined following the pull planning procedure as a collaborative effort. The pull planning is the first main tool in the application of the LPS and his name comes from the way the planning meeting is performed which is backwards, by “pulling” the tasks to be done from a determinate milestone, unlike the traditional method, which consist on a “push” methodology.

The meeting room has to be big enough for everyone to fit in and the material needed for the pull planning is not more than:

- A printed copy of the Master Schedule
- A floor or site plan big enough from the relevant area
- Blocks of sticky notes of different colours for each trade
- A roll of white paper or a large blackboard to paste the sticky notes on and to write clarifications if needed
- A paper sheet to note all the constraints that may appear during the scheduling phase

To start the pull planning, the blackboard or paper roll is divided vertically by locations, (e.g. building blocks, floors or building sections) and horizontally by time. The milestone to “pull” the activities from, is taken from the master schedule. The last task to be performed for the completion of the chosen milestone needs to be identified through the collaboration of the members involved. The trade in charge of doing this task has to elaborate a sticky note of his assigned colour with a detailed name of the tasks, the predecessors required to undertake it and its quantity and labour consumption (Figure 13) and place it at the end of the paper roll, into its correspondent location row. From there, the same process it is repeated backwards for each location, identifying each predecessor for each tasks and “pulling” from the last activity, until the very first activity from the starting location is put on schedule.

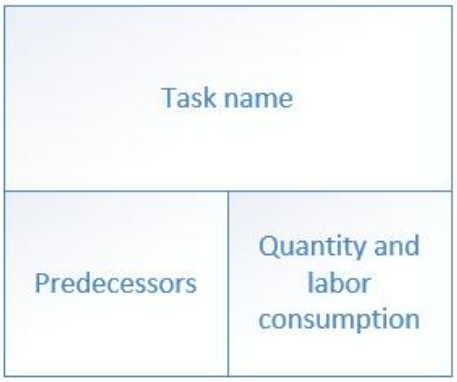


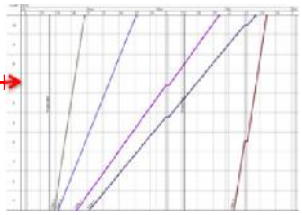
Figure 13: Template of trade's sticky note

Following this, the project manager has the necessary information to elaborate a LBS before the second meeting, assuming one crew for each task, which usually results in unaligned production rates.

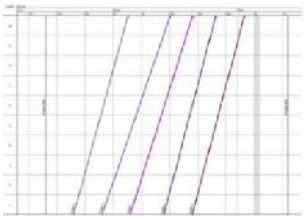
The second meeting is to optimize the workflow by identifying the subcontractors with high resource needs who may become bottlenecks and to increase or decrease resources, determine if any prefabricated work can be done, provide better equipment, etc; Thus, reducing waste and optimizing the schedule. The ideal result is an aligned schedule with parallel flow lines, while considering a reasonably high productivity ratio. If time is left after building the schedule, the remaining time is allocated as buffers between tasks.

Therefore, the phase scheduling process looks as follows:

1st meeting: Pull planning



Elaboration of the LBS



2nd meeting: Optimization of LBS

(Olli Seppanen, 2010)

Every trade involved in the phase scheduling process, needs to be honest, reasonable and prepared for meetings to determine the most realistic duration and detailed schedule as possible.

The meetings should not last longer than 3 hours, in order to have everyone's attention during the whole duration. The scheduling window depends on the size of the project, but in general it should contain around 12 to 14 weeks of work (Usually it is done from milestone to milestone) and it should be performed at least 6 weeks prior to the start of the first task, in order to have enough time to eliminate all the constraints (Ideally 3 to 4 months prior to start).

Once the LBS is predefined and optimized with specific start date for each activity, if there is any activity that cannot be performed before the determinate date and is driving the start date of its successors, is noted down into the constrain sheet to study if there is any way to resolve the issue and make a better schedule.

The last thing to remember, is to make the Location Based Phase Schedule available to all the participants, by sending it through email once is ready and placing copies in the meeting rooms and relevant areas.

Since the LPS is a continuous learning tool, it is recommendable at the end of the meetings to ask the participants what was good and what could be improved for the performance of future meetings.

7.3 LOOK AHEAD PLANNING MEETING

The look ahead planning meeting, as the name suggest, is a plan that is usually performed 6 weeks ahead of the current state. Thus every week, two different schedules need to be performed; the WWP for the incoming week and the look ahead schedule of the 6th week ahead of the weekly schedule. The scheduling window is set 6 weeks ahead because it is considered that a 6 weeks' period is enough time to resolve all the preconditions and remove any constraints that may appear, to make the activities ready to be scheduled (Ballard, 1997).

The look ahead schedule is executed based on the phase schedule previously done, considering the activities to be done 6 weeks ahead of the current date. All the trades involved in any of the activities to be done that week, need to be present in the meeting, to discuss all the requirements for the execution of the different activities and make sure that everyone is aware of the current state and the issues that may arise. The main goal of the look ahead schedule is to ensure that when an activity is about to be performed, all the constraints are removed and the activities are actually sound. The purpose is to highlight as many problems as possible, thus creating a buffer to ensure enough time during those 6 weeks to resolve them.

It is suggested to have a site visit and observe the area where the tasks in the look ahead schedule will be undertaken. Thus, improving visualization of the construction process, leading to clarifying information: working space, where the stocked material should be placed, if there are any changes from the drawings, etc. Another good initiative is to take pictures from the area and show them in the look ahead planning meeting, to discuss upon them, the requirements of each trade to perform their tasks.

Since the plan is to be performed 6 weeks ahead, it may be difficult for the trades to determine the prerequisites to undertake their tasks. A good method to help them identify the possible constraints is to ask them why they could not start tomorrow. In this way they start thinking ahead to determine the requisites they need to perform the task.

The look ahead schedule seeks the following purposes:

- Shape workflow in the most efficient sequence and rate for achieving project objectives that are within the power of the organization at each point in time.
- Identify operations to be planned jointly by multiple trades.
- Match labour and related resources to workflow.
- Group together work that is interdependent, so the work method can be planned for the whole operation.

- Produce and maintain a backlog of assignments for each frontline supervisor and crew, screened for design, materials, and completion of prerequisite work at the CPM level.

(Ballard, 1997)

Although the look ahead planning, can bring lots of benefits, such as increasing the reliability of the weekly schedule and the PPC, it also has some deficiencies. The reason is that it requires a lot of planning resources and when applied, if the planning crew is not increased, can lead to poor results. Another reason for unsuccessful planning is that not all the trades stick with the rule of only doing sound activities and since in construction the sequence is relevant, a failure in a critical activity can lead to delays in its successors. That may be caused by poor training of the staff involved in the process. All these facts need to be consider for the improvement of the look ahead planning.

Some suggestion for improving the procedure are:

- Detailing look ahead planning procedures through experimentation.
- Assembling the relevant players to agree on planning procedures and information flow.
- Training system participants in the procedures.
- Providing additional support where needed, e.g. consider assigning planners to superintendents.
- Developing means for sharing information between construction and its suppliers, e.g., post project and fabrication shop schedules on a shared network.
- Exploring attempts to use process modelling as scheduling tools.
- Aligning internal suppliers with the site production control system and philosophy, e.g., restructure fabrication shops away from mass production model toward one piece flow.

(Ballard, 1997)

In LBMS, the forecasts is used for look-ahead functions by applying control actions to remove alarms taking into account actual resources information. To clarify, LBS provides information of how the specific trades or contractors are performing on site and their work rate, hereby it is possible to forecast their completion date.

The LBMS progress and forecast is used to select the activities that can be started in 6 weeks from the current state and go through them to determine their preconditions. Thus, the forecast is used as a checklist in the look ahead planning meeting, in collaboration with the superintendents from the trades involved, to remove the warnings that can arise, identify all the preconditions required and ensure that are met before the start day of each task (Olli Seppanen, 2010).

Therefore, the progress in the LBS needs to be weekly updated in order to have a realistic forecast in the look ahead planning meeting.

7.4 WEEKLY WORK PLAN

In the WWP meeting is intended to define in detail the exact work to be performed the following week, each day of the week and to apply the necessary counter measures if there are some deviations forecasted in the Location Based Phase Schedule.

In this case, the WWP is extracted from the Location Based Phase Schedule, for the following week, to have a more understandable and zoomed in schedule of the specific week.

In a separated paper sheet where can be visible to everyone, it is recorded the PPC ratios of the different trades from the work previously done, to act as a pressure measure to get the trades back on track.

With the Location Based Phase Scheduled in front and its forecasting, can be easily seen if there is any need to modify the WWP and apply any control measure to avoid future issues.

Once the weekly schedule is reviewed and adapted, it is assumed that everyone agrees upon it and they should follow the plan, as well as being accountable with what they have previously agreed. Then a copy of the Location Based Weekly Schedule is provided to each trade. In this way everyone knows the exact plan that has been agreed and if there is any delay not caused by external conditions, the contractor's fault can be easily identified.

7.5 MAKE READY PROCESS AND THE WORKABLE BACKLOG

As mentioned before most of the construction projects are very complex and unique, increasing the workflow uncertainties as well as the interdependency among the different activities, which have increased during the years (Jang & Kim, 2008). Jang and Kim (2008) argue that the growing complexity of construction projects, requires the use of more systematic approaches to the make-ready process, especially in the production planning and control.

The construction industry has recognised the importance of constraint removal and has introduced new approaches like LPS, to ensure the successful completion of the project (Lindhard & Wandahl, 2012). The LPS has been known since the early 90s, as a planning and control tool used to increase the reliability and predictability of the tasks that needs to be executed (Ballard, 1994); (Ballard, 2000). Furthermore, the LPS method can improve the previously mentioned workflow reliability with the make-ready and the shielding processes.

LPS is based on the Lean method, thus it focuses on the elimination of non-value adding activities. In the recent years, the implementation of LPS on construction sites has grown traction, leading to significant interest in the construction constraints. Lindhard and Wandahl (2012) argue about the importance of construction constraints, because if the constraints are not removed it will lead to unnecessary waste.

According to Ballard and Howell (1998), the make-ready process consists of identifying and removing the constraints of the work that has to be performed, while the shielding process defines the criteria for making quality activities. The Make Ready method systematically checks if all the activities within the Look Ahead schedule meet their preconditions. In case of applying LBMS, the MRP starts with the activities from the Location Based Phase Schedule to be started in 6 weeks from the current date, making sure that they are ready on time.

Lindhard and Wandahl (2012) suggests that before any task can be performed, it is essential to fulfil the 9 preconditions and make activities sound.

According to Lindhard and Wandahl (2012) the introduction of LPS on construction sites has created a growing interest within the possible construction constraints. When the constraints are not removed on time leads to waste such as waiting, transportation, movement, etc. The MRP starts when the construction activities enter the Look-ahead window and the purpose of establishing the MRP is to make activities as robust and sound as possible. Thus leading to:

- Hazard analysis involved within the planning, leading to safer working environment
- Less waste – certainty of time and resources
- Ready for production tasks, when required

As already mentioned, according to Koskela (1992) there are 7 preconditions that needs to be fulfilled, however has been considered 6 of the preconditions (information, materials, people, equipment, space and prior work), and introduced the Lindhard 3 new preconditions (weather conditions, safe working conditions and known working conditions), which are based on Koskela's external conditions (Lindhard & Wandahl, 2012). The reason for selecting Lindhard's 3 preconditions is their detailed information for the external factors that need to be considered.

The preconditions have a significant role on the activities, if a precondition is not fulfilled the activity cannot be moved to the workable backlog of all the sound and robust activities. It is important to mention that when the WWP is extracted from the Location Based Phase Schedule, only sound activities from the workable backlog are left on the schedule. Any activity previously planned but not ready to be performed, is postponed until all constrains are removed and is included in the workable backlog. Ballard (2000) suggests that the workable backlog is kept at minimum 2 weeks, ensuring "*that enough sound activities can be* scheduled in *the WWP to match capacity and moreover enough ready work to buffer against unexpected constraints in the sound activities*" (Lindhard & Wandahl, 2012, p. 2).

Essential part of the MRP is to have good understanding of the different preconditions, otherwise there is no guarantee that only the sound and robust tasks are selected in the WWP for execution. Thus, resulting in an unreliable schedule, which has a negative impact on the workers' motivation and moreover on the productivity (Ballard, 1994). Lindhard and Wandahl (2012) suggest that in order to ensure the process of selecting sound activities, thus maximizing the productivity rate, it is necessary for the site managers to understand the 9 construction preconditions.

Figure 14: Planning Process (from the Six-Week Look ahead to WWP (Jang, 2008)

According to Jang and Kim (2008) it is hard for LPS to shield activities with uncertainties, due to the fact that it might affect the cost or schedule of the project. Therefore, it is suggested that in order to improve workflow reliability, not shield activities with constraints, but resolve constraints on time using make-ready process.

The MRP can be performed using a simple tick sheet, where it is possible to check if all the preconditions are met and once the preconditions are fulfilled, the activities are considered sound and are moved into the workable backlog, ready for execution. However, in order to perform the MRP and resolve constraints in a proper manner it is necessary to share, communicate and present all the required information in a unified format, where a more autonomous decision making is established (Koskela, 2000).

The workable backlog represents a reserve of assignments ready to be executed. Moreover, it is necessary for the team to agree that the execution of the task will not hinder other work, thus the task is placed on the Workable backlog as part of the WWP. The assignments that are made-ready for execution, are entered into the workable backlog, where those assignments are considered to be constraint free and are in the proper sequence for execution.

According to Jang (2008), if during the MRP is found a task with a constraint that cannot be removed on time, the task is simply not allowed to move forward. Ballard (2000) suggests that the LPS should maintain workable backlog, however it needs to assure that everything within the workable backlog is viable. The ultimate goal of the workable backlog is to increase the robustness of WWP (Jang, 2008). However, one of the major reason for non-completion of tasks is bad scheduling, due to the reason that non-sound activities are selected to the WWP. Therefore, it is important to observe and notice the individual activities, focusing on the 9 preconditions, establishing one robust schedule (Lindhard & Wandahl, 2012).

A common reason for non-completions is because of changes in soundness of the activities, therefore Lindhard and Wandahl (2013) suggest that to ensure that unsound activities are not moved from the workable backlog to the WWPs, a weekly health check of all the sound activities should be implemented. Thereby, if any of the preconditions changes, would be detected still with enough time margin to address it or make the necessary adjustment to the schedule, to avoid future delays.

The MRP is not just to ensure that the activities can start on time but also that can finish on time.

7.6 First run studies

First Run Studies (FRS) are used to get detailed information of the activities and how they can be improved, providing safer condition during the duration of the project thus completing tasks in a faster pace and in the required quality. The FRS are integral part of the LPS and are based around the Plan-Do-Check-Act cycle (PDCA) (O. Salem, 2005).

FRS is used not only for repeated tasks, but also for one-time tasks FRS are performed when a task is time critical, safety critical or when quality can be an issue (Mossman, 2013). Moreover, FRS are applied in order to redesign critical assignments, creating a continuous improvement cycle, which includes reviews and productivity studies of the work (O. Salem, 2005).

According to O. Salem (2005) the process is shown using video files, photos or graphics. Furthermore, it is essential to carefully examine the first run of selected operations, exploring into new ideas and alternative proposals of doing the examined work (Glenn Ballard, 1994). As mentioned before, the FRS suggest the use of PDCA cycle (Figure 15), in order to develop the study.

The cycle consists of four phases, which are mentioned above. Plan phase refers to the process that needs to be selected to study: Assemble the right team of people, identify the quality and process productivity and brainstorm ideas in order to eliminate unnecessary steps or waste. Do is for testing and trying out new alternative solutions on the first run, while Check is to describe and measure the tested process and what actually happens. Lastly, Act "*refers to reconvene the team, and communicate the improved method and performance as the standard to meet*". (O. Salem, 2005, p. 4)

Figure 15: PDCA cycle

7.7 PERCENT PLAN COMPLETE (PPC)

According to Lean Construction Institute, PPC is a basic measure of how well the system is performing as shown on Figure 16. PPC calculates the number of tasks that are completed on schedule for a stated day, divided by the total amount of tasks scheduled for that day. PPC is tracking the accomplishment percentage of tasks, not focusing on the faults of the different contractors, but on how the task went (O. Salem, 2005).

Figure 16: PPC in construction project (Skender, n.d.)

The method is followed by an analysis of the variances to identify the existing problems, narrowing down to the possible root causes for delays or waste of resources and improving the processes based on the experience (O. Salem, 2005). According to Ballard (1999), the PPC results are highly variable between the ranges from 30% to 70%, without the use of Lean methods. In order to achieve higher values above 70%, Ballard (1999) suggest the use of additional LPS tools such as the FRS, the MRP or LBMS.

The usage of PPC is best accomplished when all the different contractors are present and can check whether the tasks from the weekly schedule have been completed or not, however the method is only applicable to small building projects.

In case of PPC for larger and more complex projects, consisting of variety of buildings, it is necessary to print out the WWP for the individual building and provide it to the foreman and site managers on each site, so it can be simply clarified what has been done during the day and manage the progress of the tasks accordingly.

Once all the different trades have entered the information of what they have done during the week, the PPC approach does not consider them fully accomplished tasks, unless the next person that is dependent on the tasks, agrees with it and signs it in the weekly schedule. However, it is important to state, that when an activity is done before the actual day it was supposed to be done, the activity has to be considered 0% accomplished. The reason for doing that is that even though the tasks was performed earlier than expected, it still can lead to waste of resources and disorganization of the following activities, thus considering those activities not completed.

The idea behind the PPC is to keep track of performance of the individual trades, in order to increase the predictability of future work.

However, by weekly analysing the results of PPC to identify the reasons for delays or disruption of the pace observed during work, ultimately contributes to the systematic learning on the jobsite, allowing to better understanding the work processes and creating competitiveness in construction companies. Furthermore, the improvement of the tasks and process can be achieved by the use of PPC. (Nagarjuna, 2015)

The project managers need to be aware of the fact that the PPC is a ratio that can be easily manipulated by the superintendents from the different trades; e.g. if some of the assignments from a bigger activity were delayed, they can count the whole set of assignments as a sole activity, thus the ratio is less affected by the delays.

To avoid this in some extent, the project manager should review the weekly schedule of each trade and control the finish date of each activity by himself. Since it may be burdensome to monitor all the trades in a relatively big project, the project manager should emphasize the fact that the PPC is not a judgmental tool but rather a tool which supports a learning process from which all can benefit of.

As mentioned before, the combination of LPS with LBMS represents a learning procedure in which the objective is to achieve a high plan reliability, obtaining a PPC as closer as possible to 100%. Is important to note that to consider a high PPC value a good result, has to be accompanied with a high productivity ratio while being ambitious with the schedule.

7.8 TRACKING VARIANCES AND ANALYSIS OF CONSTRAINTS. THE 5 WHYS

Root cause analysis is the discipline used to identify reasons for activities not completed when planned and plays an essential role into the Lean philosophy, being necessary to ensure improvement by pursuing perfection and learning from mistakes (Lindhard, 2014).

After the work scheduled in the WWP is completed, the PPC is calculated as explained in the previous chapter. In order to improve the PPC results, the tasks that were not completed when planned, need to be analysed and the causative element of the delays needs to be identified, to determine whether the fault is from a specific stakeholder or due to external conditions such as the weather.

Once the first link to the delay is identified, it is essential to understand thoroughly the root causes for those, thus it is recommended to use 5 WHYs and cause-effect diagram tools to help the team understand what has to be performed to improve the processes.

Furthermore, the results from the root identification of problems need to be recorded using the Pareto chart (Figure 17), showing where attention is required and can yield the most results. (Mossman, 2013)

Reason	occurrence
Unclear information	X X X X X X X X X X X X X X
Too few operatives	X X X X X X X X X X X X
No promise to deliver	X X X X X X X X
Client/design change	X X X X X
Overrated capacity	X X X X X
Late request	X X X X
Unclear requirement/CoS	X X X
Pre-requisite work	X X X
Failure to request	X X
CoS not made clear	X X
Rework	X X
Other	X
Absent operatives	X
Unplanned work	

Figure 17: Example of Pareto chart reasons - the reasons depend on the project and its complexity (Mossman, 2013)

As it can be seen in Figure 17, the reason causing the most schedule variations is unclear information. For instance, if the unclear information was caused by a sole individual, for instance by the architect, the issue should be addressed directly with him to clarify what information is required and how it should be provided or determine the need of assistance or any change. On the other hand, if the unclear information was caused by different individuals such as the design teams from the different trades, perhaps in this case the ultimate solution would be to redefine and improve the communication system between trades.

As mentioned, one tool to investigate the root causes is the 5 WHYs approach, known from the Toyota production system. The 5 WHYs, is a simple technique where, as the name suggest, 5 WHYs are asked (Barry, 2011). Starting by the individual directly affected by the delay, "*why did this happen?*" is asked once and again until the root cause is identified. This technique is established through 5 steps or "Why" questions because it is considered that in most of the cases there are not more than 5 elements causing the deviation (Execution, 2009).

Even though the method has a very simple structure, it is most effective when the answers of "why" questions are coming from people involved into the examined processes. Furthermore, the 5 WHYs method can help site and project managers to narrow down causes as well as to determine the relationship between the different issues (Sondalini, 2015). Different studies suggest the use of Why Tree in order to get to the true root cause, however it is important to start the 5 WHYs analysis with a general question. Otherwise, you will be able to find symptoms but not necessarily the root of the problem (Sondalini, 2012).

Figure 18 is part of the Why Tree and highlights the first and second level causes. Furthermore, once the first question is answered and confirmed by the participants, the second question is tackled, confirming which of the given symptoms produces the level one effect. As shown on the figure below, there are 3 different branches where it is essential to select the path that is backed up with real evidence or impeccable logic. Due to the reason that only one of the paths is correct, "*presuming that there was no interaction between systems in causing the failure event*" (Sondalini, 2012, p. 4) Hereby, the path that is identified as the origin of the problems needs to be deeply investigated, until the reason is found.

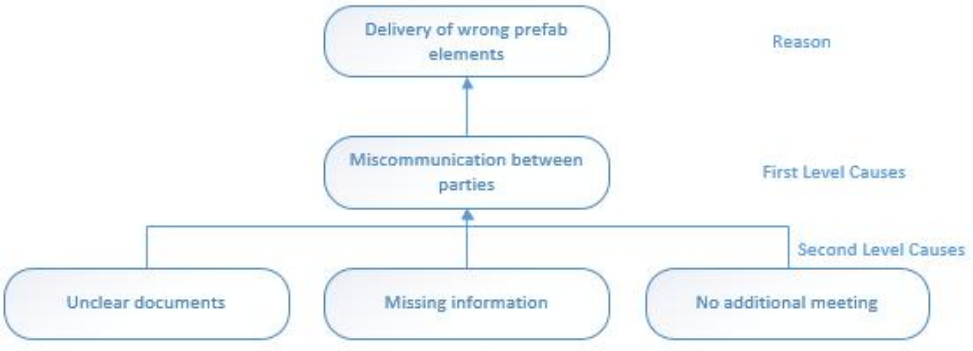


Figure 18: 5 WHYs method for root cause identification

Despite the utility of the 5 WHYs technique for the root cause identification, it is rarely used in on-site production. The reason is, besides the fact that the root cause identification in on-site production is generally underestimated; sometimes it is difficult to identify the links causing the deviation because not all the individuals involved are present on-site. That is why root cause identification can be used more easily on factory production (Lindhard, 2014).

Tsao identified, 3 main reasons why the trades may not complain about problems experienced on site:

- That the problems contractually often are the trade's responsibility.
- A determination of which battles to fight. More ''important'' problems are addressed.
- Pride and the fear that complaining will result in a poor reflection of the trades skill. Instead, they believe that workarounds are how the problems are supposed to be solved.

(Tsao, 2000)

To summarize the method is simple; however, it requires impeccable logic or real evidence in order to find the reason for the failure. Furthermore, an essential part of the process is that the team conducting the 5 WHYs analysis is involved and understands the processes that is being examined. According to Sondalini (2012), a vital part of the process is to keep all the evidence when a problem occurs, otherwise getting to the correct root of the problem is found merely based on good luck and to adequate decision-making.

7.9 LOCATION BASED SCHEDULE

The following image shows how the system appears when is put in practice:

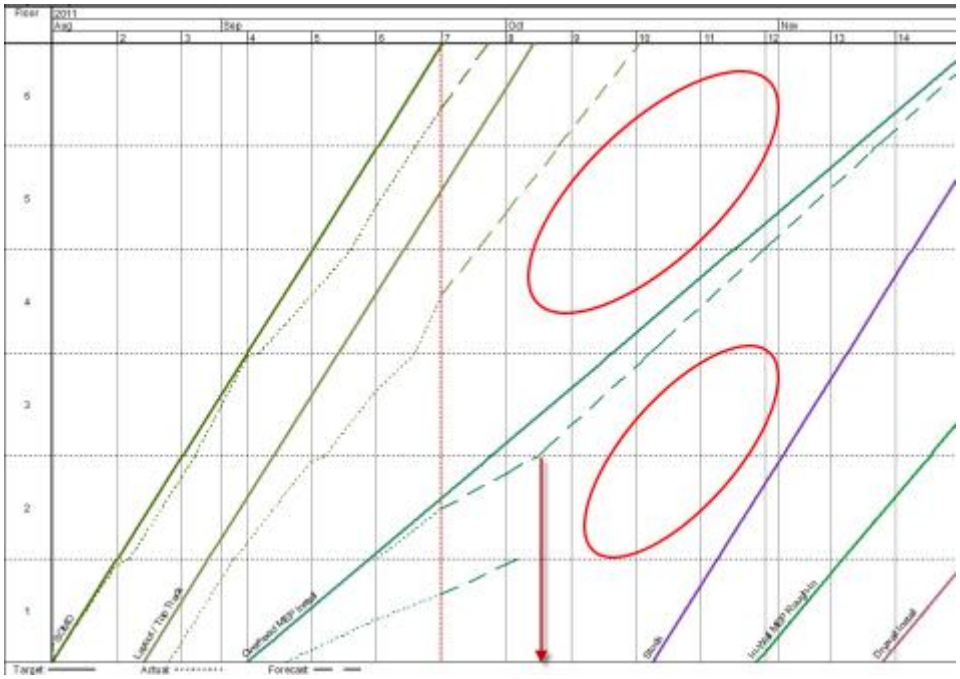


Figure 19: An example of a LBS flowline showing different tasks, their variation of competition time and the waste created

The left column on the figure represents the locations of the project; therefore, based on the fact that they are placed hierarchically, it represents the vertical axis of the flow line (e.g., the numbers can represent floors, building blocks, or different sections of a building). On the upper part of the figure is shown the daily calendar, which indicates the horizontal axis of the flow line, which can also be represented at the bottom.

The solid lines symbolise the different tasks of the project. They are displayed as different colours to differentiate between trades. The diagonal placement of the lines illustrates the workflow. The angle of each task can be influenced by the productivity ratio of the crew that performs it, by the amount of workers employed or by the quantity required. As an example, a painter will perform faster on a floor with fewer walls than on one with many small chambers. The best-case scenario is when all the tasks' lines in the schedule are close and parallel to each other, with a relatively high inclination, which would mean that the schedule is fully optimized, with no waste between tasks.

When calculating the duration of each task, the planner can rely on productivity ratios from previous projects and adjust it by the quantity required. Knowing the crew size and experience can do further adjustments to its duration (Seppanen, 2009). However, this is not applicable with the use of LPS because the process is made in collaboration with the trades.

When the real construction time deviates from the schedule, the task is defined by a dotted line of the same colour. Moreover, as seen in Figure 19, the system can predict the new completion time for the selected task if the work is continued at the same rate. Following this, the planner can monitor this new path and take action in case of overlapping with another task or trade at the same location.

When a space between the lines occurs, a space buffer is created. The red arrow in Figure 19 shows this buffer and denotes that two locations are free of work. Therefore, a waste is created in the planning. The waste can also happen by a time buffer, which is represented by a horizontal gap in the workflow.

7.10 SUMMARY

After explaining in detail each of the tools of LPS and how they should be applied together with LBMS, was decided to elaborate a flow chart followed by a description to facilitate the reader the understanding of the whole process and the sequence of actions to undertake (Figure 20).

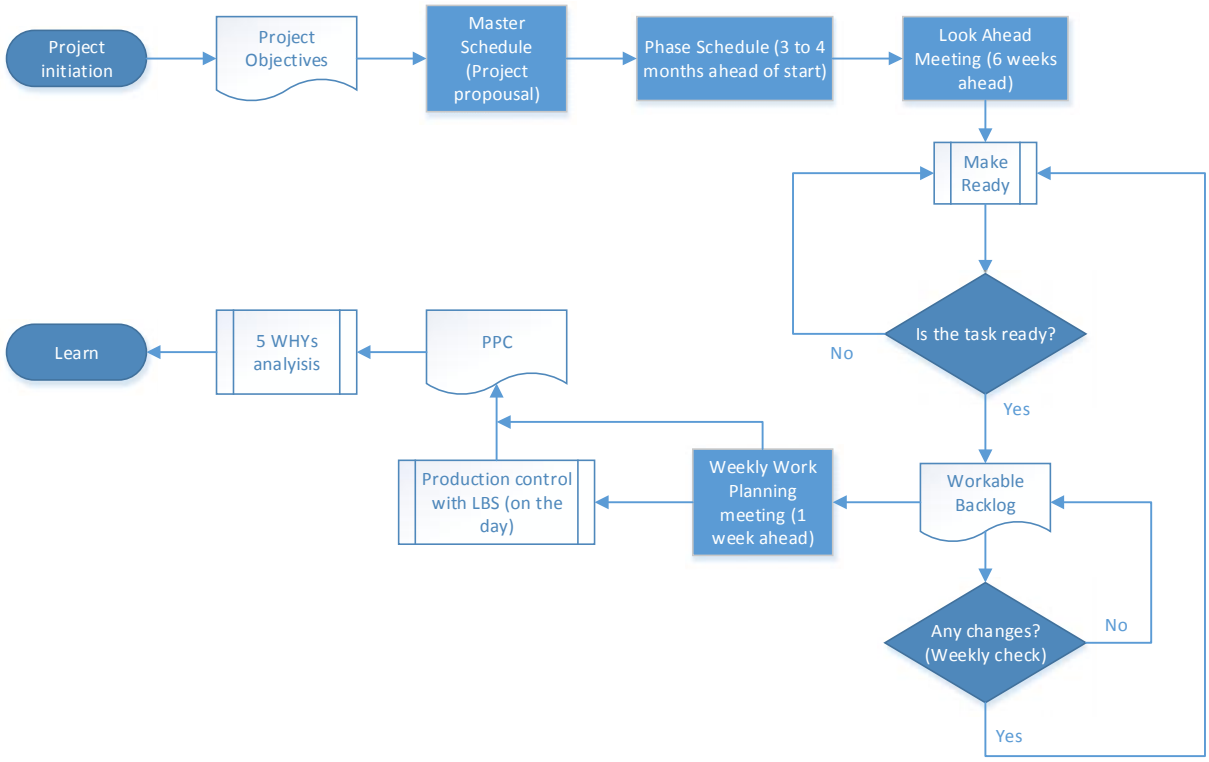


Figure 20: LPS as a flow chart

The process starts with the elaboration of the master schedule for the project proposal once the project objectives and key dates for specific elements have been determined, taking into account the client needs and other criteria.

Three to four months before the beginning of the project, the phase schedule is elaborated for the first phase, until the end of the first milestone. After 3 to 4 months before completion of the first phase of the project, a plan for the next phase is elaborated and this is repeated until the project is completed.

Six weeks ahead of any specific week, the look ahead meeting is conducted, breaking down all the activities planned in the phase schedule for the given week and determining the requirements and preconditions for their execution.

Once all the assignments and their requirements for the given week have been determined, they are included into a check list to pass the MRP. In the MRP, the planning manager

makes sure that each assignment meets its 9 preconditions (See Chapter 7.5). When an assignment has the 9 preconditions checked, meaning that is ready to be executed, is moved to the workable backlog. In a weekly basis, the assignments included in the workable backlog need to pass a health check to ensure that none of the preconditions have changed. If any of the preconditions changes, the specific assignment is sent to pass the MRP again to resolve the changed precondition.

For each week, a Weekly Work Planning meeting is conducted to go individually through all the activities to be performed in the incoming week, discuss the progress to determine if corrective actions are required and make sure that those activities passed the MRP and therefore are included into the workable backlog.

During the week, the progress is reviewed and controlled with the support of the Location Based Weekly Schedule. At the end of the week, the progress is compared with the agreed plan and the PPC is calculated. Finally, the assignments that did not follow the schedule are analysed with the 5 WHYs technique and the identified root causes are noted to learn from them and take them into account in the future planning processes, in order avoid their reoccurrence.

8 CRITICISM TOWARDS THE SYSTEM

After the theoretical introduction to the system and its application procedures and before proceeding with the study of the utilization of the system in practice, it is important to reflect about the different approaches towards the system and its principles.

According to Green (1999), most of the literature about lean production and derivatives, is too optimistic and take for granted that lean production is a "good thing". He also doubts of the applicability of the lean methods imported from the Japanese industry, into the construction industry and if "*these methods are based on nice things like loyalty, empowerment consensus, etc. or whether they are based on nasty things like managing-by-stress and exploitation*" (Green, 1999, p. 24). He also exposes the debate of the human costs of lean methods, criticising the Japanese regime of long working hours and absence of paid sick leave, presenting the term "*karoshi"* which is now in common use in Japan to describe sudden deaths and severe stress resulting from overwork.

> *"Muda* is to be eliminated, *karoshi* is the price to be paid". (Green, 1999, p. 25)

In addition, he claims that despite the relatively higher wages from lean organizations, the workers appear to have frequent concerns about safety, stress, loss of individual freedom and discriminatory practices and what is supposed to enhance flexibility quality and teamwork, in practice becomes control, exploitation and surveillance.

In response to that, Ballard and Howell (1999) argued that Green does not seem to understand that production management is first about how things are made, aiming to speed the delivery of a product and meeting the unique requirements of a specific customer and not about how people are treated. They claim that the reason of Green for raising his criticism is because "*he may not like the reality of global competition and its potential to destroy industries that do not adopt new thinking such as occurred in the British auto industry"* (Ballard, 1999, p. 35), where the choice is modernise or perish.

Lean is about reducing waste and it has no intention to add stress. It may be a result of its application but not a requirement for its implementation. It would be more reasonable to say that stress comes from inadequate response to global competition (Ballard, 1999).

Ultimately, Ballard and Howell (1999) support lean by saying that it enriches the jobs by providing more autonomy of decision-making and responsibility, which translates into higher salaries driven by the lean principles of distributed decision making, multi skilling and pursuit of perfection. They deny that health and safety of lean is worse than other types of production methods.

On the other hand, according to project manager Kristine Ann Barnes, it has been admitted by the labourers that they experienced an increase of stress since they started using the system exposed on this report (See Appendix A. Transcript of interview with Kristine Ann Barnes). She mentioned that since the LBS is a very detailed and precise planning tool, it does not leave room for changes or variations, thus the labourers feel the pressure of ever knowing exactly when and where they are supposed to work and the precise and unmovable deadlines they have.

Furthermore, she mentioned that she noticed some people being reluctant to apply the system, specifically the concrete trade's manager from Frederiskaj 2 that despite of being very experienced and professional, is very conservative minded, and resistant to apply the LBS for the planning of his work.

This affirmation of traditional and conservative mind-set among individuals from the construction industry has been confirmed by many sources. However, it is argued that the difficulties of implementing and accepting new methods are related to Leavitt's model of change. Hereby, it is suggested to test the new approach and see how the different stakeholders, technology, structure and methods of the company have to be modified in order to ensure the successful implementation (See Chapter 9).

As previously shown in Chapter 7, a guideline on how to use LPS together with LBMS is proposed. However, the diversity and complexity of construction projects as well as project and site managers experience in the industry, leads to the idea that the combination of systems can be applied differently. Therefore, has been decided to research on what are the most common traditional and LPS tools for managing projects in order to have a baseline for comparison.

9 CULTURAL CHANGE

Before introducing the case studies and the new combination of both systems, it is necessary to address the issue and adjustments to the current situation of the company in regards to change, which in this case is the implementation of a new process for planning and control.

For analysing the current situation of a company and see how it will be impacted by new methods or management change, it is important to consider Leavitt's model. The reason for introducing the model is based on the fact that change has to be considered and addressed. Hereby, the model is presented to provide the reader with better understanding of how the application has to be implemented within a company. Furthermore, the chapter servers the basis for further adjustments and changes to the application of the system, based on the two case studies and the questionnaire.

The Leavitt model is relatively new technique for analysing company's organization. It was developed by the American professor HJ Leavitt in the 1960s, providing a systematic organizational analysis highlighting on organization's composition (Bisgaard, 2014).

The main purpose of the model is to analyse and identify internal problems between different departments; furthermore, it can be used to compare two or more organizations. However, the method can be also applied to measure changes over time (Bisgaard, 2014). Leavitt's new approach analyses organizations in which every company consists of 4 interactive components: Task, People, Technology and Structure. *"It is the interaction between these 4 components, that determines the fate of an organization"* (Thakur, 2013, p. 1). Levitt suggest that a change in any of the 4 components, will result in direct effect on all the other elements, hereby they will have to be adjusted in order to accommodate the presented change (Thakur, 2013).

Starting from people (the employees of the organization), it is necessary to evaluate their skills, knowledge, expertise, productivity, etc. in order to identify how this components need to be adjusted in respect to the other 3 components. Thus, a change in tasks would require to train and educate people in order to be familiar with the new approaches. Which on the other hand, might require change in Technology and Structure (Bisgaard, 2014).

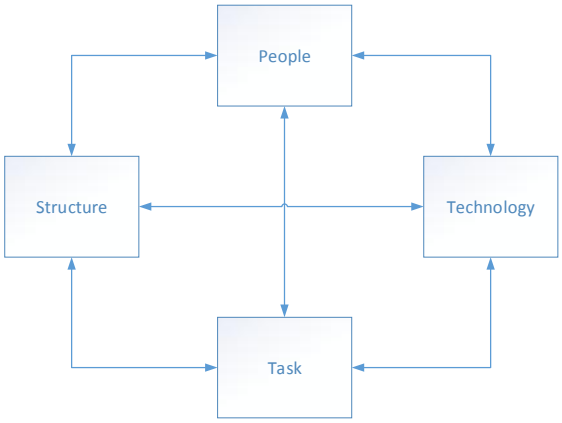


Figure 21: Leavitt model analysis of the 4 components

Hereby, the implementation of the new LPS needs to be addressed in regards to the necessary change to be done within the company. Furthermore, it is essential to adjust the new application based on the needs and requirements of the company.

The above-proposed application serves as a guideline for companies to apply, however it is suggested to modify it based on the needs, experience and size of the construction project they are working on. Thereby, it is decided to evaluate the proposed system based on gathered data throughout case studies and questionnaire. However, due to the time limitation

of the project, it has become clear that the research will mainly focus on the changes done according to the case studies and questionnaire, without the possibility to take a closer look on how the new application needs be adjusted to the other components. Therefore, it is suggested to do a closer examination of the necessary changes for future research based on Leavitt Diamond Model and Kotter's 8 steps (see 12.6 Change Management

10 INTRODUCTION TO CASE STUDIES

Two case studies were performed in order to determine the procedures and tools used on construction sites and compare them to the previously performed research. Before going into the case studies, it is necessary for the reader to get an idea of the general similarities and differences between the two projects.

Both projects consist of multi-apartments buildings, where the companies in charge of the construction, are also the developer and owner of the property. Respectfully, the owners of the apartment buildings are MT Højgaard and A. Engaard. Furthermore, the both projects had to sell a specific amount of apartments, before the actual start of the construction. However, in Engaard's case the apartments can be customized by the clients even after the beginning of the project, thus bringing more complexity and last minute changes to the project. Hereby, the construction of the building proceeds when a specific amount of sold apartments is reached.

In addition, both projects are located on the harbour, where soil is polluted and caused delays during foundation works. Furthermore, both project managers are experienced within the multi-storey residential buildings with over 10 years of experience.

The main difference between the projects derives from the fact that both companies are using a different set of tools and methods to manage and track the construction progress, as addressed in the sub chapters below. However, it is important to mention that in Case 1, the company is using a personalised lean approach to manage the construction projects (TrimByg), while in the second case, a more traditional construction approach is carried out. Furthermore, it was observed that in the first case study there was more attention towards optimization of activities, reduction of construction time, while increasing the quality of the project. On the other hand, the project manager from case 2 had a broader responsibility and needed to overview the delays and could not update the phase schedule as much as in Case 1.

It is important to mention the divergences between the culture and economics in both companies. In one hand, there is MT Højgaard, owned by two stock exchange listed companies Højgaard Holding A/S and Monberg & Thorsen A/S and is one of the Denmark's main contractors (Højgaard, 2010). On the other hand there is A. Engaard, a family owned company with presence in Nordyjlland and origins in the city of Aalborg (Anon., 2015). MT Højgaard, being a much bigger and business owed company, is more focused on a sustainable development driven by innovation and productiveness, thus the application of its own Lean approach called TrimByg and LBMS. In addition, they have a Process Manager role, responsible for the implementation of their methods and tools in all the projects they undertake. For this reason, it is believed that is easier for MT Højgaard to keep up to date with the industry's movements and implement new approaches if they wish.

In addition to the clear difference on how projects are being managed and executed, for better understanding of the case studies, it is essential to evaluate the economics of both companies. The gathered data is based on both companies' annual reports (see Figure 22) and it includes the annual reports from 2010 to 2014, where can be seen that MT Højgaard has an average revenue for the years of 8.5 billion kroner compared to 1.27 billion kroner for A. Enggaard. However, it is interesting to see that since 2010 A. Enggaard have managed to

grow their business from 870 million to 1,5 billion krone revenue. On the other side, even though MT Højgaard has an average gross revenue 3 to 4 times Enggard's, in 2013 and 2014 the company's revenue has decreased from 9,7 billion in 2012 to 6,9 billion kroner in 2014 (Figure 22). Furthermore, for the year of 2014, MT Højgaard had 3,846 employees compared to 254 for A. Enggaard.

		2010	2011	2012	2013	2014
A.Enggard A/S	Revenue (Amounts in 1000 DKK)	870,643	887,427	1,293,999	1,812,124	1,521,074
	Operating profit EBIT	194.274	83.823	99.656	175.768	179.255
	Profit (Loss) before tax	146,077	30,117	40,037	103,846	102,852
	Profit (Loss) of the year	109,725	23,398	30,431	78,699	77,218
	Equity	547,146	446,437	476,886	555,567	632,785
	Total assets	1.077.587	1.005.147	1.176.888	1.529.736	1.403.565
	Number of employees	142	188	215	319	254
MT Højgaard	Revenue (amounts in Dkk millions)	8,303	9,307	9,735	7,464	6,979
	Operating Profit Ebit	94	-332	-507	165	-201
	Profit (Loss) before tax	100	-335	-597	209	-186
	Profit (Loss) of the year	61	-261	-512	107	-252
	Equity	1,618	1,289	771	1,181	822
	Total assets	4.698	5.654	4.433	4.014	3.646
	Number of employees	5,217	4,738	4,688	4,058	3,846

Figure 22: The data is extracted from the annual reports of both companies (Anon., 2015) (mth, 2015)

Can be determined that MT Højgaard is the dominant company on the market, however based on the profits after taxes, it is deducted that A. Enggaard is performing better over MTH. Figure 22 highlights the differences in the company's profits where as shown, A. Enggaard have managed to keep a healthy profits during the years, which have helped them to steadily increase assets of the company. MT Højgaard situation is slightly different, where the company even had half a billion kroner loss in 2012 and became necessary for the company to sell some of their assets, thereby the company has decreased their assets from 5.6 billion kroner in 2011 to approximately 3.6 billion kroner in 2014.

To conclude, in regards to the observed and analysed case studies, they are similar to each other, however the difference comes from the size of the company, to how project are being managed on the construction site, down to the net profit of the companies. As already

mentioned MTH focuses on the different construction processes, thus the number of employees does not correlate with revenue, compared to A. Enggard.

10.1 CASE STUDY 1: FREDERIKSKAJ 2

This Case Study has been performed through observation and information gathered during the interview conducted on site with the MT Højgaard's project manager Kristine Ann Barnes, the 20th of October of 2015.

The reason why was decided to do a case study about this project was because MT Højgaard and specifically the project manager for this project Kristine Ann Barnes, uses LPS in conjunction with LBS for the management and control of the project. Since the application of LPS and LBMS is the topic that was decided to investigate, this case is considered a good opportunity to study the use of both methods in practice.

This chapter is divided into introduction, making a brief description of the characteristics of this project, observations where is described how the managing tools were used and conclusion where the observations are analysed and commented upon them.

10.1.1 Introduction

Frederikskaj 2 is a MT Højgaard project, designed by the architectural firm Holscher Nordberg, consisting of 7 multi-apartments building located near the centre of Copenhagen. Three of the buildings are already in construction to be delivered by the middle of December 2016 and the other 4 are still on hold, depending on the sales success rate. This is due to the fact that MT Højgaard, acts as a main contractor and developer.

Figure 23 Bird view from Frederkskaj harbour

The project features its own harbour and has all the necessary amenities and transport connections nearby. The harbour gives the possibility to perform many maritime activities such as, sailing, kayaking, swimming or fishing (mth, 2015).

The community contains a green common area inspired on the dunes at the Danish coast and a common space with two guest rooms integrated into the harbour.

The development boasts about its high quality standards and being environmentally friendly, featuring 3-layer energy glass on the windows and solar cells on the roofs.

10.1.2 Observations

Since the goal of this case study is to show the difference from the way the system is supposed to be used in theory and how it is actually used in practice, in this observation's subchapter, each of the tools are described in the way they are used in the project. Therefore, the chapter is divided into 9 points, one for each tool of the system compared to the theoretical approach.

The observations were recorded during the assistance to the planning meetings conducted on the 20th of October of 2015 and the following interview with the project manager Kristine

Ann Barnes. Two meetings were conducted that day. The first one was with the labourers and the participants were Kristine Ann Barnes as a process leader, the site manager for the concrete phase, the health and safety coordinator, the plumbing supervisor and the superintendents of sewage and dirt and concrete trades. The second meeting was with the contractors and the participants were Kristine Ann Barnes as project manager, the site manager for the concrete phase, the health and safety coordinator, the plumbing supervisor and the supervisor of the concrete trade. Both meetings lasted 1 hour.

For references about this chapter, check the Appendix A. Transcript of interview with Kristine Ann Barnes.

10.1.2.1 Kick-off meeting

The first meeting that MT Højgaard does is the kick-off meeting. This includes the project managers, foremen, subcontractors, client and advisors. The meeting is hosted by the Project Manager Kristine Ann Barnes and the purpose of the meeting is to get everyone familiar with the project. In the kick-off meeting, she talks about the process, success criteria, things to be avoided and expectations from their cooperation. Moreover, she tries to get everyone familiar with the use of TrimByg.

The following table shows, which are the driving factors, discussed at the meeting.

Success criteria: • the right resources available • good communication of the schedule • common process planning • the handover: 0 errors and defects • keep an organized workplace, focus on the work environment • common economy • fewer errors and accidents • delivery on time • openly shared responsibility • work culture • it should be fun	To be avoided: • meeting absence • not respecting other workers • unclear goal • unclear communication • closed conversations • think in a box • missing resources • missing experience/ competencies • missing flexibility • bad planning
Process: • monitoring and corrective actions • respect the time schedule • prioritization of meetings, with maximum participation • ensure common well-defined goals • weekly project follow-up • compliance of attendance • short effective meetings	Cooperation: • we report in good time/ honestly on own challenges • we hold social events at 100 days without incidents and occasionally grilling • we give constructive feedback • we take joint responsibility • we clean up after us

Following the discussion, all the key words (distinguished by different colors) and ideas are then placed on the meeting room walls, where permanently remains until the end of the project. Apart from this, a scheme is created to place the focuses on the Time-Quality-Resources triangle (Figure 24).

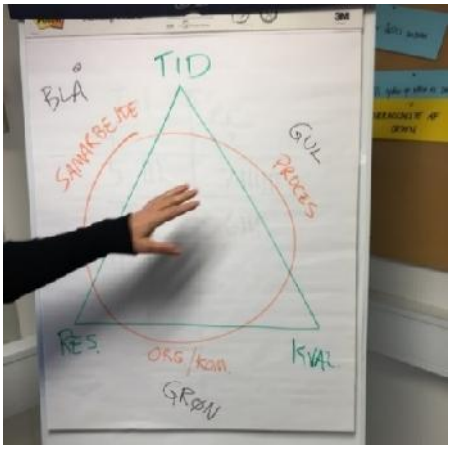


Figure 24: Focuses placed on the Time-Quality-Resources triangle

An interesting proposal made by Kristine Ann is the creation of an anonymous stress barometer. By doing so, the stress present at the workplace can be monitored and therefor, reacted to in good time. Moreover, because the barometer is anonymous, the results are most accurate.

Before the meeting is over, Kristine presents a scoreboard (Figure 25) where the quality and the performance can be observed and examined. Smiley faces are used to give a better visual understanding of the actual performance. Apart from this, the board contains information about economy planning, building site and holiday plans. Just like the other boards, the scoreboard is constantly present in the meeting room for a constant feedback of the work.

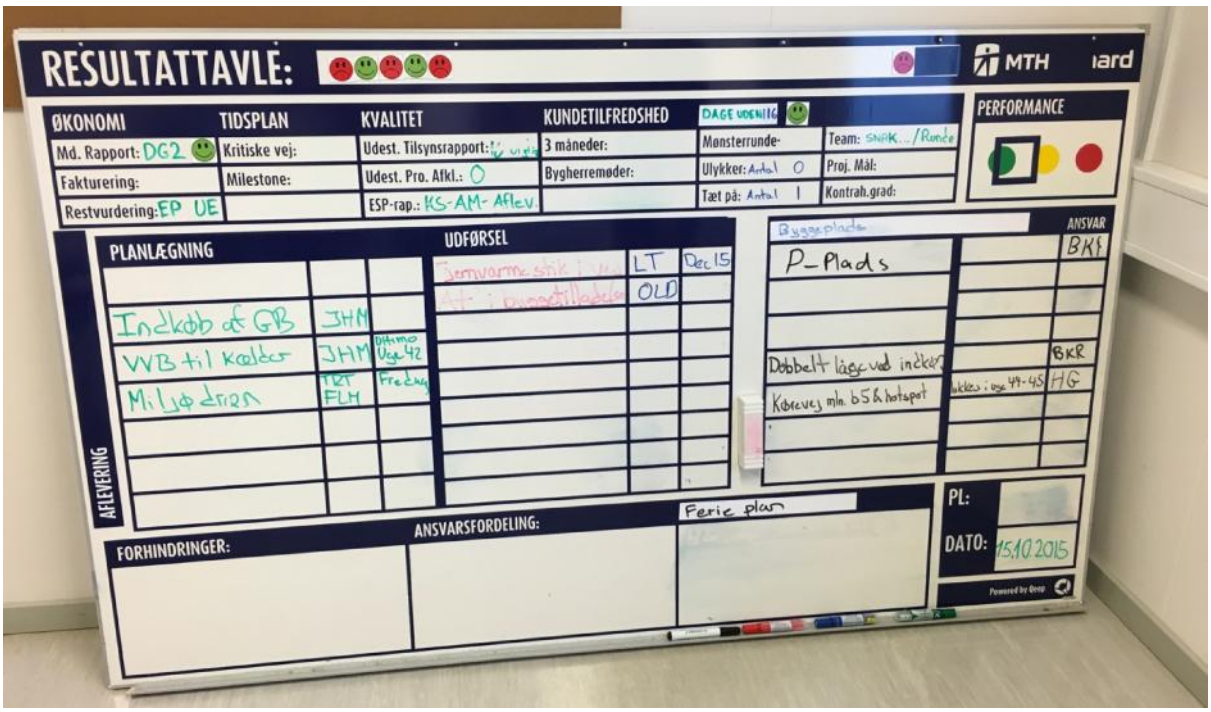


Figure 25: MT Højgaard scoreboard

10.1.2.2 Master schedule

The first master schedule was performed about two years ago, during the project proposal and it was a Gant chart type of schedule. Closer to the start of the project, Kristine elaborated the master schedule in Vico Software to create the Location Based Master Schedule for the whole duration of the project including every single activity. Thus, the project duration was shortened from July 2015 - December 2016, advancing the handover for

the first part of the project with more than two months (See Annex A: Location Based Master Schedule Fridirekskaj 2).

To elaborate a LBS with Vico, the best case scenario is when the 3D model, elaborated with Revit or any other 3D design software, contains all the quantities and information of available resources. In this way, the schedule is more precise and realistic, however Kristine considered the data input process burdensome and time consuming, therefore the length of every activity was determined by professional experience or management decision and the resources were adapted as required.

The main project buffer is added in the end of the project because Kristine considers that if she allocates buffer between the activities, the trades would relax and would not be as productive as they can.

Once the Location Based Master Schedule was done, it was sent to the superintendent of every trade to seek for their agreement and signature, committing themselves to do their part of the work as planned.

10.1.2.3 Weekly Work Plan

In the case of Frederikskaj 2, the Weekly Work Planning meeting was conducted once a week and it was elaborated for the following two weeks, therefore the planning of each week was considered twice to increase the planning precision.

The meetings are conducted on Tuesdays, and there are two of them, one with the senior labourers of each trade and the other with the contractors, lasting one hour each.

The meetings are conducted through an informal conversation, going through all the activities planned for the next two weeks using the Location Based Phase Schedule and the site plan as a reference. The topics discussed were about the requirements of tasks to be executed during these two weeks, issues regarding the construction progress such as delays, shortcomings, etc. Any unrelated topic is left out of discussion.

The Location Based Phase Schedule is used as the meeting agenda to go through all the relevant activities and the discussion and agreed decisions are recorded into the meeting's minutes. Afterwards with the use of the meeting's minutes, Kristine updated the schedule as necessary.

A part from the Weekly Work Planning meetings, the concrete trade's labourers had their own planning on site, based on a kind of Gant chart drown in a blackboard, following the directives agreed on the weekly meetings (Figure 26).

Figure 26: Labourer's two weeks work plan

10.1.2.4 Phase scheduling

Since the LBMS allows to elaborate a very detailed schedule right from the beginning, the pull planning was skipped and the phase schedule was extracted from the previously done Master Schedule, to see the schedule of the specific phase clearer and in a bigger format.

This phase schedule was used later on as an agenda on the meetings with the labourers and contractors to discuss about the construction progress and the requirements of future tasks.

By the time the site was visited, the concrete works were being performed and the phase schedule for that trade was within the time frame from the 21st of September of 2015 until 11th of December of 2015 (See Annex B: Location Based Phase Schedule Fridirekskaj 2).

10.1.2.5 Look ahead planning meeting

In the project, a 5 weeks look ahead window was applied, taken out from the LBS. The requirements for the activities to be performed the 5th week from the current state, were discussed during the weekly meeting performed every Tuesday.

The same way as for the WWP, the agreed decisions and important notes were recorded in the meeting's minutes for further consideration and the schedule was updated if necessary.

10.1.2.6 Make Ready Process and the workable backlog

The MRP as well as the workable backlog are not performed as theory suggest. The MRP and the analysis of constraints are performed using the obstacle list, showed on Figure 27.

The obstacle analysis performed during the meeting with the different trades, is done every two weeks to identify the problematic areas and people responsible for delays. According to the interview with Kristine, she usually takes pictures of the delays or problematic area of work, then takes those issues to the meetings, where she proceeds with the reasons for delays and the responsible party. Furthermore, on the meeting is enhanced the importance of the shared profitability, meaning that if someone does not perform up to the standard or is

delaying work, all the contractors will experience decrease in profitability as well as labour productivity.

Dato:		07-sep	Kappelborg	Hvem hindrer:							Ansvar	Afklares	Afklaret	Bemærkninger
Pos	Dato	Emne	Problem	Ark	Konsting	VVS.ing.	El-ing.	Byggeledelse	Bygh.	UE	initialer	senest	dato	
1	31-aug	STÅL	Hvorledes skal midlertidig afstivning udføres?		X						HKR	15-sep	31-aug	Aftalt på stedet med ING.DSH
2	31-aug	BLIK	Tegning til blikarbejdet ved pkt. A mangler	X							HKR	15-sep		
3	31-aug	BRAND	Hvilke krav er der til brandinddækning stålbjælkerne under dæk i bygning A2?		X						KMU	29-sep		
4	07-sep	MUR	Detaljer for hvorledes muren/fundamentet skal udføres i område C?		X						HKR	10-sep		

Figure 27: Example of the obstacle list used in Case Study 1

However, the MRP used by Kristine does not consider all the pre-conditions but notices only the major issues that could occur. Furthermore, based on the interview, it is observed that one of the activities have been initiated without everything in place to ensure the successful completion of the task. Therefore, it was postponed due to the lack of documentation.

The way the MRP is performed at the construction site, includes not only activities that are considered important and need to be executed accordingly to the schedule, but also includes problematic activities that need immediate attention.

The pre-conditions are not studied within the document above due to the human factor involved. It is considered that the different trades are aware of what is required to carry out the tasks. However, the risk relies on the contractor's experience and knowledge, without any way to predict or recognize an upcoming problem before the actual start of the task. Furthermore, a workable backlog is not used because it is considered a burdensome and time-consuming process.

10.1.2.7 First run studies

In this project, first run studies are not conducted.

10.1.2.8 Percent Plan Complete (PPC)

According to Kristine, she does not use the PPC tool because she considers it to be very complex and burdensome, plus it can lead to errors since if the labourers are asked about the progress of their tasks, they will answer roughly, not considering the progress of each small assignment but the whole work in general.

Instead, she uses one of the Vico software's features where she can extract the current state of each task and classify them between:

- The task has not begun
- The task is in progress
- Task completed
- There is no task for this position
- The task is in progress, but running late
- The task has not begun, running late
- On time and paused
- Late and paused

In addition, in each task and specific location is represented the target start date and finish date and the actual ones and for those in progress, an overall percentage of completion is represented. In order to provide the different trades with simple data on the projects progress, different colours are applied depending on progress of the task (Annex C: Progress Status Fridirekskaj 2).

She mentioned her intention to undertake a more exhaustive follow-up of the PPC once the interior works start, since there will be more trades working on site at the same time and a better control will be required. She intends to vary the application of the method by placing the LBS in every floor of each building block and encourage the trades to make a check mark on the schedule every time they complete an assignment on their assigned location for the given week.

10.1.2.9 Tracking variances and analysis of constraints. The 5 WHYs

Tracking variances and analysis of constraints in the case study is performed by Kristine, by going around the site, taking pictures and writing notes about it. The process is performed using Plan Grid (Figure *28*) and Vico Control and allows Kristine to draw on the plan drawings, insert notes and add pictures. Furthermore, it is easy to highlight where a problem has occurred and document it in details. The program works as a tool to keep track of the different problems on the construction site, allowing the user to not only show where the problem occurred but also to take notes and pictures with location included.

The 5 why's method is ignored. Problems are taken to the weekly meetings where the tool is used to highlight the problematic area and to find out the responsible party. However, the problem is not investigated in detail, thus it is possible for the root cause to be ignored.

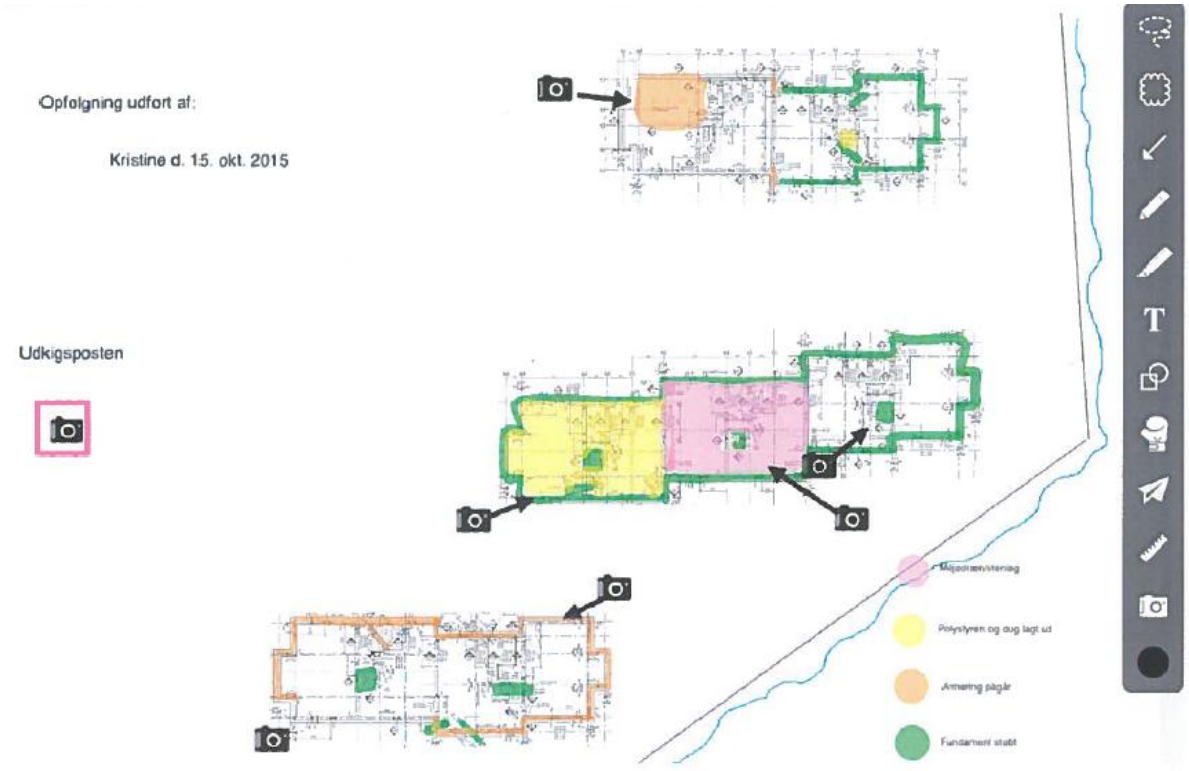


Figure 28: Plan Grid tool

10.1.2.10 Location Based Schedule

As already mentioned, Kristine supervises the different processes and updates the LBS (Figure 29). Furthermore, she keeps track on the percentage of completed activities using the Progress Status (Annex C: Progress status Fridirekskaj 2). It is important to mention that the schedule is prepared based on her experience without any data extracted from virtual construction models.

The LBS is updated at the end of every week, based on the progress and delays that have been detected as well as the agreed actions for the continuation of work. The LBS has the role of a master phase schedule; however, due to the fact that Kristine has created a very well organized and detailed schedule, it is also used as a weekly planning tool.

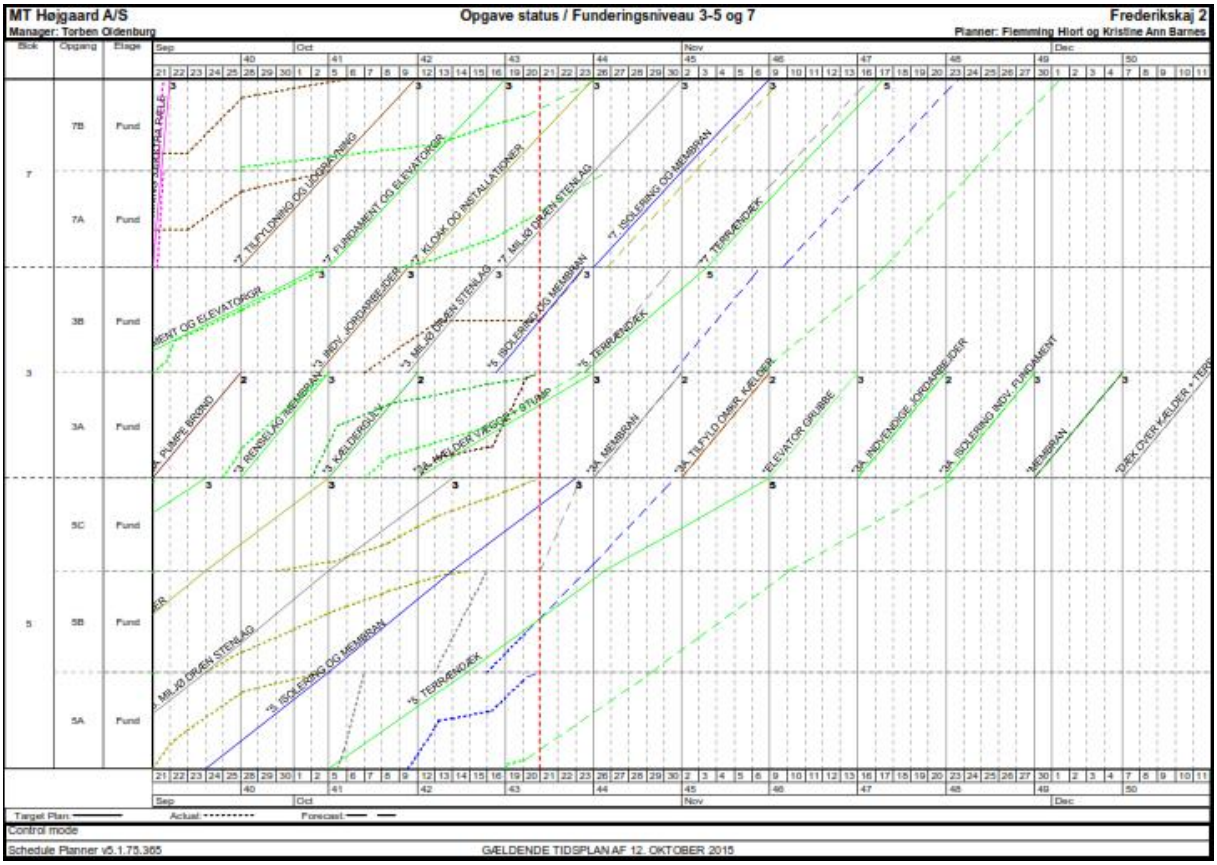


Figure 29: Location Based Phase Schedule used by Kristine

10.1.3 Conclusion

During the case study, it is observed a modification of some of the LPS tools or their elimination due to the use of LBS. First of all, it is important to mention the buffer which Kristine mostly placed at the end of the schedule, leaving a very small buffer zone for the individual activities. Performed this way, the schedule creates stress in the workforce to perform the individual tasks on time, focusing on very tight deadlines and not allowing enough time to absorb variances. Thus, in case of arising problems, the subcontractors are under pressure to keep the activities on track. This issue can be addressed using Last Planner tools for communication, focusing on the joint benefits for all contractors. Furthermore, the buffer zone can be established within the individual activities, eliminating the stress factor and allowing contractors to take on variability at ease. Using this method, leads to a decrease in productive rates, due to the more time allowed to perform the

individual tasks. It is not possible to determine the exact and most beneficial option, because both of them depend from the situation and management decision.

As already mentioned, some of the tools are modified or ignored. The elaboration of the master schedule in the observed case, did not count on the collaboration with the subcontractors and use of pull planning to establish the most optimal sequence for the completion of the construction project. In this case, the process manager created the LBS based on experience and knowledge. Furthermore, the PPC is not done according to the theoretical approach, based on the fact that it requires a lot of time to gather all the necessary information from the different contractors. Moreover, the PPC rate can be altered if the contractors consider a number of tasks as one, creating an imprecise rate, leading to a misleading and unrealistic PPC. Hereby, Kristine performs a variation of PPC with the use of the LBS, which consist on a simple chart created with VICO (Annex C: Progress status Fridirekskaj 2) to visualize the completed tasks and the ones that need serious attention. The whole process reduces the time of gathering data and eases to emphasis in the weekly meetings and have a very well documented and up-to-date status report of the project.

As presented to the reader, the MRP and the workable backlog (used to make sure that only sound activities are scheduled) is ignored in this case. It is not argued the fact that the theoretical use of the tools can significantly increase the number of activities completed on time. However, the presented method is too burdensome and disregards communication between the different parties. If a contractor is asked about all the preconditions, and if he has everything ready for the execution of tasks, he will straight forwardly say it.

Another tool that is ignored is the first run studies. It requires a lot of time and the involvement of different contractors. Usually, the root of a problem is identified on the weekly meetings in a reasonable time margin. The studies are not conducted due to the reasons that the construction is too simple as well as the extend experience of MTH in multi-story apartment buildings.

To conclude, the case study provides information of the disconnection between theory and practice as well as the idea for better use and modification of tools, which are presented to the reader in the Improvements Chapter.

10.2 CASE STUDY 2: MUSIKHUS KVARTERET PROJECT

"Project Musikhus Kvarteret" was monitored and analysed in the period from September 2014 until January 2015 and the report written, as the second semester project of Management in the Building Industry. The contributors of the report are Florin Daniel Firte, Paul Zah, Radu Cristian Zah, Andrea Lipovac and Zlatina Takeva.

The reason for choosing this project as a case study is the high amount of information gathered within that period. The research aims to investigate the tools used for planning the project and determine if things would have run better with the use of the suggested systems combination. On the other hand, if some of the tools used prove to work better than in theory, the team will attack the theory with practical arguments.

The chapter is structured in the same manner as the chapter before, offering the reader a better overview of the similarities and differences between the cases. However, because the management team does not use the LPS system, some tools are not discussed in the observation chapter.

10.2.1 Introduction

The Musikhus Kvarteret is a residential project located on the eastern harbour of Aalborg. The former industrial area is in the course of a major change that will transform its purpose into a residential and cultural one. Among the newly erected buildings are the Musikkens Hus, the new building of Aalborg University and other residential buildings. For this change, Aalborg Municipality collaborated with A. Enggaard A/S for the development of the area and created the following Local Plan.

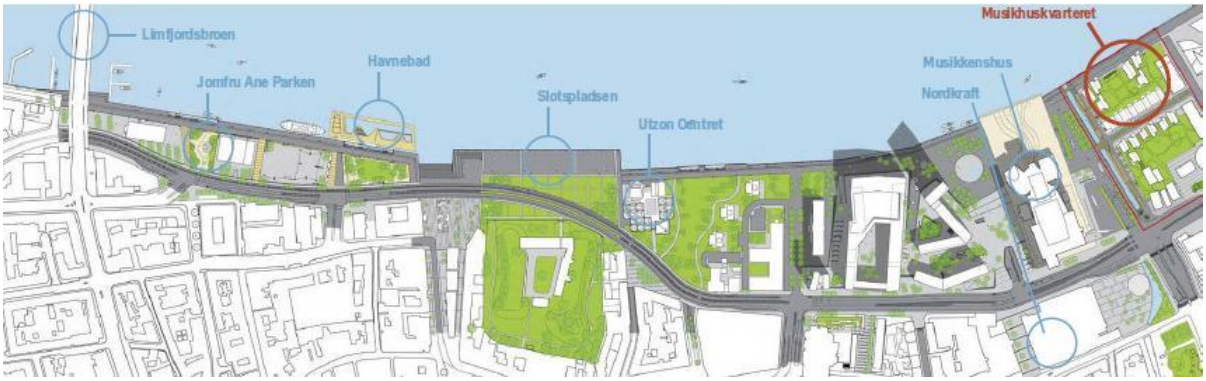


Figure 30: The development of the east harbor (Schmidt Hammer Lassen Architects, 2013)

In this project, A. Enggaard A/S is both the owner and developer of the land. Therefore, there is no contractual agreement between the client and the turnkey contractor. A. Enggaard A/S is sole responsible for all stages of the project (design, execution and the sales of apartments).

The project is comprised of 91 apartments ranging from 89 m2 to 300 m2, distributed in 3 blocks with basement and parking area.

Figure 31: Rendering of the completed buildings (Schmidt Hammer Lassen Architects, 2013)

10.2.2 Observations

The observations were conducted in the fall of 2014 through a series of interviews, building site visits and analyses of the project files. The data was used to create a report about the risk management. Now the same information data is reviewed and analysed from the LPS and LBMS point of view.

The structure of the observations chapter is divided and discussed by the tools that the management team uses and resemble similarities of the LPS system. Therefore, not all the nine tools are included.

10.2.2.1 Master schedule

The master time schedule was developed by the project manager Kristoffer Styrup as a guideline of the project (Annex D. Hovedtidsplan). It offers a brief overview of the work and it includes the basement area, stage 1 and stage 2 of the project. At the time the file was acquired (December 2014), the third stage was not yet initiated. It has been noticed that the planning was created after the actual work on site started. The reason was that A. Enggaard A/S‘s own contractor was the only working trade on the site. Moreover, the plan does not offer a detailed view of the process, but rather indicates the milestones for an easier coordination among different trades. The file has not been updated since its creation date.

10.2.2.2 Phase scheduling

The master time schedule does not stand alone. It is accompanied by a completion plan (Annex E. Komplettering) which involves all contractors and their duties on the site. The method places each trade in a working sequence driven by a location based arrangement (Figure 32). This completion plan divided by the locations was created for each stage of the project.

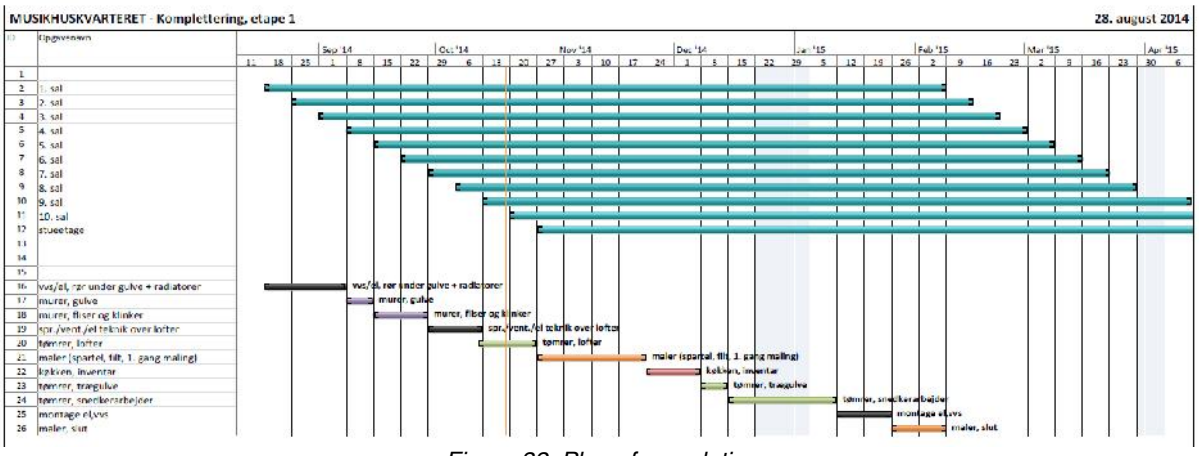


Figure 32: Plan of completion

The selection of the subcontractors was done trough a restricted tender phase, the award criterion being based on the lowest price. However, the invitations were sent to the subcontractors with a collaboration history.

Because of this past collaboration, there is a lot of trust placed on the subcontractors. When the phase schedule is made, a representative from all the subcontractors is present, so the planning is done together. However, it is safe to mention that the phase schedule is made trough the traditional method using casual conversations and not the procedures mentioned in Chapter 7.2. Figure 32 shows the work to be done on each floor placed in a sequence. Conflicts between trades still arise due to the fact that some work is being delayed and it extends on the upcoming contractor's schedule. These conflicts are solved once a week at the weekly meeting.

The right pull planning procedure is not followed in this project.

10.2.2.3 Weekly Work Plan

A detailed planning of the project takes place during the weekly meetings, which in addition to the project team, it is comprised of all the contractors involved at that moment on the site. Kristoffer Styrup chairs the meeting with the milestone plan and completion plan being displayed in the room. All discussions, updates and decisions taken at the meeting are written down as the minutes (Annex F. Byggemøde 30) and used as the planning progression of the upcoming week. Therefore, the following weekly meeting starts with the current status of the work, monitoring and noting the changes. Mention that each trade is treated separately according to its own work. Overlapping work of different trades (and therefore arguments) do happen due to small delays; nevertheless, quickly resolved due to the frequency of the meetings.

The Work Environment meetings take place every second week, beginning with a safety inspection of the site. Leading the meeting is Thomas Cleyton (which is responsible for H&S on site) accompanied by safety representatives of the involved subcontractors. The scrutiny of the site shall assure that all work is carried out in a safe and secure manner. All observations, near-accidents or accidents, are documented and later discussed (Annex G. Sikkerhedsmøde) to achieve a better work environment on site.

The Health and Safety plan, which also serves as the building site plan, is updated after each meeting and placed at the entrance to the office area. That is the only copy available on site as updating the file is done manually by drawing on top of it (Figure 33).

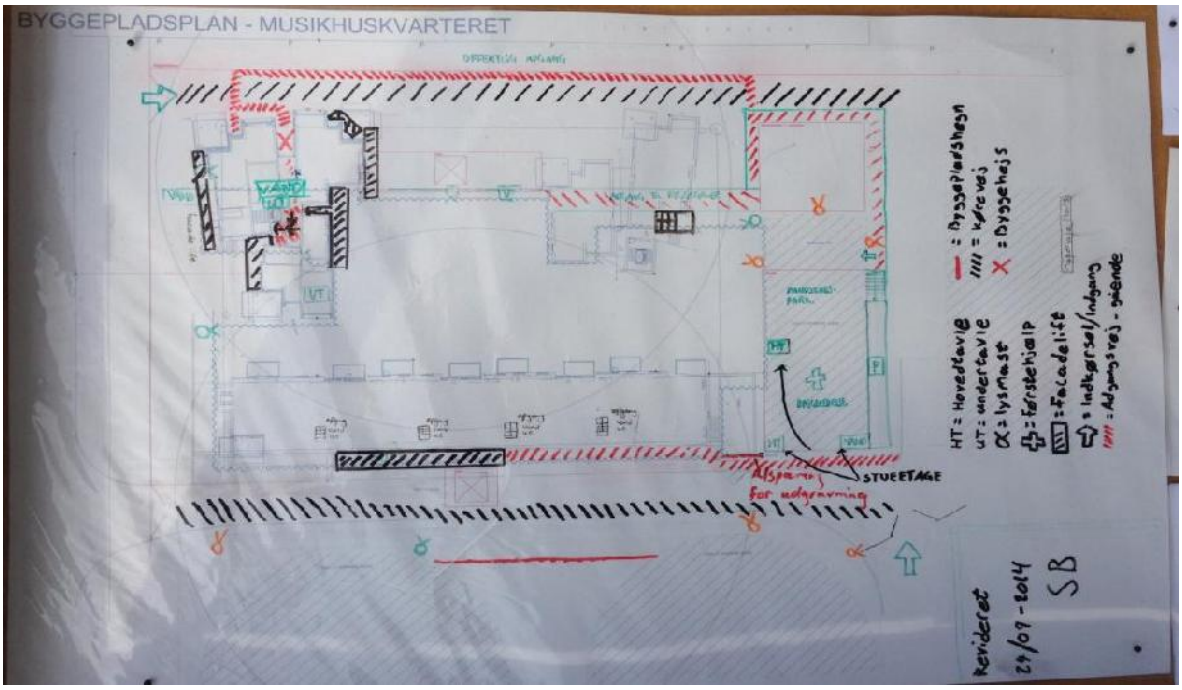


Figure 33: Health and Safety plan

10.2.2.4 Look ahead schedule

There is no official look ahead schedule on this project apart from planning of the next week. However, some unofficial discussions take place about the work ahead, but there are not on a regular basis or with certain people involved.

According to Thomas Clayton, the look ahead schedule is not possible to be performed due to the fact that the apartments are highly customizable. The client's decision for changes can greatly influence the planning as these can occur randomly.

10.2.2.5 Tracking variances and analyses of constrains. The 5 WHY's

In this project, the 5 why's tool is not used. In order to observe the H&S issues on site, the team starts the WE meeting (which is every second week) by taking a round on the site and photographing the problematic area. At the meeting, these pictures are analysed and deliberated. Other problems are most of the times discussed at the weekly meetings, where a solution is investigated.

10.2.2.6 Location Based Schedule

There are many benefits in using the LBMS on any project; however, this is not the case. The team uses instead a so called "plan of completion" (Figure 32), which shows the location and duration of each trade when performing the job. It does not show any waste because the plan is based on a Gant chart. Moreover, if the task is delayed or going on a slower rate than others, there is no way to track the progress and therefore no way to forecast the delay for its prevention.

When the same schedule is placed as a proper LBS, it looks incredibly chaotic (Figure 34).

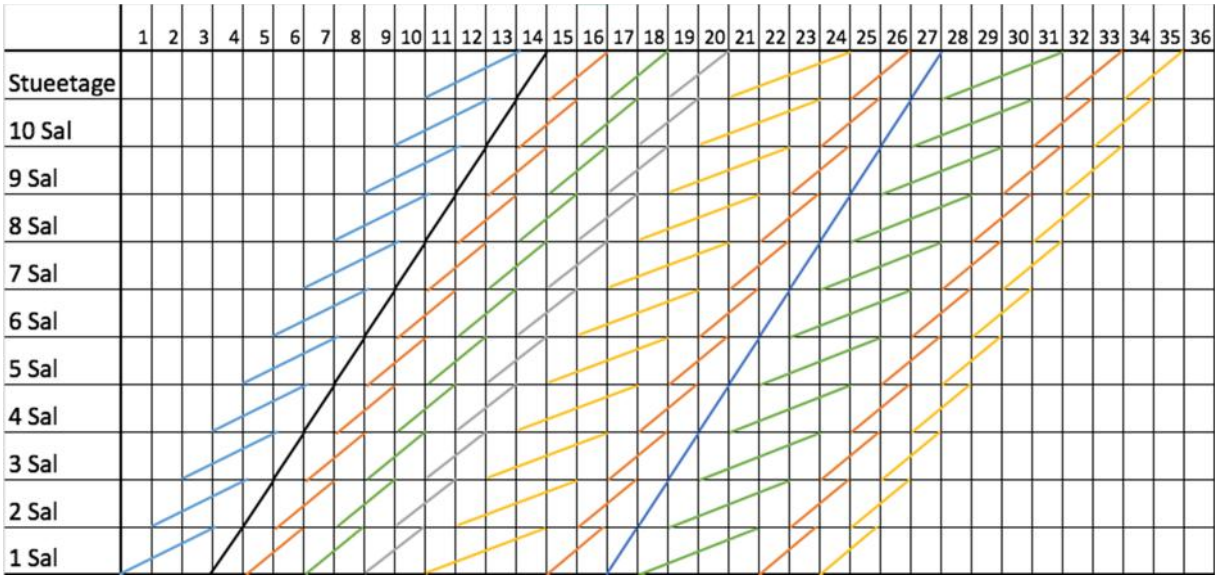


Figure 34: LBS made after the existing completion plan.

The schedule is not feasible as most of the trades have to be in multiple locations on the same week, some trades even working on four locations at the same time. If the lines are made continuous, meaning that more crews are required to finish one location and only then move to the next one, clearly can be noticed the amount of waste on the schedule (Figure 35).

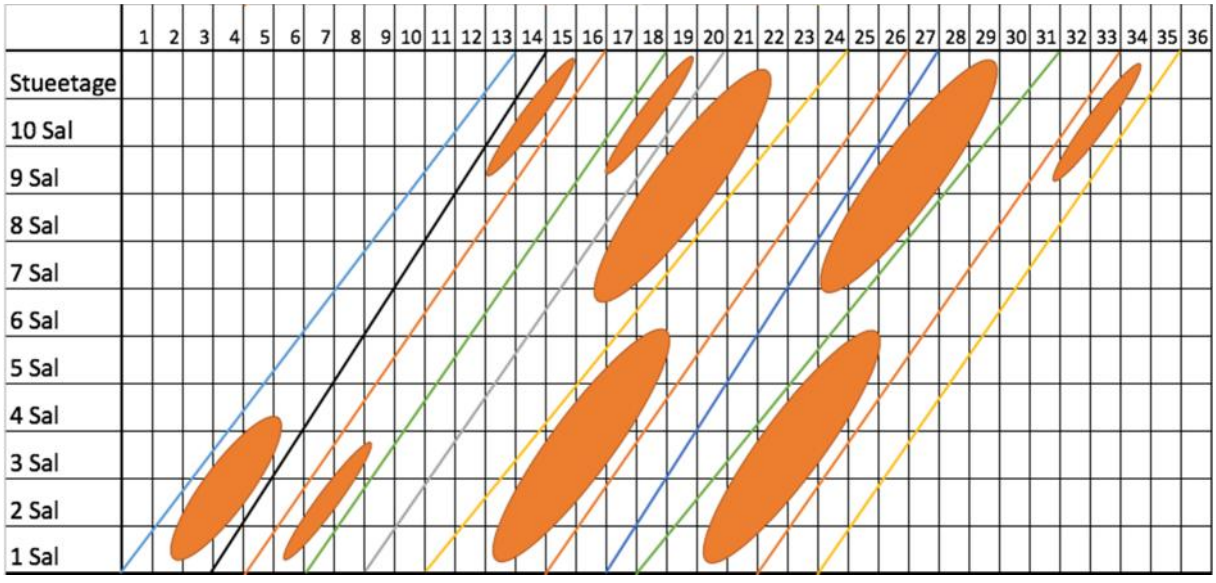


Figure 35: Waste on the LBS

10.2.3 Conclusion

It is important to learn how the managers are planning their work in order to create some powerful and concrete improved arguments. When the case study was started, the goal was also to look for methods that might work better in practice than what the theory suggests. This is however not the case. It is discovered that all the management can benefit by upgrading the system to LPS.

According to Chapter 7.1, the master time schedule should be kept simple and meant to show just the milestones and major deadlines, as subcontractors are not yet involved. However, because it has never been updated since its creation date, the master time schedule is not very complex and therefore does not offer a great deal of information. In order to create an improvement, the managers should erect a LBMS as soon as the trades come in. In this way, the progress can be forecasted and the deviations be monitored. Following this, the data can be used to create the look-ahead plans and weekly plans (Olli Seppanen, 2010).

The phase scheduling does not follow the right procedures mentioned in Chapter 7.2, where is divided into two meetings. The management team does the planning together with the subcontractors and arranges the tasks by a location sequence, but does not follow the optimization of the schedule using LBMS performed in the second meeting. In this way, the waste is not reduced and productivity ratio is not high.

Look-ahead scheduling it is not possible because of the nature of the project. Great uncertainties are involved as the client dictates how the apartment should be like. However, when the building is erected, the client is absent and therefore look-ahead scheduling would be possible. As Chapter 7.3 mentions, if LBMS is used, the forecast can then be extracted.

Tracking variances is definitely a process to be improved. The team focuses and solves often just the effect superficially and rarely analyses the root cause. As presented in Chapter 7.8, when the causes are identified, the relationship between them could be established. Learning from mistakes is a part of Lean concept in pursuing perfection. A fit for this process is the 5 WHY's tool. It is an easy to use tool and suitable when the human factor is involved. As an example, a clear concern on the site is the fact that a red smiley was issued by the Danish Work Environment Authorities meaning that the workplace does not meet the requirements imposed by the WEA. The team knows that it has been issued because the minimum WE documentation was not met, but does not investigate the problem further. If the 5 WHY's tool had been used, the team would have found out that the real reason to this was that there was not enough time allocated for the creation of documents as the WE team did not consider it a practical process. The next figure illustrates the causes and effects of this matter.

In an interview with the Health & Safety coordinator Thomas Cleyton, he mentioned that they had an issue with the supplier of prefabricated balconies. The required elements were delivered to a different site and that caused them some delays. It is argued that this misunderstanding could have been avoided by applying the LPS tool MRP, by which, the team would have made sure that the right elements were going to be delivered at the correct location.

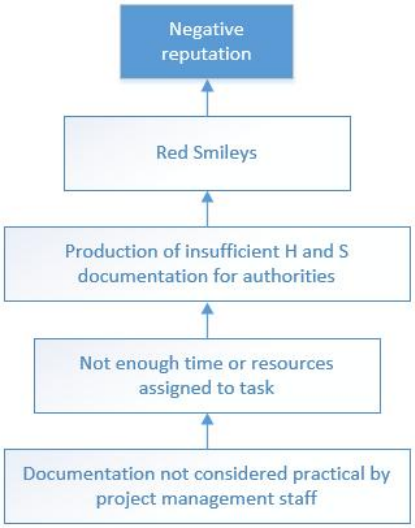


Figure 36 Red smiley problem tree

Location based scheduling is not used on this project. A location schedule is present but according to the observations made it is not a feasible one. The work overlaps and there is a great deal of waste present. This could easily be the reason for misunderstandings and conflicts between the trades. The original schedule provided by A. Enggaard A/S was transformed into a LBS and optimized, to show the benefits of using LBMS. After making it realistic and eliminating the waste, the schedule was reduced by six weeks (Figure 37).

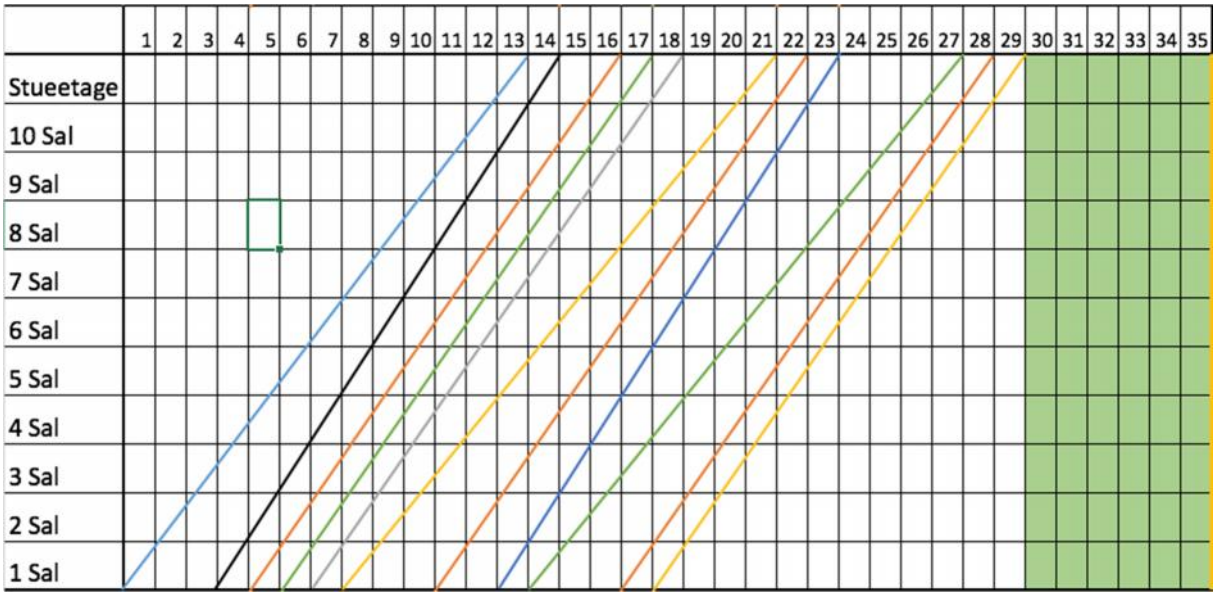


Figure 37: Optimized plan of completion using LBMS

The schedule has to be further adjusted by assigning the right amount of labour for each trade, nonetheless the results are astonishing.

A major change is heavy on the shoulders of everyone and therefore the crew in general is not very positive towards the transformation. According to Lean Construction Journal (2010), one US contractor argued that since the upgrade made by implementing LBMS and LPS, the work was doubled and because of this, he decided to utilize the LBMS and leave out the controlling phase of the LPS. This seems like a logical choice in order to keep the motivation going. When the crew feels comfortable with the actual work and results, the controlling phase can be added.

10.3 Conclusion of case studies

As presented above, both case studies are very similar; however, in regards to the planning methods and preparation of tasks, the presented companies are very different. There could be many reasons for the differences in regards to planning methods, like the size of the company (see Figure 22), as well as the trades they have and the culture of the company. It was decided to draw a comparison between both, based on the conducted observations and the cultural differences on the construction site. The economical aspect is neglected, due to the time frame of the research. However, it is interesting to see that even that MT Højgaard is the dominant company on the market compared to A. Enggard and is using different Lean principles as TrimByg, A. Enggard seems to be managing their projects better in correlation to the net profits of the companies. It is commonly known that the construction industry is very complex and unpredictable, thus it cannot be clearly defined whether the better net

profits are based on the applied processes or the project teams, their experience and number of employees. It is argued that the broad responsibilities and control the project manager have over the project in Enggaard, allows them to take immediate decision and the projects are considered personal, due to the family business relationship with the owners. Hereby, they have full control over the project and are highly motivated to succeed, while on the other hand, project manager at MTH are constraint with protocols and do not have as much decision making freedom as in A. Enggard.

Figure 38 represents the summarized difference between MT Højgaard and A.Enggard management tools in regards to LPS and LBMS. Based on the conducted interviews and case studies, was possible to clearly distinguish both companies' management tools.

It has become obvious that MT Højgaard's culture focuses on the optimization of processes, not only based on the construction site observation but also due to the reason that MTH has developed and applied TrimByg. Furthermore, the company has a process manager on their construction sites in order to optimize the processes and support the site manager role. While, A. Enggaard, has a different structure in place, where the role of the site manager includes a lot more responsibilities and does not have the same support as at MT Højgaard. Thus, the difference of management tools can be easily recognized.

As shown on Figure 38, MT Højgaard has applied LPS and LBMS tools even thought they might have been alternated, while on the other side, A. Enggaard is not using large portion of the tools. Thus, in case 1 it is easier to track the progress of the project and take decisions based on accurate data, while in case 2 decisions are usually taken after occurrence of problems.

In regards to implementation of new methods for improving the construction processes, case 1 has better chance to successfully implement them, due to their experience and company culture of reducing waste. While case 2 may experience difficulties in implementing new technologies, based on their long way using standard tools for navigating construction projects. However, when implementing new method, both companies should address the necessary 8- steps to the whole organization of the company, creating a clear vision with milestones (see sub-chapter 12.6).

To summarize, the presented cases study projects are very similar in regards to location, size of buildings as well as the fact that both companies act as developer and main contractor. However, their management aspect is very different, thus it can be concluded that in case of applying additional Lean principles and tools it would be easier for MT Højgaard to implement and apply them in real life projects, due to their focus on process management.

LPS and LBMS tools	MT Højgaard	A. Enggaard
Master Schedule	Applied using LBS	Simple
WWP	2 week schedule performed on Tuesdays, going through the activities taken from LBS	Updates on weekly meeting with contractors on site
Phase Schedule	Used	Used
Look Ahead	5 weeks ahead taken from LBS schedule	Not used
MRP	Simplified method used, known as obstacle list; does not consider preconditions only major issues that might occur	Not used
Workable backlog	Not used, considered burdensome and time consuming	Not used
First run studies	Not used	Not used
PPC	Used before; inaccurate information from contractors. Instead MTH uses VICO feature extracting current state of each task and classifying them, tracking the progress of the task with different colours.	Not used
Tracking variances	Plan Grid and Vico Control used to take notes and images of the problems, taken to the weekly meetings	During the WE meeting, the parties go around the site and take pictures and notes, analysing the status on the site
LBS	LBS is used; schedule is prepared based on experience, without any data extracted from virtual construction models. The schedule is updated once a week, depending on the progress or delays.	Plan of completion is used; the schedule shows the location and duration of each trade when performing the job. It does not show any waste, because the plan is based on a Gant chart.

Figure 38: Difference between MT Højgaard and A.Enggaard Management tools

11 SURVEY ANALYSIS

In this chapter, the responses recorded on the online survey performed from 22/10/2015 to 30/11/2015 are analysed. The survey was elaborated using the Google forms application and spread to individuals from the construction industry through personal contacts, LinkedIn related groups and construction forums.

A total of 28 responses were recorded during the mentioned period, which is argued to be a fair amount considering the time limit and the type of survey, containing some open answers which require more time and reflexion of the respondents.

The professional role of the respondents were: 13 Project managers, 7 Site managers and 14 different others (Researcher, Contracts Manager, Business Manager, Process Consultant, H&S coordinator, Quality inspector, etc.). The sum of the roles is higher than the amount of responses recorded because some of them registered as having more than one role.

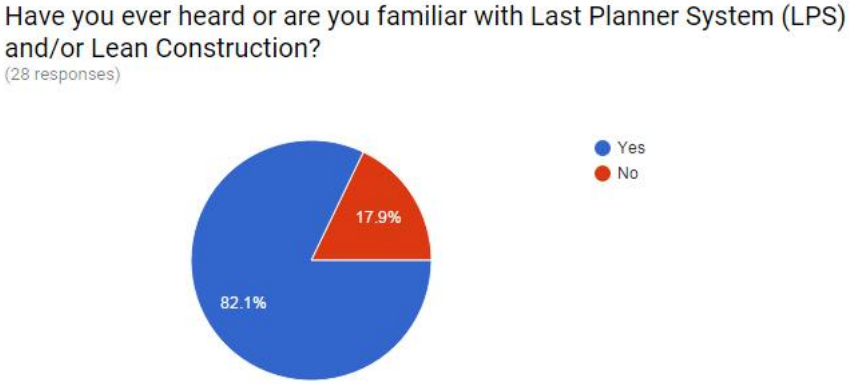


Figure 39: Survey question showing the percentage of respondents familiar and not with LPS

The above figure shows that 82,1% of the respondents are familiar with LPS against 17,9% who are not. These results may be disturbed from the overall construction industry due to the fact that the survey was posted in some groups specifically related to Lean Construction or LPS. This does not give a real heterogenic result but was considered that the answers gathered from those using LPS would be more useful and relevant given the topic of the report.

Figure 40 shows the percentage of respondents familiar with LPS with actually experience applying it, which results in a 60,9% versus 39,1% with no experience. This represents a 50% of the total respondents who use or have used LPS during their professional career in the construction industry.

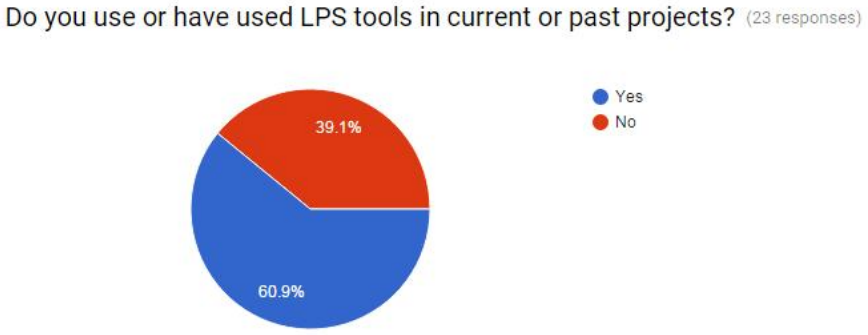


Figure 40: Survey question showing the percentage of LPS usage from those familiar with it

This chapter is structured into subchapters, analysing the responses gathered in each question and comparing it with its respective from the respondents using traditional planning methods, without experience in LPS.

Is important to mention that during the period that the survey was open to answers, eventual modifications were made to the survey, based on external feedback and the quality of responses. That is the reason why some of the recorded answers, restarted after the change and the number do not correspond to the total amount of responses. To have a deeper analysis of the survey and see the original register of responses, see Appendix C. Online Survey responses.

11.1 METHODS AND TOOLS USED BY LPS AND NON-LPS USERS

An essential part of investigating LPS and LBMS tools is the gathering of information on what are the most common used tools, not only from LPS users but also from the traditional non-LPS users. Furthermore, the gathered data is used to analyse the reasons for not using some of the tools, which in theory are known to have a positive impact on the construction process. As shown on Figure 41, it can be clearly identified that some of the tools are not being applied even thought are part of LPS and are considered to be vital part in reducing waste and optimization of processes.

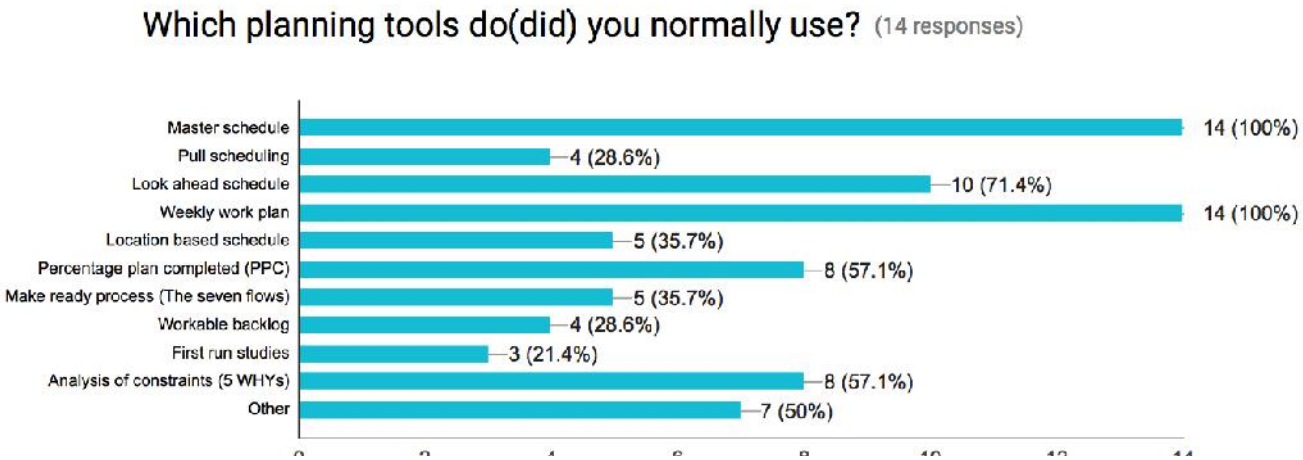


Figure 41: Percentage of use of LPS tools

Starting from the LPS-users where all 14 (100%) of the respondents are using master schedule, WWP, 71,4% of them are using in addition look ahead schedule, followed by PPC and analysis of constraints with 57,1% , it has become clear that LPS users are putting more effort in identifying major road blocks that could occur on the construction site. Their answers on how they are using those systems on the construction sites are mainly in regards to better track the different activities, not only on going but the ones planned 2-3 weeks in advance. Furthermore, based on their answers on how they are using the selected above tools, it is important to mention that they are actually applying a simplified version of MRP. Even though only 35,7% are using the MRP, based on some of the other's respondents elaborative answers, has been concluded that MRP is also applied by them, but in a simplified manner, thus it is not considered by them to be a MRP. However, the process is similar to the Obstacle list in Case Study 1, which detects problems when they happen, ignoring the .preconditions.

In some of the cases where all of the LPS tools are applied, the respondents are using tools like IMPERA to better manage their projects. Furthermore, in one of the answers it was made clear that in order to use all of the tools, they are conducting workshops in order to familiarize the team with Lean principles and the use of LPS. An additional workshop is set for "*trade contractors and site staff to develop both a collaborative Master Schedule, plus the initial 6 week look- ahead and the initial WWP. Once on site, weekly meetings would be held to not only review the previous week's work completed (including reasons why work was not completed as planned, and PPC reports) but also develop the next WWP, including Plan B options"* (Appendix C. Online Survey responses). Any changes required to the overall Master Schedule are also identified during these meetings.

It is argued whether the whole process is too complicated, time consuming and if everyone gets familiar with the use of LPS, thus it is suggested to simplify the current LPS with the help of LBMS with reasonable measures to apply in practice, as described in Chapter 12 Improvements to the system.

In addition, some of the tools as Workable backlog, First Run Studies, Pull scheduling have the lowest use rate 28,6%. However, data related to the Pull scheduling is shown incorrectly, due to the fact that changes were made to the survey in order to improve its quality. Thus, based on the evaluated data, it is argued that the pull scheduling is used by 80% of the people. Nevertheless, the other low rated tools in their standard form are too complicated and time consuming, even being claimed not worth the potential benefits (Appendix C. Online Survey responses). It is clear that the construction professionals prefer short meetings with simplified methods for gathering of information on site. Another reason that those tools are not as widely used as some of the others is based on the fact that professionals do not have enough knowledge about them, thus leading towards resistance to apply and use them.

The non-LPS construction professionals use tools like CPM methods, weekly and monthly meetings in order to keep track of the construction project. Those are the general tools used by non-LPS in 85% of the survey's answers. In some cases, Location Based Scheduling is applied using Excel programme, however it limits the user to a simple schedule without the possibility to adjust work rates, thus updating it becomes burdensome.

Furthermore, additional computer programme that is used by the Non-LPS users is Primavera P6, which helps the team to handle the management aspect of ongoing construction sites. The program helps construction managers to deliver the project faster, with a higher quality on a lower cost. The users can monitor performance and mitigate unexpected risk (Oracle, 2015). A respondent considers Primavera to be a good tool for "Collaborative high performance; teams delivering projects using Lean Construction Principles" (Appendix C. Online Survey responses).

Moreover, it is observed that the professionals using Primavera P6 have a higher PPC rate, from 59% to 79%, while the people using only the above mentioned standard tools have a significantly lower PPC in the range of 49% to 69%.

In regards to the changes made by the users in the application of their methods, it was interesting to see how the wide majority of the respondents using LPS did not make any major changes to the system. Most of the changes are in accordance to the complexity of the tools, thus users prefer to simplify them or ignore some of the burdensome tools. On the other hand, the non-LPS users, as stated in most of the responses, are constantly making changes, which can be counterproductive for resource consumption and waste of time to implement and adapt to the changes.

11.2 BENEFITS AND DOWNSIDES OF THE PLANNING METHODS

In this chapter are analysed the benefits and possible downsides experienced by LPS and non-LPS users. In Figure 42, is shown the percentage of the most common benefits experienced when using LPS from a total register of 14 responses. Thus the most common benefits experienced by 64,3% to 71,4% of the respondents are the following:

- Increases predictability
- Reduces waiting, waste and costs
- Better overall quality of the project
- Better management of conflicting objectives
- Avoids conflict between different trades and contractors.

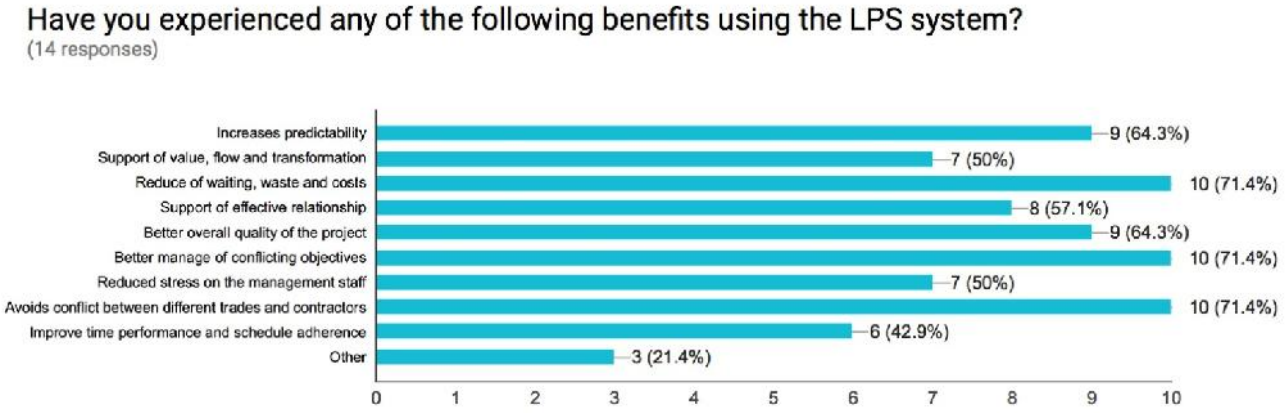


Figure 42: Survey question showing the most common benefits experienced by LPS users

This is confirmed by the high ratio of agreement achieved in the Likert scale (See Appendix C. Online Survey responses). Is important to mention that the benefit "Improves time performance and schedule adherence" was added later in the question and still got 42,9% of the responses. It is argued that if this benefit was included from the beginning, would have reached a ratio over 70% based on the ratio of agreement achieved in the Likert scale, the 7 responses of which are either agree or strongly agree.

In addition, some of the respondents added additional benefits such as *"Faster delivery"* or *"Gives the tools to execute the project to the field superintendent",* which are interrelated to *"Reduced stress in management staff"(*Online Survey responses*).*

Furthermore, the people using traditional planning methods, it has been stated that is difficult to generalize pros and cons because they use different methods and there is a high disparity of computer software used. However, some responses are worth to mention.

From the stated benefits not entirely related to LPS methods, has been recorded that MS Project programmes, are understandable by most of the people. This is reasonable to say because it is true that LB type of schedule may be more difficult to understand but as has been proven before, MS Project programmes do not give as much information as LBS. Moreover, it is mentioned that traditional type of methods reduce stress, which is argued to be referring to onsite staff, since traditional methods relay all the planning responsibility on the Management staff.

From the cons of traditional methods, have been registered the following statements:

1. Unforeseen delays later in the project cannot be avoided, affecting final completions
2. Difficulties to get the team to collaborate together
3. Team members thinking that meetings are too lengthy and useless
4. Difficulties to track the project status
5. Requires very experienced personal
6. Software are not user friendly

The downsides from the statements 2 and 3 can be addressed by adding the Kick-off meeting (presented in Chapter 12.1 Kick-off meeting), in which is intended to get the team in the same page and make everyone understand the management processes, project objectives and the importance of team collaboration.

Statements 1 and 4, are reduced by the application of LBMS as has been argued before and since LPS is a highly collaborative approach, the experience required on management staff, mentioned in the 5th statement, may be reduced.

Again, the analysis of the pros and cons of both methods named by the respondents, has served to confirm the fact that by applying LPS and LBMS, some of the issues from traditional systems can be mitigated or even avoided.

11.3 PPC ANALYSIS

In this subchapter, the PPC experienced by the LPS and non-LPS users is analysed.

In Figure 43, is shown the percentage of different PPC ratios experienced by LPS users. As can be seen, 3 of the 14 respondents registered a PPC ratio lower than 20%. Since the

results are unrealistically low considering the industry averages, was assumed that the question was misunderstood by those respondents. It is believed that these respondents refer to the PPC as being the percentage of activities non completed when planned instead of the nº activities completed as scheduled divided by total nº of scheduled activities, as it was clarified in the question. Therefore, these responses are disregarded.

Nonetheless, a brief analysis of the answers shows how the most common PPC ratio experienced by 42,9% of the respondents is between 70 and 79% which from the literature research is considered to be reasonably high and 64,3% or the respondents experienced PPC ratios over 60%.

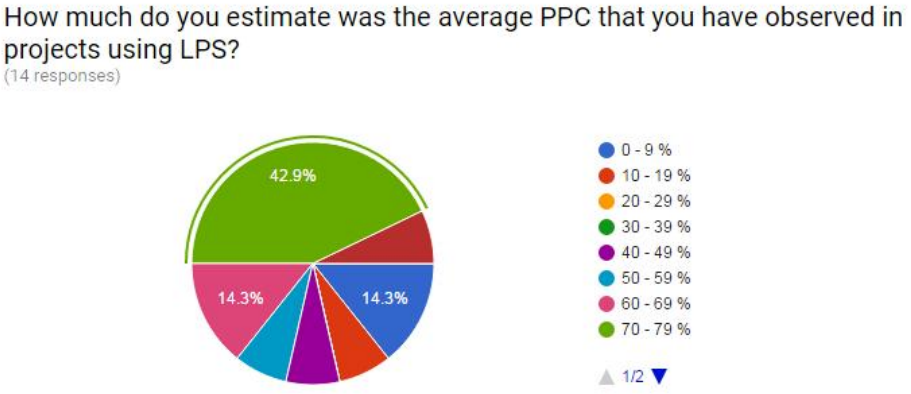


Figure 43: Percentage of PPC ratios experienced by LPS users

In the other hand, in Figure 44 can be seen the percentage of different PPC ratios experienced by non-LPS users. Disregarding as well the unrealistic responses, unlike LPS users, just 21,4% of the respondents using traditional methods experienced PPC ratios over 60%, being a ratio between 50 and 59% the most common with 21,4% of the responses.

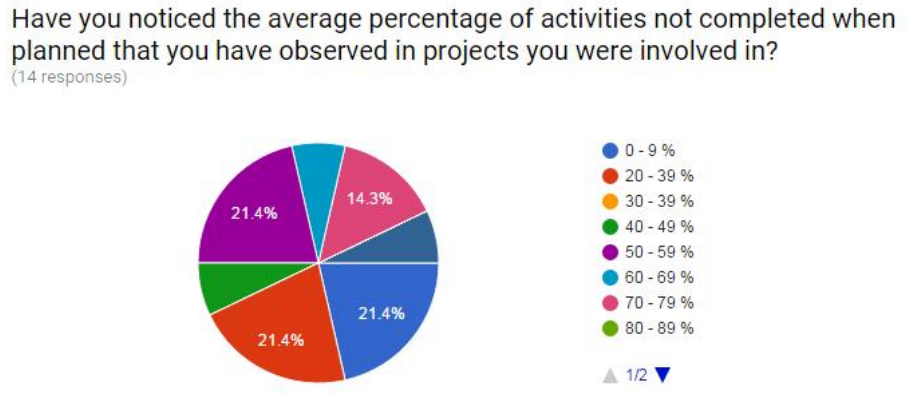


Figure 44: Percentage of PPC ratios experienced by non-LPS users

Even though that a record of 14 responses for each method is not enough to establish a rule, it gives a clear picture to determine that LPS provides higher schedule reliability than traditional planning methods.

11.4 COMMON REASONS FOR DELAYS

After analysis the PPC ratios experienced by LPS and non-LPS users, is worth to mention the most common reason for delays in each case. This question was elaborated giving the option to the respondents to select which of the 7 preconditions presented by Koskela (1992) were missing more frequently and to introduce other common causes leading to delays.

As has been proved, since the PPC ratio is generally higher in projects using LPS than using traditional methods, is obvious that those disturbances happen less frequently when LPS is applied. This can be seen in Figure *45* and Figure 46, which show the most common reasons for delays experienced by the respondents in each case. Of course, this can not be taken as a general rule because it depends on the type of project and the quality of the management.

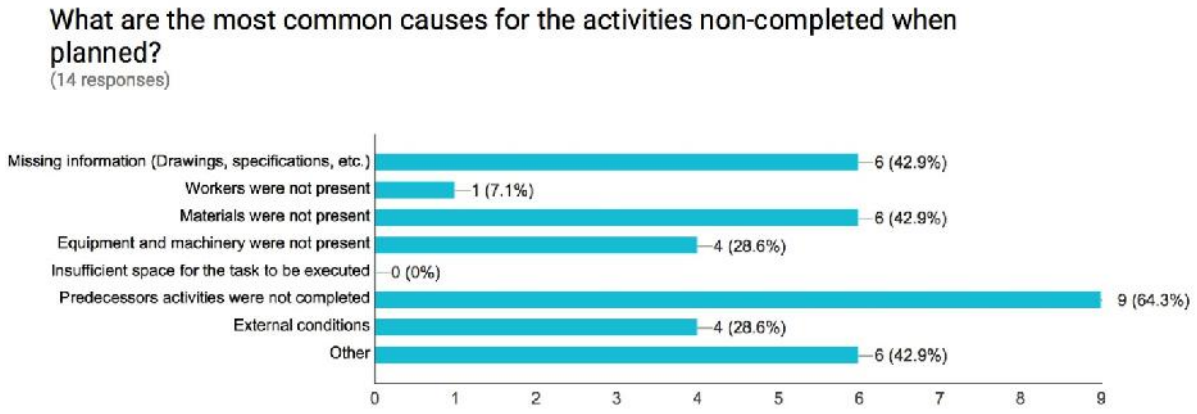


Figure 45*: Common reasons for delays in projects using LPS*

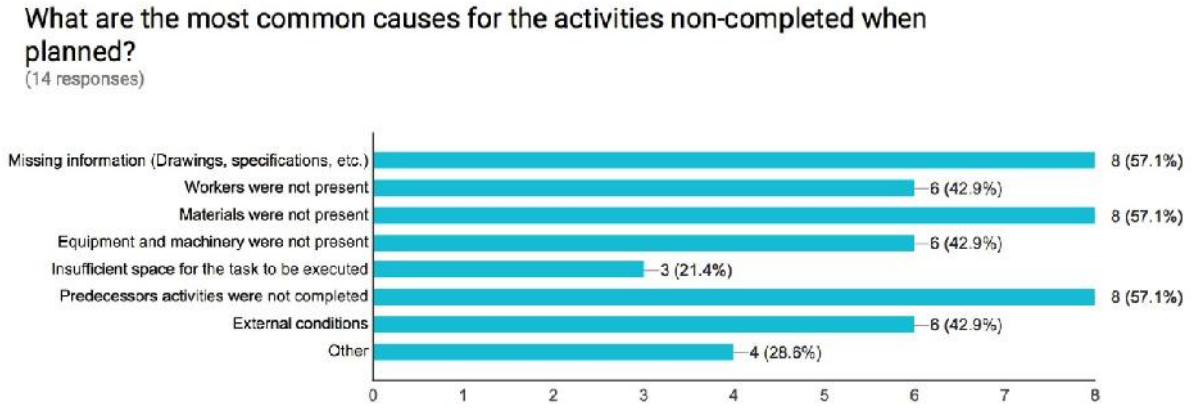


Figure 46: Common reasons for delays in projects using traditional planning methods

Is interesting to mention some of the "Other" reasons registered in both cases such as owner's problems, equipment loss at sea or overestimated productivity of crews. The latest may be in some cases, the cause of "Predecessor activities were not completed" which in the case of LPS users is the most common reasons for delays. Overestimating the productivity of crews may be due to unexperienced management, poor or overoptimistic planning.

Since the LPS's tool MRP is specifically to avoid these issues to happen by ensuring that all the 7 preconditions are met before to start the task, was interesting to see how some of the respondents who used the mentioned tool, still experienced some of these disturbances. This fact could be minimized by introducing the weekly health check proposed by Linhard

and Wandahl (2013) (See Chapter 7.5), to make sure that none of the preconditions has changed before the task is put on schedule.

11.5 BEHAVIOUR OF THE USERS TOWARDS THE SYSTEMS

Even though the construction industry is considered a very conservative and traditional sector, as can be seen in Figure 47 more than 50% of the respondents experienced an open mind-set and collaboration from the people involved in planning towards the use of LPS.

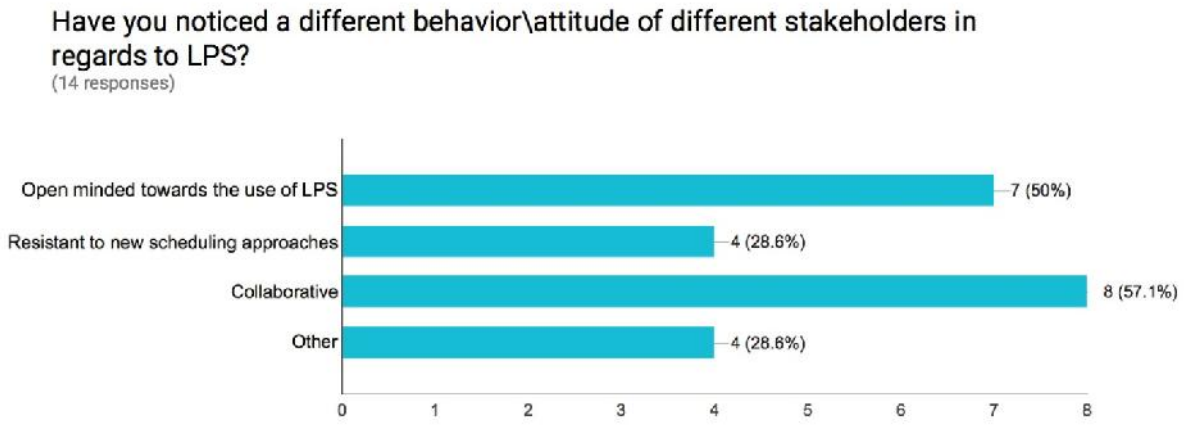


Figure 47: Different behaviours experienced by LPS users

Moreover, in the other hand, from the respondents using traditional methods, when asked whether they would be open to change if they were presented to a different and maybe better planning tool, more than 80% of the respondents answered affirmatively. To quote some of them as examples of opinions:

- *"Yes, it can not get much worse than the chaos that exists right now in the construction industry."*
- *"Absolutely. Results depend on predictability. Any method to improve the latter shall improve the results."*
- *"A big yes. If I don't change and improve an likely to become extinct. Ask the dinosaurs, they wish they had adapted to the changes."*

The question now would be, if there is a common agreement to change to better planning approaches, why they do not do it? Because of lack of knowledge, resources, top management decision, culture differences, industry standards?

12 IMPROVEMENTS TO THE SYSTEM

The Improvements chapter presents the most efficient and optimal solution for using LPS together with LBMS. The system is modified based on the gathered data throughout the questionnaire, interviews and the case studies. The gathered data has served the role of verifying or dismissing the reviewed theoretical application of the system as well as including other sub-application (TrimByg) within the author's suggested system. Furthermore, the theoretical use of the different system tools is tested and evaluated based on their practical use on site, in order to prove their insufficiencies or find alternative ways of using the tools. However, all those modifications of the system have brought a new question to light: where is the boundary between LPS and LBMS becoming something different, have those systems evolved?

12.1 KICK-OFF MEETING

Has been decided to take the presented by MT Højgaard's Kick-off meeting from TrimByg and use it as a tool to further elaborate the importance of LPS together with LBMS. A kick-off is a start-up meeting prior to the construction start where the involved contractors are gathered and informed about the project, the organization at the building site and the schedule (Højgaard, 2010).

The reason for including the kick-off meeting as an additional tool for better management of the project is the fact that it can be used, not only to set the goals of the project, but to highlight the importance of the different tools that can lead to optimization of activities. Furthermore, the meeting can be utilized to ensure contractors' focus to meet their deadlines without experiencing stressful situations, ultimately improving the atmosphere on the construction site.

The kick-off meeting is a good opportunity to energize the different trades working on the construction site, emphasising on establishing common goals as well as better understanding with each other. The kick-off meeting should have a well-structured agenda, starting from the common understanding of the project goals in regards to time, quality, costs, etc; as well as work as a tool for the different subcontractors to get to know each other, establishing team spirit and cooperation.

As mentioned before, the meeting should be well organized where the agenda for the meeting should be sent to participants beforehand. In this way, the participants are aware of the structure of the meeting and the desired outcome. It is important to keep the meeting brief and simple without going into details. The sole purpose of the meeting is to get everyone on the same page.

Once the common goal is agreed and the tone is set for discussion, it is a good idea to talk about project assumptions and how the project plan was developed. It is important to go through the main tasks and discuss the challenges that might come across. Furthermore, when talking about the activities and milestones, it is possible for the contractors to come up with better ideas, thus leading to optimization of the schedule. During this stage of the meeting, it is necessary to emphasis on the fact that the schedule is still in initial phase and any suggestion are welcome. Moreover, in this way the project manager is able to identify any bottlenecks or difficult tasks during the construction process (Højgaard, 2010).

During the kick-off meeting, it is essential to decide on convenient and regular meetings for the participants in order to discuss the progress of the project. Furthermore, a communication plan has to be developed and agreed by all the contractors. Thus, it is essential for the project leader to introduce LPS and LBMS and the different tools that can be used to optimize the communication between parties, as well as to optimize the construction activities. Moreover, it is important for the project manager to highlight the importance of using the different tools, clearly defining the benefits for all parties involved. Furthermore, the project leader should make it clear that using those tools will help them identify problems before their actual occurrence, thus helping them to manage resources in a better manner.

The meeting should end with an open Questions and Answers seasons, where the different contractors are able to freely express themselves. Furthermore, if the time is not enough, make sure that the contractors can reach the project manager via email to ask any question they may have. Before the end of the meeting, it is recommended to briefly summarize the discussion and the necessary steps to be taken.

An agenda for the kick-off meeting is proposed (based on MT Højgaard):

- Introduction to contractors (stakeholders)
- Understanding of project's information and requirements
- Goals of the project (time, quality, economy, etc.)
- Expectations for collaboration, success criteria and how to get there
- General Discussion about Lean Principle
- Introduction to LPS and LBMS
- Scheduling and Communication Planning
- Process planning for specific periods during the construction time
- Q&A

To conclude, the purpose of the meeting is to develop teamwork, assign responsibilities as well as nurture collaboration between the members. Furthermore, the meeting is a good opportunity to introduce new methods for managing construction activities as well as to bond the team.

12.2 MAKE READY PROCESS

In this chapter, a modification of the MRP presented in Chapter 7.5, is proposed after some insights acquired through the elaboration of the case study 1.

The proposed modification consists in a collaborative checking process in which the project manager elaborates a form to be handed in to each trade with all the activities that they need to perform, the planned start date for each of them and a list with the 7 preconditions to be checked, as shown in the following figure.

Make Ready (Trade)											Company:		(Company's logo)
Project:											Contracts manager:		
Phase:											Prepared by:		
Area:											Date prepared:		
ref.	Task description	Program start date	Preconditions Check List								Notes		
			Information	Materials	Labour	Equipment	Space	Pre task	Weather	Can do			
1													
2													
3													
4													

Figure 48: Make Ready Process template

The idea behind this proposal is to help the trades to prepare for the execution of their activities and detect any missing requirement to be shouted out in the weekly meeting and find a solution before the start date, making sure that all the activities are ready for execution when needed.

The “Can do” check box from the template shown in Figure 48, will act as the workable backlog mentioned in chapter 7.5 and a box for notes is left for the trades to write comments or other constraints that may arise.

With this initiative, the time will not be wasted in the meetings asking the trades if they meet the preconditions for the execution of their tasks and still the reliability of the program is increased.

12.3 PPC APPROACH

Based on the gathered data from the questionnaire as well as the case studies, it was found necessary to simplify the use of the PPC. As already mentioned in Chapter 7.7 Percent plan complete (PPC), all the different trades are supposed to agree on the accomplishment of tasks, leading to time consumption and unrealistic PPC tracking of the different trades.

It is argued that the use of LBMS eliminates the need of percentages within the PPC, thus allowing the contractors to enter simplified data. With the use of LBS, it is redundant to follow an exact percentage of completion due to the fact that the system allows forecasting of the different activities. Thus, allowing the project/site manager to adjust construction rates for activities and have a better overview of when an activity is going to finish, even months in advance.

The simplified method consist on a LBS covering two weeks of work for each individual contractor, which are placed in the relevant areas for all the trades to see. If there are not so many trades involved, a single schedule containing all the trades can be used.

With the detailed definition of locations and the representation of the days of the week, a grid is formed representing the exact location where a trade needs to work a given day of the week (See Figure 49). At the end of the day, if a trade finish the scheduled task for that day, the completion is registered with a checkmark in the corresponding square of the schedule or if any delay occur, there is enough space to describe it. In this way, the unrealistic percent of completion given by the different trades is avoided and the project/site manager has a

quicker way to check the project status just by checking the LBS sheets of each trade for the check marks of completed activities.

It is important to emphasis that in this way the contractors do not have any additional documents to do themselves and the check mark method provides a simple and informative PPC to the project/site manager, easing the gathering of clear and correct data.

Has been analysed the possibility for the contractors to enter percentages within the table, allowing the process manager to get better insides on the current progress of the project. However, it became obvious that the same issues of unrealistic and confusing data can occur and again, with the forecasting tool of LBMS it losses sense to keep a so detailed track of the PPC, thus the reason why was decided to simplify the process.

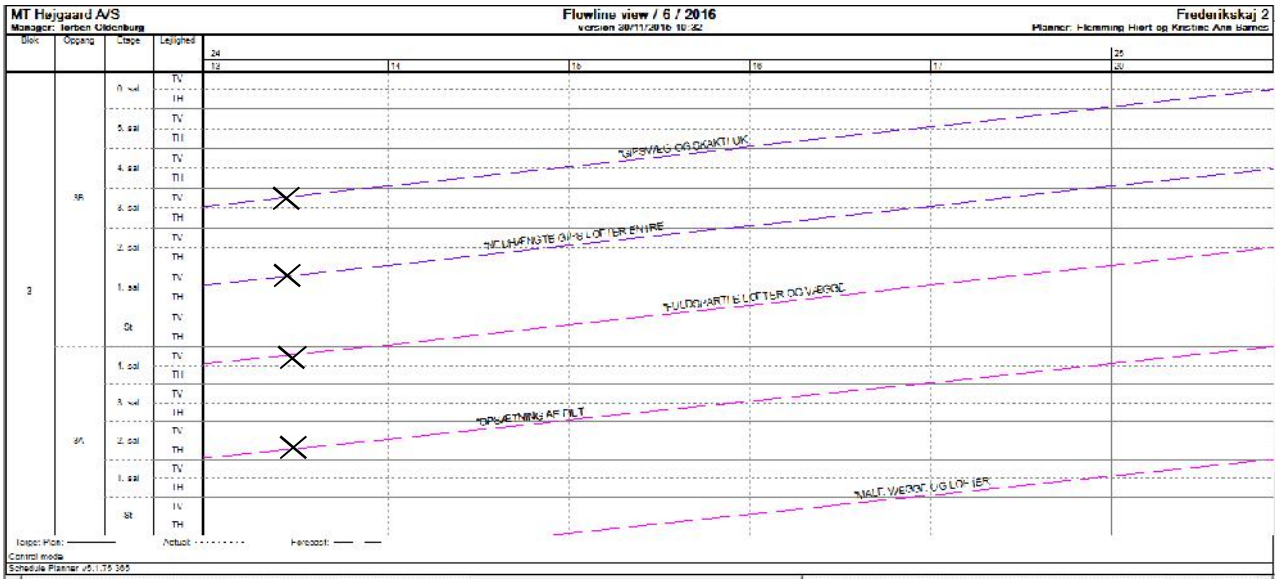


Figure 49: LBS week 24 – Block 3 with marks showing the work done on Monday 13/06/2016

12.4 TRACKING VARIANCES

For the tracking of variances, after observing the obstacle list used in case 1 for the MRP, an addition to the tracking of variances procedure is suggested, to have a more rigorous and recorded analysis of constraints.

The improvement consist on a template performed with excel as shown in Figure 50 to be fulfilled with:

- A register of problems observed
- The affected trade
- The responsible person
- A check of the missing precondition which caused the problem
- “Others” in case that something exceptional occurred
- Clarifications if needed

Register of variances				Company:								(Company's logo)
Project:				Contracts manager:								
Phase:				Prepared by:								
Area:				Time period:								
ref.	Problem desciption	Afected trade	Responsable person	Reason								Notes
				Information	Materials	Labour	Equipment	Space	Pre task	Weather	Other	
1												
2												
3												
4												

Figure 50: Register of variances template

In this way, all the problems occurred, their reasons and the potential responsible are registered to keep a record of the project's deviations. Furthermore, by ordering the column of "Responsible person" alphabetically, can easily be identified who is causing most delays and address it in some way.

In addition, if the problem occurred onsite, a picture can be taken and saved in a company's server folder with the reference number of the problem noted in the register of variances, to show it in case of complains or future clarifications.

Besides that, is recommendable to draw in a blackboard at the meeting room, a Pareto chart as presented in Chapter 7.8, with all the identified reasons of deviations for all the trades to see and be more careful with them, especially the most frequent. Furthermore, the use of Pareto chart in a meeting room's board enhances collaboration between contractors, not only helping them to identify the most common causes for delays of the project, but also to further think of possible ways to prevent those mistakes from happening again.

12.5 LBMS

The report introduces the use of other software (VICO, Naviswork) in order to optimize the effectiveness of the combined system (LPS and LBMS). According to the author's investigations of the above mentioned computer programmes, it is possible to connect the combined system with 4D and 5D for further improvements of the newly presented system.

In this project, has been described the elaboration of the LBS (having as a base just a 3D model) through planning meetings, in collaboration with the subcontractors following the LPS methodology. However, has been considered that the most optimal and precise solution to elaborate a LBS is through a 4D model which also can be used with additional software features to bring more benefits to production control and project collaboration. This is due to the fact that a 4D model provides the quantities and dividing these quantities into locations and multiplying them by the production rate of each trade, a very precise and realistic LBS can be created, thus following the sequence shown below:

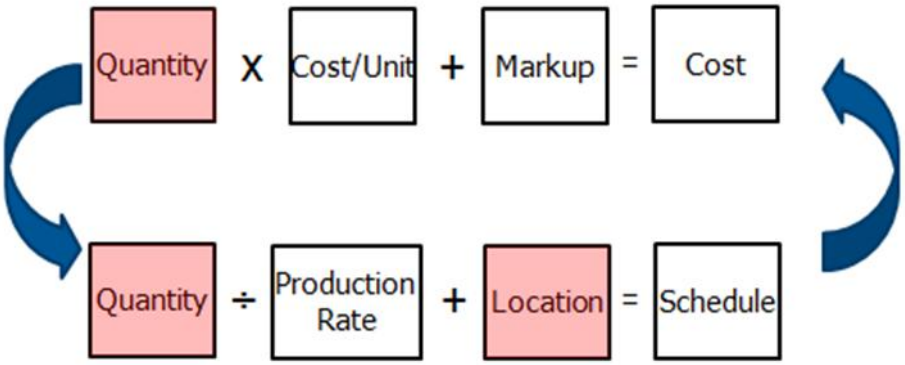


Figure 51: Sequence of Schedule and Cost estimation elaboration (VICO, 2015)

As it can be seen in the Figure 51, the sequence also describes how by multiplying the quantities per Cost/Unit and adding the mark-up, can be taken a precise estimation of costs, which constitutes a 5D model. Thus, allowing user to have a better control over costs, time and quality of the project. Furthermore, the LBS is further improved and can help to control the process with the use of different LPS tools. This can be done through software features called Take-off Manager and Cost Planner (VICO, 2015).

Determine project's locations for the location based quantities take-off, which as seen in Figure 51, is the starting point for the location-based cost and schedule planning. The schedule and cost planner modules, use quantities per location to calculate labour, material and equipment amounts and subsequently for determining number of work hours per location (VICO, 2015).

The goal of the Location Breakdown Structure is to determine the most optimal sequence for each trade, avoiding overlapping of activities and to achieve a continuous workflow without breaks. The optimal sequence can be applied with Schedule Planner, which uses the flowline theory as a key differentiator.

Since the 4D model provides very precise quantities estimation and together with information of resource availability and production ratios, a very precise and detailed schedule can be elaborated. Therefore, the time spent in planning during phase scheduling meetings and weekly meetings is greatly shorten to a casual conversation using the schedule as the meeting's agenda, to discuss the project progress, the requirements and method statement of each activity.

12.6 CHANGE MANAGEMENT

Change the traditional planning methods by the system presented in this report may imply an improvement to the construction process, resulting in benefits for the organization but only if it is done right. Many organizations fail when applying process or organizational changes, therefore is important to state a successful way to implement the suggested system.

Kotter (2006) suggest that many change initiatives fail because the managers do not realize that transformation is a process not an event and that makes them commit critical mistakes.

"Leaders who successfully transform businesses do eight things right (and they do them in the right order)." (Kotter, 2006)

For giving a transformation initiative the best chance to succeed, Kotter suggest an 8 steps process with actions to be followed in each of them, which are based on avoiding the most common mistakes. These 8 steps are the following:

1. *Establish a sense of urgency*
   - *Examine market and competitive realities for potential crises and untapped opportunities.*
   - *Convince at least 75% of your managers that the status quo is more dangerous than the unknown.*
2. *Form a powerful guiding coalition*
   - *Assemble a group with shared commitment and enough power to lead the change effort.*
   - *Encourage them to work as a team outside the normal hierarchy.*
3. *Create a vision*
   - *Create a vision to direct the change effort.*
   - *Develop strategies for realizing that vision.*
4. *Communicate the vision*
   - *Use every vehicle possible to communicate the new vision and strategies for achieving it.*
   - *Teach new behaviours by the example of the guiding coalition.*
5. *Empower others to act on the vision*
   - *Remove or alter systems or structures undermining the vision.*
   - *Encourage risk taking and non-traditional ideas, activities, and actions.*
6. *Plan for and create short-term wins*
   - *Define and engineer visible performance improvements.*
   - *Recognize and reward employees contributing to those improvements.*
7. *Consolidate improvements and produce more change*
   - *Use increased credibility from early wins to change systems, structures, and policies undermining the vision.*
   - *Hire, promote, and develop employees who can implement the vision.*
   - *Reinvigorate the change process with new projects and change agents.*
8. *Institutionalize new approaches*
   - *Articulate connections between new behaviours and corporate success.*
   - *Create leadership development and succession plans consistent with the new approach.*

(Kotter, 2006, p. 3)

The importance of change, as argued by some of the survey respondents, leads on the fact that no organization survives if it is not capable to adapt to the ever-changing market environment. In addition, Kotter argues that the lesson to learn from some of the cases that succeeded when implementing a change is that the process goes through a series of phases relatively long and that skipping steps just gives the illusion of fastening the process but does not lead to a successful outcome. Another lesson to be learnt is that critical mistakes, in any of the mentioned phases, can greatly influence the result. These facts is what makes the task of guiding a change absolutely essential and difficult at the same time, becoming the ultimate test of any leader

(Kotter, 2006).

13 CONCLUSION

The initial observations revealed some issues in the current production control systems. The productivity of construction sites in Denmark has increased by just 10% in the last 50 years. It has been reported that LPS and LBMS have a positive effect on schedule reliability and control. By combining the two tools, the effect can be highly beneficial for the construction industry, however the research available is limited in this matter.

The literature review of LPS and LBMS highlighted the need for a guideline on how to apply both methods and combine them together. An important fact to mention is that most of the existing research and theories about LPS are very positive in regards to the efficiency, focusing on the fact that it can increase construction rates drastically; it does not however explore the human factor involved. Chapter 7 (Application of the combine system) presents a theoretical step by step guide on how to successfully apply LBMS with LPS.

In order to emphasize the divergences between theory and practice, the research presents two case studies where the LPS and LBMS tools used are analysed and compared with the theoretical approach.

The first case study confirmed the fact that some of the LPS tools are too complicated and unrealistic to follow, creating even more confusion on site without any significant improvement.

- PPC for instance requires much time to gather all the information from different contractors. Moreover, the PPC rate can be altered if the contractors consider a number of tasks as one, creating an imprecise rate, leading to a misleading and unrealistic PPC ratio. The alternative chosen by the project manager consists in a simple chart created in VICO to visualize the completed tasks and the ones that require attention. The new process greatly reduces the time of gathering data.
- The MRP is not used in the selected case study due to the fact that the process is too burdensome and disregards the communication between different parties.
- The First Run Studies is another tool that the project manager chose to ignore in this case study. Because the project is not too complex, the tool would simply spend the time of different contractors. The root of a problem is discussed at the weekly meeting.

Frederikskaj 2 case study serves as a great example to show how different tools can be adjusted and modified in order for the involved parties to apply it properly.

It is clear that the construction process in its traditional form is a complex and unpredictable industry with many variables; therefore, applying even more complexity throughout different tools for optimization is meaningless. Arguing on the complexity of LPS methods, a new version of the system in conjunction with LBMS is presented, which can effectively navigate the construction processes without creating unnecessary confusion on the construction site, ensuring a sound and robust process.

Because of the limited time frame, the new system has not been tested, but it is argued that based on the simplifications and adjustments according to the gather feedback, it will have a positive impact on the construction processes.

In the second case study (Musikhus Kvarteret) a more traditional construction method was applied. When the method has been analysed it surfaced the delayed work and the miscommunications between parties. It is arguable that every construction site has its own issues, not only because of the tools that are being applied, but also based on the project management team and their experience. However, these two case studies were chosen because of their similarities of the projects, in order to see a clear difference in the way tools are being applied and the outcome of it.

The construction process in case study 2 can be significantly improved by the use of LBMS and LPS.

- By using the LBMS system, the time schedule can be reduced by a staggering 6 weeks.
- The optimization of the schedule is not done in the phase scheduling and therefore the waste is not reduced to a minimum and the productivity ratio is not kept high.
- As Thomas Clayton (H&S coordinator) has mentioned, the miscommunication between parties could be improved by the use of procedures like Make-Ready process and Tracking variances.

The fact that A. Enggaard A/S should change the management style from the traditional method remains to be disputed because at the end of the day, everything is about making money and A. Enggaard A/S current income is much higher than MTHøjgaard A/S which uses the LBMS combined with LPS.

In order to see how the construction companies currently plan and control the project, a survey has been created and sent to different project managers, site managers and other working on construction sites. During the period of 22/10/2015 and 30/11/2015, a total of 28 responses were recorded. The gathered data from the case studies is supported by the answers from the questionnaire, where most of the theoretical LPS tools are perceived as too complicated and unrealistic, leading to the suggested modifications presented in Chapter 12 (Improvements to the system). The improvements consist of:

- The addition of a kick-off meeting
- A more collaborative Make Ready Process
- A simplified PPC approach
- A more detailed and transparent Tracking of Variances
- Connect the combined system with 4D and 5D for further improvements
- The openness to change by following Kotter's 8 steps in change management

It is argued whether the proposed new system has become something different from LPS, however it is clear that the foundations of the new system are based on Lean Principles and can be even further improved with the proper connection of LBMS with 4D and 5D design, thus serving as a control frame for the alternative version of LPS.

14 DISCUSSION

The chapter presents future possibilities for improving the proposed system, the link between BIM, LBMS and LPS, highlighting their common goal to reduce waste. The reasons for introducing the previously mentioned link is due to the close relationship of the 3 systems, where their common goal is to reduce waste. Before further investigating the topic, it is vital to test the already proposed version of LPS and LBMS in order to see any possible flows the system might have. Only then, it is possible to further investigate and improve upon the new version of the system.

According to Epstein (2012), BIM is the process of creation and management of a building model, which contains information during the development of the project. Within its core, BIM uses intelligent 3D model, where users can interact with the model in 3 dimensional vies as well as 2 dimensional (drawings). Furthermore, BIM plays the role of a collaboration process where engineers, owners, contractors and architects can oversee and adjust the construction process. The information stored in the 3D model could be energy, time, cost, schedules, etc. Once all those criteria are placed in the 3D model, the user has better control over them.

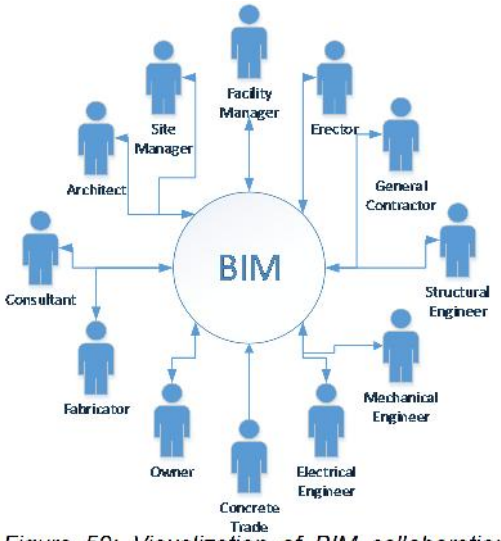


Figure 52: Visualization of BIM collaboration (inspired by © www.tekla.com)

It is important to explain the difference between BIM and Virtual Design and Construction (VDC). Moreover, it is necessary to analyse the connection both systems have to Lean Construction, narrowing it down to the Location Based Scheduling.

According to different sources VDC involves BIM, however it adds even more tools to build, to simulate and bring to life a project, setting not only 3D model of the project but including time and economy (4D and 5D) (Edilizia, 2015). According to Chris France (2013) VDC is a term used by the contractors to virtually create the building before it is actually built on-site. Moreover, France argues that VDC is not the same as BIM, due to the reason that BIM primarily focuses on design and creating drawings as their product. Furthermore, BIM does not generally address methods and means in regards to safety, logistics, inventory, schedules and manufacturing, however the VDC does (France, 2013).

The main difference between BIM and VDC comes from the fact that VDC optimizes the entire lifecycle of the project with the technology, processes and the people to support it, while BIM is only optimizing the sub-processes (France, 2013). To clarify, VDC utilizes the BIM model in order to visualize, plan and organize both construction and design activities in order to reduce cost and time, while maximizing value, sustainability and quality (Luth, 2013).

According to Leite and Hamdi (2012), the BIM aspect, enhances the Lean construction principles such as reduction of variability, validation and verification of alternative solutions as well as decisions by consensus. Furthermore, a well-developed technology on site meetings, is able to show the latest BIM model for the last minute coordination of activities,

drawings, etc. Thus, this level of visualization helps to achieve a learning process of work, due to its high level of involvement and communication within the project.

Different case studies suggest that BIM is considered a supporting tool for Lean; however, there are mutual interactions between the two approaches (France, 2013). Furthermore, Hamdi and Leite (2012) suggest that the Lean construction implementation involves 3 main components (Figure 53). The idea behind those 3 principles is the collaboration in design and construction, optimization of the whole project and system as well as involvement of the end users area, all facilitated by the use of VDC.

In addition, Philosophy and Culture have high element of synergy between VDC and Lean. Thus, Lean Construction method promotes an early involvement of all members and contractors in all aspects of the project, which is also the VDC goal. However, VDC can also support Lean Implementation as well as sustaining Lean principles throughout the project, due to its powerful technology. Both the VDC and Lean approach can be carried out independently and in order to reach a higher potential, it is necessary to collide the 3 approaches shown on Figure 53, ultimately creating a greater potential to sustain VDC and Lean on a greater performance level of the project (Leite, 2012).

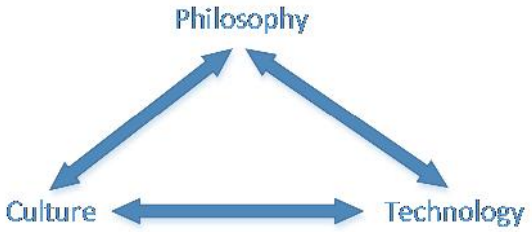


Figure 53: Collision between Culture, Technology and Philosophy (Leite, 2012)

Even though Location Based Scheduling has been used for decades and is a planning tool that can be used on its own, for optimal solutions is best to be considered together with VDC (VICO, 2015).

Because of the time limitations to research the synergy between VDC and LPS was decided to focus on LPS combined with LBS, having a better narrowed down perspective within the construction industry. However, other possible alternatives that can be applied in order to enhance the construction process are searched. Thus, the chapter serves as foundations for further research to the already developed system. Furthermore, some of the possible tools were investigated in order to create synergy between LPS, LBMS and BIM/VDC; although is important to mention that the possible effects the following presented tools might have on the new alternative version of LPS and LBMS have not been investigated.

14.1 Additional BIM tools

As already mentioned, VDC and BIM can refine the process of extracting, analysing and generating accurate model data, which ultimately enhances the different processes starting from the design of the project, up to the handing over and maintenance of the building. Some of the tools that can be used with 4D and 5D models are:

- **Take-off Manager**

The Take-Off Manager allows the user to quickly generate highly accurate information model, thus it is possible to quickly extract quantity take-offs from the 3D models. The Take-Off Manager scans the 3D models in order to create the take-off of quantities, thus providing additional information for the creation of the construction schedule and cost of the project. By

simply highlighting a 3D element, it becomes possible to review the linked data. Furthermore, the tool lets you manage and filter the model based quantities, organize the quantities take-off the way you want and generate reports (Autodesk, 2015). Thus, allowing the user to have a detailed LBS, with more knowledge in regards to quantities and the relevant time it will take to finish an activity. Moreover, this process would allow for better management in regards to the Make-Ready process, due to the fact that the activities that have to be performed in the next weeks will have more data stored in them, allowing the construction professional to take an information decision.

- **Cost Planner**

The Cost Planner (CP) tool provides the user the possibility to build a "living cost" estimation, allowing to make information driven decisions and keep your budget on track. Furthermore, CP enables continued cost feedback throughout the different phases of the project. The cost analyses are based on the quantities of materials, as well as the considered rate of work that will be performed on the site. The BIM model is simultaneously linked to the cost plan in order to easily visualize cost and budget of the project (Autodesk, 2015). Thus allowing the process or site manager to have a better overview not only on the time frame of the project, but also on how the project is developing according to the agreed budget. It is suggested to test the tool together with the LPS's tracking of variances tool for further investigating the occurrence of problems.

- **Production Controller**

The report presents the LBS as a tool to plan and optimize the construction process; however, it is necessary to manage the same schedule on-site. The Production Controller tool from programmes like VICO or Naviswork, provide better control over the project. The tool provides an easy to use table with color-coded feedback about the project progress, thus helping to identify problems on the schedule. The tool is actually used by Krisitine, as shown in Case Study 1.

Another of the benefits of using 4D and 5D models is that it is possible for the general contractor and subcontractors to visualize a virtual simulation of the construction process, following the previously elaborated LBS. This can be used to analyse the schedule and identify possible sequence problems or find suggestions to optimize it even more.

All the above-mentioned tools can enhance the coordination and management of data, not only for the individual trades but also in regards to collaboration between different contractors or stakeholders.

14.2 SUGGESTIONS FOR FURTHER RESEARCH

As previously discussed in this chapter, creating a 5D model (time + money) with accurate data, provides the user with better understanding of the different processes, better control over them as well as increases communication efficiency between the involved parties. Moreover, it simplifies the process of LBMS and LPS, allowing the user to navigate and control the project efficiently, increasing communication between parties, ultimately leading to the successful completion of the project. However, it is important to emphasis on the fact that the above-mentioned tools have not been deeply investigated; therefore, it is suggested to continue testing the tools together with the newly presented system.

It is important to mention that any of these changes to technology or methods needs to be addressed considering the Leavitt model and to ensure the successful implementation of the project, it is advised the use of Kotter's 8 steps for the successful organizational change and implementation of the new system. In regards to this, further research could be used to study the differences of change management to be applied considering the culture's divergences from the two companies presented on the case studies of this report.

In addition to that, it could be studied the relation between the economy of these two companies with the management processes used on their projects. This is suggested after realizing of the decreasing revenue of MT Højgaard the latest years compared to the growth of A. Engaard (See Chapter 10 Introduction to Case Studies) having in mind that MT Højgaard is actually using a similar system to the one presented on this report, which is supposed to enhance the performance of their activities.

TABLE OF FIGURES

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AALBORG UNIVERSITET
STUDENTERRAPPORT

APPENDIXES

A. TRANSCRIPT OF INTERVIEW WITH KRISTINE ANN BARNES

A: Kristine

B: Group 8

B: Actually all the trades, parthning trades are part from MT højgaard or are different subcontractors ?

A: Concrete is ours, dirt is ours and electrical work is ours, but the plumbing is someone else, external. and the carpenters are ours. Everything else is external. So at this phase is pretty much ourselves right now. And we have a joint venture, economy, so everything we cost money, all of us pay. We didn't do it before, each department was on its responsibility, but now we do it together. On constructions like this is much better.

A: So this is, I prefer to make it short, so if they start talking about something that doesn't concern anyone else on the meeting, I say Ok can you continue somewhere else, because we need to go through all the staff

B: Yes

A: I haven't made this, how do you say it... Someone else says oh we need to talk about this time schedule, we need to talk about this look ahead schedule, we need to talk about the quality

B: Agenda?

A: Yes, Agenda and I follow it. So on every agenda I take the 5 weeks look ahead and I ask are we ready to make the activities that have to be performed next. .... and for example, we are behind schedule on the pipe drawings and now i am trying to get them so we can continue with the project, otherwise we are on hold.

A: It is our own sewerage project and we have to do it as soon as possible. So they have to look at this and finish it. it is our own trade that has to provide the drawings, so we need to sit down and ask for it.

B: are those the 7 preconditions (pointing at filled obstacle list) ?

A: the documents refers to who didnt do his job, it could be the architect, it could be the construction engineer and electrician, plumbing engineer or it could be me the byggeledelse. or it could be the developers. So I am asking now V and E to pull themselves together and come with the final project.

B: for example if the reason for delays is the weather, it is raining and you cannot continue the work, do you put it somewhere?

A: No, not in this file, we put in the minutes.

B: This document is only for big, complex project, if I do not get the drawings, so this is what we need to put inside.

A: As you can see on this paper (Location based scheduling with percentage of completed work) we have some activities that need to be addressed and I sent the agenda and schedule to everyone, so we are all aware of the progress of the project.

B: So you sent those files to everyone

A: Yes

B: You are using LPS, you are using the LPS, however it seems like you are not using all the tools that are.

B: According to theory you have 6 weeks scheduling and MRP. Do you actually calculate the percent plant completed from the activites that are finished?

A: that is PPU

B: Yes, that is in danish

A: this is kinda the same(referring to the LBS with the percentage of completed tasks). This is how many percentage is done, however it does not say how many percentage did i do, compared to what I had. You know, I have been process consultant since 2001 and I have been working together with some other guys on the lean principles and I know all of this theoretical staff. But sometimes it is nice to hear what people like have to say and ask about the different tools.

A: You say PPU, I do not use it anymore, because it is too heavy to do, it was to tiring, but this is maybe a new way of doing it. (referred to the same LBS percent completion of tasks) At least I did this on a very big construction site Nordea, its one 1 billion kr, and it is pretty big and what i learned from is that the dirt and sewage they work very close together, much closer than I have expected. so you can see, even when they are working on the different blocks A and B they are very close. A and B modules are not very big, and that is why i though when they are done here (points on the LBS) they can start with the 3 module. But know I know they are even closer than what i thought, but for a longer period of time, so next time i will know that they will take longer time but actually closer and they will be done at the same time.

B: but they could not, I mean when you did the phase and scheduling meetings with the trades, they couldn't foresee how long it will take for them to complete the tasks.

A: Yes, but on this project we had issues with pollution, its not just polluted, it is almost anything.

B: So that is what caused most of the delays

A: mostly it is because our own engineer is busy and they need to give us the project. so instead of starting the next day we had to wait 3 weeks and we started here (LBS). so it is annoying just because we didnt have the drawings, we have to wait and thats how it is.

B: So before the start of the project the engineer was not avaible and he could not do any ground study, geothecnical studies.

A: No, we did, but they just didn't do it right and we have to wait.

B: I am curious to know, it seems like you are doing quite a lot of quality control with the use of Location Based Scheduling, but do you use it as a tool to support your Lean kinda principles

A: Yes, I do

B: and then you just you overview those 7 preconditions

A: Yes, that is why i stopped being a process consultant, because i wanted to see how good these method is on real life projects. One thing is in theory and one thing is in practice and i am trying to look ahead on this project. However if i take 5 weeks ahead planning on the meetings it just gets too wide and that is why I use 2 week planning.

B: what is your experience in practice using LBS

A: I am so happy, you cannot imagine. Especially when our planning for example the bricklayer, i want him to start the minute after a section is selected. (referring to the LBS in the meeting room)

A: I have no chance to see all the activities especially in this case using the traditional master schedule, while now I can see what can it be done, and see where we have waste of resources and we can optimize the time. I woudnt see a lot of things in MS project.

A: I have a better overview on the processes and can tell them with this rate you wont finish on time. Even today on the meeting because I have mentioned some time issues the concrete guys will have to work extra. And that is my main job, looking into time and speed, making sure that we are finishin on time. I am also trying to look further in the schedule.

A: I have an exaple from Nordea project , where we have divided the project into 8 blocks, I told them there is going to be a problem in area 5 -6 you will not finish on time. Their answer was that they will finish on time. I told them the speed you are in right now, you will finish 4 weeks too late. I showed him what would happened , and then he took more man to work on the tasks and managed to deliver on time. I told him this 7 months before the actual finish of the task. This allowed me to have the flexibility to adjust the speed and the resources and make it on time. I am very pleased from the outcome.

B: Do you experience any challenges in regards to applying your method to the other trades?

A: yes many, for example the guy from the meeting today, responsible for concrete works, he is very old fashioned, but he is very smart and always delivers on time. However, I saw him recently using a ruler on my schedules, and I was really surprised to see that even him has accepted to some extend this new method, even though he does not want to admit it. He will maybe learn it one day, but he is so old school.

B: the question here is should you change for everyone, if he delivers in time and he is good is there a point ?

A: No, as long as they go according to plan and are flexible it is fine with the tools they are using. I wont change him.

B: do you think everyone have the knowledge from other trades to check for all the preconditions

A: I wish they did it the way you did.

A: once we have build the staircases on the buildings, I will let the plumber guys or someone else, I will put a week LBS planning in the building so they will make a follow up each time they work on the site, and I will have a better overview of how the process is going, without requiring to educate them in something knew. If I can make the workers to make a cross on the shcedule, meaning i was here, i was here.

B: Actually this is the same area, so maybe they will need to know how much of work they did. because maybe at the of the week they would have done 50%, but it is about here, the middle of the line.

A: Showing on the LBS, if this was activity and this locations going for 5 days in this apartment, he can go and cross this, and will know that he will be done in 13th of November. He will be aware that he will have to be done and he can see that he is behind and can work extra to finish on time. Once he is done the next one can come in.

A: Using LBS it is easy to see, when you are behind schdule and you know where exactly you have to focus, but you cant get this overview from MS project. Maybe using this method and giving them precise details on how many apartments they will have to finish per day will be stressful for them, but I am really curious to see how it will works. You know at the end of the day, if this works they will make money. They will be able to work on there own without someone else disturbing them.

B: and they all of them understand how the LBS will work

A: I dont know, i havent met them yet, but we will show them once we meet and we will have a small introduction meeting.

B: We have found a lot of project where LPS fails, and here it seems you are very positive about those methods and everything is working. Do you have some downside of the tools , are you using all of the tools

A: I dropped PPU, it is not accurate, the subcontractors will always have 100%, which gives me a very unrealistic overview of how things went according to the planning.

B: It can be a very useful tool if it properly used, but it can be easily cheated.

B: Actually if the crosses that you talked about before, that can be considered as PPC, because if this area is considered 100%, you can split the squre in 4 pieces and say that they have crossed 1 of them, that will mean that they have done 25% on the whole tasks, so they are actually tracking their time accurately.

A: Yes, Yes that is correct. I haven’t thought about that.

B: The thing is we are studying all the tools from LPS, just with the LPS on its own. but when you use it LBS they are different. you are kinda using it them, but they are not used the same as LPS alone.

A: Yes you are kinda right.

B: I would like to tell them that they are 70% done, but no they want to know where they have to be done.and there is no activities that are presented.

B: do you have meeting for finding the reasons for delays.

A: yes yes but it is very easy. But now i need to know that I have to keep an eye on the plumber.

B: do you think it is actually a good thing that most of the trades a part of the company and it is easy to see the reasons for delays

A: I do not see there is a difference. Now it is different, we are all together in the same boat, we have the economy, if they are behind schedule, everyone is. The plumber is behind schedule, but I am not scared, He will come and do his job and it will be just fine. I just need to have this helicopter view to know what is going to happen tomorrow.

B: do you think there is a difference on what kind of tools are used, based on the different project complexity

B: so when you are working on another site with a less complex project, are you going to use the same tools

A: I will try to do that , because I have so many example of this method working. I worked with a carpenter and he came to me saying lol amazing I will be working alone, none will be disturbing me. I have one week just for me. The electrician thought it was a little stressful, because he had to do an apartment a day, otherwise he would have been behind schedule.

B: so you think this a such a good controlling tool, that they might be stressed about.

A: Yes, but that is my job to tell them do not be stressed, because you are making money.

....

B: do you make sure that everyone knows the 7 preconditions and have everything on the site so they can perform the task.

A: I wish we did that, but if i ask do you have the materials or resources. They will just look at me and say Yes, but do not ask me that.

B: you suppose that they have all the preconditions ready.

A: yes, because we talk about those meetings. I think it will take too much time for them to perform and check if they can do it or not, but i think they have it in the back of their heads.

B. ONLINE SURVEY QUESTIONS

The Last Planner System (English)

Spørgeskemaet er udført på engelsk, men besvarelserne i kommentarfelterne må gerne udføres på dansk.

We are three M.Sc. students in Management of the Building Industry working in our thesis about "The Last Planner System". Since you are involved into planning and control of construction projects, we would greatly appreciate if you could spend 10 minutes of your time answering this survey. It would be very helpful for the quality of our work. Thanks in advanced.

*Required

1. **What is your professional position in the construction industry?** *
   Tick all that apply.
   - [ ] Project Manager
   - [ ] Site Manager
   - [ ] Logistics Coordinator
   - [ ] Foreman
   - [ ] Trade's supervisor
   - [ ] Health and Safety Coordinator
   - [ ] Other: _____

2. **Have you ever heard or are you familiar with Last Planner System (LPS) and/or Lean Construction?** *
   Mark only one oval.
   - ◯ Yes
   - ◯ No *Skip to question 14.*

3. **Do you use or have used LPS tools in current or past projects?** *
   Mark only one oval.
   - ◯ Yes
   - ◯ No *Skip to question 14.*

4. **Which planning tools do(did) you normally use?** *
Tick all that apply.

- [ ] Master schedule
- [ ] Pull scheduling
- [ ] Look ahead schedule
- [ ] Weekly work plan
- [ ] Location based schedule
- [ ] Percentage plan completed (PPC)
- [ ] Make ready process (The seven flows)
- [ ] Workable backlog
- [ ] First run studies
- [ ] Analysis of constraints (5 WHYs)
- [ ] Other: _____

5. **Please describe in a few words how you use each of the tools selected in the previous question** *

_____

_____

_____

_____

_____

6. **What are the reasons for not using the non-selected tools if any?** *
Go back to the question if necessary

_____

_____

_____

_____

_____

7. **Have you experienced any of the following benefits using the LPS system?** *
Tick all that apply.

- [ ] Increases predictability
- [ ] Support of value, flow and transformation
- [ ] Reduce of waiting, waste and costs
- [ ] Support of effective relationship
- [ ] Better overall quality of the project
- [ ] Better manage of conflicting objectives
- [ ] Reduced stress on the management staff
- [ ] Avoids conflict between different trades and contractors
- [ ] Improve time performance and schedule adherence
- [ ] Other: _____

8. **Scale** *
Mark only one oval per row.

	Disagree Strongly	Disagree	Neutral/neither Agree or Disagree	Agree	Agree Strongly
Increased predictability	◯	◯	◯	◯	◯
Support of value, flow and transformation	◯	◯	◯	◯	◯
Reduce of waiting, waste and costs	◯	◯	◯	◯	◯
Support of effective relationship	◯	◯	◯	◯	◯
Better overall quality of the project	◯	◯	◯	◯	◯
Better manage of conflicting objectives	◯	◯	◯	◯	◯
Reduced stress	◯	◯	◯	◯	◯
Avoids conflict between different trades and contractors	◯	◯	◯	◯	◯
Improve time performance and schedule adherence	◯	◯	◯	◯	◯

9. **Did you make any improvements or changes to the LPS system? If yes, please specify.** *

_____

_____

_____

_____

_____

10. **How much do you estimate was the average PPC that you have observed in projects using LPS?** *
PPC = (nº activities completed as scheduled / total nº of scheduled activities)
Mark only one oval.

- ◯ 0 - 9 %
- ◯ 10 - 19 %
- ◯ 20 - 29 %
- ◯ 30 - 39 %
- ◯ 40 - 49 %
- ◯ 50 - 59 %
- ◯ 60 - 69 %
- ◯ 70 - 79 %
- ◯ 80 - 89 %
- ◯ 90 - 100 %

11. **What are the most common causes for the activities non-completed when planned?** *
Tick all that apply.

- [ ] Missing information (Drawings, specifications, etc.)
- [ ] Workers were not present
- [ ] Materials were not present
- [ ] Equipment and machinery were not present
- [ ] Insufficient space for the task to be executed
- [ ] Predecessors activities were not completed
- [ ] External conditions
- [ ] Other: _____

12. **Have you experienced any progress while using LPS in your projects? Can you describe in a few words the reasons for your answer?** *

_____

_____

_____

_____

_____

13. **Have you noticed a different behavior\attitude of different stakeholders in regards to LPS?** *
Tick all that apply.

- [ ] Open minded towards the use of LPS
- [ ] Resistant to new scheduling approaches
- [ ] Collaborative
- [ ] Other: _____

Stop filling out this form.

14. **What methods do you use for planning and control of projects? (Meetings, schedules, software, templates, etc.)** *

_____

_____

_____

_____

_____

15. **Please describe in a few words how you use the methods mentioned in the previous question.** *

_____

_____

_____

_____

_____

16. **What do you think that are the possible benefits and downsides of your methods?** *

17. **Have you noticed the average percentage of activities not completed when planned that you have observed in projects you were involved in?** *
(completed earlier or later than planned)
Mark only one oval.

- ◯ 0 - 9 %
- ◯ 20 - 39 %
- ◯ 30 - 39 %
- ◯ 40 - 49 %
- ◯ 50 - 59 %
- ◯ 60 - 69 %
- ◯ 70 - 79 %
- ◯ 80 - 89 %
- ◯ 90 - 100 %
- ◯ No

18. **What are the most common causes for the activities non-completed when planned?** *
Tick all that apply.

- ☐ Missing information (Drawings, specifications, etc.)
- ☐ Workers were not present
- ☐ Materials were not present
- ☐ Equipment and machinery were not present
- ☐ Insufficient space for the task to be executed
- ☐ Predecessors activities were not completed
- ☐ External conditions
- ☐ Other: _____

19. **Have you improved or made any changes to your methods over time? If yes, please specify.** *

20. **If you were presented to a different and maybe better planning method, would you be open to change? Why or why not?** *

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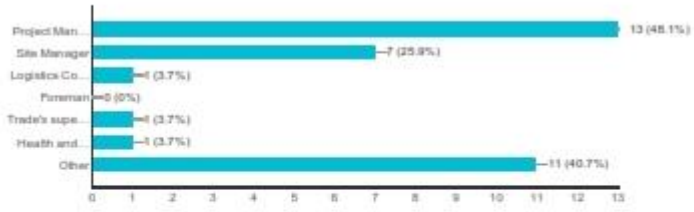
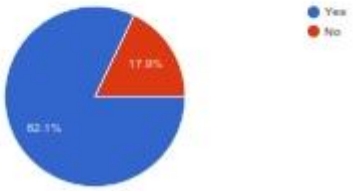
C. ONLINE SURVEY RESPONSES

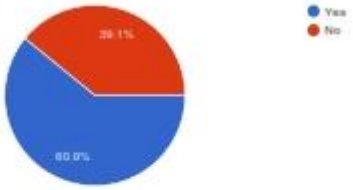
What is your professional position in the construction industry? (27 responses)



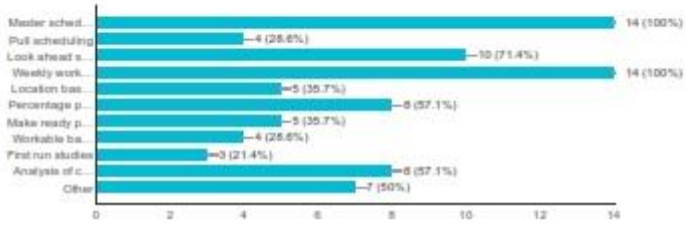
Have you ever heard or are you familiar with Last Planner System (LPS) and/or Lean Construction? (28 responses)



Do you use or have used LPS tools in current or past projects? (23 responses)



Which planning tools do(did) you normally use? (14 responses)



Please describe in a few words how you use each of the tools selected in the previous question (14 responses)

In accordance with the contractual requirements of the project, as well as contractor, owner, etc. needs

It varies a lot, depending on the specific task and project.

Having master schedule as a wish list and go with weekly or two week schedule; make everything ready for it and try to deliver defined milestone on weekly or two week

Master schedule...Weekplans...And Completion timeschedules is used and runby during the weekly sitemeetings with the subcontractors

And loadingplans with the suppliers..

I support procesleaders in using the tools. The tools are used on site to plan the daily work.

Very good tools, simple to use and very effective!

Master schedule for baselining, 3-week look aheads for short term planning, pull schedules for major milestones

Using pull planning for design phase tracking. Will continue into all phases.

They work

I am supporting the site managers and proces-leaders on site using these tools.

Other than that, I use some of them in the tender phase.

The overall planning of any major construction project requires careful and detailed planning. These tools are used to identify road blocks and ensure plans are in place for counter measures and contingencies to ensure overall schedule , budget and quality are met. The four key components to any project are as follows - budget, quality, schedule and most important safety which is integral to all the preceding activities.

A workshop was carried out to familiarise project team members with the concepts of Lean and the use of the LPS.

A second workshop was held to enable trade contractors and site staff to develop both a collaborative Master Schedule, plus the initial 6 week look- ahead and the initial weekly work plan.

Once on site, weekly meetings would be held to not only review the previous week's work completed (including reasons why work was not completed as planned, and PPC reports) but also develop the next weekly work plan, including Plan B options. Any changes required to the overall Master Schedule were also identified during these meetings.

In addition to the overall PPC report which was presented at the meeting, each trade contractor was provided with their own PPC report and where performance was continually sub-standard, corrective action would be taken at the necessary level.

We use in every project those tools. There is a software prepare by a university in chile that join those concepts. It is name is Impera

I am a researcher and I have observe it use on various projects.

What are the reasons for not using the non-selected tools if any? (9 responses)

Unforseen surcomstances inables working within all tools...(My opinion)

not enough time and ressources to perform all tasks

They are not a part of our strategy.

Not considered necessary or were too time consuming, for the potential benefit.

Not as important as selected

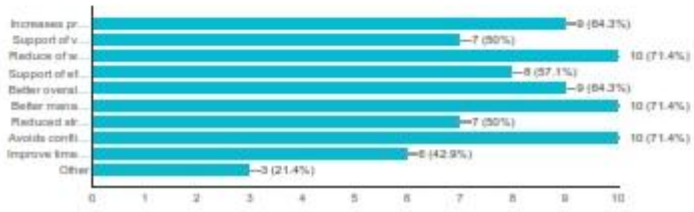
Based on project scope and complexity all these tools would be used. I only highlighted what I would see as the common tools for any project.

GC doesnt use those

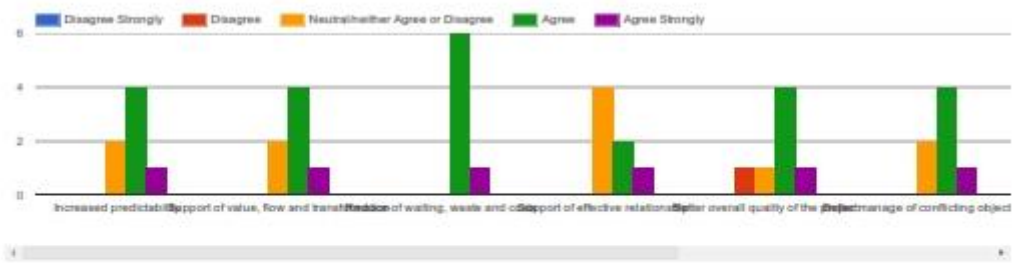
Not familiar with those tools.

Not a part of the strategy.

Have you experienced any of the following benefits using the LPS system? (14 responses)



Scale



Did you make any improvements or changes to the LPS system? If yes, please specify. (14 responses)

Continuos intercompany development, sorry but it's not for public use.

Not sure

Shorter duration and more specific target is better

Yes. Work with

No.

Yes, we have improved LPS by adding Kick-offs. Time-outs and exectutionschedules.

none specifically

Nope. We use TrimByg, which is a variety of LPS.

no

Looked at PPC on an individual contractor basis as well as overall.

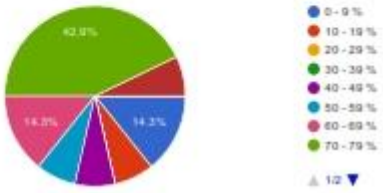
No

No

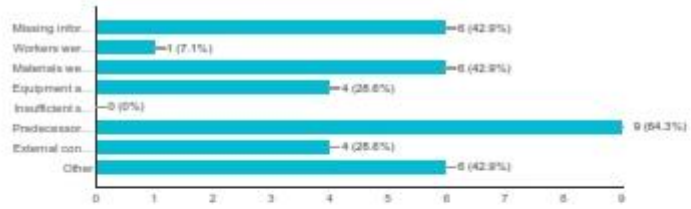
No

Some changes or adaptations are made based on the characteristics of the project, for instance, projects with a high level of uncertainty might demand daily work plans instead of weekly work plans. In such projects, the lookahead planning window might be shorter than other projects.

How much do you estimate was the average PPC that you have observed in projects using LPS? (14 responses)



What are the most common causes for the activities non-completed when planned? (14 responses)



Have you experienced any progress while using LPS in your projects? Can you describe in a few words the reasons for your answer?
(14 responses)

some times

Increase collaboration among project stakeholders

?

Question is too vague. You needed to better define what you meant by this question.

If you meant did the project improve its performance (as rated by PPC) over the life of the project... then yes it did, as team members got more used to the system and began to trust each other more.

I don't understand the question

Yes, we have more reliable schedules.

Overall tracking of performance is key

yes, as all teams participate and take ownership

Yes, an EPC project was so confusing to do it based on CPM. I believe as long as:

- clear milestone
- correct sequence
- shorter planning phase

Considered by site erection team the result is good.

- Way to work
- look head thinking
- clear coordination
- action over problems before

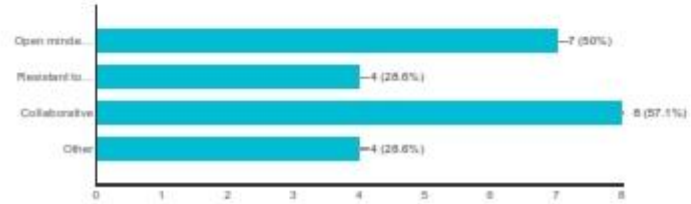
The flow is better. Better control.

Just new form on old systems. No difference.

Yes, LPS enables people engagement to the planning process, creates predictable workflow, and enables rapid learning.

Not for public use

Have you noticed a different behavior\attitude of different stakeholders in regards to LPS? (14 responses)



What methods do you use for planning and control of projects? (Meetings, schedules, software, templates, etc.)

(14 responses)

Various projects have had different software, weekly meetings- schedule review- update, milestone targets etc

Weekly construction meetings with share holders and sub-contractors, CPM schedules, ProCore software

Work programs and weekly meetings

MS Project for Gantt Chart, Excel for Location-Based Scheduling, Master Schedule, Look-ahead Schedule, Weekly Schedule, Safety meeting every 14 days, weekly meeting with sub-contractors (what should be done in 2-3 weeks ahead), Weekly (process) meetings with the craftsmen on site

P6
Construction Manager
Microsoft Outlook
Microsoft Excel Spreadsheets

All of them, and Lync/Skype

Time Schedule and Daily Progress Follow-up
3 Weekly Look Ahead Schedule (The previous wee and 2 weeks ahead)
Budget Monitoring
Daily / Weekly / Monthly Meetings

project critical path method schedule, periodic meetings, submittals, Quality Control Management system

OneNote til daglig brug på pladsen for opgave kontrol. På uge basis.

Proprietary methodology and spreadsheets plus Primavera.
Based on earned value methodology.

Primavera P6

Meetings - daily, weekly & monthly
Schedule - P6
Software - Prolog and several custom developed for our company. Workface planning, Model reviews through out design.

Primavera for Administration (Correspondence, submittals, RFI's, etc)and Scheduling

Use Sainsburys Data Stream and Project Hive on TSL Projects

Please describe in a few words how you use the methods mentioned in the previous question. (14 responses)

The Time Schedule is the main instrument to track progress. from the Time Schedule, 3 weekly schedules are prepared and monitored to ensure project runs on time.
Budget is almost daily monitored to see if the project is loosing money or not.
Meetings between the project team and the subcontractors ensure that there is complete coordination between the companies and trades.

Described in the previous step

I used them to control the production and any conflicting objectives.

Meeting reviews - track dollars spent and track progress on schedule

Monthly/ weekly changes tweaked so project can meet critical path

Safety and Communication are very important in delivering an exceptional product to the Client. A safe project helps in quality, schedule and cost. Get construction involved early to assist with the engineering and design.

Collaborative high performance teams delivering projects using Lean Construction Principles

Der er flere sektioner, Opgaver status, opfølgning mangler, projekt info. Der skrives alle opgaver ind, status på dem, hvornår de ønskes færdige og hvornår de faktisk bliver færdige.

For Progress - Earned Value Measurement - Meetings - Scheduling collaboration

Not sure what is being asked...

Trade contractors meetings-Design team meetings- V/E meetings fixed cost projects-Risk reg etc..

Meetings to resolve issues from all parties, schedules & updates to keep projects on schedule. Budget meetings to keep focus on project cost and ProCore to disseminate and record information.

at the commencement stage of the project I prepare my work program showing targeted timelines and deadlines. From this I generate weekly and monthly targets that have to be met coupled with the requisite materials,plant and labour. We schedule weekly meetings and I review the progress with the site manager and foremen. Briefing clients and consultants along the way.

The project is planned with each definable feature of work identified and then we apply the quality control management system to these DFOWs. For production, once the buyout is completed, all the stakeholders are provided the project schedule and expected to comply with activity completion dates. Obviously the plan will change during the project and all subcontractors effected by the changes are involved in adjusting the plan to hopefully recover lost time and compete on schedule and within the budget.

Earned value based on confirmed original (or last approved) budget
combined with single currency CPM schedule, calibrated by Operational Risk Analysis.

What do you think that are the possible benefits and downsides of your methods? (14 responses)

n/a

Since am involved from inception I understand the flow of work,also most people can understand programs developed from Ms project.The meetings create an inter-phase for feedback and brainstorming

Unforseen delays later in the project that cannot be avoided and seriously affect final completions

Provides information early good or bad, reduced stress and better time management.

Downside getting the team together to collaborate.

A happy client, quality project, below cost and ahead of schedule. Repeat business with the client.

Benefits are timely delivery of the project, within budget and intended quality.

Downsides come up when team members start thinking that the meetings are lengthy and useless. This should be prevented by the team leaders.

Nogle gange får man ikke udfyldt status på opgaver og dermed kan overblikket godt ryge engang imellem

Benefits
Proved.
Open

Cons
Requires very experienced personnel

Requires BIM modelling

Retailers are really inflexible in regard to construction and never understand that we are not a just in time sector. In the UK we have a limited supply chain as well as the depression took away a major part of our skill set and stocks.

No systematic approach (they use their own "system" called "Green Process"). They have achieved good collaboration out of it, but nothing in relation to actual planning.

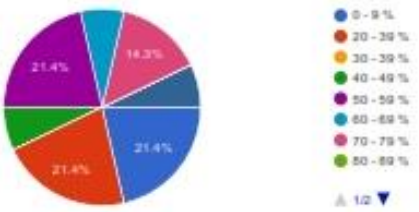
Electronic system speeds-up processes, reduces paper.

This method requires a lot of face to face meeting time and review of documents. It would be most helpful if the design community would adopt standard processes like BIM and then builders could get on board and eliminate weeks and months of back and forth regarding requirements. Also, in the US there is no one accepted software system for construction management. Industry is ripe for improvement from prefabrication of standard assemblies and adoption of best practices. Owners tend to go for cheapest acquisition cost vice proven performance.

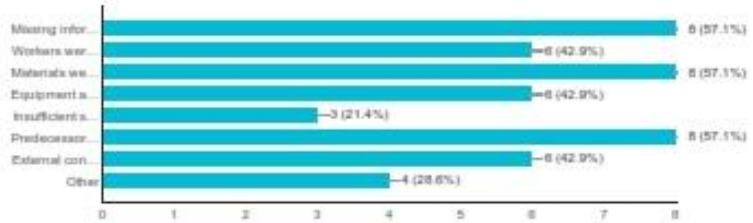
I think the biggest downside is that people assume that if you have high powered software that everything can be done by a push of a button but that is not the case nothing beats a person to decipher the information that the software spits out.

The software is not always the most user friendly.

Have you noticed the average percentage of activities not completed when planned that you have observed in projects you were involved in?
(14 responses)



What are the most common causes for the activities non-completed when planned? (14 responses)



Have you improved or made any changes to your methods over time? If yes, please specify. (14 responses)

n/a

With each new project the learning curve keeps improving. With renovations works I endeavor to sequence the tasks and picture their flow,match this with the requisite tools. Also I study drawings and all relevant project documents e.g bills of quantities to identify grey areas.For specialist works e.g lifts I ask for the model and make to be installed so that we build the right shaft. basically fine tuning what I have used in the past.

Always making improvements.
Work smart not hard.
Be safer, quicker, better, faster, smarter than the competition.

Incorporated requirement of WBS
Summary on Balanced Scorecard
Regular reviews by management
More precise procedures

We are constantly refining our processes to be more effective and efficient

Improvement is not required, what needs to be done is to follow up and implement the system.

Recruit and hire experienced personnel that are competent and effective communicators. Also to select the project and client more carefully. Some clients are just painful to work for as there is no trust or desire to improve the process.

Its improving almost every day

to many to list - custom reports and templates

Every project brings different challenges.. What works for one project doesn't always work for all

Some years ago they adopted a new approach called "Green Process", which was inspired by BygSol initiative, as part of LEAN Construction DK development initiative

Yes. Introduced BIM modelling and Lean Construiction

Programme using MS Projects 10,ongoing training plus work coupled with supply chain,drilling down on what they can achieve not just what our expectations are..Plus what they think we want to hear!

No

If you were presented to a different and maybe better planning method, would you be open to change? Why or why not?
(14 responses)

Yes, it can not get much worse than the chaos that exists right now in the construction industry. Some organizations such as the Design Build Institute of America have taken the time and effort to draft standard processes and have reached out to train the clients which is a huge help. DBIA is more focused on the overall relationship with the owner/designer/builder vice the nuts and bolts of getting the project built.

I would be open.. I have taken project management courses in 1980,1990,2007.. some old ideas have been changed only in terminology with all other things remaining the same... Paper and communications media are changing so software/ presentation of charts and data have more smoke and mirrors now so it is interesting to see how old problems are dealt with using modern sleight of hand tricks

I would be open to see and understand new planning methods, then I shall decide if it is better or not and change to the new method shall come afterwards.

Yes. Planning is key, men at få det udført til tiden er svært

They are open to new approaches and suggestions,

Certainly. Better is Better

Yes, always looking to stay ahead of the competition.

Absolutely.

Results depend on predictability. Any method to improve the latter shall improve the results.

A big yes. If I don't change and improve an likely to become extinct. Ask the dinosaurs,they wish they had adapted to the changes.

Yes, always look to improve

Yes if it was better than M/S Projects.

No. If the system isn't broke it does not need fixing.

No. P6 is the industry standard

Yes if it was truly better

ANNEXES

A. Location Based Master Schedule Frederikskaj 2

B. Location Based Phase Schedule Frederikskaj 2

C. Progress Status Frederikskaj 2

D. Hovedtidsplan Musikhus kvarteret project

E. Komplettering Musikhus kcarteret project

F. Byggemøde 30