AALBORG UNIVERSITY
DENMARK

REDUCTION OF NON-PHYSICAL WASTE ON CONSTRUCTION SITES USING RESOURCE MANAGEMENT

Master Thesis of Construction Management, 4^{th} Semester

Hasiyana Aleksandrova and Egle Eismontaite

Aalborg University
Faculty of Civil Engineering

Aalborg, 2021

Title:

Reduction of non-physical waste on construction sites using Resource Management

Source of the cover picture:

(PERI GmbH, 2014)

Project topics:

Construction sites

Non-physical waste

Resource Management

Project period:

September 2020 – January 2021

Project group:

Aleksandrova Hasiyana (20190178)

Eismontaite Egle (20190524)

Supervisors:

Søren Munch Lindhard

Dan Eggert Møller

Characters in total: 317 101

Characters of the report: 242 006

Report pages: 104

Appendix pages: 45 (pp. 118-163)

Completed: 08.01.2021

Preface

This report has been written as a master thesis by a project group of master's degree students in Construction Management study program at Aalborg University. The thesis has been written throughout fall semester of 2020.

The idea of the topic mainly came from personal experiences of waste issues on construction sites in the past. More defined topic originated from a deeper analysis of the issue and a research done by group's supervisor Søren Munch Lindhard about labour productivity, analysing different labour productivity factors in construction industry based on numerous case studies conducted in Asia.

The aim of this report is to suggest possible Resource Management (RM) solutions to reduce non-physical waste by analysing how such waste is perceived in the Danish construction industry and how it is being handled at the moment. Having previous experience of negligence of the issue was the basis of realization that important changes and solutions must be offered if the waste is to be reduced in the future. Even though the physical waste receives much greater attention than non-physical one, it is important to treat such waste with the same amount of importance if immense economic issues are to be avoided. The main target audience is building engineering department at Aalborg University and everyone who would have interest and use of this paper in construction industry. The report should benefit any company facing the issue and provide an idea of how the waste can be reduced.

The project group would like to express gratitude and thank supervisors Søren Munch Lindhard and Dan Eggert Møller for sharing their knowledge and insight throughout the whole writing period of this thesis. Also, the study analysed by Lindhard, (2020) has been a great help, allowing the group to specify one of the focus areas. Besides that, the working group would like to thank all construction companies which participated in the survey, allowing to achieve valid research and conclusions of the topic.

Abstract

Construction projects create significant amounts of waste and some of that waste is physical, some – not. Non-physical waste is a difficult issue to address, resulting in wasted time and money as well physical resources. It does not only impact construction companies, but on bigger projects can impact city's or even country's economic situation. These problems and threats create a need to reduce non-physical waste and it should be done in a practical and realistic way. Since non-physical waste is closely related to resource utilization on construction sites, it is natural that a more optimal handling of resources or resource management could solve reoccurring waste. To find out how this could be done, a quantitative data collection method – questionnaire has been used, giving information about current utilization of resource management on sites and what is seen as the most beneficial part of it. Afterwards results have been combined with analysis of literature and case studies, to find out the most beneficial solution to the problem.

Since survey revealed that Danish companies see non-physical waste as an issue and that improved resource management could reduce occurrence of the problem, three fields of Resource Management have been analysed: Labour, Space, and Material management. All three fields were looked into by usage of factors affecting the field, which were graded by participant in the survey. Knowing the most important factors allowed to find the most suitable solutions for improving specific RM area. Besides that, many of the solutions were apparent in all fields, such as BIM, education, and cloud-based systems, thus a common solution involving all three aspects has been suggested. To make the selection of solutions more practical for the construction industry, a framework based on Resource Based View has been created and explained.

The thesis has also risen new questions about other sources of generation of non-physical waste besides improper usage of Resource Management and whether there are other methods to reduce such waste. Besides that, since BIM related concepts are often suggested as a solution which can solve numerous problems on sites, it is of interest why it is still not used to its' full potential. Finally, the thesis has risen a question if the RBV framework can be used in project level, since Resource Based View has been done for company level and no framework has been created for a project level before.

Glossary

The glossary contains a list of abbreviations and terminology used in the report that should be explained beforehand to gain a full understanding of the used concept. The terminology is written in *italic* and is underlined when mentioned for the first time.

Abbreviations:

- ERP – Enterprise Resource Planning
- Danish WEA – The Danish Work Environment Authorities
- GIS – Geographic Information Systems
- ICT – Information Communication Technologies
- IFC – Information Foundation Classes
- LBS – Location-Based Scheduling
- LC – Lean Construction
- MRP - Material Requirement Planning
- RBF – Resource Based Framework
- RBV – Resource Based View
- RII – Relative Importance Index
- RM – Resource Management
- VDC – Visual Design and Construction
- VSM – Value Stream Mapping

Terminology:

- *Cyclical expenditure* – reoccurring action of spending funds (Rigsrevisionen, 2009).
- *Enterprise Resource Planning* – *“<…> integrated information technology (IT) solution, to better integrate various business functions and resources, particularly those related to project accounting procedures and practices”* (Chung, et al., 2008).
- *Environmental movements* – *“<…> a political movement that focuses on protecting the environment, reducing environmental damage and unsustainable use of natural resources*” (Park, 2007).
- *Heijunka* – a Lean concept that teaches levelling work in process which helps control variation and thus, limits a source of waste (Seppänen, et al., 2015).
- *Hierarchical approach* – an approach where resources can be categorized into value-added, non-value added and waste (Kunc & Morecroft, 2009).
- *Material Requirement Planning* – method for tracking project progress and updates on material usage (Olalusi & Jesuloluwa, 2013).
- *Stop-and-go operations* – an operation that occurs when an essential component of an activity is not available when it is required (Dozzi & AbouRizk, 1993).
- *The Last Planner System* – *“<…> is a philosophy and a set of principles and tools designed to improve workflow reliability through better planning strategies*” (Liu, et al., 2011).
- *Value Stream Mapping* – lean tool used for material and information flow mapping (Yu, et al., 2009).

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List of figures and tables

1. Introduction

Construction sites generate a lot of waste, both physical and non-physical which is a significant issue world-wide (Bossink & Brouwersz, 1996). While physical waste can be more obvious and easier to manage, non-physical waste can be much harder to control. As non-physical waste includes time, money (figure 1) and resources that cannot be physically measured, they should be preserved in a different way, allowing managers to track them. Naturally, waste is something that is unwanted and does not add any residue value, thus projects would be more successful if waste was drastically reduced (Nagapan, et al., 2012c).

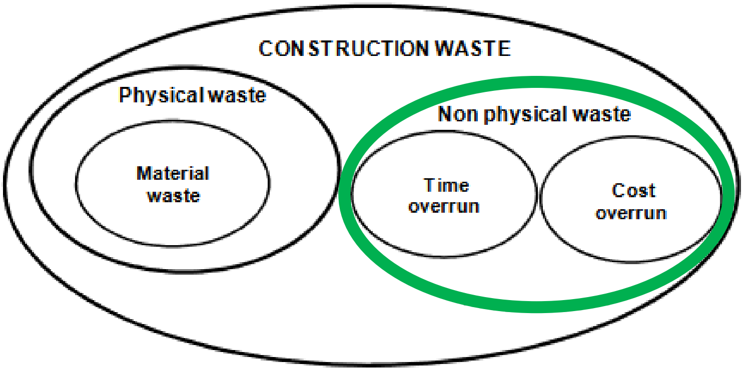

Figure 1. Types of construction waste. Source: (Nagapan, et al., 2012b).

Non-physical waste on construction sites is usually defined by time or cost overruns. It can occur e.g., during delays, waiting time or repairs and is an inefficient way of using resources such as equipment, materials, labour, and money. Waste also includes overproduction, poor material or inventory handling and movement of workers. Even though both types of waste are strongly affecting construction projects, the industry focuses more on physical waste and less attention is given for non-physical one (Nagapan, et al., 2012c). This means that non-physical waste is an issue requiring more awareness and practical solutions.

Given that non-physical waste is not as seriously addressed, issues concerning time and cost are constantly rising leading to bankruptcies of companies and abandoned projects. The problems are often caused by poor management, specifications, delays, lack of rules and supervision. On top of that, abandonment of projects can result in declining number of investors and buyers, meaning that non-physical waste can have a big impact on economic situation of the country (Nagapan, et al., 2012c). This is why construction industry should put more effort into identifying non-physical waste and finding ways how to manage it and prevent projects from experiencing major loss, influencing not only the company, but the whole country as well.

2. Methodology

This chapter includes considerations about the overall structure of the research paper to ensure that the problem question is successfully answered in a most unambiguous and explicit way. Moreover, to explain the choices made and their importance for the paper and to create a logical structure that helps to stay on the "red thread", thoughts on the structure of the report, together with strategies, approaches and philosophies will be described in the sub-chapters below.

2.1. Research design

The purpose of the research design is to outline and emphasize the area of interest and to describe and examine the approach used for solving the initial problem of this paper (Creswell, 2014).

Research philosophy – Pragmatism

Describing the research philosophy used in this paper is essential to explain what the general orientation about the world and the nature of the research is. According to Creswell (2014), these perceptions are normally influenced by "<…> *the discipline area of the student, the beliefs of advisers and faculty in a student's area, and past research experiences.*" therefore having significant influence on how the report is structured and written.

In this study the natural choice in research philosophy was pragmatism. This choice was based on the fact that the research is problem-centred with focus on finding a real-word practical solution (see figure 2 below). This research philosophy focuses on practical application and solutions to problems - "what works", instead of focusing on only theoretical assumptions.

Figure 2. Factors defining pragmatism worldview. Source: (Creswell, 2014) and own production.

Approach – Inductive

According to various literature, the inductive approach starts by gathering empirical data and ends with conclusion based on theory, while the deductive approach starts from hypothesis being stated and ends with measuring empirical data (Bryman, 2004). Since the nature of the study does not imply an initial hypothesis, an inductive approach was used, where first empirical data was collected, which was then supported by theory, thus leading to the problem formulation. The initially collected data and theory, followed by a scientific research formed the conclusion of the specific problem, giving an answer to the problem statement.

Data collection methods – Mixed

The paper is using mixed data collection methods, since a combination of both qualitative and quantitative methods were applied. **Mixed research method** (figure 3) gives information not only for the statistical data gathered, but it also informs what people feel and think about the area of interest (Creswell, 2014). Using **Quantitative methods**, as the name suggests, concerns quantifying data and generalising results from a survey, e.g., questionnaire, where a specific group of people is targeted and asked closed-ended questions to gather empirical data which can be later computed and analysed. This method can also be used to *"<…> measure the incidence of various views and opinions in a chosen sample for example or aggregate results"* (Headlam, 2009). **Qualitative methods**, on the other hand, concern the "*<…> quality of information <…>*" (Headlam, 2009). By using them it is attempted to find "<…> *an understanding of the underlying reasons and motivations for actions and establish how people interpret their experiences and the world around them*" (Headlam, 2009).

Mixed methods

- Both pre-determined and emerging methods
- Both open- and closed-ended questions
- Multiple forms of data drawing on all possibilities
- Statistical and text analysis
- Across databases interpretation

Figure 3. Factors of mixed methods. Source: (Creswell, 2014) and own production.

The use of both qualitative and quantitative perspectives, by including a broad range of approaches such as empirical data, literature reviews, expert opinions and content validation gave the possibility to find an unbiased answer to the problem question. The following research has both pre-determined and emerging methods, since it starts by having pre-determined methods like collecting empirical data achieved by survey and theory research and based on findings and emerges to a solution of the given problem (Creswell, 2014).

Type of strategy - Concurrent mixed methods

As mentioned above since mixed methods were used in the research, it was logical that the strategy chosen was also concerning the same method. Creswell (2014) identifies **Concurrent mixed methods** as a strategy in which there are procedures where *"<...> the researcher converges or merges quantitative and qualitative data in order to provide a comprehensive analysis of the research problem*". The strategy involves collection of both types of data and integrating it in the interpretation of the overall results (Creswell, 2014). Summary of the whole research design can be seen in figure 4.

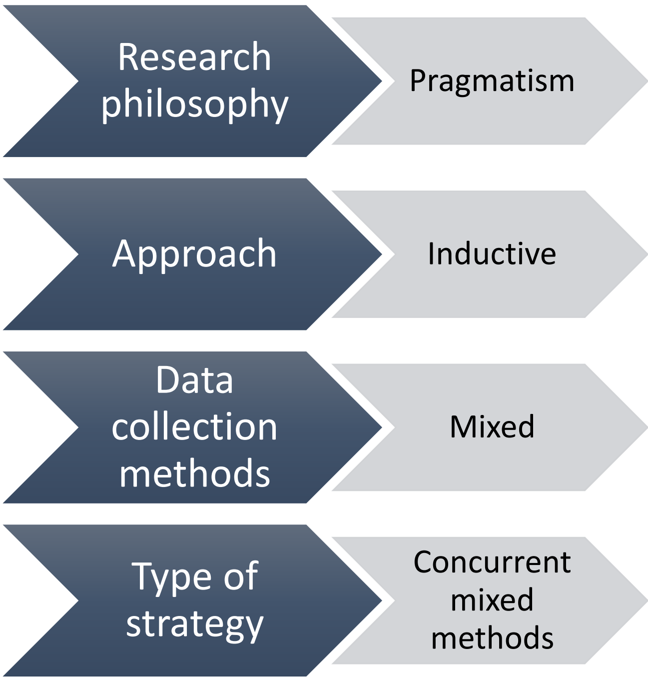

Figure 4. Summary of project's research design. Source: own production.

2.2. Research methods

In this section, it will be comment on how the data was collected, which methods and techniques were used and what strategies were applied to ensure the reliability and validity of the paper. The study was using both quantitative and qualitative data for a better and more comprehensive understanding of the problem question and for finding an optimal and practical solution that is realistic and feasible. For the purpose, two methods were intended to be used – survey questionnaire (quantitative) and analysis, reviews of previously done studies together with an interview (qualitative). The interview, however, could not be made, due to Covid-19 and lack of time. Methods and related strategies will be described below.

Survey Questionnaire

The primary data of the report was collected by questionnaire with predominantly closed-ended questions, which have been prepared in advance, specifically concerning the areas of interest. The purpose of the survey was to gather information on whether Danish professionals working at construction sites are aware of non-physical waste and to see if they understand the need for minimizing it, so budget and time overruns are reduced or even eliminated. Moreover, the questionnaire also aimed to get a deeper and more detailed information about Resource Management and how it is used to deal with non-physical waste, or if it is used at all. The topic of RM targeted three specific aspects – Labour, Material and Space management. The information gathered from the questionnaire was used to validate theoretical findings and to help come up with a practical solution for minimizing non-physical waste at Danish construction sites.

In addition, to establish a reasonable validity of the results obtained by this survey, and to ensure that the questions measure everything needed, a preliminary test run was conducted on a small group of people. The aim of the test run was to assess if there was clarity of the questions and structure of the survey, to see if the respondents could easily understand and answer the questions asked, to check if the terminology used in the survey was understandable and clear and to determine the efficiency with which the respondents completed the questionnaire. The feedback received consisted of several comments, related to the terminology used in some questions and accuracy of language grammar which were later fixed by using simpler expressions to avoid any future confusion and misunderstanding.

The target group of the questionnaire were people who work on the construction site and are Project managers (Projektchef), Project leaders (Projektleder) or Construction managers (Byggeleder) by profession. The time frame used to carry out the survey was about one month, during which all targeted professionals received an invite to answer the survey followed by a reminder that was sent after two weeks to those who did not respond.

The questionnaire was sent digitally to the people of interest by emails containing the link to the survey platform "Survey Xact" where 20 questions were asked. The questions asked were general questions like area of expertise, experience, and age group, followed by specific questions about practices, known methods, experience and understanding concerning the topic of non-physical waste. The total time of carrying out the survey was planned to be 10 minutes, so that the quality of the questions would not be affected by the reluctance of participating in more time-consuming questionnaire. The survey was anonymous, in order for the participants to answer honestly without being concerned whether their answers would affect them or the company they work in, in any way. The structure of the survey is illustrated in the figure 5 below:

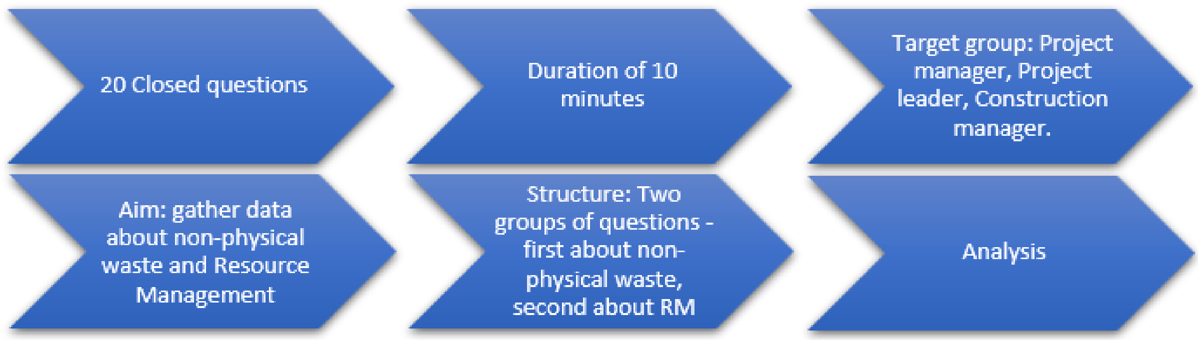

Figure 5. Questionnaire strategy sequence. Source: own production.

The data acquired from the survey was analysed in several different ways. For the questions with specific answers the proportion of respondents having the same answer for each question was calculated. For the questions where the Likert scale was applied the answers were analysed by calculating the Relative Importance Index (RII) for each answer. The RII was calculated by using the following formula:

Relative Importance Index Formula: $\mathrm{RII} = \frac{\sum W}{(A * N)}$

Where, "W" represents the Weight given to each factor - from 1 to 5, "A" is the highest weight (5) and "N" is the total number of respondents. The factors and/or categories that have received the highest RII were considered the most important and the ones with the lowest - less important (Othman I., 2014). Full calculations for each factor can be found in Appendix 1.

The formation of the survey and its questions were influenced by a theoretical research done in advance to find possible ways to eliminate non-physical waste. The preliminary research led to the benefits of improving Resource Management regarding cutting down non-value adding activities in the construction process and to discovery of the three fields of RM – Labour, Space and Material management. The selection of factors affecting the mentioned fields was mainly influenced by a study done by group's supervisor Lindhard (2020) about Labour productivity, who presented a list of factors categorised in five main categories - *Project Factors, Labour Factors, Management Factors, Technical Factors* and *External Factors*. The factor categories and sub-factors have been based on Hwang, et al., (2017) whereas the sub-factors were adjusted and reviewed when examining different studies, such as Alaghbari, et al., (2017) and Kadir, et al., (2005). The factors influencing the other two Resource Management fields were obtained from reviewing other studies like Ayegba (2013) and Kulkarni, et al., (2017) for Material management, which were also adjusted for Space management. The summary of studies used for identification of factors can be found in table 1 below. More detailed information including factor selection and categorization from specific studies can be found in Appendices 2 and 3.

RM area	Studies used for identifying factors
Labour management and productivity	(Lindhard, 2020) (Alaghbari, et al., 2017) (Kadir, et al., 2005)
Space management	(Lindhard, 2020) (adjusted to RM area) (Kulkarni, et al., 2017) (adjusted to RM area) (Ayegba, 2013) (adjusted to RM area)
Material management	(Lindhard, 2020) (adjusted to RM area) (Kulkarni, et al., 2017) (Ayegba, 2013)
All RM areas	(Chan, et al., 2004)

Table 1. Studies used for identifying different resource management area factors. Source: own production.

Reviews of other studies

The paper used many different studies to build its theoretical part and validate findings, yet some of them were more beneficial. For this reason, the most significant studies for this project have been summarized in this section, highlighting their principal aspects. The main concern while working on the issue was the fact that many construction professionals focus on physical waste, rather than non-physical one, which is as important and has the same unwanted negative effects (Nagapan, et al., 2012a). In order to show the importance of also taking in consideration non-physical waste, several researches were studied to gather both quantitative and qualitative data indicating how essential non-physical waste is. One of those studies is done by Rigsrevisionen whose aim was to conduct analysis about the reasons of cost overruns in national building and construction projects in Denmark and to come up with recommendations for initiatives which can prevent it.

Another study used in this report is about "Productivity in Renovation" made by Wandahl and Neve (2018) from Aarhus University who gathered information about work productivity at Danish construction sites to see if there was a need for improvement. The study was done as a part of bigger scale project in Denmark called REVALUE, which was conducted in the period of 2016-2019 and had a financial framework of DKK 21.2 million. The findings of the study showed that besides an actual construction, a lot of time was consumed by conversations, explanations, transportation, walking, being away and waiting times (Wandahl & Neve, 2018). This created a need to see how processes could be optimized to reduce wasted time and increase productivity on sites.

Other studies of interest were about factors influencing non-physical waste. Even though several studies have been conducted regarding this topic, the one made by Nagapan et al., (2012a) about "Factors Contributing to Physical and Non-Physical Waste Generation in Construction Industry" was found to be the most relevant for this paper. It addresses construction waste worldwide proving it to be a global issue and compares physical and non-physical waste generation confirming them to be equally important. On top of that, the paper carried out a thorough study investigating different sources about factors influencing construction waste and defining significant factors as well as their categories. The study was relevant as it covered many previous analyses done in the past and combined them into specific results which were necessary for this project.

Another study that had an impact for space management and usage of 4D BIM was made by Choi, et al., (2014). The study had a relevant analysis of standardized methods while planning the space on building sites which have proven to have a positive and much needed effect on space management. It mostly analysed the classification, division, and usage of workspaces, which is necessary yet often neglected step. Besides that the study included a thorough analysis of usage of 4D BIM, which was backed up by, Deng, et al., (2019), Jupp, (2017), Jin, et al., (2019), Ma, et al., (2005), Shou, et al., (2018), Wang, et al., (2004) and others as well and thus was used as a solution for several RM areas.

The project was also influenced by the opportunity to participate in a research made by one of the research group's supervisors Lindhard, (2020) who gathered information about factors influencing labour productivity on construction sites. As labour productivity is often the non-physical resource that is wasted or misused on building sites, the research was found beneficial and was used as one of the bases for forming the questionnaire and part of the report, concerning labour productivity. However, since the study was of a large scale, only the relevant parts were extracted and used. Originally, numerous Asian studies were investigated within productivity and factors influencing it were extracted and categorized into five areas: *Project Factors, Labour Factors, Management Factors, Technical Factors* and *External Factors*. Each factor was assigned several different sub-factors and those included more detailed elaboration of what is incorporated in the sub-factor. The information from the study was used for the survey and analysis of Resource Management areas.

Literature selection criteria

The evaluation and assessment of the used sources was based on what type of source it is, e.g., books, journals, case studies and scientific researches were considered reliable sources, whereas web pages are not. Other criteria applied was the publication date. It was considered preferable if the dates of the sources were more current, in order to ensure that the information to which the research paper refers to is up to date. Yet, if the information used from analysed study contained references to original sources, then the older dates were acceptable.

Another criterion was relevance. All sources were sought to be relevant to the construction industry and the related researched topics. It was important to select literature which was answering raised questions and was giving possible answers or solutions for specific matters. This was also done to avoid having specific pre-selected statements and ensure validity of the project. Moreover, of great importance was also if the information present in the sources could be found in other relevant literature, thus confirming validity and reliability of information. Reliability was found to be a criterion for literature selection and choice of solution, which will be explained more in the next chapter 2.3. Less importance was paid to the authors of the sources and their origin, but all sources were extracted from reliable platforms like AAU library, Google Scholar, Pro Quest, etc., which were considered trustworthy for scientific papers. The strategy behind ensuring overall reliability and validity of the sources is also explained in the next chapter.

Solution selection criteria

Method for selecting solutions described in chapters 6 and 7 was based on reliability. Since problems can be solved in many different ways, it was needed to find a technique to pick the best solutions fitting the issues within Resource Management. As the efficiency and quality of solutions could not be tested in this project, it was decided to use reliability as the measure. This means that the solutions that have been analysed and proven to be effective by several researches were used over the ones with low numbers of studies conducted. This decision was made based on the idea behind reliability, which indicates that if something has been proven to be true many times, then it is highly reliable (Bryman, 2004). Thus, it is important to note here that many different proposed solutions were considered without being predefined by primary decisions or rejections, yet the less reliable solutions were not included as the project scope cannot cover all possibilities. Solutions with higher reliability have also a higher chance to bring positive results when implemented, as they have been tried out several times and proven to be working.

2.3. Reliability and validity

Describing the reliability and validity of the paper is essential part of writing the research because the two concepts are used to evaluate the quality of the study and indicate if the findings are trustworthy.

Reliability is related to "*consistency of a measure*", meaning that if something can be found numerous times then the chance of its reliability is higher. Based on that a conclusion can be made if the findings of the report are reliable. **Validity**, on the other hand, is about the "*integrity of conclusions*", meaning that it indicates to what extent the findings of the research are reliable, trustworthy, and related to the matter (Bryman, 2004).

As mentioned, in this paper both qualitative and quantitative data collection methods were used and therefore it was considered that reliability and validity were achieved since the sources used were reliable and consistent (see the chapter 2.2. Research methods). The report findings were supported by the quantitative data gathered from the questionnaire which was considered partly subjective as it was the opinion of the survey participants. However, the answers were considered also objective because of the big number of answers received from the participants (84), which made the final findings objective and thus reliable. Moreover, the reliability of the sources was also ensured by following a specific criterion to evaluate potential sources and to select the ones containing relevant and reliable information (see chapter 2.2. above). Reliability was also an important measure used in chapters 6 and 7 while identifying the possible solutions for improvement of different RM areas and reducing non-physical waste.

The validity of the paper and its findings was also ensured by the reliable sources and the collected questionnaire data, but in order to make it higher it was decided that the findings would be compared with data collected from real life by the means of a follow up interview. As the goal of the proposed solution was not only to be helpful in reducing non-physical waste, but also to be relevant, practical, and easy to use, interview with experts was chosen as the best way to validate it. Unfortunately, as mentioned before the interview could not be done due to Covid-19 and lack of time, however it should have helped to check how well the paper findings corresponded to established theories and practices regarding the same concept in real life.

3. Problem area

Even though waste in general is an issue on construction sites, non-physical waste has recently been attracting more attention. It is something that has been witnessed in the previous experiences on construction sites and projects with different construction companies. While the world has *environmental movements* in many different industries and forms such as lean – *“<…> systematic identification and quantification of waste <…>*” (Lee, et al., 1999), physical waste attracts more attention and has more practical solutions that are already being implemented in different industries as well as construction one. Yet, it is equally important to address non-physical waste, which occurs in every building project and contributes to wasted resources as time, money, etc. (Nagapan, et al., 2012a)

Non-physical waste has been also seen as an issue by specialists in Denmark (Wandahl & Neve, 2018). According to them, today the coordination and planning of non-physical resources is not sufficient on Danish construction sites and many workers with years of experience have a lot of professional pride and tend to do things in the traditional way (Videbæk, 2018). This is often a challenge for project managers to deal with while trying to reduce the above-mentioned waste. Because the issue is quite severe and difficult to solve, it was also influencing the choice of problem area of the thesis. While it is a matter that has to be addressed, solutions must not only work in theory, but also in practise, meaning that practical aspects of complexity, time consumption, investments and similar must be considered. Yet, to understand the reasons behind non-physical waste, it is beneficial to analyse the issue deeper and define the parts it consists of.

The non-physical waste in this report and context is referred to a waste generated by different lost resources. Normally, this type of waste occurs during the process of construction projects and it is divided into two large groups – time and cost overruns. Besides that, non-physical waste includes waiting time, delays, repairs, inefficient use of materials or equipment, wasted labour. It can also be associated with overproduction, deliveries of wrong materials and their handling, unnecessary movements of inventories or workers and similar. Even though non-physical waste includes many important factors defining the success of construction projects, it is the type of waste that has the least attention at the moment (Rahman & Janagan, 2015)

According to the new working productivity study from Aarhus University, where four construction sites were investigated, only 34% of the day is used for the actual construction work. The rest of it is spent on tidying up the site, logistics and waiting time (Wandahl & Neve, 2018). Other entrepreneurs on building sites in Aalborg East have also confirmed that a lot of time is wasted while tidying up working places and trying to communicate with people on site (Videbæk, 2018).

It is important however to understand that waste can be necessary or excessive. Necessary waste cannot be avoided and is needed for operations on site to happen efficiently. On the other hand, excessive one interrupts planned activities and delays overall project work. The study made by Aarhus University has revealed that the necessary waste includes preparation, tidying up and other necessary works that must be done by each entrepreneur for the work to continue. Yet, wasted resources include waiting times, searching for lost or misplaced things and mistakes which prevent further work from happening (see figure 6). Since the unnecessary waste consumes approximately 25% of the working time, it is an area that could be improved and could save both time and money (Wandahl & Neve, 2018).

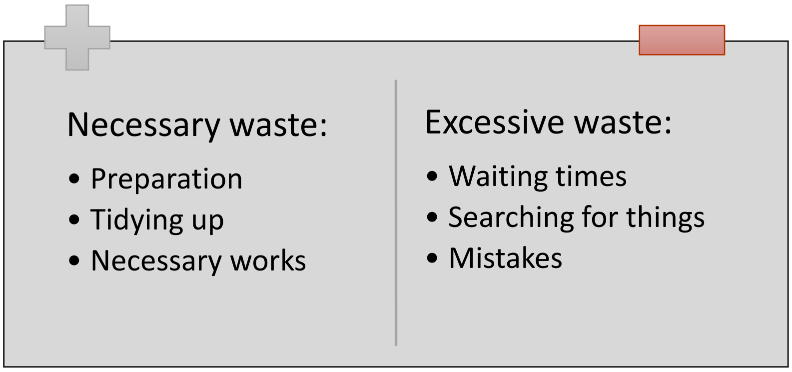

Figure 6. Different categories of non-physical waste. Source: (Wandahl & Neve, 2018) and own production.

Even though already mentioned process of Lean is trying to deal with the issue by eliminating all non-value adding activities, in many construction projects outside Japan it is experienced to be impractical and difficult to implement, therefore a different approach must be thought through. Some critics explain that even though Lean has a positive defiance and has been proven to work in many Japanese industries, other countries trying to take upon this approach should be realistic and know the reasons why it can fully work. It is naive to think that cultures with a lower amount of hierarchy in companies, e.g., Denmark, can successfully manage to use full Lean concept which involves a lot of strict management (Green, 1999).

Looking back at the general construction waste, it has been mentioned before that non-physical waste receives much less attention than the physical one and while it could appear as physical waste is more important since it is occurring more often, looking into study (figure 7) made by Nagapan et al., (2012) it is visible that both types of waste are almost equally generated from the same factors meaning that they should receive the same amount of attention.

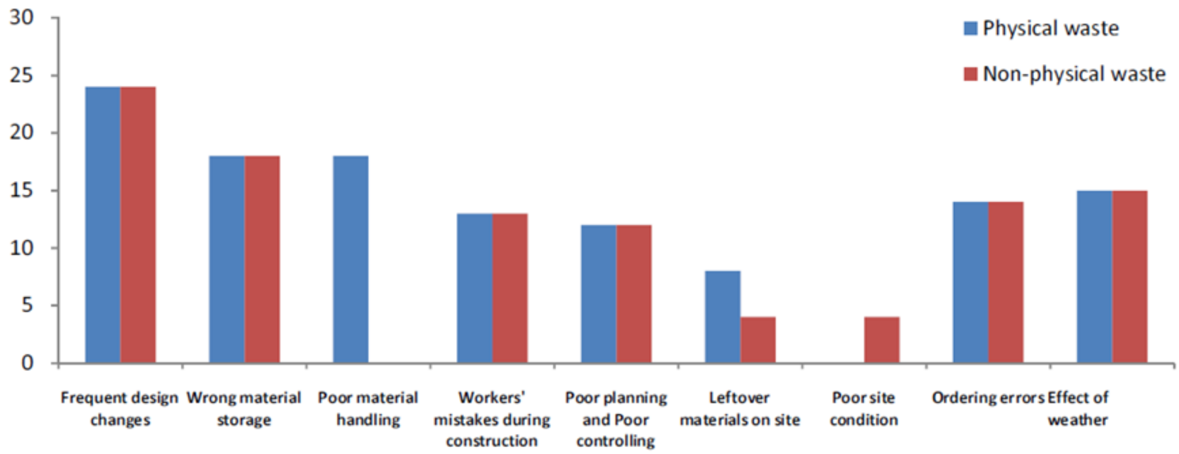

Figure 7. Bar Chart of physical and non-physical waste generation. Source: (Nagapan, et al., 2012a)

According to the chart, the same amount of physical and non-physical waste is being generated in 6 out of 9 cases, where leftover materials on site generate twice as much physical waste, poor material handling generates only physical and poor site condition only non-physical waste. This leads to a conclusion that non-physical waste is being produced approximately 94% of the time of physical waste production. Ignoring such waste means ignoring almost half of overall project waste which drastically dissipates time and costs.

Overall, non-physical waste is as important as physical one, but it is much less investigated and is still lacking practical solutions. While it is necessary to minimize it, it is also needed to understand that not all non-physical waste can or should be removed. It must be analysed whether the activity is adding some value for the further construction work or not and based on that according decisions on how to deal with wasteful activities can be made. Nevertheless, non-physical waste it is an issue on building sites requiring more attention and more applied solutions that can be implemented by construction companies.

3.1. Cost and time overruns

Having non-value activities that absorb construction project's resources can often lead to cost and time overruns. As mentioned above, non-value activities during construction period often originate from the work process, site conditions, workers, management procedures, or other external reasons like design changes, delays in deliveries, weather conditions, etc. The non-physical waste created due to delays, rework, poor project management, or inefficient work process can affect the project's schedule and budget negatively resulting in unexpected costs and time delays. Therefore, it is essential that non-value adding activities are minimized and that the project's resources are used in an optimal way ensuring that the planned cost and time are as agreed with clients and stakeholders.

A report on cost overruns in national building and construction projects done by the Danish Rigsrevisionen in 2009, where 49 projects (32 building projects and 17 construction projects) were examined, shows that 20% of the examined projects had cost overruns. The research was focused on cost overruns exceeding 10 percent of the original budget, since cost overruns amounting to DKK 10 million or up to 10 percent of the total costs of certain projects may be covered by insurances or contract and will not result in disputes and arbitration. The other 80% were either implemented within the original budget costs or with cost overruns under 10% of the total budget. The factors influencing cost overruns on these projects were identified to be due to missing requirements specification, late changes to project design and/or function, errors on the part of the builder, contractor, and consultant, resulting in both physical and non-physical waste, or unpredictable events like *cyclical expenditure*, soil condition and new regulations (Rigsrevisionen, 2009).

A review of three projects which were within the original budget has shown that in order to keep the estimated cost, functional changes not fully matching the project's objectives had to be made, or that overestimation, due to the application of inadequate key indicators helped to remain within the original budget. Only in one of the projects tight finance management procedures were applied and helped to make some savings to ensure that cost was kept within the original budget (Rigsrevisionen, 2009).

Another study shows that the most frequently identified cost overrun causes are due to frequent design changes, financing and payments delays, lack of contractors' experience, poor cost estimation, poor tendering and/or poor material management (Moore, 2017). In Denmark, financing and payments delays are not often a cause, since contracts based on General Conditions (AB 18, ABT 18, ABR 18) ensure that such problems are minimized or even eliminated. However, the rest of the causes, as also identified by the research made by Rigsrevisionen (2009), are present on the Danish construction sites and often lead to cost and/or time overruns. Therefore, it is important that such causes are identified and eliminated early in the process ensuring that the created non-value adding activities concerning them are also eliminated.

Moreover, literature shows that there is a lot of time waste at construction sites all over the world, as well as in Denmark, and that about two thirds of a working day is wasted on tasks that do not contribute to the construction project itself (Videbæk, 2018). The time waste affects the productivity on site and results in time overruns and cost overruns. Studies on time overruns show that the most common factors affecting the time schedules during construction are unskilled labour force, poor management, changes in design, weather condition, etc. (Sweis, 2013). This means that time and cost overruns result from similar causes (see table 2 below), which leads to the conclusion that by eliminating or minimizing the effect of these factors and ensuring that time is spent on activities that are needed and have value on the project, cost and time overruns will be prevented from happening.

<table>
<tr><th></th><th>Cost overruns</th><th>Time overruns</th></tr>
<tr><td>Common factors:</td><td colspan="2">• Work process
• Site conditions
• Workers motivation/productivity
• Management procedures
• Design changes
• Delivery times
• Errors/rework
• Weather conditions
• Soil conditions
• Lack of contractors’ experience</td></tr>
<tr><td>Other:</td><td>• Missing information/specification
• Cyclical expenditure
• Financing and payment delays</td><td>• Poor planning
• Site organization</td></tr>
</table>

Table 2. Summary of factors contributing to cost and time overruns at construction projects found by Rigsrevisionen (2009), Moore, (2017) and Sweis, (2013). Source: own production.

Additionally, since time and cost overruns are interrelated and can occur as a result of similar factors, they can affect each other greatly. For example, if time is delayed it will have effect on the cost, by either resulting in higher budget costs due to delays and fines from the stakeholders or additional costs due to buying more labour force and resources to finish the required tasks on time. Cost, on the other hand, can also be affected by time especially when there are specific activities that require to be carried out at a certain time. This interrelation is also known from the concept of the project management triangle, which implies that the success of every construction project is determined by three constraints - time, cost, and scope, which can impact the quality of the project (Dobson, 2004).

3.2. Reasons for waste

As it becomes clear, non-physical waste occurs because of different reasons and it happens when specific factors lead to wasted resources. There are numerous factors which can result in non-physical waste, but they can be categorized to narrow down the main reasons. Nagapan, et al. (2012) and his study about physical and non-physical waste generation in construction industry have been chosen as the basis of the investigation. According to him, there are seven main categories contributing to general waste on sites: *design, handling, workers, management, site conditions, procurement*, and *external factor* (see table 3). All categories result in waste on construction sites and they are influencing both – physical and non-physical waste in a very similar matter. It is visible from the table that significant factors are almost the same on both sides, as different categories influence both types of waste, once again proving that non-physical waste is always generated when physical waste occurs.

Category	Significant factors	
	Physical	**Non-physical**
Design	Frequent design changes	Frequent design changes
Handling	Wrong material storage and poor materials handling	Wrong material storage
Worker	Workers' mistakes during construction	Workers' mistakes during construction
Management	Poor planning and poor controlling	Poor planning and poor controlling
Site conditions	Leftover materials on site	Poor site conditions
Procurement	Ordering errors	Ordering errors
External factor	Effect of weather	Effect of weather

Table 3. Significant factors that contribute to the construction waste based on category. Source: (Nagapan, et al., 2012).

Design contributes to occurrence of non-physical waste when changes are made after the construction process has started. Not only client and contractor have to spend time discussing changes and agreeing on final design but often rework is required as well, leading to wasted materials, working time and workers' productivity. That is why communication is important in early design phases. On top of that, contractors should also advice clients to make final decisions before construction starts, informing them about the importance of waste elimination and benefits of time and cost savings.

Handling includes material storage and usage. If materials are ruined because of improper handling or storage, this does not only lead to a physical material waste, but also to waste of time and money, since new materials will have to be bought and stoppage of construction work can occur during the waiting time of the new order. The manpower becomes a wasted resource as well if workers must wait for the order to continue the work. Thus, proper storage facilities together with comprehensive techniques are needed to protect materials at the site.

Workers mistakes is another important factor contributing to a non-physical waste. Mistakes during the works can cause rework, delays, extra costs and wasted manpower. Besides that, improper handling of materials or equipment can cause damage, which contributes to stoppage of work, delays, and unpredicted wasted resources. This issue requires training of the staff and selection of experienced workers.

Management issues include inadequate planning and controlling. Uncoordinated planning can lead to interference with subcontractors, arguments and waiting times, whereas lack of control and knowledge of other trades work progress on site can cause confusions and delays. Choice of unsuited staff and subcontractors or improper equipment can also cause stoppage of work, meaning that project managers must always pay enough attention to selection and planning to make thoughtful decisions.

Site condition has been analysed to be the most common issue contributing to a non-physical waste (Wang & Li, 2011). Poor site conditions and roadwork can cause equipment failure, ruined materials, and lead to delays. Improper planning of the site can also cause difficulties with deliveries leading to time overruns. That is why, thorough site investigation is necessary before every building project, allowing to systematically access its condition and location.

Procurement involves wrong orders and deliveries, which result in resource waste. Insufficient amounts of materials can lead to stoppage of work and wasted time. Wrong deliveries often have to be sent back and waiting time is generated until the correct order is received. Thus, correct and sufficient orders are important for reduction of non-physical waste.

External factor is something that is often more difficult to predict, such as weather or soil conditions, but when completely ignored it can generate a lot of waste. Work can be disturbed in case of heavy rains or landslides, which leads to wasted resources. Even though project managers often account for weather factor, by adding in extra time and money, they should still try to follow the forecast and look into previous experiences during different times of the year to minimize the possibility of external factor impacting the project resources.

All factors are different and influence construction waste in a distinct way, however all of them are very important in every project and must always be accounted for as they are all closely connected. It can be difficult to rectify all issues causing occurrence of non-physical waste yet having them categorized into bigger areas helps to identify the main reason causing the waste. Identifying a category allows not only to see what the issues have in common, but also to set focus on the root cause. Looking at the categories identified by Nagapan et al., (2012), it is visible that all factors include handling of resources. All seven of them include necessary resources for every construction project and the way they are handled and organized determines project's success which also includes the amount of waste it produces. Thus, if a well-thought through resource utilization is an important aspect of success in construction projects, this leads to a conclusion that improper resource management is one of the main reasons for non-physical waste.

3.3. Resource management

According to Karaa & Nasr, (1986) "*Resource planning and management is one of the most important ingredients for competitiveness and profitability in today's construction industry*". Resource Management is important when it comes to staying profitable and competitive in the industry as if done correctly, it helps to organize resources of the project in a way that reduces costs and time overruns. In other words, Resource Management helps to save money and reduce construction time, to make sure it does not exceed what was agreed. It is also required to plan resources in a way that will make them available when necessary during the project by tracking inputs and outputs (figure 8). The success of any project can often be determined by available resources because every activity that must be completed cannot be done without it. Resources can be identified as something that contribute to completion of the project, which mainly includes time, money, manpower, materials, equipment, and space. Since these are also part of non-physical resources, it makes RM one of the solutions that can help in reduction of non-physical waste (Chaudhuri, et al., 2012).

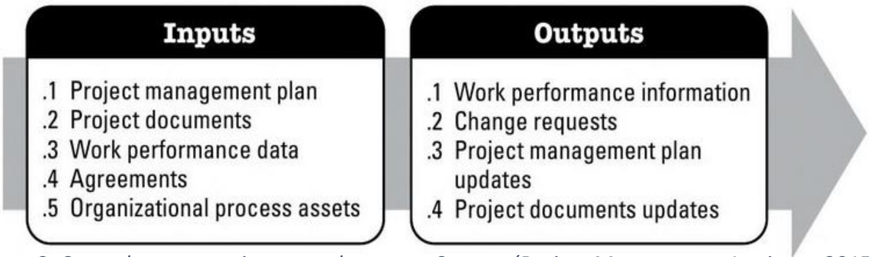

Figure 8. Control resources: inputs and outputs. Source: (Project Management Institute, 2017)

Many construction companies consciously or unconsciously already use Resource Management. When companies are not aware of it, it is mostly done by means of planning, scheduling, or organizing. Every contractor knows that a project cannot function without management of available resources, yet they do not specifically identify it as a Resource Management, which is a system by itself. The other part of contractors who do use the RM principle often fail in achieving the wanted success rate or results and end up realizing that their management process is broken (Othman, et al., 2014). This happens when managers fail to constantly strive for efficient usage of resources and try new, advanced equipment or innovative methods (Othman, et al., 2012). There are however basic and universal methods that can be used in most of the cases, such as optimization of labor productivity, space, and material management.

As mentioned in the chapter 3.1, time and costs are closely interrelated and, in most cases, whatever affects costs will affect time and vice versa. They are also the main parts of non-physical waste, therefore, it is important to analyze which resources affect them both directly. For this reason, it is not necessary to analyze how to manage budget or schedule itself, but more importantly how to control resources, such us materials, manpower, equipment, and space affecting time and budget to reduce these main parts of non-physical waste (Chaudhuri, et al., 2012).

To know how different non-physical waste factors suggested by Nagapan, et. al, (2012) are connected with Resource Management, it has been chosen to separate RM into three areas: Labour, Space and Material management. RM in construction industry can have several different areas, yet Labour, Space and Material areas were identified as the most important ones according to Sears, (2015), Othman, et al., (2014) and Igwe, et al., (2020) as they include resources which are essential for construction sites. It is important to distinguish which areas are directly influenced by specific factors and are the most important to be analysed further. Thus, handling, workers, management, site conditions and external factors have been identified to have direct effect on *Labour management*; design, workers, management, site conditions and external factors on *Space management;* and all listed factors on *Material management* (see table 4). Even though Material management is directly influenced by all factors, it is not necessarily the RM area, which is the most beneficial to improve, thus the other two areas should be considered as well and further analysed.

Factors influencing non-physical waste	**Resource Management areas**		
	Labour management	Space management	Material management
Design		**x**	**x**
Handling	**x**		**x**
Workers	**x**	**x**	**x**
Management	**x**	**x**	**x**
Site conditions	**x**	**x**	**x**
Procurement			**x**
External factors	**x**	**x**	**x**

Table 4. Factors influencing non-physical waste combined into Resource Management areas. Source: own production.

To understand how waste is influenced by Resource Management areas, it is important to look at all three and understand how they are defined. To control the project time and costs, it is essential to have different resources utilized in an efficient way. Unless they are planned, nothing can be made within the given time frame (Karaa & Nasr, 1986). This can be done by diverse methods, but one of them is managing labor. The manager must have a good overview of the resource, how much is needed and how much is available, to develop a plan of action, which helps to control and direct manpower. Cost of labor is difficult to control, because it is usually set as an hourly wage and either good or bad work will cost the same for a particular worker (Chaudhuri, et al., 2012). However, it is possible to control labor productivity and that is defined to be the major concern for those controlling costs of the project (Othman, et al., 2012).

Another important resource contributing to time and cost overruns include materials and their usage. Cost of materials can reach up to 70% of total project costs, but it can be well controlled and managed. Efficient and rational material usage does not only reduce physical construction waste, but also saves a lot of time and money (Ayegba, 2013). Material management often starts in early phases of the project as many projects have tight schedules and availability of materials can greatly impact it, both positively and negatively. Besides that, it is needed to plan site, logistics and the storage of materials since improperly treated or damaged materials result in shortage and expanded timeframe as well as costs.

This leads to a third area – handling space organization, which does not only allow to avoid material damage, but it also prevents unnecessary movements of workers and creates an organized flow of the project. Building sites must be carefully thought through before the project begins and be constantly updated to achieve the best movement and placement of resources. Since deficiencies and defects were identified as major reasons for financial losses and loss of productivity on many construction sites (Ahzahar, et al., 2011), it makes space management an important part of resource management.

All three RM areas contribute to constant occurrence of non-physical waste on construction sites meaning that those areas should be improved. Since it is nearly impossible to improve all flaws at once, an option is to start with the main factors affecting the area the most and if those are improved, then the whole RM area should experience a change leading to a drastic reduction of non-physical waste and increased success of the project.

3.4. Assessment of problem area

To find out solutions for non-physical waste, Danish construction industry has been analysed to show how such waste with possible solutions are perceived by professionals. The survey itself has been already described in methods, therefore only the summary of answers and conclusions will be presented. A total of 489 surveys have been distributed and only 64 have been fully answered, whereas 20 have not been finished. As expected, the majority of answers have been collected from project leaders (37) and construction managers (32), whereas it was much more difficult to receive answers from project managers – only 15 were received. Surveys have been sent in mails, specifically targeting construction companies in Denmark.

Almost half of the respondents belong to the age group ranging from 30 to 40 years, however one third of respondents turned out to be above 50 years old, meaning that answers were received from both: younger and senior generation (see figure 9). This pattern can also be seen in the amount of their experience (figure 10). There was almost an equal amount of people belonging to experience group below 10 years and above 10 years. The surprising fact was that most of respondents have more than 20 years' experience on construction sites, meaning that the answers to the questionnaire have high validity and experience level.

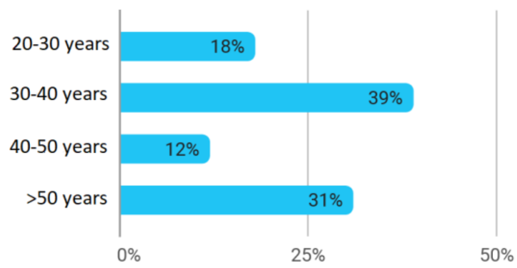

Figure 9. Age groups of respondents. Source: own production.

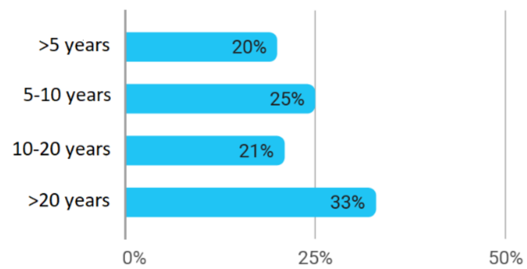

Figure 10. Years of experience of respondents. Source: own production.

When it comes to resource waste or non-physical waste in forms of time, costs or labour productivity, all respondents agreed that they are aware of such waste happening on building sites. Everyone also agreed that it would be beneficial for the companies and projects to know the reasons behind such waste and to act out to minimize them. Moreover, 90% of people responded to be aware of cost and time overruns caused by resource waste. However, the answers revealed, that such waste has almost the same impact on both time and money.

To the question about the size of effect that waste has on both overruns, respondents identified that on budget it has an effect of 3.4/5, whereas on time – 3.3/5. Yet, questions about type of resource waste having the biggest effect on construction projects and being the most common revealed a drastic difference between overruns. Around 60% of respondents identified that time waste has the biggest effect on projects and is the most common. 31% thought it was costs and the rest identified that both are equal (see figures 11 and 12).

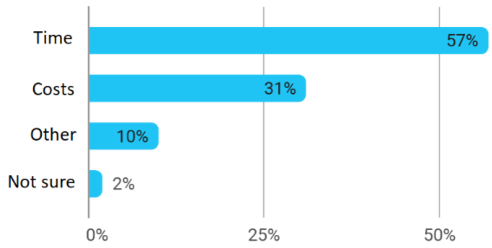

Figure 12. Types of resource waste having the biggest effect on construction projects. Source: own production.

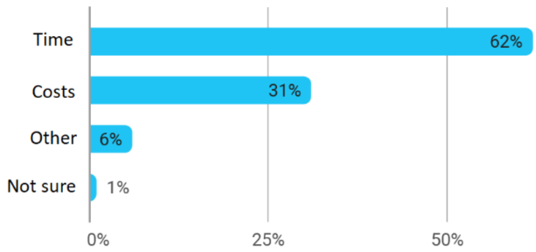

Figure 11. The most common types of resource waste in construction projects. Source: own production.

After defining whether or not respondents are aware of non-physical waste and its effect, it was needed to find out which factors influence resource waste the most. Four categories were identified: *mistakes caused by planning and design, organisation and management, knowledge of workers and management as well as insufficient communication between workers*. According to respondents, the most important factor is organisation and management, in average receiving 3 out of 5 points (see table 5). Knowledge of workers and managers has also received high scores from both project leaders and construction managers. However, it is also visible that all other factors received a similar average grading, being 2.9 out of 5. This means that even though organisation and management received the highest score, all other factors are almost as equally important in generation of resource waste.

Profession	Factors influencing resource waste on construction sites			
	Mistakes because of planning and design	Organisation and management	Knowledge of workers and managers	Bad communication between workers
Project manager	3.1	2.8	2.3	2.6
Project leader	2.8	3.0	3.1	3.1
Construction manager	2.9	3.0	3.0	2.7
	Average grading			
	2.9	3.0	2.9	2.9

Table 5. Grading of factors influencing resource waste on construction sites. Source: own production.

The last question defining the problem formulation was identifying whether respondents think that Resource Management is an important factor in reducing non-physical waste and how it is perceived. As for importance, respondents gave an average of 3.2 out of 5, confirming our previous assumptions that RM is important.

Discovering that Resource Management is as important as it has been assumed was a positive finding, however it was also needed to see and understand how such management is perceived and used by the experts. The survey revealed that only 67% of respondents actually know and use RM while 9% where not sure or not aware of using it. Distribution between different profession choices regarding the question can be seen in figure 13. This showed that even though respondents do believe Resource Management to be important, quite a lot of them are either not using it or they do not really understand it and are not aware of how to use it efficiently.

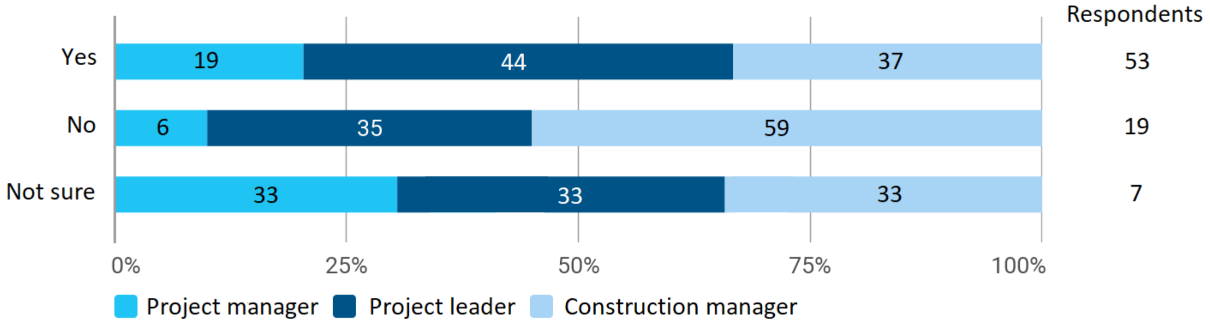

Figure 13. Usage of resource management by management people on construction sites. Source: own production.

The above gained results about different types of resource waste and usage of Resource Management lead to an overall conclusion that non-physical waste on Danish construction sites is perceived as an issue and managers would be interested in practical solutions on how to reduce it. It also believed that to reduce non-physical waste all four areas such as *mistakes caused by planning and design, organisation and management, knowledge of workers and management* as well as *insufficient communication between workers* should be improved. Besides that, respondents agreed that as a bigger solution - Resource Management can really help in reducing waste, however as for now it is unclear how to optimize it and what exact actions of RM can help to control cost and time overruns and as other wasted resources.

4. Problem formulation

From the initial analysis done so far it becomes clear that non-physical waste is present at construction sites everywhere, as well as in Denmark. Moreover, it is also clear that this type of waste leads to many unfortunate results like time and cost overruns, which affect projects negatively and can impact the company's reputation and future in relation to stakeholders like clients, sub-contractors, or suppliers. However, the analysis done about reasons for the occurrence of non-physical waste and cost and time overruns in construction projects show that they are mainly related to improper handling of resources, misinformation, and poor planning. Therefore, focusing on Resource Management and its optimal implementation in construction projects can positively influence the occurrence of non-physical waste leading to its minimization or even elimination in some cases. Thus, the research question for the paper is formulated as follows:

How to reduce non-physical waste at construction sites by optimizing the management of resources?

Construction projects are complex and unique, and it is often difficult to predict all factors that could influence them. Moreover, in regard to RM, the construction industry uses larger scale equipment, materials and labour force in comparison to other industries, which makes it difficult to plan and organize efficiently. The stakeholders involved in managing the resources also differ in terms of education, experience, and perceptions, thus also leading to improper planning and inefficiency (Othman, 2014). All so far mentioned, results in waste of resources and negatively influences the project's performance, success, budget and/or time.

Therefore, applicable methods of better optimization of Resource Management practices on construction sites are needed to improve the performance of projects and to minimize, or even eliminate non-physical waste and other unwanted effects. And even though, as it becomes clear from the survey, some people at the construction sites are aware of Resource Management practices, the applied techniques and methods are only scratching the surface of the potential that RM could have on projects if it is fully optimized and implemented, thus making it essential to find a good set of practices that could be used in future projects.

5. Delimitation

The research was focused on finding ways to minimize non-physical waste at construction sites, since there are numerous other studies done for elimination of such waste in different processes in all industries, as well as for the construction industry, but there are not much practical ones for the construction period. Therefore, the paper was delimited to the construction period since it is a phase were a lot of waste can be produced, both physical and non-physical. Moreover, the scope of the report was narrowed down by focusing only on non-physical waste because physical waste, as it is easier to notice and reduce, has been broadly discussed and researched and many construction companies have already taken measures to reduce it. There are even requirements and government strategies encouraging construction professionals to strictly follow the rules as well as reduce and recycle construction waste, however, there is not much done for reducing the non-physical one.

There are many different ways to deal with non-physical waste, also known from Lean Construction (LC), but after a thorough research and data collection, it was decided that by looking deeper into the topic of Resource Management a lot of non-physical waste could be reduced. Thus, the research was aimed to find ways for waste minimization by focusing on management of resources, and in particular Labour, Material and Space management. These areas were chosen since they cover the most important resources managed during the construction phase and in addition, they have more practical orientation and can be used to give practical knowledge and approaches to construction professionals and other people interested in the topic. The report did not investigate other types of resources, like equipment and inventory, etc., because the concept of handing these resources is similar to the material one and also due to the wish for simplicity of the solution so that it is more feasible, easier to understand and be applied during the process of construction.

The report and data collected in form of survey was focused on people in the management departments of Danish construction companies to get practical knowledge of the management procedures used on site and to make sure that the solutions chosen could be used by people that are responsible for managing the projects and their resources. Construction workers were not part of the survey because it is considered that the changes should come from top management first.

The selection of solutions both for each RM field or the final solution was delimited according to the proposed solution's influence on management of resources, practicality, and feasibility. Solutions, which were found to solve one or more problems (factors) were chosen to be further researched, whereas solutions which were not related to management of resources or were found to be too complex and solving only one problem were not researched further. Even tough, some lean solutions like *Last Planner System* (LPS), *Value stream mapping* (VSM) or the concept of 5S: Sort, Set, Shine, Standardize, Sustain, were also found befitting to solve some of the identified issues affecting the researched RM fields, they were not offered as solutions since they are complex concepts that require project managers to have sufficient knowledge and do thorough research about the whole lean philosophy in order to implement them successfully and were therefore, not considered feasible and practical. Moreover, many computer-based software found suitable for solving some of the identified issues were also not further researched, due to the academical nature of the paper, instead, the paper focused on available concepts and practices.

The final solution of the paper was also limited to finding a solution, or set of solutions, that could both help optimize the management of resources on construction sites and reduce non-physical waste. Solutions that reduce non-physical waste but were not related to management of resources were not looked at. It would have been of additional value if the efficiency and quality of solution or set of solutions could be tested in real life, but since the project was limited by time, this was not possible. Instead, solutions that have been analysed and proven to be effective by several researchers were further studied over the ones with low numbers of studies conducted.

To help managers identify project areas where non-physical waste is generated and where project resources are wasted a framework was created. The framework was based on *Resource Based View* (RBV), but it was adapted so it could be used on project level and at construction sites in order to help identify areas of occurrence of non-physical waste and poorly managed resources. It would have been of additional value if the framework could also be tested in real life to see if it could really help managers identify Resource Management issues, but that was not possible since the project was limited by time.

6. Resource Management optimization

The completion of a construction project with an optimal efficiency in relation to time and cost requires thorough planning and allocation of all resources including manpower, equipment, materials, space, time, and money. Therefore, the purpose of Resource Management is to guarantee that the established objectives of a project can be met by ensuring that all resources connected to the construction process and supplying and supporting field operations are available and ready to be used (Sears, 2015).

According to Johnson, et al., (2017) "*The efficiency and effectiveness of physical or financial resources, or the people in an organization, depend not just on their existence, but on the systems and processes by which they are managed, the relationships and cooperation between people, their adaptability, their innovative capacity, the relationship with customers and suppliers, and the experience and learning about what works well and what does not*". The project resources are important and therefore it is also important how a construction manager utilizes these resources because there would be no point in having skilled workers for example, if they are not used effectively in the specific area of expertise but on a task that is not part of their competencies.

A factor influencing how resources are handled on construction sites is the knowledge that the site or project manager have concerning the topic and if they apply any of their knowledge to optimize the project. It is essential that they understand the benefits that optimal resource management will have both on the project and their personal project related tasks, such as cutting down non-value activities (excess work, waiting times, mistakes, etc.) and optimizing the working process, budget and time objectives, and quality of the project. Moreover, optimization of the project and its objectives will lead to high client/customer satisfaction, good reputation for the company and the project manager as well as it can contribute to high workers' productivity and good relationship with project stakeholders. According to the survey carried out for this paper, half of the target group, including project managers, construction

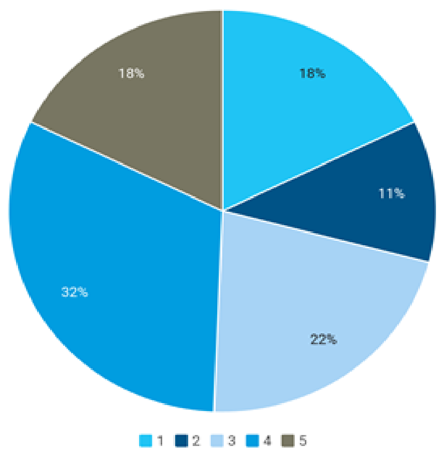

Figure 14. Importance of Resource Management (RM) for reducing non-physical waste on sites. Source: own production.

managers and project leaders, recognize RM as an important aspect for cutting down non-physical waste on construction sites and have given it grades of 4 (32%) and 5 (18%) for respectively important and most important (see figure 14).

As mentioned before, the percentage of people working in companies who have already implemented some aspects of Resource Management is big – about 67%, however, there are also 24%, who have responded that they do not use any and 9% who are not aware of it. Moreover, in their further answers the people who use RM have answered that they mainly use it regarding workforce management (49%) and site and space organization (29%) and only 22% use material management. This means that there is potential for optimizing the management of resources not only in companies that do not use it at all, but also in companies who have implemented it partly and not in its full potential.

When it comes to management of a company's resources - Resource Based View (RBV) framework is recognized as means used to identify what resources (physical, financial, human, technological, reputation and organizational), competencies and capabilities a company has, making sure that they are used in the most optimal and efficient way possible. Yet, when it comes to resources used in the construction process there are not many frameworks or guidelines that can help manage many different and complex types of resources used daily at construction sites (Madhani, 2009). Therefore, a framework is needed to help managers see how resources can be managed optimally at construction sites, ensuring that there are no unnecessary resources available that are being unused due to mistakes, waiting times or the inability to allocate them on time.

In addition, 97% of all participants think that improving Resource Management in the fields of Labour, Space and Material management can help reduce non-physical waste, whereas the other 3% includes people who do not know (2%) and people who think it will not help (1%). However, having in mind that part of these are also people who do not use RM or are not aware of using it shows that in general the participants think that the optimization of these areas can help. For that purpose, in the following chapters a deeper analysis of how exactly the three fields of RM can be used, which factors affect them and what benefits they could bring for construction projects would be explained thoroughly.

6.1. Labour management and productivity

The construction industry is considered labour-intensive industry in which the workforce has great effect that can be either positive or negative depending on its level of productivity. Despite the advances and automation of technology, the construction sector remains one of the most people-reliant sectors. Labour is essential in this industry and therefore, people are considered an organization's most valuable resource, however, they are also considered difficult to manage (Loosemore, et al., 2003). Unlike physical resources such as equipment, materials, supplies and facilities, people have their own needs, perspectives, values, skills etc., which are sometimes hard to manage and predict. Yet, these traits make workforce management the field of RM that holds the best possibilities for improvement, elimination of potential construction risks and enhancement of the productivity potential (Loosemore, et al., 2003).

Productivity, in economics refers to measures of outputs per unit of input and can be defined as the ratio of output energy divided by input energy. In the construction industry productivity usually corresponds to labour productivity (see figure 15) and is measured as units of work produced per man-hour, or as man-hour per unit (Shehata & El-Gohary, 2012). According to literature, productivity is a *"<…> dominating aspect in the construction industry as it encourages cost savings and effective utilization of resources"* (Alaghbari, et al., 2017).

$$Productivity = \frac{Outputs}{Inputs\ (manhours\ or\ labour\ cost)}$$

$$Productivity\ in\ construction = \frac{Units\ of\ work}{Manhours}$$

Figure 15. Productivity ratio. Source: (Shehata & El-Gohary, 2012) and own production.

In most countries, labour costs correspond to between 30 to 50% of the overall project's costs, meaning that if there is low productivity the negative effect on the project costs can be high (Jarkas & Bitar, 2012). This confirms the importance of this resource in the construction industry and ensures that improvement of labour productivity will contribute to high overall productivity and project performance (Mahamid, 2013). However, as mentioned earlier in chapter 3.3, since the cost of labour is difficult to control, because it can be set as e.g., an hourly, fixed wage or payment for finished task, and either good or bad work will cost the same for a particular worker, thus causing the limited control, a solution can be to control the level of labour productivity, so it is assured that the outcome of the labour corresponds to the paid wage. Another factor to consider is that construction industry is project-based, in which according to the specific project on hand, a specific labour is needed with a specific area of expertise. However, the employees on the construction sites can be skilled or unskilled. In Denmark, due to the high labour costs, it is a common mistake of construction professionals to hire unskilled labour because it is cheaper, contributing to reduced quality and productivity of the work (Dansk Byggeri, 2019). Unskilled workers lack knowledge, construction skills, expertise, and have poor workmanship, which leads to a negative impact on the overall project performance resulting in time overrun, cost overrun, quality defects, etc. Skilled labour force, on the other hand has better experience, knowledge, and expertise but is normally more expensive to buy and less flexible when it comes to availability without previously done agreements (Hussain, et al., 2020).

All in all, labour has a significant impact on the construction time, costs, and overall construction procedures, and is thus considered to have an impact on the level of non-physical waste that a project generates. Since labour productivity in the construction industry is believed to be primarily affected by the ability of construction managers to plan, schedule and manage the work process (Dai, et al., 2007) and because of their inefficient management of construction resources like materials, machinery, space, time and budget (Shehata & El-Gohary, 2012), it is therefore important for contractors and construction managers to be aware of the importance of sufficient management and allocation of resources. According to literature, the management of labour, i.e., hours, assigned tasks, number of workers assigned, etc., is more susceptible to the influence of management than materials, capital, provided space and machinery, etc., and it holds the most efficient opportunity to be improved (Shashank, et al., 2014). To see which factors, affect Labour management in Denmark, the analysis in the next chapter is made.

6.1.1. Factors affecting Labour management and productivity

As it becomes clear, labour productivity plays a big role in determining the success of a project but there are many unexpected variables that can affect it greatly. Such variables may be related to different factors like workers, materials, tools and equipment, management, finance, etc. (Alaghbari, et al., 2017). A study done by group's supervisor - Lindhard, (2020) - shows classification of different factors affecting labour productivity that have been identified and classified by numerous studies in Asia. These factors have been categorized into five primary groups, namely Project, Labour, Management, Technical and External factors. Each primary group consists of several sub-factors which show in depth the list of factors identified to influence the primary group and the labour productivity in construction projects. Since the key to raising the productivity level lies in improving the performance and ensuring the efficiency of the specified primary factors, a deeper and more holistic explanation of each primary category will be given in the pages below, together with advises, reflections and analysis on how each of them can be improved to cut down non-physical waste and improve the overall Resource Management techniques.

Management factors

According to literature*, "management ineffectiveness is widely perceived as a principal cause for poor construction productivity"* (Dai, et al., 2007). Poor management skills and inefficient management of construction resources can result in demotivation of workers and low productivity (Shehata & El-Gohary, 2012). And since workers are essential for executing construction processes and activities, they have influence on the overall project productivity and performance. The project-based nature of construction leads to complexity and variation in number of work locations and manpower needs throughout the different projects or work process. Not all potential work locations in a construction site are manned all the time, as well as not all available human resources are used all together. The amount of work and employees available on site is determined by "*schedule demands, changes, design errors, weather, sequencing, crew interferences, etc*." and thus the explicit management of the labour resources is essential in achieving good project performance (Thomas, et al., 2003).

The analysis and categorization done by Lindhard (2020) has led to an identification of 8 main management sub-factors that are believed to have the most importance, namely *supervision, planning and sequencing, competency of project manager, poor site layout, inspections, information, coordination and collaboration, safety and work environment and congestion and overmanning*. According to the survey data gathered for this paper, most important based on the opinion of Danish construction professionals are planning and sequencing, coordination and collaboration and competencies of project manager and foremen (see table 6).

Rank №	Management factors	RII
1	Planning and sequencing	0.87
2	Coordination and collaboration	0.86
3	Competency of project manager	0.84
4	Competency of foremen	0.83
5	Site layout	0.74
6	Safety and work environment	0.72
7	Congestion and overmanning	0.72
8	Supervision and inspections	0.70
		Average RII: 0.79

Table 6. Management factors affecting labour productivity and their ranking according to RII. Source: own production.

As mentioned earlier, labour productivity is primarily influenced by the ability of the construction managers to plan and organize the work (Dai, et al., 2007). This fact is also supported by the findings of the survey according to which **planning and sequencing** is listed as the most important factor affecting labour productivity (see table 6). The second most important factor identified is **coordination and collaboration**. It is considered essential to improve the coordination and collaboration between the different actors in order to avoid non-value adding activities like mistakes, delays, rework, etc. which will also result in cost and time overruns and diminishing the quality of the work. In other studies, coordination and collaboration were also found as major reasons for labour inefficiency (Huang et al., 2008; Dozzi and AbouRizk, 1993). The authors suggested that using available concepts and technologies to collaborate and monitor the performance of the construction operatives can help reduce the effect of this factor and improve productivity.

The third and fourth most essential factors constraining the labour productivity at construction sites is considered to be the **competency of the project manager and the project's foremen**. Leadership qualities, people and technical skills are necessary for both the project success and the productivity of the workers, because if the management group shows negligence and incompetence, the workforce will not feel motivated to do their best or to follow orders and plans as supposed. Therefore, a combination of the expertise and personal skills are necessary. **Site layout, safety and work environment, congestion and overmanning** are considered as less important, but they should still be kept in mind. Unorganized site layout with congestion and overmanning will reduce the labour productivity and can lead to waiting times, rework, delays, as well as frustration and irritation of the workforce which can result not only in non-physical waste but also physical and will reduce the whole project productivity and efficiency. **Lack of supervision and inspection** is listed as the factor with the lowest importance but according to other studies it is also important since it can lead to workers engaging in unproductive activities, having frequent unscheduled breaks, or even leaving the job sites during working hours (Jarkas & Bitar, 2012). According to the authors, *"Direct supervision of labour is required to avoid faulty and nonconforming work to contractual specifications and thus minimize the expensive incidents of rework and the associated delays to activities at hand"* (Jarkas & Bitar, 2012). Thus, meaning that it should be also considered.

Project factors

As mentioned before, construction industry is project-based industry, in which each project is different from the previous one. The ever-changing nature of projects and work is considered to increase the level of satisfaction and productivity of construction workers because it is diverse and more exciting for labourers (Bernold & AbouRizk, 2010). However, there are some project-related factors that affect labour productivity negatively, resulting in non-physical waste and inefficiency. These factors have been identified and categorized as seen in the table 7 below:

Rank №	Project factors	RII
1	Rework and delay	0.75
2	Construction method	0.74
3	Project characteristics	0.73
4	Financial capability	0.73
5	Subcontracting	0.72
6	Contracts and procurement	0.65
7	Location	0.50
		Average RII: 0.69

Table 7. Project factors affecting labour productivity and their ranking according to RII. Source: own production.

Rework and delays are ranked to be the most essential for affecting labour productivity (see table 7). In literature, rework is described as a direct result of unclear drawings and specifications, design complexity, lack of supervision, unskilled workers, etc. (Jarkas & Bitar, 2012). Delays, on the other hand are often caused due to improper planning from the construction manager, overcrowded construction sites, or inefficient crew composition (Dozzi & AbouRizk, 1993). The second most important factor affecting workers and their efficiency is **construction method**. *Stop-and-go operations*, for example, are found to be demotivating and lowering labour productivity (Dozzi & AbouRizk, 1993). A stoppage of work can occur when an essential component for completing an activity is not available, e.g., drawing, management decision, adequate workforce, delays of supplied materials, etc. Another example of construction method affecting productivity is working environment safety. According to literature, "*Craftsmen are more productive when they know that management is genuinely concerned about their well-being"* (Dozzi & AbouRizk, 1993).

Project characteristics and **financial capability** are ranked as third and fourth most important factors with the same percentage of RII. Project characteristics, like construction methods affect labour productivity by affecting the level of motivation of the workers. If the labourers know what to expect in regard to project's size, buildability and complexity they would feel more motivated and satisfied to work on the project. If, however, they are not informed about it in advance, it will result in confusion, low productivity, and non-physical waste, such as rework, delays, waiting time, etc. (Dozzi and AbouRizk, 2010). Financial capability, on the other hand, is also found important, since if there is more financial resource, monetary incentives like bonuses can be given to the construction workers who show efficiency which can increase their productivity and motivation to do their best (Hiyassat, et al., 2016).

Subcontracting, contracts and procurement, and **location** are found to be with less importance to labour productivity since they are more project-related than labour-related and the workforce productivity is not as much influenced by them. Undoubtedly, the number of projects contracted plays an important role on the motivation and productivity of workers because it also affects their salaries but according to Danish professionals that is not as big of a problem affecting productivity as the other mentioned factors.

Labour factors

The management of labour force includes identification of labour needs for each project activity and determination of the number of workers required and their necessary skills (Sears, 2015). However, since construction industry is labour intensive industry, the labour productivity is dependent on how the different workers act and if they are efficient. After identifying which factors affect labour productivity, they were ranked according to their Relative Importance Index corresponding to the grades that each of the factors received in the carried-out survey. The ranking and RII can be found in the table 8 below:

Rank №	Labour factors	RII
1	Motivation	0.80
2	Labour work facilities and satisfaction	0.77
3	Skill and experience	0.76
4	Crew composition	0.76
5	Personal issues and disputes	0.66
6	Absenteeism	0.65
7	Labour fatigue	0.62
		Average RII: 0.72

Table 8. Labour factors affecting labour productivity and their ranking according to RII. Source: own production.

In this category, **labour motivation** is ranked as the most important factor affecting the construction workforce. As known, if building construction workers lack motivation to carry out their duties, this can affect both the rate and quality of productivity (Asibuodu, et al., 2016). According to Jarkas & Bitar, (2012) "*Motivated operatives are usually more enthusiastic and initiative. They work harder and respond faster to instructions. Their pace is, moreover, associated with a greater sense of pride, satisfaction, and responsibility, thus they typically achieve more, in comparison with demotivated or discouraged laborers*". Additionally, if there is demotivation of the people in the management group of the project, this could lead to a ripple (domino) effect and affect all participants in the project resulting in high unproductivity.

The second most important factor ranked according to the participants of the survey is **labour work facilities and satisfaction**. In the construction process work facilities include workspace, storage rooms and available machinery. The provided workspace influences the workers productivity and satisfaction (more will be described in the next chapter - 6.2). The same counts for satisfaction as well, since unsatisfied workforce leads to demotivation and demotivation leads to inefficiency (Jarkas & Bitar, 2012). The third relatively important factor is **skill and experience**. As mentioned previously, in the construction industry there can be both skilled and unskilled employees, however, with unskilled employees it is often that a rework, rectifications, or repairs are required resulting in non-physical waste and unproductivity. On the contrary, experienced workers possess adequate intellectual abilities to find practical solutions to problems, and high technical skills to do quality work. All this can lead to higher productivity and better quality of finished outputs (Jarkas & Bitar, 2012).

Crew composition is ranked as the fourth most important factor. Construction tasks often require a group of diverse workers acting as a team with specific objectives. According to Dozzi and AbouRizk, (1993) "*Mild competition in production objectives is also healthy and useful, i.e., productivity competitions between crews or between shifts. Supervisors can achieve higher levels of productivity by appealing to a worker's pride, competence, sense of duty, and team play*". Therefore, it can be considered that working in a highly efficient team can help people be motivated and productive in order to do better. On the contrary, if the team is inefficient the workers will feel unmotivated and reluctant to do their best to fulfil the tasks at hand.

Personal issues and disputes, absenteeism and labour fatigue are ranked not as important as the other mentioned, but they are still considered to have some impact on labour productivity. According to Dozzi and AbouRizk, (1993) all three of them are demotivation factors, resulting in low productivity.

Technical factors

Rank №	Technical factors	RII
1	Incomplete design or specifications	0.82
2	Misinformation	0.82
3	Materials	0.77
4	Design changes	0.74
5	Client and consultants	0.73
6	Tools and equipment	0.69
7	Technology and culture	0.69
		Average RII: 0.75

Table 9. Technical factors affecting labour productivity and their ranking according to RII. Source: own production.

The first two factors with the highest RII are **incomplete design or specifications** and **misinformation** (see table 9), and they are both with RII of 0.82, which is significantly higher than the RII of the other mentioned factors. The incomplete and/or unclear technical specifications and information will require continuous requests for clarifications, which can lead to interruptions of the work progress and annoyance among the working crew. Moreover, incomplete specifications or design could lead to revisions and changes of the design, resulting in the creation of non-physical waste like rework and delays (Jarkas & Bitar, 2012). All this will then lead to frustration among the workforce and low productivity and it is therefore considered of high importance. These two factors were also ranked among the most important in other researches (Jarkas & Bitar, 2012 and Alaghbari, et al., 2017).

Materials are ranked as the third most important factor affecting labour productivity. The reason for this is because without available or suitable materials the required work cannot be accomplished, thus leading to waiting times, delays and low productivity. The same counts for **design changes** which is therefore graded as the fourth most important factor with RII of 0.74. **Client and consultants** is ranked as the next important factor affecting the productivity of the workforce. This is because they are people who have big authority on the project and it is them who will evaluate the work done in the end of the project or make changes through the process. A good relationship and cooperation between the client and the management group of the project can contribute to higher satisfaction from both the client, consultants and the management group, also affecting the workforce and leading to high productivity and efficiency.

Tools and equipment, like materials, also affect the level of productivity on construction projects, but since most construction companies in Denmark have their tools and equipment up to date it is not considered as important for the productivity of the labour force. Similarly, **technology and culture** are also considered not as important, since as in all other industries, the construction industry has adapted to some of the new emerging technologies in order to achieve efficiency and to improve the work processes. In other sectors, technology has undoubtedly helped to achieve higher labour and project productivity by optimizing the work processes, but in the construction industry this was harder to accomplish due to its fundamental nature and labour culture to resist change (Holt, et al., 2015). However, the customers' demands for technological solutions has resulted in significant use of new technology also in the construction industry, which has led to higher labour productivity (Holt, et al., 2015). Moreover, in some Danish construction companies, workers are provided with work phones or tablets, which improves the communication and cooperation between the workforce and also their productivity.

External factors

From the listed external factors that can affect a project, **legislation** and **permits** are found to be the most important (see table 10). The legislation process during construction phase could be, for example, approval from the working environment authorities, which if not met an enforcement notice will be issued closing the site until the working environment problem is not fixed (BAR Bygge & Anlæg, 2016). Another example could be if the building authorities delay or (temporarily) stop the project due to high level excess noise coming from the site and disturbing neighbouring buildings occupants. All this can lead not only to productivity loss, but also to other non-physical waste like delays in schedules, deliveries and waiting times.

Rank №	External factors	RII
1	Legislation	0.62
2	Permits	0.61
3	Weather	0.61
4	Financial stability	0.59
		Average RII: 0.61

Table 10. External factors affecting labour productivity and their ranking according to RII. Source: own production.

The thirds essential external factor graded with RII of 0.61 is **weather**. "*Cold, rain, wind and draughts cool your body and increase the stress on the circulation and metabolism*", which also affects the person's ability carry out a task in such a weather (BAR Bygge & Anlæg, 2016). For example, when the hands are chilled, this impacts the sense of touch and the ability to work. According to literature poor weather conditions have adverse effects on productivity, comfort, safety, and health (Oglesby, et al., 1989).

Financial stability is ranked as the least important external factor affecting labour productivity. This is so, because of the use of the Danish General Conditions (AB18, ABT18, ABR 18) according to which all construction actors, including labourers, are protected in regard to financial agreements. The rules for financial agreements between the client and contractors can be found in AB18 under *Clause 24. Additional payment and cost reductions*, *Clause 34. Price and indexation*, and *Clause 36. Payment and retention* (AB18, 2018). These regulations prevent any financial problems, thus making sure that labourers feel safe regarding both the financial stability of the project and their own incomes. All so far mentioned, leads to the small RII given by the Danish construction professionals, confirming that even though in other countries this might be a significant factor, in Denmark it is not.

6.1.2. Ways to improve Labour management and productivity

Labour productivity is one of the key areas on which construction managers need to focus on in order to improve the overall performance of construction projects (Mahamid, 2013). According to literature, **management** is regarded as a major influence on the labour productivity (Shehata & El-Gohary, 2012; Thomas, et al., 2003). This fact is also supported by the average RII calculated for all main categories' factors gathered from the survey data of this paper (tables 6-10 in chapter 6.1.1). Management factors have an average RII of 0.78 (table 11), meaning that they are considered as the most influential on labour productivity according to danish professionals, followed by technical factors (0.75) and labour factors (0.72). Project and external factors were found to be not that important for labour productivity and have receiver lower RII values of respectively 0.69 and 0.62. Moreover, as seen in the table below, management factors consist of four of the topmost essential subfactors for all categories with RII values higher than 0.80. From this top ranking, planning and sequencing is rated as the first most important (RII of 0.87), followed by coordination and collaboration (0.86).

Rank №	Related category	Factors	RII	Category's RII
1	Management	Planning and sequencing	0.87	0.78
2	Management	Coordination and collaboration	0.86	0.78
3	Management	Competency of project manager	0.84	0.78
4	Management	Competency of foremen	0.83	0.78
5	Technical	Incomplete design or specifications	0.82	0.75
6	Technical	Misinformation	0.82	0.75
7	Labour	Motivation	0.80	0.72

Table 11. Top seven factors affecting labour productivity. Source: Own production.

In order to improve labour management in regard to these two factors and minimize the negative effect they have on labour productivity, a suggestion could be to use management concepts and approaches which can help plan and track both workflow activities and available labour resources during the construction phase (Liu, et al., 2011). Reducing workflow variations has been also found as a possibility to improve labour productivity (Liu, et al., 2011). Making sure that workflow activities are predictable or repetitive can prevent occurrence of mistakes and reworks since laborers will be more familiar to the work processes and work techniques necessary. It is argued that if workflow can be made more conventional, labour, and other resources can be predicted and better matched to the workload, thus improving productivity (Ballard & Howell, 1994). By having predictable workflow in construction projects, a lot of time can be saved for communication and confirmation of the necessary tasks and the required techniques or approaches. Moreover, this will also help to prevent the occurrence of mistakes and reworks, further leading to higher project efficiency and labour productivity.

Existing concepts like Location based scheduling (LBS), suggested by several researchers (Olivieri, et al., 2018; Kenley, 2004; Buchmann-Slorup, 2014), can help improve workflow, plan and manage activities and available resources such as labour, materials, and equipment during the construction phase and therefore can be used to lessen the effect that **planning and sequencing** have on labour productivity. According to literature, "*the goal of LB systems is to achieve continuous flow, maximize the continuous use of labour, improve productivity, balance production, and improve the visualization of schedules"* (Olivieri, et al., 2019). LBS can be done manually or with the help of some program or software and it can be used for allocating resources, organizing the logistics of resources, monitor progress, cost, and quality, and for reporting data to take the required actions (Kenley & Seppanen, 2010). With LBS it is possible to add location to the different construction activities so that the needed resources can be allocated to the right place and the right time in order to prevent possible overcrowding, confusion and time waste (Andersson & Christensen, 2007). By doing this, the risks of having workers at the same place and time can be reduced, which will also prevent having non-physical waste such as waiting time, delays, conflicts, frustration among workers and inefficiency.

Moreover, if LBS is combined with BIM and the 3D model of a project, available information can be acquired from other phases and actors, so that the planning can be more precise and detailed. By using the LBS concept and the information stored in the BIM model managers can create detailed schedules and associate activities with the corresponding materials, equipment, and labour forces to achieve better workflow, better use of the resources, and to reduce the occurrence of interruptions (Kenley & Seppanen, 2009). Combination of LBS with 3D BIM model can be additionally made more detailed by adding costs, since each used resource can have unit prices. This can be used to automatically generate a 5D model where visualisation of each model element, or information about labour crew can be shown in order to see what resources belong to a specific location (Kala, et al., 2010). However, some difficulties are found as well, both connected to the application of the LBS concept or LBS-software, or connected to more general things, like the need for a significant amount of input information in the initial stage of the planning process, or difficulties to change the level of detail once the scheduling has commenced (Andersson & Christensen, 2007).

Huang et al., (2008) and Dozzi and AbouRizk, (2010) have suggested that using available concepts and technologies to **collaborate and coordinate** can also help improve labour productivity. According to literature, technology has a positive effect on construction labour productivity, for example, Loosemore (2014) suggests that by using technology, labour productivity could be improved by approximately 30% to 40%. Other researchers (Hewage, et al., 2008 and Holt, et al., 2015) also believe that tools, machinery, automation, and integration of information systems increase labour productivity. Workers who are equipped with suitable technology such as tablets, for example, can be informed simultaneously of changes to design or work tasks which could save time and prevent mistakes and reworks from happening.

Competency of project manager and **foremen** are the other two essential factors considered to have the most effect on labour productivity. And as mentioned earlier, this fact is supported by a study carried out by Shehata & El-Gohary in (2012), who suggest that poor management skills and inefficient management of construction resources result in demotivation of workers and low productivity. Competency of project manager and foremen is a very broad topic and there could be many solutions to it, such as education and/or technical training, management courses, or implementation of new approach concepts and technologies to improve work processes, etc. However, since the factor is mentioned in regard to labour productivity, researchers Buli, (2017) and Tabassi et al., (2014) suggest that "*by applying an efficient and appropriate leadership style, leaders can direct the laborers and move the project team in the right direction, thus improving labour productivity and ensuring that a construction project runs smoothly*". In general, educating construction workers can bring a lot of benefits, but sometimes it can be also a difficult task to carry out if employees are showing resistance to learn (Stackhouse, et al., 2020). Besides that, courses are expensive and increase company's debt (Li, et al., 2017), so it is important to evaluate how much benefits it will bring.

Incomplete specification or design and **misinformation** are two technical factors which are also evaluated to be essential. As mentioned, incomplete specifications or design could lead to revisions and changes of the design, resulting in the creation of non-physical waste like rework and delays, thus leading to frustration among the workforce and low productivity (Jarkas & Bitar, 2012 and Alaghbari, et al., 2017). The influence of these two factors can be minimized by having a good cloud-based platform on site that can make sure that even if there is incomplete specifications and design data, or that important information is missing, there is an available platform where the management group, foremen and workers can easily communicate problems and clarify misinformation and mistakes or make updates (Mell & Grance, 2011).

The doctoral study done by Lakew G. Buli (2017) has also concluded upon another management skill that is essential, namely "*motivating the workforce*", and as seen from table 11., **motivation** is the last of the top seven most important factors affecting labour productivity identified for this paper. According to participants in the study motivation will be significantly improved when the leaders "*clearly explain targets and objectives*", "*fairly evaluate performance*" and "*strive to support their teams to achieve their targets*". Moreover, the study has concluded that if there is "*a system of evaluating and rewarding performance fairly, correctly, and in a transparent manner*" this would help improve labour productivity and minimize non-physical waste (Buli, 2017).

All in all, providing educational training regarding management or technical skills and/or implementing or optimizing available concepts and (IT) software can help to improve labour productivity on construction sites. However, as mentioned earlier, the construction industry is resistant to change, so the process of adapting to these concepts and technologies can be hard (Holt, et al., 2015). And even though, there are many available concepts and technologies that can be used, selected and mentioned are the ones that have influence on labour productivity and help improve the process of Labour management. A summary of everything discussed so far can be seen in the table 12 below:

Rank №	Related category	Factors	RII	Available proposal solutions

1	Management	Planning and sequencing	0.87	• **LBS**
				  • BIM-based Software
				  • Manually
				• **Cloud-based platforms**

2	Management	Coordination and collaboration	0.86	• **LBS**
				  • BIM-based Software
				  • Manually
				• **Cloud-based platforms**

3	Management	Competency of project manager	0.84	• **Educational and/or technical training** • **Leadership and Motivational training** • **Application of available concept and technological solutions**
4	Management	Competency of foremen	0.83	• **Educational and/or technical training** • **Leadership and Motivational training** • **Application of available concept and technological solutions**
5	Technical	Incomplete specification or design	0.82	• **Cloud-based platforms** • **Technology**
6	Technical	Information	0.82	• **Cloud-based platforms** • **Technology**
7	Labour	Motivation	0.80	• **Leadership and Motivational training** • **Application of available concept and technological solutions**

Table 12. Idea proposal for optimization of Labour management productivity by improvement of the top seven most essential factors. Source: own production.

6.2. Space management

Every task and every participant on a construction site requires a dedicated space to carry out quality work, which can be organized with a Space management. Space management is a part of Resource Management and can be divided into two stages: planning and managing space (Igwe, et al., 2020). Space must be thoroughly planned before the construction begins and managed afterwards by constantly updating area plans adapted to the construction process of the project. If space planning and management are not carried out properly, it can result in safety hazards, loss of productivity and inadequate quality (Choi, et al., 2014) Even though workspace could be considered as one of the most important resources, currently it is not taken seriously enough during construction planning (Igwe, et al., 2020). Although some of the construction projects have a massive scale, they are limited with available area. Such projects have different participants, activities and equipment involved, requiring separate spacing. Space properties are influenced by the nature of activity and its construction plan which can change during the project while the project progresses (Riley & Sanvido, 1995).

Currently, most of the space planning and management issues deal with either inability to allocate space or considering that the space is only occupied by one crew at a time. Therefore, the majority of space management on construction sites depends on intuitive, experience and empirical knowledge of project managers (Choi, et al., 2014). Experience is naturally a valuable asset in every construction project and when used right, can bring many positive results. This was proven by a Norwegian contractor Hersleth Entreprenør AS, when the company was responsible for a construction of residential facility. The project had a very skilled and experienced manager, who used his previous knowledge of planning to carry out the project and completed it with great success (Skjelbred, et al., 2015). However, depending only on previous experience does not always bring positive results as often it is important to consider uniqueness of the project, possible innovative solutions and methods that could improve the planning of construction space. Ignoring various possibilities due to previous experiences can lead to failures as every project is different and currently many of them are becoming more complex and what worked on previous projects will not necessarily work on the future ones. That is why having the lack of formalized processes made especially for workspace management results in lost resources that project managers cannot handle, especially with the increasing demand on reduced project durations (Igwe, et al., 2020).

6.2.1. Planning space

An early planning of the building site, resources and logistics is required for the success of any construction project (Skjelbred, et al., 2015). It can be done in many ways, but first and foremost it must be done early enough before the beginning of a construction to avoid lost resources. Another aspect of planning a site layout is to have a structured process allowing to identify, understand and rationally use different areas within construction site. The flow of the project should never be disturbed by insufficient planning and usage of available space making planning stage of Space management and important first step (Skjelbred, et al., 2015).

As mentioned before, until any space planning can begin, it is necessary to understand differences between available areas within building sites. To analyse space planning in an efficient way, workspace should be organized by two features: function and movability (see figure 16). *“<…> function represents the whole workspace requirement without exception <…>”* and movability identifies the purpose of the space for a specific activity (Riley & Sanvido, 1995). Understanding the workspace is important to achieve the right and suitable space planning. It is necessary to know available space resources and plan early enough how they should be distributed and changed throughout the project. However, before anything can be put into the plan, the manager must be familiar with differences between workspaces and what they depend on. Knowing requirements for different types of areas allows to sensibly select their location and assign diverse activities, crews, materials, or equipment.

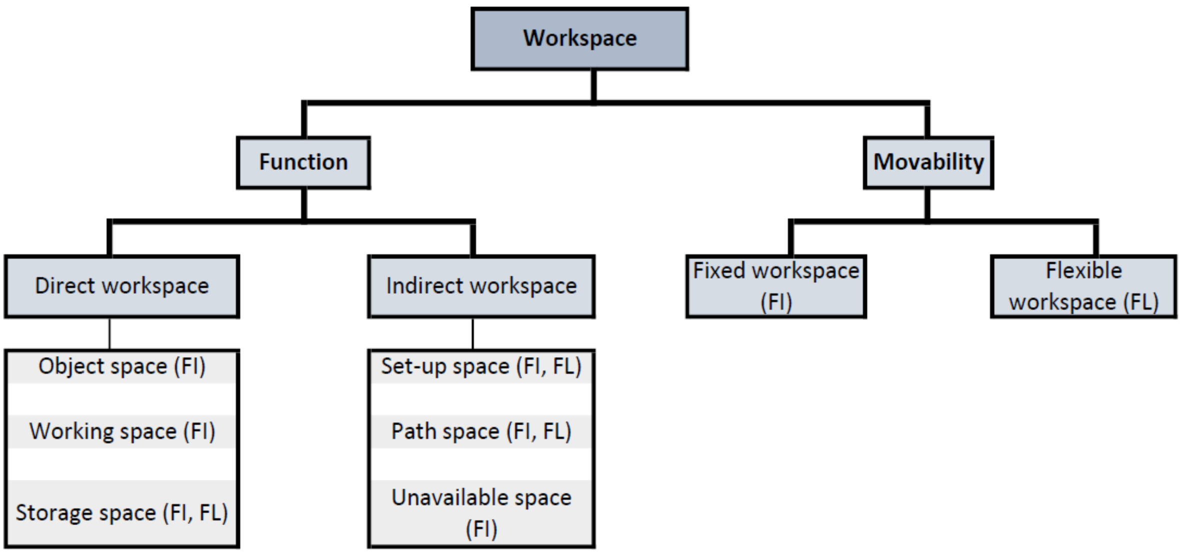

Figure 16. Classification of different workspaces. Source: (Choi, et al., 2014) and own production.

To make sure that nothing is left out and to avoid difficult changes during the building process, space planning can be done following several steps identified by Choi, et al., (2014). According to them, workspace planning consists of four or five phases: *4D BIM generation* (which is optional), *workspace requirements identification, occupation representation, problem identification and problem resolution*. To create a sufficient planning of available space on sites involves understanding about requirements for different spaces, representation of occupied spaces and preparation for possible problems. Having defined way and method for carrying out such plan allows to make sure that everything has been though through and the plan will be made in the most efficient and convenient way. This leads to less mistakes during the management process and ensures the quality work of every project (Choi, et al., 2014).

Overall, to achieve sufficient results in Space management, planning phase should be the first step to be completed. Without good planning of a building site, management processes can become chaotic and create many issues leading to wasted non-physical resources (Choi, et al., 2014). For that it is important to prepare, understand and classify the workspace and plan it according to defined and approved methods. Having standards and methods that everyone can follow, can lead to a better overall organization of building sites (Skjelbred, et al., 2015).

6.2.2. Factors affecting Space management

In order to have construction projects which are following the schedule and meeting deadlines, it is important to have a good management of the building site. It is needed to have a well-thought-through planning of the site layout but since the plans are constantly evolving and changing during the construction phase, Space management is necessary to control that. Managing building sites involves many aspects, such as relocating designated areas when necessary, updating plans according to the changes, establishing new routes, managing movement of workers or materials and similar (Wang, et al., 2004). As construction phase is rather chaotic, it can be difficult to keep track of everything that is happening and changing fast. Besides that, it involves many decisions that have to be made quickly, therefore a structure and constant overview of a current situation on construction sites is needed for reduction of non-physical waste.

Construction sites face many issues, and it is the project manager's job to prevent them or ensure that the problems are eliminated. It is quite common that most of the main contractors have many subcontractors working under them. Even though each of them is responsible for their own work, when it comes to larger issues such as safety or problems influencing the whole project, responsibility falls under the main contractor (Choudhry & Fang, 2008). This means that managing construction site is a complex task involving solving everyone's problems. Many different issues within construction sites have been identified concerning management among which are some associated with decision making (Aboelmagd, 2018), safety of workers (Hamid, et al., 2011), keeping with site organization (Igwe, et al., 2020) and similar. All these problems come with a price which is often lost resources and non-physical waste. To reduce such waste and avoid mistakes carried out while managing building sites, it is possible to divide Space management into different areas and find out which are the most essential for a successful management process and reduced lost resources.

Space management can be divided and analysed with the same main categories as in previously examined labour productivity (Lindhard, 2020). Each of these factors have several sub-factors which have been carefully selected from sub-factors mentioned according to their relevance and importance. Some of them have also been combined and slightly changed where it was necessary. Analysing Space management according to these factors allows to see how this resource management area is affected by different fields and what can be done to reduce the occurrence of lost non-physical waste.

Management factors

Management factors are important for space management and in this RM area the management factor is understood as constant administration and control of a building project throughout its' construction phase (Igwe, et al., 2020). It involves constant updating of plans, supervision, organization, communication, assurance of satisfactory working conditions which are achieved with competence of people in charge (Opsahl, et al., 2015). Management factors have been divided into eight categories that influence Space management and are essential to avoid non-physical waste (table 13).

Rank №	Management factors	RII
1	Planning and sequencing	0.85
2	Coordination and collaboration	0.84
3	Competency of project manager	0.83
4	Competency of foremen	0.82
5	Safety and work environment	0.73
6	Site layout	0.72
7	Congestion and overmanning	0.70
8	Supervision and inspections	0.69
		Average RII: 0.77

Table 13. Management factors influencing Space management and their RII according to survey results. Source: own production.

Planning and sequencing has been evaluated to be the most important sub-factor within management factors that influences Space management. With RII of 0.85 it is not drastically higher than the other marked sub-factors, but it is more significant than e.g., supervision and inspection with RII of 0.69. Considering what has been established in the chapter 6.2.1. about planning, it is not surprising that respondents found planning and sequencing to be the most important sub-factor. The whole construction process is based on planning of activities and organizing them in the best way to have the shortest and most efficient sequence. This sequence does not only establish the way activities must follow one another, but also allows to avoid delays, organize the construction site in a way where everyone has a satisfactory workstation and to reduce non-physical waste (Choi, et al., 2014). This allows working crews to complete their activities proving why insufficient planning and sequencing at construction sites can lead to many wasted resources. To prevent that, project managers could use a planning system that includes both the view of the construction sites and activities happening in different areas such as 4D BIM, which connects 3D drawings of the project and construction schedule allowing to see what, where and when is happening (Wang, et al., 2004).

Coordination and collaboration has been chosen as the second most important factor affecting space management. Its' RII of 0.84 has been very close to the previous factor of planning and sequencing, showing that it is almost as equally important. Since construction sites are involving many different activities and people, it often gets very hectic therefore good coordination and collaboration from a project manager is needed (Opsahl, et al., 2015). Communication issues have been named to be one the biggest issues on building sites for many years (Guevara & Boyer, 1981 and Kwofie, et al., 2020) thus this sub-factor is still causing a lot of lost resources. This means that to avoid miscommunications and mistakes leading to lost labour productivity, time and money, the project manager must establish sufficient working culture and make sure that all activities, people, and materials on site are coordinated in an appropriate manner.

Competency of project manager and **Competency of foreman** are the other two most important factors that the building projects depend on. During construction phase a lot of decisions have to be made based on previous experiences and knowledge of people in charge (Skjelbred, et al., 2015), so managers must be competent people (Dzwigol, et al., 2020). This can be described in an example of a manager who has competency in technologies and is able to efficiently use them in coordinating tasks on site or material logistics. If decisions are made by incompetent people, it can result in bad choices of activities, people and material allocation which produces a lot of non-physical waste. To avoid such waste, it is important to have competent staff running projects and people, who knows how to evaluate different options and make the best decisions.

The other four sub-factors received much lower rating and therefore are considered less important, however they are still an essential part of management factor in Space management. Building site cannot be managed without following laws and ensuring **safe working environment**. Even though **site layout** received a low RII of 0.72, it is a fundamental factor of space management as described in chapter 6.2.1. It must be well thought through during planning and constantly controlled by ensuring appropriate people and activities allocation as well as providing **supervision** (Skjelbred, et al., 2015). It is a project managers' task to ensure quality of the construction project thus constant inspections are necessary. Although such sub-factors received lower RII than the average of the whole category, building projects would not be successful if they were not accounted for.

Project factors

Project factors are an important part of Space management and as seen in the table 14, they define what type of building it is, how and where it will be constructed and what are the financial boundaries that must be considered. Most of the choices made on construction sites must depend on these factors as managerial decisions are often made based on type of the building and its' location which allows to form the basis of any site planning and management

(Dallasega, et al., 2013). When thoroughly considered, project factors can not only improve the quality of Space management, but also reduce the amount of non-physical waste occurring for the building projects.

Rank №	Project factors	RII
1	Execution method	0.79
2	Project characteristics (size, buildability, complexity)	0.74
3	Defects	0.71
4	Client, project and own finances	0.70
5	Project location	0.62
		Average RII: 0.71

Table 14. Project factors influencing Space management and their RII according to survey results. Source: own production.

Execution method has been indicated to be the most important project factor within Space management. With RII much higher than the category's average, it has been proven to be more significant than other factors. Execution method of a construction project can include many things, but it mostly relates to the construction process and the way it is done. Execution is connected with the planned construction method and can include process plans, organization of works, construction boundaries, requirements, prospects and risks. It must take into consideration actual conditions on the construction site and make sure that the plans are transferred into actions (Koskela & Howell, 2001). Execution method defines different needs for a construction site allowing project manager to make the necessary decisions while running the building site. A building constructed from premade elements can have a simpler, faster, and less risky execution method resulting in less complexed schedule and process, workers, and material coordination. Conversely, a structure which must be assembled on site can result in higher number of tasks and cluttered site space.

Project characteristics refer to a detailed explanation of type of the project. In this context characteristics include size of the building, buildability, and complexity. It is important to consider these features as different projects require different solutions and such characteristics can influence execution methods, planning, construction speed and uncertainty (Cho, et al., 2009). Planning and managing a site can be much more complex for large buildings than the small ones, as they include more activities, people, and require more working areas. However, smaller scope project might have less flexibility as they often have smaller plot or less space if they are executed within e.g., city area. However, the size of the building is not always the key factor as a building can be large, yet easy to build compared to a complicated smaller scale project. Buildability refers to a way the project is constructed, and the materials used. This is closely related to complexity which by literature is defined as large number of interacting parts (Wood & Gidado, 2008). Construction projects are generally considered to be complexed (Baccarini, 1996) as they involve many different tasks that must be carefully planned referring to difficulty of the construction (Gidado, 1996), the solutions used, space available and similar (Wood & Gidado, 2008). Thus, projects characteristics can have a big influence for managing construction site which depending on buildability and complexity can either help or overcomplicate space management.

Defects is another project factor that has been chosen to be rather important with RII of 0.71. Defects are very common in construction industry and can affect many parts of the project as cost, time, and resources (Ahzahar, et al., 2011). Being rather common and having a big influence on different project parts, defects are a big part of Space management. They create rework, extra deliveries of new materials or elements, thus they require organization of logistics and workspaces (Ali & Wen, 2011). Defects can cause many problems for the site layout resulting in a chaotic construction site, where materials or elements have to be sent back and new ones must come in. Besides that, mistakes by working crews can cause longer unpredicted time of area usage. To avoid that it is a good idea to have a backup plan, as defects are quite common and knowing how to deal with them beforehand gives an advantage in controlling the site.

Finances have received slightly lower RII (0.70) than defects, showing that it is also very important, whereas **location** has a drastically lower RII (0.62) than any other project factors, indicating that is of less importance. Finances of client and contractor define the construction capabilities and can be of great influence for running the site. It can provide possibilities for flexibility in size of the plot, inventory, and storage capabilities. Larger budget can offer better, more innovative solutions as well as better logistics indicating that economy is an overall important factor. Yet location is of less importance in a way that it can be rarely chosen or changed. Since most of construction sites are already limited in the amount of space and usable areas, it is not a factor that is under the control of a project manager.

Labour factors

Construction industry is considered to be a labour-intensive industry, where building sites cannot function without interference of the people (Alaghbari, et al., 2017). Even though capabilities of machines are improving rapidly, most of the main decisions, choices and different work must still be done by humans (Ghate, et al., 2016). Besides that, labour productivity has an effect on time and cost overruns, thus meaning that the factor cannot be overlooked to avoid non-physical waste (Kadir, et al., 2005). Building projects involve different types of people, including clients, contractors, and workers, so managing construction sites requires constant interaction with people making labour factors (table 15) important in Space management (Ghate, et al., 2016).

Rank №	Labour factors	RII
1	Tidiness	0.81
2	Motivation	0.76
3	Composition of work crew	0.72
4	Number of workers	0.70
5	Culture	0.70
		Average RII: 0.74

Table 15. Labour factors influencing Space management and their RII according to survey results. Source: own production.

Tidiness is essential to ensure workers' safety and to keep different areas organized (Shazwan, et al., 2017). Since construction sites have numerous activities happening at the same time, it can easily get cluttered if not tidied (Cheng, et al., 2017). Keeping building sites organized cannot be done without involvement of labour as clutter can be created by different types of workers, including improper management resulting in poor site layout and updates as well as a mess that different working crews can leave. As for organisation of site layout, tidiness is required while considering placement of workstations, material, and equipment stations. Considerations of these things can avoid clutter as it is often created when areas that are closely related are placed far apart (Choi, et al., 2014). While the manager should make sure to organize a site which results in generating as little mess as possible, he should also make sure to establish clear policies that different working crews must follow. A way to make sure that the construction site stays tidy and does not disturb any activities is to do constant check-ups and report the findings during the meetings showing where the clutter has been gathered and who is responsible for eliminating it (Bajjou, et al., 2017).

Motivation of project manager and working crews can have a big influence in space management. Motivation of the manager to have a well-organized and run building site can lead to non-disturbed activities flow which saves time and financial resources (Yeheyis, et al., 2016). On top of that, motivated working crew results in striking to achieve better results not only in their own tasks, but in the whole project. However, different subcontractors often only focus on their own work, ignoring the work of others working in the same work area. This leads to poor communication and mistakes on construction sites which end up causing non-physical waste. Motivating workers to strive for the success of the whole project can help them to improve their communication with project manager, different working teams and to report mistakes of others (Zuo, et al., 2018).

Composition of work crew must be well thought through in environments where many different types of people are involved (Mathieu, et al., 2017). Since it has been established before that construction is a labour-intensive industry (Alaghbari, et al., 2017), working with different types of people and creating efficient teams is an important aspect. If a crew is working coherent and has a proper team leader, it can lead to better understanding of workers, knowledge of what and where must happen and result in a synergy effect (Oke, et al., 2016). Besides that, well composed teams must have strong leaders and be able to follow orders. Space management requires constant organization of manpower throughout different workstations, thus a proper leading can improve the condition of building sites which contributes greatly to reduction of non-physical waste.

Number of workers and their **culture** have been identified as the least important factors receiving the same RII of 0.70. It is more difficult to manage a building site with large number of people as this leads to more workstations and a bigger chance of people's activities colliding. Besides that, the culture that each crew has, defines the way they are going to treat their and other workstations as well as the way they are going to follow orders from the leaders. However, these have probably been chosen as factors of lower importance since the main choices, decisions and planning are done by the project manager who must control the work of others too.

Technical factors

Cambridge dictionary describes technical as something "*relating to the knowledge, methods and practical skills that are used in a particular activity*" (Cambridge Dictionary, 2016). In construction Space management this refers to technical issues that can create non-physical waste, such as misinformation between different actors, unclear specification or late changes, issues with logistics or tools, interferences from the clients and problems with technologies and culture (see table 16). All these sub-factors can also be identified as uncertainties as they are harder to predict risks which can cause lost resources (Horlick-Jones, 1998). Technical factors are as important as the above-mentioned ones for the Space management since they can considerably affect the flow of work in different activity stations.

Rank №	Technical factors	RII
1	Misinformation	0.81
2	Incomplete design or specifications	0.77
3	Materials and logistics	0.75
4	Design changes	0.72
5	Equipment and tools	0.70
6	Interference from the client and consultant	0.68
7	Technology and culture	0.67
		Average RII: 0.73

Table 16. Technical factors influencing Space management and their RII according to survey results. Source: own production.

Misinformation has been graded as the most important subfactor within technical category affecting Space management. It is understood to be an incorrect or inaccurate information, which can negatively affect decisions (Southwell, et al., 2019). Even though it is not intentional, misinformation can cause great damage connected with communication (Michaelian, 2013). It can be explained in a situation where a client defines his criteria and specifications for the project, but with lack of technical knowledge and experience, the criteria can translate in a different form for the contractor. This can create incomplete design and specifications, causing problems described in the paragraph below. Another aspect of this can occur between working crews and management. To create a sufficient building site layout, a contractor must know all requirements and needs for different working stations (Igwe, et al., 2020). While some of it can be defined using manager's experience, some needs are distinctive for different subcontractors. If those needs are not clearly defined, a poor planning of construction site follows causing problems within workstations, logistics and leading to lost resources.

Incomplete design or specifications have shown to be the second most important technical factor affecting Space management. Project design and specifications influence numerous decisions on logistics, material and equipment location, distribution of workstations, movement of working crews, path and similar. Unfinished design means that changes will occur during construction phase causing lost time and money (Choi, et al., 2014). It has been mentioned before, that building site should be planned early in the design phase, as it has a complex layout involving many different activities in various locations (Skjelbred, et al., 2015). Unfinished design and insufficient specifications interfere with the early planning of the site layout, creating difficulties during the management phase.

Materials and logistics has been considered a serious technical factor as well, receiving RII higher than the category's average. Having the right materials, in the right place at the right time is as equally important as the cash flow and capital to run the project (Okorocha, 2013). In Space management materials are required to be properly located, organized, and stored to avoid wastage (Kulkarni, et al., 2017). This means that the project manager must be in full control of the logistics and orders, making sure that everything arrives upon the need. Managing materials and logistics, can be a challenging task due to ever changing processes on the site, implying that such job requires a lot of experience and rapid decisions. If materials are being delayed and logistics flow is disturbed, this can create stoppage of work and an overall loss of resources (Nagapan, et al., 2012a).

The rest four factors have been less significant in affecting Space management, yet they cannot be discarded. While **design changes** have a similar impact as unfinished design and specifications, **equipment and tools** must always be provided in a convenient location allowing to speed the workflow of the process. **Interference from the client and consultant** can also be of an issue if it is meddling with decisions made by the manager and affects the current organization of the site. **Technology and culture** is a big part of Space management too, as advanced technologies can help in detecting issues which are difficult to notice in the early construction stage (Minh, et al., 2017). However, it is still a difficulty in construction sector as the current culture focuses more on experience rather than new technologies (Videbæk, 2018).

External factors

External factors is the last analysed category affecting Space management and for construction projects it addresses environmental aspects that cannot be controlled by neither contractor nor client (Chan, et al., 2004). Such factors are hard to predict, therefore they have a great uncertainty and influence on the projects (Biswas & Zaman, 2019). They must always be considered and accounted for, yet it is done using assumptions which are not always close to the reality. Such factors are listed below in the table 17.

Rank №	External factors	RII
1	Weather	0.63
2	Building permit and other permits	0.62
3	Economic stability, including crises and inflation	0.60
4	Construction law and other legal regulations	0.59
		Average RII: 0.61

Table 17. External factors influencing Space management and their RII according to survey results. Source: own production.

Weather has been identified as the greatest impact having sub-factor. However, its' RII is very close to the rest of the sub-factors, identifying that all four are of nearly the same importance. In construction, weather is evaluated to be the second most important aspect affecting the projects (Odeyinka, et al., 2008). Weather can have a unique effect, depending on projects' properties and construction projects mostly suffer from strong winds, snow, frost, and rain (Pan, 2005). All these aspects of weather do not only influence the project itself, but also its' Space management, e.g., too much snow can result in a collapse of a construction, causing various damage and disturbing the work in all working areas. Besides that, the "Manual – building and construction working environment" (2016) indicates, that wind limits the usage of a crane, lifts, and work on platforms, thus it can cause stoppage of work. This can require replanning of workstations and moving around working crews in order to achieve as much productivity on a building site as possible. Whereas cold must be also considered during Space management and sufficient/heated workstations must be provided to deliver sufficient conditions for workers to carry out work and to prevent damaging materials or equipment (BAR Bygge & Anlæg, 2016). As for the rain, it is regarded as one of the most uncertainty having weather factor, which can result in suspension of work and lost resources (Pan, 2005). Even though Denmark does not experience heavy rainfalls, it still has an impact on Danish construction sites, since if it rains for too long, the water sets in the ground impacting all outdoor work areas and paths. This was a big issue in the autumn of 2019 which created a lot of non-physical waste (Josevski, 2019).

Building permit and other permits are as important as weather in Space management as they define whether the building and site plans are approved and if the construction processes can take place. Because approvals of building processes take a lot of time, it is important that applications are done much earlier before the construction has to start (Chognard, et al., 2018). Besides that, permits are needed for an on-going operations and logistics especially for the projects located within the city areas, meaning that without a permit construction site can often stop functioning. For example, a project manager must carefully plan the transportation of materials, equipment and other supplies to the construction site and receive permit for that if it interferes with the common roads (BAR Bygge & Anlæg, 2016). Sufficient logistics often requires closing parts of the roads which needs good space planning and logistics solutions that do not interfere with the neighbour areas. Because of that, permits can either allow or stop the construction work (AB18, 2018, §§ 4 and 5) and together with long waiting time of approval, they are considered important in saving time and money, thus reducing non-physical waste (Frandsen, et al., 2012).

Economic stability and **construction law** have been defined to be less important which could be due to the fact that most of the rules and regulations are known and followed, meaning that they do not create as many issues. Economic stability here refers to crises and inflations, which are effects outside the power of project actors. This can become an issue, as it could be seen in the worldwide crises in 2008 (Bivens, 2010). Space management can be influenced if the company is not able to hire enough workers, resulting in lack of workforce or unavailable materials, which prevents tasks from happening. Construction law on the other hand handles more practical issues, which can arise on building sites due to e.g., vibrations and issues with the neighbours, regulations about distancing making it difficult to organize workstations and similar (BAR Bygge & Anlæg, 2016). Following construction law is mandatory and failing to do that during Space management can result in interference with processes.

6.2.3. Ways to improve Space management

Optimization of Space management is essential in preventing safety hazards, loss of productivity and inadequate quality (Choi, et al., 2014). The previous chapter revealed how different factors affect Space management and afterwards they have been evaluated according to their RII, calculating its' average for each category, and defining different RIIs for all the sub-categories. Thus, to find a solution for occurring issues, it is important to know which factors have the highest effect on Space management and non-physical waste. For that table 18 has been made, indicating factors with the highest RII and their category.

Rank №	Related category	Factors	Factor's RII	Category's RII
1	Management	Planning and sequencing	0.85	0.77
2	Management	Coordination and collaboration	0.84	0.77
3	Management	Competency of project manager	0.83	0.77
4	Management	Competency of foremen	0.82	0.77
5	Labour	Tidiness	0.81	0.74
6	Technical	Misinformation	0.81	0.73
7	Project	Execution method	0.79	0.71

Table 18. Top seven factors affecting Space management. Source: Own production.

It is visible that almost all main categories except the external one, have an important effect on Space management. Management category has been defined as the most important one, having an average RII of 0.77. Besides that, it contains the four most significant factors, all having RII above 0.80. The second category that has been evaluated to be the most important is related with labour factors as tidiness has been identified to be necessary in managing building sites (Shazwan, et al., 2017). Technical category has an average RII of 0.73 whereas misinformation has the same RII score as tidiness, which is equal to 0.81. The last category to be included in the table was the project one and it contains the only factor in the table having RII lower than 0.80. Even though, execution method is very important, there are other factors with higher RII in Space management that must be looked into to optimize this RM area and to reduce the occurrence of non-physical waste on building sites.

Knowing the main factors influencing Space management creates an opportunity to find solutions for each of them, which should improve this RM area and reduce the occurrence of non-physical waste. Different solutions with high validity had to be researched and analysed to find out how they could affect each factor. The first two identified factors are related with **planning, sequencing, coordination, and collaboration**, meaning that better organizational skills must be introduced. It has been mentioned before that Space management involves a lot of processes stemming from planned activities and since they are often planned in scheduling programs, processes could also be defined in BIM. To improve Space management, BIM is often indicated as the most common solution and it has been seen as a possibility by several researchers such as Choi, et al., (2014), Deng, et al., (2019), Wang, et al., (2004), Wang, et al., (2019) who defined 4D BIM as a future of the construction projects.

BIM related concepts have been proven to generally provide a better quality of information and its' handling, thus planning with BIM should also result in a higher quality site organization (Gledson & Greenwood, 2017). Currently, the majority of project managers are using 2D drawings to create the main layout of the site and those can rarely be used when changes are happening as updates are occurring in accordance with time and activity planning. 2D drawings do not provide any information about current construction process status and project managers must use their experience, intuition, and imagination to relate processes with the drawings they have (Wang, et al., 2004). This can lead to poor planning of a building site and lost resources, creating a need for an improved BIM usage.

To manage complex tasks and different crews working on building sites, 4D building information model can been used, combining 3D models with scheduled corresponding activities (Choi, et al., 2014). Eastman, et al., (2018) has also confirmed that 3D BIM models contain a lot of useful information and parameters about the building, which can be used to simulate and track changes on site during construction period. 4D models can help in identifying changes in the building and work areas within construction site (Choi, et al., 2014). For an efficient usage, 4D BIM should be set up in the early phase of a site layout planning as it helps to detect clashes of working areas (Choi, et al., 2014), foresee path obstructions (Wang, et al., 2019), plan logistics (Deng, et al., 2019) and generally reduce hazards and risks by simulating BIM-based planning of the building site (Jin, et al., 2019). The significance of an early site planning and usage of structured processes has also been noticed by a Norwegian contractor Veidekke Entreprenør AS (Skjelbred, et al., 2015). Since the contractor was responsible for planning, design and construction phases, a well-structured system was needed to carry out all processes, for that 4D BIM was applied. Besides planning, 4D can also be very beneficial after the activities are scheduled and site layout has been decided. Using 4D BIM allows contractors to see any issues that might arise from the schedule of activities within the building site. The 3D model should be daily updated with the progress of the schedule and current situation of the site, which can show where the problem areas of e.g., colliding activities, workstations, paths and similar are, allowing to solve them before the damage has been done and time, money and productivity has been wasted (Choi, et al., 2014).

4D BIM can also improve **communication and collaboration** with client as the model can be modified by all parties and the contractor will instantly be alerted by the changes that influence work on the building site (Wang, et al., 2004). Yet, it is still important to have established policies about the way changes must be done and who should bear responsibility in doing that for each party to avoid chaos and clashes in the model (Cheng, et al., 2010). Coordination of construction processes also includes managing materials and logistics which must be delivered and allocated on a building site. These interacting processes which are also known as a supply chain management (Christopher, 2016) require constant tracking, transparency of information, coordinated mechanisms (Deng, et al., 2019). Using innovative technologies and tools to coordinate supply chains can improve time efficiency by approximately 32% (Shin, et al., 2011) making 4D BIM a suitable solution for construction space management when planning activities, coordinating processes on site, and collaborating with different parties. Yet, it is important to know that 4D BIM has drawback as well. Firstly, it is time consuming (Wang, et al., 2019), as it requires a 3D model which must be created manually (Shou, et al., 2018) and not all construction sites have one. Besides that, Shou, et al. (2018), has also identified that creating 4D BIM requires a deep analysis and studies, which is not always done, resulting in improper usage of BIM. Lastly, since 4D BIM is meant to be shared and updated by different parties, thus it can be difficult to define and use the same files format combined in one system (Ma, et al., 2005).

As it comes to **competency of leaders**, it can be improved by different aspects, such as experience (Jarkas & Bitar, 2012) or effective goal setting and development (Dzwigol, et al., 2020), however the most valid and beneficial ones were found to be education (Wolf, 1990 and Dubinina, et al., 2015) and technologies (Minh, et al., 2017 and Dubinina, et al., 2015). Technologies are a big part of leaders' competency which allow them to be up to date with current innovations involved in the industry, use better tools and techniques to carry out the work and help their subordinates in solving problems (Minh, et al., 2017). Technical knowledge about available and beneficial technologies and their incorporation gives leaders' an advantage of using different, more appropriate methods, being innovative and finding the best solutions (Minh, et al., 2017) which can be used in space organization and management on building sites. Thus, knowledge about benefits of before mentioned 4D BIM can have a great impact to their competence. Another way to ensure the competence of leaders is to constantly update their knowledge which can be done with qualification courses (Wolf, 1990). Wolf (1990) has also stated that competence can be raised by *"<…> learning of higher-level skills, acquisition of generalizable knowledge (and understanding), and with broad based courses."* Such courses can help with technologies including 4D BIM, and in general for Space management and organization and supervision on building sites (Nohrcon ApS, 2020). Even though education brings a lot of benefits, it can be a difficult task to carry out if employees are showing resistance to learn (Stackhouse, et al., 2020). Besides that, courses are expensive and increase company's debt (Li, et al., 2017), thus it is important to evaluate how much benefits it will bring.

Another important factor affecting Space management is **tidiness** and it has been identified before that tidiness allows to keep different workstations on a building site organized (Shazwan, et al., 2017). Besides that, to avoid clutter being created within activities and workstations, tidiness must be pinpointed to be an important value on a building site (Cheng, et al., 2017). The manager cannot always ensure that work areas are clean, therefore he needs to make sure that workers are aware of it (Vitharana, et al., 2015). For that reason, education and changing workers culture has been found to be the first step that should be taken to ensure that building site will be kept as neat as possible. The manager must establish a culture, where workers are educated to tidy after themselves (Höök & Stehn, 2008). This can be done by indicating waste deposition station and making sure they are properly used by having a simple follow up, where check-up plans are made. Such plans allow to quickly update the status of the site, by writing down the issues and their locations (Özcan & Bal, 2017). However, these plans can hardly be transferred to a program and linked to a model, thus the only option is to discuss them in the meeting (Oke, et al., 2016). To have a better visual update and to help project manager to see the issues while organizing building site generating less clutter, 4D BIM can be used. It allows to have daily updates, showing clashes of activities, messy areas on site and need for relocations. It can be a good visual tool for planning and moving stations, storage areas and paths around (Wang, et al., 2004).

Since **misinformation** during Space management comes from miscommunication (Michaelian, 2013), it is important to create defined ways how the technical information can be translated between different parties. Even though, building site layout is organized and managed by a contractor, it must consider the needs for the building, storage, workstations, paths, etc. that must be included in a site layout. Those needs come from different parties and can change when the project progresses. To ensure a possibility for everyone to update their needs or requirements, a common cloud platform could be established, where everyone has a timely access to it and an option to report and mark the changes (Mell & Grance, 2011). Due to the real time-delivery of information containing updates and changes, the manager can make fast and efficient decisions which allow him to monitor, manage and update the site in the best way that fits everyone's needs and does not interfere with processes (Matthews, et al., 2015). 4D BIM can be useful here as well and when combined with a cloud system it gives everyone an access to indicate the changes that should be made (Jupp, 2017). However, cloud-based platforms have some issues as well. They do not always support real time information sharing, meaning that the information can be delayed. Besides that, users cannot manage and operate the system, creating a need of IT specialists. It is also internet-based, thus if internet issues occur in the company, the file sharing is completely stopped (Zou, et al., 2017).

The last factor that has been identified to be important in Space management is **execution method**. Since building projects are a combination of different types of structures and activities, they result in different execution methods carried out when the project progresses which can affect Space management. If the project is experiencing late changes, it is possible that some of the execution methods will change as well requiring updates on a site layout. It has been found by Afolabi, et al., (2017) and Mathews, et al., (2015) that this problem can be minimized by technologies, as according to the study carried by Shou (2018), 4D BIM allows *"<…> to engage external contractors and/or out-of-plant personnel to evaluate the critical path, and come up with alternative execution methods to shorten the project duration."* Knowing changes in execution methods early enough allows contractor to evaluate them according to the projects' layout and make fast decisions about changes which result in minimal interference with other processes happing on a building site.

To conclude, keeping up with technologies emerging in construction industry has been identified as the main aspect that could optimize Space management and help to reduce the occurrence of non-physical waste. Usage of BIM concept such as 4D would have a positive impact for all seven factors that affect Space management the most. The ability to combine visualization of a building site and process schedules, makes it an attractive solution for managing activities at construction sites. Besides that, cloud-based platforms have also been recognized to improve communication on site and help to update site plans according to constant changes from different actors. Management of project area can also be improved by raising qualification of leaders, providing them with new information about space organization and management. This can be achieved by qualification courses and improved technical knowledge, which would allow them to use the above-mentioned concepts. Summary of available solutions for different factors can be seen in the table 19 below.

Rank №	Related category	Factors	RII	Available proposal solutions
1	Management	Planning and sequencing	0.85	• **3D Models, simulations** • **4D BIM** • **Cloud-based platform** • **Early planning of the site**
2	Management	Coordination and collaboration	0.84	• **4D BIM** • **Cloud-based platform** • **Early planning of the site**
3	Management	Competency of project manager	0.83	• **4D BIM** • **Qualification courses** • **Technical knowledge/courses**
4	Management	Competency of foremen	0.82	• **4D BIM** • **Qualification courses** • **Technical knowledge/courses**
5	Labour	Tidiness	0.81	• **Education of workers by establishing culture** • **Check-up plans** • **4D BIM**
6	Technical	Misinformation	0.81	• **Cloud-based platform** • **4D BIM** • **Early planning of the site**
7	Project	Execution method	0.79	• **4D BIM** • **Early planning of the site**

Table 19. Idea proposal for optimization of Space Management by improvement of the top seven most essential factors. Source: own production.

6.3. Material management

Material management in the construction industry is "*a process for planning, executing and controlling the field and office activities*", where the aim is to ensure that materials are available in the right quantity and at the exact time and place when needed (Patel & Vyas, 2011). At construction sites this process includes planning, assessing, purchasing, transporting, storing, and controlling materials (Patel & Vyas, 2011). According to literature, materials typically account to 60-70% (Ayegba, 2013 and Patel & Vyas, 2011) of the total construction project costs, from which, according to a study in Denmark, about 10% of newly ordered construction materials are being wasted (Miljøstyrelsen, 2017). The study carried out by the Danish Environmental Protection Agency (2017) has also found out that more than one contractor has claimed that it is common to order about 10% more materials than needed to ensure sufficient on-site quantity.

The findings of another study have concluded that poor Material management on site can result in wasted materials and increased costs (Patel & Vyas, 2011). Improperly stored and handled materials on site can lead to deterioration of materials during storage, damaging, misplacing and/or even loosing of materials, due to theft if special precautions are not taken (Miljøstyrelsen, 2017). Materials can also be damaged during deliveries if planning of logistics and storage are not done properly and available space is not provided for correct unloading and/or storing. Moreover, if materials required for particular activities are not available on time and at the right place, this can result in possible time delays, extra expenses and unproductivity. This is due to the fact that every construction project is different, making also some of the materials necessary unique and different as well, with specific size, shape, colour, etc., and in case when the right material is not present at the necessary time often the particular activity is delayed. For example, prefabricated concrete elements have specific sizes, shape, function, etc., and if wrong materials are delivered, or due to improper handling and/or storage the materials are damaged, this could result in unfortunate time delays that would lead to waiting times and unproductivity since ordering a new material and producing it will take time. Therefore, ensuring a timely flow of materials and proper managing is an important concern of Resource Management and is essential for cutting down non-physical waste (Patel & Vyas, 2011).

In general, at construction projects materials are ordered, transported, delivered, stored, moved around, and processed before final installation. And it is necessary that these activities are made as efficient as possible, since steps like moving and temporarily storing materials are considered waste and should be avoided (Koskela, et al., 2002). Material management on construction sites is normally a responsibility of the contractor running the site and in case of new building projects it is essential that he/she avoids procuring excess materials, store materials properly and keeps a good tracking of which materials are in storage and where exactly (Miljøstyrelsen, 2017). And even though, accurate planning and management of materials, tools, and equipment is a difficult task, it is required for the success of any construction project (Almohsen & Ruwanpura, 2011). Moreover, since materials correspond to a substantial part of the total project budget, their inefficient handling will increase costs and decrease productivity (Fei, et al., 2008).

In recent years, a special attention has been paid to the environment, construction waste and non-value activities and in result some concepts related to Material management have been introduced. One of the most commonly known concepts is Lean Construction, which offers several principles for proper management of materials at construction sites, such as Just-in-Time, Standardization, Prefabrication, *Heijunka*, etc. However, the complexity of Lean Construction has led to the opinion of some construction managers that the concept is vague, difficult to comprehend and hard to implement at site level (Thomas, et al., 2002b) and therefore would be no further researched. Regardless, it is undoubtful, that "*any interruption to the normal flow of materials will result in causing serious degradations on performance and labour productivity*" (Thomas, et al., 2002a). And unfortunately, "*ineffective material management practices are evident on many projects"* (Thomas, et al., 2005), which means that special attention should be paid to the factors contributing to poor Material management and possible ways for reducing their influence should be investigated and analysed in order to minimize non-physical waste and optimize the management of resources, specifically in regard to Material management.

6.3.1. Factors affecting Material management

As it becomes clear, Material management can be defined as a process that coordinates planning, sourcing, purchasing, transporting, storing, and controlling of materials, minimizing the wastage, and optimizing the profitability by reducing cost of material. And since materials correspond to a big part of the total project cost it is important that factors affecting Material management are identified. For the purpose, factors similar to the ones affecting the other two researched RM fields were identified in order to evaluate and analyse their effect on Material management and the generation of non-physical waste. The identified factors were inspired from other factors related to Material management studies (Patel & Vyas, 2011, Ayegba, 2013 and Kulkarni, et al., 2017) and the main categorization of factors done for Labour and Space management (Lindhard, 2020). Analysis and evaluation of the factor categories and their sub-factors can be found in the pages below.

Management factors

Since poor Material management on site results in wasted materials and increased project costs (Patel & Vyas, 2011), it is logical to assume that management factors are essential too. This assumption is also supported by the fact that this category factors are found to be the most important for Material management with an average RII of 0.76 (see table 20).

Rank №	Management factors	RII
1	Planning and sequencing	0.86
2	Competency of project manager	0.82
3	Coordination and collaboration	0.81
4	Competency of foremen	0.80
5	Waste on construction site	0.77
6	Storage facilities	0.73
7	Congestion and overmanning	0.72
8	Supervision and inspections	0.69
9	Poor site layout	0.69
10	Safety and work environment	0.68
		Average RII: 0.76

Table 20. Management factors influencing Material management and their RII according to survey results. Source: own production.

Planning and sequencing is yet again ranked as the most important factor from the management factors category (see table 20). Planning and sequencing are concerned with the management of the flow of materials and establishment of timetables for ordering, delivering, processing, and storing materials on site (Albert et al., 2014). As mentioned before, the whole construction process is based on planning of activities and organizing them in the best way to have the shortest and most efficient sequence (Choi, et al., 2014). Thus, planning and sequencing is considered to have a great influence on Material management since proper planning and sequencing of needed materials, deliveries, orders, and proper storage are needed for achieving optimal project efficiency (Gurmu, 2019). The importance of this factor has been also confirmed by another study where it was ranked as the third most important factor affecting Material management on site (Ayegba, 2013).

Competency of project manager is ranked as the second most influential factor for Material management and since managing materials on construction sites is one of the responsibilities of the project manager it is essential that he/she has the right competency to manage material logistics and avoid procuring excess materials (Miljøstyrelsen, 2017). Moreover, it is also important that the manager is organized and manages the storing and handling of materials properly by keeping a good track of what materials are in storage, what is their location and making sure that the storing method is appropriate. For example, dry materials like insulation should be carefully stored in special material storage spaces or at least covered properly so in case of rain, the insulation abilities of the material are not destroyed.

Coordination and collaboration, similarly, to planning and sequencing, are also of high importance for Material management. This is because, there can be many different contractors or work teams present at the construction site and if there is not a good coordination and collaboration process between them this can affect the management of material resources greatly (Ayegba, 2013). Therefore, the factor was graded as third most important with RII of 0.81. The fourth factor identified is **competency of foremen** and in construction, the foremen are responsible of leading a team or crew in completing a construction task or a project in accordance with the project characteristics and targets. Regarding Material management, however, the foreman is responsible to provide all necessary materials for accomplishing the required task (Dzwigol, et al., 2020).

Unfortunately, there are many issues such as waste, transport difficulties, improper handling on site, lack of a proper work plans, inappropriate materials delivery, etc. which contribute to poor material management in construction projects (Ahmed, 2017). Specifically, **waste at construction site (RII 0.77)** is related to Material management in two different ways. On one hand, if there is physical presence of waste at the construction site this could take up space for storage and can lead to unproper handling of materials and on the other hand, by improving Material management practices construction waste can be significantly reduced (Dainty & Brooke, 2004).

However, to avoid waste, loss, and damage of materials close attention to **facility storage** is required, which is also rated as the sixth most important factor according to its RII. This is because, in case of improper storage and protection facilities problems can often arise during materials supply (Canter, 1993). According to the type of materials required, they may be kept on the building site over long or short periods of time until they are needed. Moreover, materials can be kept in closed facility storage units or stored outside at the construction site. Materials that are stored outside can sometimes obstruct the access requirements, thus blocking the workspace and material deliveries (Thomas, et al., 2005). When storing materials outside it is essential that special precautions are taken to prevent possible damages from moist and other weather conditions. Yet, there are some materials that need to be stored inside in assigned facility storage units (Thomas, et al., 2005). When there is not enough space for storing materials in the right conditions, where they can stay dry and protected from weather and moist, e.g., storage containers, many problems can arise (Canter, 1993).

Congestion and overmanning, as elaborated before, can reduce productivity, and can result in both non-physical and physical waste. Regarding Material management, this factor is not rated to be that important, but it can still be influential since, e.g., congestion at the construction site could mean that deliveries cannot be made since the site is overcrowded with materials, people, vehicles, machinery, etc. and there is no available space for the required delivery and unloading of the supplied materials. Therefore, this factor should also be considered from the management team.

Supervision and inspections and **poor site layout** are two other identified factors that influence the area. Supervision and inspection, for example, can inspire better handling and storage of materials. As mentioned in Space management, a way to make sure that the construction site is organized and there is no clutter, is to do constant check-ups and report the findings during the meetings to show where the clutter has been gathered and who is responsible for eliminating it (Bajjou, et al., 2017). This could also help to minimize the effect of poor site layout. Site check-ups and inspections can help notice site layout flaws. Regarding Material management, such flaws can be improper storing and handling of materials.

The least influential factor rated by the participants in the survey is **safety and work environment**, which is logical since the Danish regulations for work and safety environment contribute positively to reduce some of the effects of this factor. According to "Manual – Building and Construction working environment" (2016) messy building sites create a greater risk of accidents and may cause problems and conflicts between the different contractors on site and therefore it is required that in the project's Health and Safety Plan (PSS) it is stated how to keep the building site in order, when it should be tidied, and by whom. Concerning material management and work safety they advise to "*do not stack materials a way that they may topple or otherwise cause a hazard*" and to "*only place materials in the locations designated for them*" (BAR Bygge & Anlæg, 2016).

Project factors

From the identified project factors, **execution method** is found to be most essential factor affecting Material management (see table 21). Execution method normally refers to standards, methods, and practices used during the construction period (Koskela & Howell, 2001). Depending on the construction execution method there could be several different types of material handling. In case of handling prefabricated concrete walls, for example, few different material handling methods can be used - storing the materials on site and then installing or delivering them just before instalment and unloading them from the delivery truck by means of hoisting and vertical handling (Dozzi & AbouRizk, 1993). Another example could be if the construction execution method requires cast-in-situ concrete. This will also affect the Material management processes, because in this case the concrete must be delivered right before usage otherwise it will be ineligible for usage.

Rank №	Project factors	RII
1	Execution method	0.78
2	Project characteristics (size, buildability, complexity)	0.75
3	Defects	0.73
4	Client, project and own finances	0.72
5	Contracts with suppliers	0.71
6	Project location	0.53
		Average RII: 0.70

Table 21. Project factors influencing Material management and their RII according to survey results. Source: own production.

Project characteristics, and in particular the size of a building and plot, as mentioned in Space management, affects the availability of storage space for materials. In case of small building projects, the space for storage of materials could be limited, and in case of a bigger size project, with bigger plot there could be enough space provided. Thus, leading to the conclusion that project characteristics like project's size have relatively high influence on Material management and are therefore graded as second most important according to the participants of the survey.

Defects directly affect Material management because when there are material defects, defective work, etc., it means that materials are being wasted. AB 18 states that defect is considered when or if the work is not executed in accordance with the contract, good professional practices, and the client's instructions (AB18, 2018). As for materials, the General Conditions stipulate that if the nature of materials is not exclusively stated, they must be of customary good quality and if the work done or materials used do not meet these requirements, they are considered defective (AB18, 2018).

Client, project and own finances are rated to be the third most important project factor for Material management with RII of 0.73. As mentioned in Space management, finances of client and contractor define the construction capabilities and can be of great influence for running the site. Larger budget can offer better, more innovative solutions for material usage as well as better logistics, thus indicating that economy is an overall important factor. Next factor with RII of 0.71 is **contracts with suppliers.** This factor is graded not to be of a great importance since it is covered by the Danish consumers act and AB18 where it is stated that materials and other supplies to be used in the construction project must be covered by a five-year supplier liability period for defects in the supply (AB18, 2018).

Project location is ranked to be of a significantly less influence for Material management with RII of 0.53, which compared to the RII of the previous factor is drastically lower. According to literature, there could be delays of supplies depending on the project's location (Ramli, et al., 2018). Nowadays, material deliveries to a certain location are not a problem because with the help of available technology like GPS and Google Maps, it is relatively easy to find the necessary location, or to predict and plan the time needed for transportation. However, project location is important when it comes to projects situated in narrow spaces, e.g., city areas, with limited building plot and storage spaces.

Labour factors

Labour productivity has a significant effect on time and cost overruns in construction project and labour factors are therefore essential for avoiding non-physical waste (Kadir, et al., 2005). After identifying which labour factors affect Material management, they were ranked according to their relativity importance index calculated based on the grades that each of the factors received in the carried-out survey for this paper. The ranking and RII can be found in the table 22 below:

Rank №	Labour factors	RII
1	Motivation	0.76
2	Skills and experience (Improper handling of materials)	0.75
3	Composition of work crew	0.73
4	Number of workers	0.70
		Average RII: 0.73

Table 22. Labour factors affecting Material management and their ranking according to RII. Source: own production.

Motivation as elaborated in Labour and Space management, is an important factor because motivated workers are usually more enthusiastic, initiative, they work harder and respond faster to instructions (Jarkas & Bitar, 2012). This is also why the factor is ranked as the most important sub-factor from labour factors with RII of 0.76. On the other hand, motivation of project manager and the management group can have a big influence on Material management since if they are motivated to have a well-organized and managed building site this can lead to a non-disturbed activity flow which saves time and cost resources (Yeheyis, et al., 2016). Thus, also leading to a better and more efficient Material management practices.

Skills and experience is the second most important factor in this category with RII of 0.75. This is influential factor for Material management because, unskilled workers often make mistakes, which require rework, rectifications, or repairs, resulting in wasted materials and unproductivity (Jarkas & Bitar, 2012). Moreover, depending on the skills and experience of the project manager and foremen it will vary how materials are procured, managed, stored, or handled on site and if they do not have the right competency to manage material logistics and avoid procuring excess materials this can result in material waste and unproductivity (Miljøstyrelsen, 2017).

Composition of work crew is ranked as the second least important factor with RII of 0.73. However, crew composition affects motivation and productivity (Bernold & AbouRizk, 2010; Dozzi & AbouRizk, 1993) leading to indirect influence over Material management as well. An example could be if the working crew consists of members differing in culture, where some of them are unaware or reluctant to the requirements to keep a site tidy and organized. This can result in new materials left at workstations where they are unprotected from weather conditions and moist, leading to wasted materials and lost resources.

Number of workers is ranked as the least important factor from the labour category factors with RII of 0.70. Here, similarly, to overmanning, the factor can reduce productivity and result in both non-physical and physical waste. Insufficient number of workers can lead to problems related to handling of materials, e.g., unloading or moving them around the building site. However, it is more difficult to manage a building site with large number of people as this leads to more work locations and a bigger chance of people’s activities colliding, resulting in wasted materials and resources in general.

Technical Factors

Technical factors in Material management deal with *“<…> design aspects, materials, and tools needed to efficiently finish a project.”* (Hwang, et al., 2017). It includes specifications of materials, deliveries, handling, and similar technical factors which are indicated in table 23. It has been indicated that specification and availability of required materials increase projects’ productivity (Olomolaiye & Ogunlana, 1989). Increased productivity results in reduced occurrence of non-physical waste, which is why technical factors are the second most important category in Material management according to average RII.

Rank №	Technical factors	RII
1	Incomplete design or specifications	0.81
2	Misinformation	0.80
3	Approval of materials by client and consultants	0.79
4	Materials and logistic	0.78
5	Design changes	0.74
6	Equipment and tools	0.72
7	Deliveries of defected/wrong materials	0.69
8	Technology and culture	0.66
		Average RII: 0.75

Table 23. Technical factors influencing Material management and their RII according to survey results. Source: own production.

Incomplete design and specifications have the biggest effect on Material management with RII of 0.81, as seen in the table 23 with distribution of RIIs. It has also been identified as one of the most significant factors in the area by Ayegba (2013). Material management begins in the design phase (Kasim, et al., 2005) as this is where specific materials and quantities are defined. The process for materials to reach the building site as minimum includes planning, estimations of quantity, placement of order and inspection of materials (Kulkarni, et al., 2017). Since ordering materials involves many steps, deliveries can take a long time before they reach building site. Besides that, some materials, e.g., concrete elements have a big demand and take a long time to be produced, meaning that orders must be made in a good time before materials have to be used on site (Varneskov, 2017). For this reason, unfinished designs and specifications can create many issues when materials must be ordered as it is needed to know what type of elements must be used. If materials are not specified or have incomplete specification, there is a big risk that the order is going to be made too late or it is going to be wrong. Both options result in wasted resources such as time, money, productivity and similar, as materials might have to be returned, stored, or end up being wasted.

Misinformation (RII 0.80) has a similar effect on Material management as a previously described factor. According to Yang, et al., (2018) successful Material management should have barrier-free communication between demander and supplier, without hiding any information. However, currently Material management experiences minimum communication (Awang & Fared, 2019) which results in misinformation. Lack of communication between actors involved in material handling has also been identified as a big issue by Chenvidyakarn, (2007), where misinformation between various parties has been described to lead to different issues. If a contractor misunderstands the materials requirements from the client, he can end up making the wrong order, whereas if miscommunication happens between contractor and supplier, it can lead to wrong amounts, type of orders and dates for deliveries. If materials arrive before time, there is a risk of lack of storage space resulting in improper storage and ruined materials. If they arrive too late – work processes are being delayed. In these cases, materials end up either being send back, improperly stored or just wasted, which creates time and cost overruns.

Approval of materials by client and consultants (RII 0.79) happens after materials have been delivered to the building site and can have a big influence on construction processes. Since construction projects involve large amounts of different types of materials, client cannot approve everything. Structural materials and elements are usually taken care of by the contractor, however materials, that the client has specifically indicated in specifications must be accepted by him or his consultant (AB18, 2018). Different literature indicates that late approvals of materials from the client cause many delays in construction projects (Kumar, 2019, Johnson & Babu, 2020 and Umar, 2018), therefore they have a big impact on generation of non-physical waste. On top of that, if materials are rejected, they must either be sent back or are utilized, which in either case requires new orders wasting project's time and cost resources.

Materials and logistic (RII 0.78) are directly connected with Material management and represent physical handling of materials. Since materials can take up to 70% of project costs, it is important to make sure that the right materials are ordered in needed quantities and that they are prevented from being wasted (Ayegba, 2013). It is also required to make sure that the right materials arrive at the right time as lack of materials creates interruptions in processes, stoppage of work, delays and results in overruns which creates waste (Azarova, 2015). When it comes to logistics, it is considered to be significant in Material management, as if done right, it can reduce financial losses and increase the profit of the project (Lanko, et al., 2017). It includes transportation of materials, approval, storing and handling. Successful logistics in Material management includes ability to choose the right supplier which offers a fair delivery price (Lanko, et al., 2017) because logistics costs take up a large amount of total construction costs (Sundquist, et al., 2017). Besides that, logistics should always be transparent during all material handling processes (Lanko, et al., 2017). Communication issues in logistics can decreases Material management productivity as it jeopardises the way different parties are dealing with materials, transportation method, time, and handling of materials on site.

The last four factors in technical category have been identified as less important for Material management, having RIIs below the category's average. **Design changes** (RII 0.74) have a similar influence on this RM area as unfinished design and specifications, because changes in design can also lead to changes in material requirements after they have been ordered leading to an overall waste of resources. **Equipment and tools** (RII 0.72) is also a factor that must be considered, especially in logistics and handling phases. Some materials require special equipment and handling, thus equipped crew can make sure that materials are treated according to specifications, so wastage is avoided (Pethaperumal & Sivakumar, 2017). **Deliveries of defected or wrong materials** (RII 0.69) is a relatively often occurrence in construction projects, creating many issues which disturb the process flow and creates partial stoppage of work (Ali & Wen, 2011). If materials are wrong or unusable, they need to be sent back or disposed. If they have minor defects and can be used, they still require extra work for fixing them. In both cases generation of non-physical waste is present and can occur in many different forms. The last factor considered in technical aspects of Material management is **technology and culture**. This factor has the least impact on material management with RII of 0.66, as it is less direct and can be easier controlled, but it can still make a difference. It has been mentioned before that technologies allow improvements in majority of construction management areas by offering better coordination and collaboration possibilities (Minh, et al., 2017), so a change of culture and implementation of technological solution can improve Material management and reduce non-physical waste.

External factors

Material management as the other two RM areas is also affected by external factors *"<…> which are uncontrollable but <…> still affect a project."* (Hwang, et al., 2017). Material management can be influenced by poor weather conditions, economic problems with crises and inflation, interference of construction law, lack of permits and lack of security personnel (see table 24). Since external factors are often beyond managers ability to interfere with, it is important to take them into account as risks and make sure that materials will be protected in case those factors happened.

Rank №	External factors	RII
1	Weather	0.60
2	Economic stability, including crises and inflation	0.60
3	Construction law and other legal regulations	0.59
4	Building permit and other permits	0.58
5	Lack of security personnel	0.57
		Average RII: 0.59

Table 24. External factors influencing Material management and their RII according to survey results. Source: own production.

Weather influences all elements of construction process including handling of materials (Evseev, et al., 2019). It has been chosen as the most important factor in external category of Material management by the majority of survey responds, receiving RII of 0.60. Poor weather includes rains and other topographic conditions that can affect materials and lead to delays (Frimponga, et al., 2003). Since material logistics and storing happens outside, they are constantly exposed to the atmospheric environment which can affect their properties (Apipattanavis, et al., 2010). If weather sensitive materials are exposed to unsuitable conditions, they can get ruined and become dangerous to handle. If materials quality is affected by weather conditions by improper storing, the work can be suspended until new, suitable materials arrive (Jung, et al., 2016). Weather conditions can also endanger building construction if the unsuitable materials are used. As an example, can be taken a project case, where reinforcement in the concrete has been exposed to the rain and corroded afterwards, affecting the whole construction (Veerakumar & Sreekumar, 2016). For these reasons it is important to ensure sufficient material storage and order materials which are able to resist the influence of the weather in case they cannot be stored/protected. Besides that, weather can affect Material management from logistics side if e.g., the roads become too muddy due to heavy rainfall or if materials cannot be craned due to strong wind (Jung, et al., 2016). All these issues lead to waiting times, rework, waste of materials, delays, and extra costs.

According to respondents of the survey, **economic stability** is as important in Material management as weather conditions. Economic stability here includes crisis and inflations, meaning that it refers to a wider economic stability, concerning the country or even the world. If economy is varying, it can result in changes of interest rates and taxations, which affects profitability of companies (Edwards, et al., 2010). This can lead to financial risks for the company if prices of materials are raised, whereas if material prices drop due to inflation, it can lead to insufficient amounts. Besides that, if government funded projects are experiencing economic instability, Material management can be affected by insufficient funding for purchasing goods, which prevents construction work from happening. Overall, economic stability is important on both, project, and company level, especially in Material management as all processes are directly dependant on provided materials (Kulkarni, et al., 2017).

Construction law and other legal regulations mostly affects type and usage of materials on a building site. When choosing and ordering materials, it is important to make sure that such materials are legal and allowed to be used, as for example asbestos has been used as a popular construction material between 1930 and 1980, but since 1986 it has been forbidden to be used due to dangers it causes to human health (Miljø- og Fødevareministeriet, 2015). There are also many regulations defined in e.g., “Manual – Building and Construction working environment” (2016), about how to work with different materials, how to store them and under which conditions it is not allowed to handle them. On top of that, some of the law includes regulations of how and where materials must be placed as well as how they should be disposed (Bygningsreglementet, 2017). Failure to comply with law and regulations can result in building projects getting a notice or being shut down. Stoppage of not only one activity, but the whole project process can have consequences time and money wise.

Building permit and other permits (RII 0.58) in Material management are connected with type of materials, their handling and logistics. Since environment is an important and highly discussed global topic, building projects are also pressed to be greener. For this reason, some of the materials might require a permit, showing that they do not have excessive effect on environment (Zhang & Wang, 2017). Some permits might be required regarding method of handling materials, e.g., if pile foundation is to be used in an area, where water level in soil can be disturbed and affect other buildings, it must receive a permit to be hammered (Miljø- og Energiforvaltningen, 2019). Besides that, if elements have extraordinary size which requires special logistics, it should also be approved by a permit, as transporting such materials can create dangerous situations if not done properly (Miljøstyrelsen, 2000). As for **lack of security personnel** (RII 0.57), which has been identified as the least important external factor, it can also directly affect materials and their management. Construction sites are full of stored materials, some locked in warehouses, some stacked in storage areas. Contractors are demanded to ensure material security, as if a construction site lacks security, such materials can be stolen, which will have drastic consequences for the project (Walker, 2008). Stealing results in lack of materials and damaged equipment which leads to suspended work, delays, and general non-physical waste in forms of time, money, productivity, etc.

6.3.2. Ways to improve Material management

Material management as well as the other two RM areas contributes to generation of a lot of non-physical waste on building sites too (Patel & Vyas, 2011). To know which factors of Material management, have the greatest impact on generating such waste, an analysis has been made summarized in the table 25 below. There the factors with the highest RII have been selected, identifying their category and category's RII. Knowing the most common categories allows to identify which of them are the most influential and can help to minimize the loss of resources.

Rank №	Related category	Factors	Factor's RII	Category's RII
1	Management	Planning and sequencing	0.86	0.76
2	Management	Competency of project manager	0.82	0.76
3	Management	Coordination and collaboration	0.81	0.76
4	Technical	Incomplete design or specifications	0.81	0.75
5	Management	Competency of foremen	0.80	0.76
6	Technical	Misinformation	0.80	0.75
7	Technical	Approval of materials by client and consultants	0.79	0.75

Table 25. Top seven factors affecting Material management. Source: Own production.

It is visible in the table that once again the management category is the most common one and with the highest RIIs. Material management is mostly influenced by planning and sequencing and competency of project manager. The factors accordingly received RIIs of 0.86 and 0.82, which are much higher than the category's average of 0.76. The third and fourth factors of coordination and collaboration as well as unfinished design and specifications received the same RII of 0.81, however they belong to different categories – management and technical, proving that technical category has a great importance to Material management as well. The same can be seen with the factors in fifth and sixth places – competency of foreman and misinformation. Both received RII of 0.80 respectively belonging to management and technical categories. The last factor to have the most significant effect on Material management is approval of materials by client and consultants belonging to technical category and having RII of 0.79. This factor as all the others has a higher RII than the category's average, which in this case is 0.75. All factors contribute to generation of delays, cost and time overruns, wasted resources and create a negative effect for the building projects. For that it is important to look into solutions that could improve the effect of such factors resulting in lower non-physical waste.

It has been discovered that **planning and sequencing** together with **collaboration and coordination** can be rectified with similar solutions. They both require better planning and organization of materials before and after their deliveries. The general and wide solution has been proposed by many researchers to be the use of technologies or BIM. According to Afolabi, et al., (2017), Irizarry, et al., (2013), and Glendson & Greenwood (2017) if used right, BIM can improve planning and assigning of materials, ordering the right amounts and managing their usage on a building site. BIM helps to map the time and cost resources, analyse transportation (London & Kenley, 2001), monitor deliveries (Elizabeth A. Williamson, 2004) thus ensuring better logistics. It also helps to optimize costs of supplies reducing waste of materials (Tserng, et al., 2006). BIM can also be used to create a list of materials that must be ordered, show their location on the site, and warn when the site is running low on needed materials (Vaidyanathan & O'Brien, 2003). However, since BIM is a very broad term, it cannot work efficiently unless it is used specifically and aimed at improved organization of Material management. For this reason, two specific concepts in usage of BIM have been defined by Cheng & Yang, (2001), Deng, et al., (2019), Irizarry, et al., (2013), Su, et al., (2012) and others: Geographic Information Systems (GIS) and Web-based technologies with planning.

Geographic Information Systems or GIS is a technology which allows to identify problems and solutions regarding material layout (Cheng & Yang, 2001 and Yang, et al., 2018). When combined with 3D model, material circulation on site can be visualized (Ma, et al., 2005) and it provides automated tracking of transportation of materials (Castro-Lacouture, et al., 2007). Using GIS in Material management allows *"<…> to improve efficiency, reduce data entry errors caused by human transcription, and reduce labour costs*" (Nasir, et al., 2010). GIS has functions such as purchasing, receiving, warehousing, inventory control, materials distribution, provision of efficient, low-cost transport, security, and materials storage on construction sites. One of the advantages of GIS is that it allows to have an accurate material quantity take-off from the 3D model and use the information in construction phase for material orders, which results in reduced waste (Cheng & Yang, 2001). Yet, planning of materials does not only depend on the design and specifications of the project, but also on a building site layout (Su, et al., 2012). It is important to plan orders in a way that materials can be placed in convenient locations on site and receive a proper storage needed to protect their quality. This is where GIS comes in handy, allowing to see the current status of the building site and base material planning and ordering decisions on that (Irizarry, et al., 2013). This also helps in better collaboration on the site when materials have to be moved around, are used and/or must be reordered. As for the tracking of deliveries, GIS allows to know the status of supplies, immediately informing about delays. This can help to save a lot of time, as when informed early enough the manager can make decisions about change of activities.

Another BIM system that has been studied to help with waste generated by both factors is Web-Based technologies which is a part of Information Communication Technologies (ICT). ICT is an important part of BIM in any project, where parties need to communicate digitally (Underwood & Khosrowshahi, 2012). On construction sites such communication is necessary when planning materials, their orders and coordinating their distribution on site (Su, et al., 2012). ICT has many different formats and can be used with various concepts, software or methods (Zhang, et al., 2013), but the one suggested by Afolabi, et al., (2017), Olalusi & Jesuloluwa, (2013) and Qiang, et al., (2001), etc., is web-based technologies. "*A web-based material planning system is defined as a computer-based information system connected to the internet designed to keep inventory, control, estimate and keep track of availability of materials to be used on a construction site at any particular period*." (Afolabi, et al., 2017). Web-Based technologies allow quick updates of changes in materials creating an opportunity for the manager to react fast on updates and change orders if necessary. Besides that, as well as GIS it enables real time communication which allows to receive the information and status of materials and their deliveries (Afolabi, et al., 2017). It has been estimated that usage of Web-based systems can save up to 10% of construction project costs (Afolabi, et al., 2017). It can be adapted to the company and serve different purposes of Material management. So far it has been used to develop *Enterprise Resource Planning* (ERP) (Ptak & Schragenheim, 2004), *Material Requirement Planning* (MRP) (Qiang, et al., 2001), method for tracking project progress and updates on material usage (Olalusi & Jesuloluwa, 2013) and similar. Yet ICT and Web-Based technologies require proper setting if to be used right, which can be a complicated task in building industry, as it involves many parties and materials which are constantly circulating within the project. Besides that, it creates an access to many people involved in the project, thus reducing security of project material (Underwood & Khosrowshahi, 2012).

Competency of project manager and **foreman** in Material management as in the previous RM areas can be improved by technologies and qualification courses. Minh, et al., (2017) has analysed that technical knowledge allows leaders to be open to new methods which can be used on building sites as well as to solve reoccurring issues. Since such methods allow to achieve better planning of materials, their coordination and collaboration with different parties involved in Material management, leaders who want to engage in such activities must be open to technologies. Besides that, their competency must be raised by knowledge of such technologies and ability to use different tools in different situations of Material management process, eliminating loss of resources, such as time, costs and similar (Wolf, 1990). This leads to the conclusion, that leaders must also receive extra education which can be done with qualification courses. Such courses have been mentioned before by Wolf (1990) and are locally offered by Nohrcon ApS (2020). Yet again, such courses require sufficient funding and motivation for learning (Stackhouse, et al., 2020 and Li, et al., 2017).

Unfinished design or specifications together with **misinformation** within material handling can have less of a negative effect with establishment of 4D BIM, Web-Based technologies, or common cloud-based platform as studies by Choi, et al., (2014), Deng, et al., (2019), Wang, et al., (2004) and Zou, et al., (2017) have shown. 4D has been widely described in Space management and has been proven to have a positive effect on management of a building site, however it can be a great tool for Material management as well (Deng, et al., 2019). Since it can connect processes to the 3D model, it can show where and when different materials will be used. Besides that, the model can be updated by different parties, which allows the manager to know where the changes have been made (Wang, et al., 2004). This decreases the chance of misunderstandings and allows a quick update of unfinished designs but for everyone to be able to connect to the model and share updates, a cloud-based system is required. Such systems allow not only to modify the model, but also make requests and exchange different kinds of files increasing the level of knowledge (Zou, et al., 2017).

Approval of materials by client and consultants to some extent can also be done faster and in a more efficient way with a use of cloud-based platforms and web-based technologies (Zou, et al., 2017). Yet, this factor is more difficult to improve as most of the approval must happen with a physical presence of the client or consultant. However, this can be improved by making sure that the right materials are ordered and delivered as well as ensuring material quality before the approval of the client takes place. These assurances can be made by usage of Web-Based technologies and cloud-based platform in a way where changes can be tracked faster, resulting in better communication, and understanding of required materials. By using Web-Based technologies managers can ensure that the materials arrive on time for the approval of the client (Afolabi, et al., 2017). These actions allow to improve the quality of such approval and reduce their impact on the project by reducing non-physical waste.

All in all, technologies tend to be the main solution suggested by the majority of researchers, improving different Material management factors in different forms (see table 26). Such management requires constant information tracking, as materials are constantly on the move, whether they are being delivered from the supplier or being moved and used around the building site. For that GIS and Web-Based technologies have been identified to help the most. Besides that, project changes during construction phase are inevitable (Chan, et al., 2004), thus constant availability of the newest information is needed for reducing the costs of the late changes. There 4D BIM and cloud-based platforms are effective. Even though technologies have their own drawbacks complicating their usage, manual work is not enough anymore, and it has been proven by different studies mentioned in the chapter that non-physical waste cannot be reduced without practising some form of BIM.

Rank №	Related category	Factors	RII	Available proposal solutions
1	Management	Planning and sequencing	0.86	• **BIM:** ○ **Improved usage of ICT** ○ **GIS (Geographic Information Systems)** ○ **Web-based technologies**
2	Management	Competency of project manager	0.82	• **Usage of technologies** • **Qualification courses**
3	Management	Coordination and collaboration	0.81	• **BIM** ○ **Improved usage of ICT** ○ **GIS (Geographic Information Systems)** ○ **Web-based technologies**
4	Technical	Incomplete design or specifications	0.81	• **4D BIM** • **Cloud-based platform** • **Web-based technologies**
5	Management	Competency of foremen	0.80	• **Usage of technologies** • **Qualification courses**
6	Technical	Misinformation	0.80	• **4D BIM** • **Cloud-based platform** • **Web-based planning**
7	Technical	Approval of materials by client and consultants	0.79	• **Cloud-based platform** • **Web-based planning**

Table 26. Idea proposal for optimization of Material management by improvement of the top seven most essential factors. Source: own production.

6.4. Interrelation of RM factors

After analysing all three resource management fields and evaluating the influence that the different factors have on them, it was discovered that *management* and *technical factors* are essential for Labour, Space, and Material management. Table 27 shows that factors connected to management process, like *planning and sequencing, coordination and collaboration, competency of project manager and/or foremen* are graded to be important for optimal resource management of all three fields and thus can be used to form the basis of a solution that can help improve Resource Management practises and reduce non-physical waste. Also, technical factors like *incomplete design or specification and misinformation*, are also graded important for all three fields and should be considered as well. To summarize, the analyses have shown that these factors have influence on the generation of non-physical waste, and therefore a solution that helps to improve them will be analysed in chapter 7.

Rank №	Related category	Factors	RII
		Labour Management and productivity	
1	**Management**	**Planning and sequencing**	0.87
2	**Management**	**Coordination and collaboration**	0.86
3	**Management**	**Competency of project manager**	0.84
4	**Management**	**Competency of foremen**	0.83
5	**Technical**	**Incomplete design or specifications**	0.82
6	**Technical**	**Misinformation**	0.82
7	Labour	Motivation	0.80
		Space management	
1	**Management**	**Planning and sequencing**	0.85
2	**Management**	**Coordination and collaboration**	0.84
3	**Management**	**Competency of project manager**	0.83
4	**Management**	**Competency of foremen**	0.82
5	Labour	Tidiness	0.81
6	**Technical**	**Misinformation**	0.81
7	Project	Execution method	0.79
		Material management	
1	**Management**	**Planning and sequencing**	0.86
2	**Management**	**Competency of project manager**	0.82
3	**Management**	**Coordination and collaboration**	0.81
4	**Technical**	**Incomplete design or specifications**	0.81
5	**Management**	**Competency of foremen**	0.80
6	**Technical**	**Misinformation**	0.80
7	**Technical**	Approval of materials by client and consultants	0.79

Table 27. Interrelation of factors affecting Labour, Space and Material Management. Source: own production.

7. Summary assessment of proposed solutions

From the analysis of the topmost influential factors affecting different RM fields (see table 27) and the proposed solutions which were found to reduce their influence (see tables 12,19,26), it was discovered that a change of management processes together with implementation of new concepts, technology, and education can help to improve all three areas. The solutions given in table 28 are a summary of the ones proposed for Labour, Space and Material management.

Nr.	RM Field	Average RII for the category	Solutions

1	Labour management and productivity	0.712	• **LBS**
			  ○ Software ± 3D BIM model
			  ○ Manual
			• **Cloud Based platform**
			• **Education** and technical training

2	Space management	0.712	• 4D **BIM** • Qualification courses and **Education** • **Cloud Based platform**

3	Material management	0.706	• **BIM**:
			  ○ Improved usage of ICT
			  ○ GIS (Geographic Information Systems)
			• 4D BIM
			• Web-based technologies
			• **Cloud-based platform**
			• **Education**

Table 28. General solutions for Labour, Space and Material management. Source: own production.

The concept of **Location-Based Scheduling** is found to be befitting the aim of this paper, since it helps to optimize not only labour resources, but resources in general. As mentioned before, LBS has many benefits for improvement of management of resources because it can help to achieve continuous flow of construction activities, maximize the continuous use of labour and other resources like space, materials, machinery equipment, etc., consequently leading to an improved productivity, optimized use of available resources and reduced waste (Olivieri, et al., 2019, Kenley & Seppanen, 2010 and Andersson & Christensen, 2007). Location-Based scheduling can be done manually or by using a software, regardless, both implementation of a new concept or new software has its challenges. Such challenges have been discovered in a study done by Andersson & Christensen, (2007) in which the site management group of three different construction sites were asked to implement LBS while carrying out a construction project. The management groups had none or limited experience with LBS when the study was initiated and even though the results were generally positive, some difficulties and challenges were met as well. The difficulties were directly connected to the application of the LBS concept or the LBS-software that was used, or with more general things, like the need for a significant amount of input information in the initial stage of the planning process and difficulties to change the level of detail once the scheduling has commenced (Andersson & Christensen, 2007). Similarly, another example of the challenges that using LBS software together with a 3D model can have is a study done by González, et al., (2016) where a Danish project manager, Kristine Ann Barnes, considered the data input process burdensome and time consuming, however combining a LBS with a 3D model, that contains all the quantities and information of available resources can make the schedule more precise and realistic. Moreover, the mentioned study and project manager also found out and managed to shorten the project duration with more than two months, but that was achieved by manual input of information based on experience and not information acquired from the 3D BIM model (González, et al., 2016). Regardless, whether the concept is implemented with the help of software and use of 3D BIM model, or used manually, the benefits that LBS can bring regarding reduction of non-physical waste together with optimization of management process of labourers and other resources like space, materials, machinery, tools, and equipment, etc., are exactly the reasons why this concept is found suitable for optimization and improvement of Resource Management in general.

4D BIM has been identified and proposed as a solution for two of the three Resource Management fields – Space management and Material management, but its implementation can help to improve the overall management process at construction sites and optimize the management of available resources and therefore is also found befitting the needs of this paper. As mentioned, 4D BIM can be used to manage complex tasks, workspace, and workforce during construction projects, since its purpose is to combine 3D models with scheduled corresponding activities (Choi, et al., 2014) and visualise each project stage, so managers and stakeholders can acquire a detailed overview of the entire process in order to manage it in an optimal way. By doing this, they can keep better track of available workspaces and work crews, as well as optimize the working process and reduce non-physical waste (Wang, et al., 2019). As stated before, 3D BIM models contain a lot of useful information and parameters about the building which can be used to simulate and track changes on site during construction period (Eastman, et al., 2018), thus helping them to detect clashes of working areas (Choi, et al., 2014), foresee path obstructions (Wang, et al., 2019), plan logistics (Deng, et al., 2019) and generally reduce hazards and risks by simulating BIM-based planning of the building site (Jin, et al., 2019). The benefits of the 3D model information combined with scheduled activities (4D) allow contractors to see any issues, like colliding activities, workstations, paths and similar and/or wasted time, money, and productivity (Choi, et al., 2014) and is thus also considered suitable for optimization of RM processes.

To optimize Material management two **BIM related concepts** were identified (mentioned in chapter 6.3.2) - Geographic Information Systems (GIS) and Web-Based technologies and planning. Where, GIS is a technology that allows identify problems and solutions regarding material layout (Cheng, Yang). The system can be combined with a 3D BIM model, so material circulation on site can be visualized (Ma, et al., 2005) and automated tracking of transportation of materials can be provided (Castro-Lacouture, et al., 2007). Whereas, Web-Based technologies and improved use of ICT can be used to develop Enterprise Resource Planning (ERP) (Ptak & Schragenheim, 2004), Material Requirement Planning (MRP) (Qiang, et al., 2001), method for tracking project progress and updates on material usage (Olalusi & Jesuloluwa, 2013) and similar. However, the implementation of either both suggested options, or just one, can help optimize Material management, also leading to optimization of the overall Resource Management.

In general, all above mentioned concepts are related to BIM or the project’s 3D model and therefore it is important to know the general disadvantages that BIM has. As established before, construction industry is resistant to change and is used to working based on the previous experience (Holt, et al., 2015). This creates a big barrier when trying to implement technologies and new concepts as it requires training and an innovative attitude. Besides that, there is a common misconception in the industry that implementation of BIM must solve all problems and that it must be done fast, however, the use of BIM requires time and can be a difficult process with some disadvantages.

One of the disadvantages that implementation of BIM, or BIM related software and concepts can have, is that it can be very expensive. There are costs of needed hardware, training, and courses as well as a need of new, professional staff (Afolabi, et al., 2017). Even though BIM shows positive results in the end, it can take a while until usage of it turns into profit.

Moreover, a study done by Migilinskas, et al., (2013) shows that barriers like fear of failure, high initial investment costs, time for education and training, and the lack of support from senior leadership of the company are all big disadvantages for the implementation of BIM in construction projects. Another study has found out that challenges in connection to BIM and its implementation and usage, such as "*technical skills and training challenges, legal procedural challenges and economy*" can obstruct construction companies from upgrading of their available systems to a system which is BIM oriented (Diaz, 2016). And since the suggested software and concepts are part of BIM, they also have the same disadvantages - the process of implementation is difficult, costly and time consuming. Additionally, implementation of BIM related software and concepts requires educational courses and training of the labourers so that it can be used efficiently.

Education and technical training are also one of the proposed solutions for improving and optimizing the three RM fields. According to Minh, et al., (2017) technical and educational knowledge allows leaders to be open to new methods which can be used on building sites to solve reoccurring issues. Moreover, it provides the opportunity to use different tools to decrease the loss of resources, such as time, costs and similar (Wolf, 1990). However, according to literature, some construction workers find training as a non-earning period, thus impelling them to prefer working over training (Carley, et al., 2003 and Johari & Jha, 2019), leading to a lack of interest and wish to participate in educational courses and technical training. Regardless, according to the Danish WEA (BAR Bygge & Anlæg, 2016), it is an obligation of the employers to give the employees adequate training and instructions so that work can be performed safely and securely. The economical aspect of having a course or technical training is also a disadvantage. Therefore, both employers and workers are reluctant to attending additional training because it is costly and time consuming. For example, a simple course in operating a telescopic handler, takes 5 days (37 working hours) and costs about 600 DKK (Tradium, 2020). Whereas training or courses in BIM and BIM-based software like e.g., making LBS (2 days), use of BIM/VDC (3 days), or getting insight in ICT (3 half days), etc., which if combined will be much more time consuming and expensive (Exigo A/S, 2020).

Usage of **cloud-based platform**, similarly to BIM, requires education and training of the workforce so it can be used efficiently. And even though having such platform can bring many benefits, if employees do not use it accordingly, a lot of its value would be lost (Zou, et al., 2017). Therefore, an important aspect of using such platform is having standardized way of information and data exchange, specified in the ICT requirements of the project, like sharing IFC files, for example. An issue of having cloud-based platform, however, can be data access and security. The collaborative nature of cloud-based platforms may cause security challenges such as issues regarding liability. This is because in platforms like this access is granted to many different construction actors who can edit and exchange data thus making it difficult to track the ownership of the change (Afsaria, et al., 2016). In addition, learning how to use a platform like this is also time consuming and costly. There could be expenses for both training the workforce, maintaining it, and paying the monthly or annual subscription fees. A summary of the advantages and disadvantages of the proposed solutions can be seen in the table 29.

Solution	Improving factors / categories	Advantages	Disadvantages
Implementation of mentioned BIM related concepts: • LBS • 4D BIM • GIS • ICT	ALL	• Gives greater insight into the project (like labour, space, and material information) • Helps reduce certain risks • Creates a better process • Better overview, management, and quality • Better coordination and cooperation • Improves health and safety • Better communication	• Requires training and an innovative attitude • Time consuming • High investment costs • Requires new software • Difficult implementation process • Fear of failure • Lack of support • Industry is resistant to changes
Education and technical training (courses)	ALL	• Improves processes (Efficiency) • Reducing occurrence of mistakes and rework • Reducing time and cost overruns • Motivates and inspires productivity	• Time consuming • Cost consuming • Non-earning period • Lack of interest

Implementation of cloud-based platform	ALL	• Better coordination and cooperation • Better communication • Creates a better process • Reduces non-physical waste, e.g., waiting time • Easy information and data exchange	• Requires education and technical training • Time consuming (educating and training) • Cost consuming • Data access and liability

Table 29. Advantages and Disadvantages of proposed solutions. Source: own production.

To conclude, the suggested BIM related concepts and technologies, together with education and technical training, and use of cloud-based platforms are offered together as a general solution that can help optimize the management of resources and reduce the occurrence and generation of non-physical waste. Even though the proposed solutions have some disadvantages, the benefits they can bring for reducing non-physical waste and optimization of RM are much higher and therefore should still be considered. Project managers in some advanced and innovative Danish companies like MT Højgaard A/S, for example, who are already working vastly with BIM and related BIM-based software for doing Location-Based Scheduling, etc., (González, et al., 2016) can implement the concept or technologies that they do not have or optimize the usage of the once they do. Whereas managers in other companies who are not that advanced and innovative, may need to implement more than one of the proposed solutions.

To further help project managers identify how they can improve and optimize the management of resources in their construction projects, a Resource Based View inspired Framework will be introduced in next chapter 8. The purpose of creating such framework is to help the construction managers, or the management group to identify what issues they have in relation to Resource Management, locate the area where the problem is stemming from and find suitable solution to eliminate non-physical waste.

7.1. Resource Based View framework

For the companies to grow and stay competitive, analysis of their current situation must be done (Goh & Loosemore, 2017). There are many different strategies which help the companies to stay competitive, such as Porter's five forces, SWOT analysis and Resource Based View (RBV). These strategies help in analysing different aspects of firms, however, what they all have in common is that the analysis is done on the company's level and changes are implemented from the managerial level (Barney, 1991). Construction industry is special and differs from the others in a way that it is project based and more practical (Li, et al., 2019). Construction companies depend on construction projects, which have their own organization. Since every project is unique, with different needs and issues, it requires management on site, which creates a need for a practical strategy which can be used for individual projects. Thus, a strategy analysis has been done, offering a way for the construction companies to make choices and use solutions based on the issue area they have in specific building projects.

It has been defined before in this study, that better Resource Management can improve the success of construction projects. For this reason, Resource Based View has been selected to be used for creation of framework which could be used not by the top level of the company, but by a lower organizational level on different construction projects. Resource based view is a strategy "<…> *determining objectives for resources and capabilities such as being a valuable resource, being a rare resource, and not being imitated* <…>" and defines company's organizational structure (Geylani & Dikbas, 2019). Creator of RBV, Jay Barney, identified resources as *"<…> everything, such as all assets, abilities, competencies, organizational processes, firm characteristics, knowledge, and know-how, that can be controlled by the firm and that provides efficacy and allows them to use strategies providing efficiency."* (Barney, 2001). Such resources can be categorized into financial, physical/technological, organizational, human, intellectual and social (Barney, 1991). This also includes several most important resources that have been analysed in this research and have been proven to be significant for construction projects: time, budget, and productivity. Besides that, RBV identifies that every company has unique resources that should be utilized and that they give every company a special identity and character (Rumelt, 2002). All these RBV features describe a company, but they can be used to identify construction projects too. To do that, a Resource Based Framework (RBF) has been created, which is compared with RBV in table 30:

Characteristics	Resource Based View	Resource Based Framework
Level	Company	Project
Type	Theoretical	Practical
Defines	Company's uniqueness, identity, character	Project issues within different RM areas, providing specific solutions
Goal	Improve company's competitiveness	Improve project's success
Main resources	Financial, physical/technological, organizational, human, intellectual and social.	Time, finances, and productivity within labour, space, and material management.
Backed up by literature	(Barney, 1991), (Geylani & Dikbas, 2019) (Goh & Loosemore, 2017), *etc.*	None

Table 30. Comparison between RBV theory and modified RBF. Source: own production.

The table 30 shows a summary of differences and similarities between RBV and RBF. The differences are that RBV is done on the company level and is more theoretical, whereas RBF is done on a project level and is executed in a practical way. Besides that, the view is done to improve company's competitiveness by means of focusing on its uniqueness, whereas the framework focuses on the issues within RM areas and how to solve them. The main resources are broader in RBV, however the ones in RBF are more specific for construction industry and projects. Having such practical framework makes it possible to apply J. Berney's Resource Based View on a project level, following the same principle, yet adjusting it to fit construction industry requirements. Since RBV has been proven to be a success in different companies (Kunc & Morecroft, 2009 and Papetti, et al., 2019) it is possible that a practical framework based on it can improve construction projects too, exploiting available resources and reducing their waste.

The solutions which could improve different Resource Management areas were summarized in the previous chapter. However, since all construction projects are unique, it can be difficult to apply the same solutions everywhere. To narrow down different solution options and to pick the one that can be the most beneficial for a specific project, it is essential to know where the problems are stemming from. This is where the Resource Based Framework can be helpful, allowing to select solutions based on the issue areas. RBF is shown in the figure 17 and includes the four main steps:

1. Identifying the issues and resource waste by resource mapping;
2. Finding an area where the problem is stemming from;
3. Based on what is missing, defining RM area and choosing a particular solution(s);
4. If analysis cannot be done, a universal solution affecting all three fields can be used.

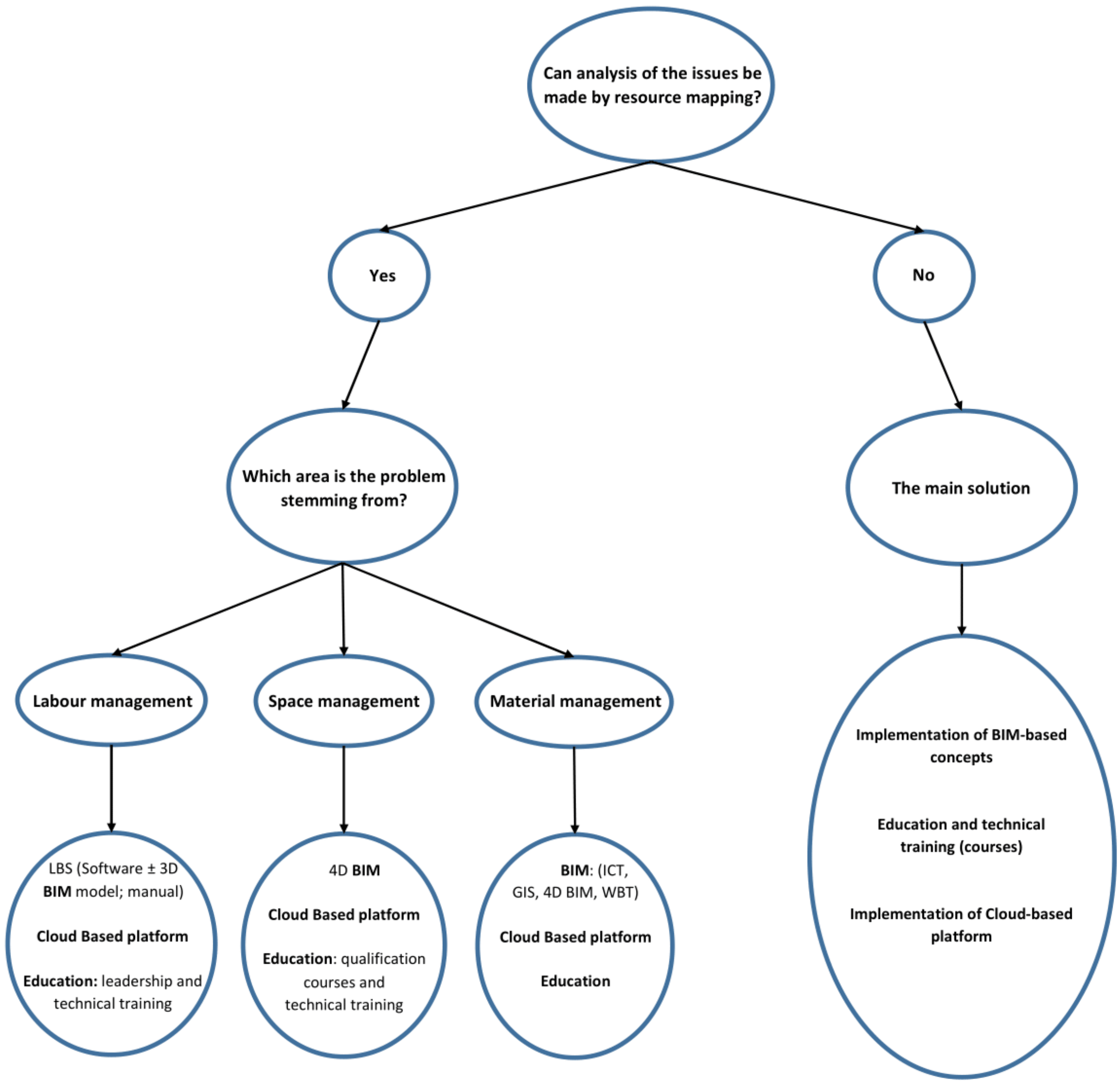

Figure 17. Resource Based Framework allowing to identify the source of non-physical waste and choose solution accordingly. Source: own production.

The first step in the framework is to **analyse the issues** occurring in the construction projects which allows to identify what type of non-physical waste is occurring. In this step it is important to mention, that analysis cannot always be done. If the manager does not have competency to do a sufficient resource mapping or identify specific problems in different areas, then it must be considered that the analysis cannot be made. It is also possible that the problem is rather large, involving different interacting issues and affecting more than one Resource Management areas, thus this step raises questions whether such analysis can be made and gives an option of “yes” and “no” answers. If the answer is “yes” and the analysis can be made, the framework goes to step three: finding the problem area. If the answer is “no”, then a universal solution affecting all three RM fields is offered, which will be discussed at the end of this chapter. However, if the analysis can be made, then it is important to look into company's resources, their availability and usage, which can be done with resource mapping. Resource mapping is a qualitative methodology allowing to visualize company's resources, their usage, availability, linkages, and relevance (Kunc & Morecroft, 2009). Coyle (1999) has written, that describing the organization, processes and resources can lead to a better understanding of occurring issues, which is the purpose of the first step in RBF. In construction industry, resource mapping addresses resources *"<...> locations with attributes such as physical characteristic properties, material availability, distance from the nearest primary road in geo-referenced map, thereby creating a scientific information on the availability and suitability of construction materials"* (Salini, et al., 2017). However, it is important to remember, that initially resource mapping together with RBV has been developed for the companies and not specific projects, yet it can be adjusted to fit RBF. Thus, resource mapping in RBF is very similar to the one included in RBV and consists of three steps:

1. Identifying resources and capabilities of the project
2. Assessing the strength and importance of the resources and capabilities
3. Mapping resources and capabilities

When resource mapping is used in companies, resources are gathered and analysed from different sources, e.g., annual statements, but the idea is always the same – finding the most important resources which can define companies' competitiveness (Kunc & Morecroft, 2009). On construction sites identification of resources can be done by defining available and needed resources for different tasks through hierarchical approach. This allows to distinguish resource importance and accessibility as with hierarchical approach resources can be categorized into value-added, non-value added and waste, which is the second step of mapping. Finally, a map is completed in a way that it is functional and easily understood, involving key performance indicators which show where and how the resources are used (Papetti, et al., 2019). Mapping resources according to such three steps does not only allow to know which resources the project has, but also which ones are experiencing problems or are wasted. It is a practical visual way to track different resources and assign them to different Resource Management areas, which helps in identifying what areas have problems and leads to the next step of the framework.

Finding an area where the problem is stemming from can be a difficult task, requiring experience, knowledge, and insight. Since construction projects involve many interacting activities and processes, they also contain many resources, both physical and non-physical. Without a defined system it can be difficult to find which resources are being wasted, thus a mapping process described above should be used. When resources are mapped and their management areas are assigned, the framework gives three options for issue areas: Labour, Space and Material management. This is where the manager must make an argued decision about where resource loss and occurrence of non-physical waste is stemming from: productivity of workers, building site organization or materials and logistics. If it is possible to define a specific area, then solutions for that area are suggested (see figure 17). If more than one area is defined, then a use of universal solution is proposed.

Choosing a solution is the last step of the RBF and it can be done is several ways. If the whole framework analysis was caried out, a solution is chosen from different fields. Since every RM area has several solution options, a manager can decide what is lacking in his project and decide whether to implement only the lacking concepts or everything defined under the proposed solutions. The same can be applied for the universal solution, which is chosen in case analysis of resource availability, usage and waste cannot be conducted. The main solution contains aspects that help to improve all RM fields and should be able to solve most of the non-physical waste issues occurring on building sites.

Overall, the Resource Based Framework should allow project managers to identify the problems related with non-physical waste and optimize usage of resources by selecting matching solutions. The focus while creating RBF has been directed on creating a framework that is visual and easily understood, practical to use and informative. It has been important to define how managers can reach different solutions by following a simple path of problem identification and pick a reasoned solution. Such solution would either help by eliminating specific resource(s) waste and improving a certain RM field or by reducing general non-physical waste appearing in all fields, thus increasing quality of the project.

8. Discussion

The results of the research revealed that there is potential for optimization of Resource Management processes at construction sites and reduction of non-physical waste. Moreover, it has become clear that time and cost overruns can be avoided by reducing non-physical waste and optimizing Resource Management practices on sites. These results have been supported not only by theory but also by the professional opinion of the participants in the carried-out survey, according to which 90% of the respondents have confirmed that RM has effect on time and cost in construction projects and is therefore, an important factor in reducing non-physical waste.

The analysed survey results and theory about different types of Resource Management has led to an overall conclusion that non-physical waste on Danish construction sites is perceived as an issue and managers would be interested in practical solutions on how to reduce it. It was also discovered that many of the issues for generation of non-physical waste and improper Resource Management are connected to the management process and thus can be avoided. According to Danish professionals, the most important factor influencing resource waste on construction sites is organisation and management, in average receiving 3 out of 5 points (see table 5, p. 24). This was later confirmed by more thorough analysis done for each RM field, where management factors have received the highest average RII for Labour, Space and Material management.

The deeper and more thorough analysis of the three chosen Resource Management fields has showed that the most important factor categories recognized to have biggest influence on Resource Management and project productivity are related to either management, labour or technical aspects of the project. Moreover, this repeating pattern was found not only in the results gathered from the survey data for this project, but also by many other surveys and studies done all over the world. The factor categories, their subfactors and related RII gradings, have been found to match the results of other findings from different countries and researchers, and has therefore been considered as a confirmation for reliable and valid data, corresponding to real life issues, experiences, and practices.

Furthermore, the significant relationship between factors affecting Resource Management and non-physical waste was also revealed. The outcome of the analysed data and theory gives a confirmation that improving RM on construction sites can help to reduce non-physical waste and avoid unwanted time and cost overruns. The detailed study of factors affecting Resource Management can also help project managers to discover issue areas within their resource management procedures on site and thus help them identify what areas they can optimize, in order to avoid generation of non-physical waste and improve the project's productivity and efficiency. Doing that can benefit them not only by saving project money and time, but also by creating a competitive advantage for their company and hence earn them a good name, portfolio and future projects.

In addition, the overall survey results and researched theory have both showed that improving management procedures can help to cut down non-physical waste and optimize resource usage. This has been seen as a positive result since it means that avoiding generation of waste and improving Resource Management are within the project manger's control. Thus, by changing the management methods on construction sites optimal RM procedures with reduced non-physical waste can be achieved. In this research it is argued that this can be done by implementing new management concepts, like the suggested ones in chapter 7, or by developing the already existing ones but in respect to Resource Management.

The general solution was aimed to be practical and simple but also efficient. Construction projects are complex in nature and project managers have many difficult tasks to deal with daily and thus are limited in time and effort to research new management procedures and be educated in complex concepts. Therefore, the paper was aimed at finding a practical solution that does not necessarily require significant effort, but on the contrary, is something that has been already discussed and/or implemented in some construction companies but has not been efficiently used regarding minimization of non-physical waste and optimization of RM. However, the successful implementation of the general solution also requires additional training and education, knowledge and will to improve the construction process and wish to change, not only by the management group but also from the workforce.

Since the aim of the project was to find practical solution that is relatively easy to implement, the suggested set of solutions is considered efficient and suitable to optimize the Resource Management process at construction sites and reduce non-physical waste. It has been also acknowledged that implementation of concepts like Lean Construction and BIM as a whole, even though complex in nature, can be considered as an even more successful option as well.

To help project managers identify issue areas in their Resource Management processes and at the same time reduce non-physical waste, a RBV inspired framework was introduced. The framework's purpose is to guide managers to identify project areas where resources are wasted in order to find the root causes of it. Unfortunately, such framework has not been created and investigated by other researchers yet and therefore, the one suggested in this paper cannot be supported by theory, or practise. However, since it follows the concept of RBV, but adapted to project level instead of company level, it is considered that the framework should be theoretically correct as well.

The report methodology and delimitations adjusted throughout the writing period as they have been affected by the survey and findings in the literature. Nevertheless, the report has kept its consistency and logical path which created a natural flow from problem area to establishment of problem formulation and suggestion of possible solutions. Since the study has been carried out for construction industry, where stakeholders involved in managing the projects differ in terms of education, experience, and perceptions (Othman, 2014), it was found necessary to be more explanatory especially regarding complex concepts. This has resulted in more detailed descriptions of analyses and proposed solutions.

In connection to the carried out survey, there were also few things that could not be seen before the project has reached a certain point of development, that is why some parts, approaches and methods could have been changed and improved. After the survey has been completed and answers have been used in continuation of the report, it has been noticed, that some questions could have had a different formulation to give more diverse answers and more information. On top of that, some questions in Labour management have been targeted more towards labour productivity rather than the whole management area, possibly being too concentrated on productivity. For this reason, labour productivity has also had a question about grading the importance of different categories whereas other two RM areas have been neglected in that aspect. In the end these issues did not have a significant influence for the development of problem question or finding solutions, yet questionnaire could have been done in a better way.

9. Conclusion

From the report findings it has become clear that in order to reduce non-physical waste as well as time and cost overruns it is important to utilize project resources efficiently. To do this, three areas of RM were analysed – Labour, Space and Material management. Both literature and collected survey data have showed that Resource Management can help to reduce non-physical waste at construction sites. According to survey data 90% of 82 danish construction professionals are aware of cost and time overruns being caused by resource waste, whereas 97% think that improving Resource Management in the fields of Labour, Space and Material management can help reduce non-physical waste.

Moreover, the analyses have discovered that there is potential for optimization of Resource Management practices at construction sites in Denmark, since 24% of survey participants have responded that they do not use any RM and 9% are not aware of it. In addition, the rest of the respondents (67%) who use it, have further elaborated that 49% of them use it regarding workforce management, 29% for site and space organization and 22% for material management. This has led to the overall conclusion that there is potential for optimizing the Resource Management practices not only in companies that do not use it at all, but also in companies who have implemented it partly and not in its full potential.

To see which areas of the three fields should be improved upon, a detailed analysis was done about factors influencing them. More detailed analyses have discovered that management procedures and knowledge are required for efficient Resource Management and therefore should be thoroughly considered. Factors like *Planning and sequencing, Coordination and collaboration, Competency of project manager, Competency of foremen, Incomplete specification or design* and *Misinformation*, have been found to be essential for all three Resource Management fields. The findings have showed that these factors have influence also on the generation of non-physical waste, thus confirming that by improving the RM procedures non-physical waste can be reduced or even eliminated.

In order to minimize the effect that the aforementioned factors have on Resource Management and construction projects' productivity, different solutions were proposed and analysed. It was discovered that in general, the influence of the different factors can be reduced by implementation of new management practices, combined with educating project managers and labourers, and use of cloud-based platforms. Management concepts like LBS and implementation of BIM-based concepts like 4D BIM, GIS, and ICT were found to optimize RM procedures and reduce non-physical waste in the fields of Labour, Space, and Material management. Yet, they require special knowledge and therefore should be combined with education. Educating the labour force is discovered to be essential not only to improve the management process but also to reduce non-physical waste and optimize resource utilization, since well-educated and experienced staff is more productive and efficient. The third part of the solution - cloud-based platform, is as well found required for improving both the construction process and Resource Management procedures and reducing non-physical waste. To help project managers identify issue areas in their Resource Management processes and to determine what specific solution they need to implement in order to improve them, a Resource Based View inspired framework has been created.

In conclusion, a lot can be done to reduce non-physical waste regarding Resource Management, however, project managers should be aware of the importance it plays over the project's time and cost and should act out to optimize their processes in a way that is efficient and free from non-value adding activities. Even though the report proposes several solution options and a framework helping to make the most suitable choice, such solutions should be sensibly evaluated. Every project is different and has special properties, which must be considered when trying to reduce non-physical waste, therefore it is important to analyse to which extent Resource Management is exploited in the project and which solutions are already in use. For this reason, solutions and the framework should be treated as a guideline and not as a solution eliminating all non-physical waste. They can be used to ensure better allocation and organization of resources within Labour, Space and Material management categories, thus creating an opportunity to reduce generation of non-physical waste.

10. Perspective

As mentioned in the conclusion, the report established that non-physical waste on building sites can be reduced by improving usage of Resource Management areas with implementation of BIM-related concepts, education, and cloud-based systems. One of the goals throughout this project has been to keep the report, analysis, and findings practical, creating solution that could be taken on by professionals in the industry. Besides that, survey answers from project executives have been important in confirming that the problem of non-physical waste generation on sites is relevant to look into and is significant for the building industry. The proposed solution can help managers to organize their resources better, detect not only specific problems, but also assign them to RM areas which can help them to pick more problem-oriented solutions and efficiently reduce generation of non-physical waste.

It would have been of additional value if the report's findings could be tested in real life, but since the project is limited by time, it could not be done. This is also an aspect that could have been changed as it was intended to add a follow up interview with companies, both using and not using RM. The idea behind such interviews was to find out how the solution is perceived by professionals in the industry and whether they would be willing to use it. The prepared questions for the interview focused on evaluating solutions practicality and complexity as well as integrity and explicitness. Questions for companies using and not using RM were slightly different as they should have revealed the difference in thinking between such companies. It was assumed that the company already using RM to some extent would be more open-minded, thus if a company without a knowledge of how RM can be used would still be interested in trying the proposed solution, the project would have been considered a success. Unfortunately, such interview could not be done, as none of the contacted companies could participate in it, due to current pandemic situation and relatively short notice.

Besides these two major parts that could have been improved or done differently, the report had more minor areas where changes could have been applied, as it is common to have more knowledge and understanding about the report and theory after some amount of work has been done. However, each of these areas have been evaluated throughout the report and were changed when necessary. In other cases, it has been considered a better idea to leave the parts as they were avoiding disturbing the flow and clearness of the report with constant changes, which would also be time consuming. For these reasons survey has not been redone as well as at certain point of the report, the idea of the interview has been dropped too.

The project has started with a statement that non-physical waste is an important issue in construction industry and an assumption that improved RM can help to reduce it. While these statements and assumptions have later been analysed and proved, the report has also risen new questions which were not covered in this report. Some of these questions include curiosity of what are other sources of generation of non-physical waste besides improper usage of Resource Management? Are there other methods to reduce such waste? Since BIM and education have been considered by many to be the future of construction projects, solving numerous problems on sites, why is it still not used to its' full potential? Since analysis of proposed solutions has been based on theory and studies mostly conducted outside Denmark, how would they fit within Danish culture and construction industry? As Resource Based View has been done for company level and no framework has been created for a project level before, can it actually work? How can it be tested? These and many other questions cannot be answered in this project, however if the project had a continuation in the future, this analysis could be part of it.

In the future the study could be continued with investigation of solutions usage in practice. The interview that could not be conducted this time, could be completed later to evaluate how the framework and solutions are perceived by construction managers in different firms. Besides that, usage of framework could be tested by companies having issues with non-physical waste and loss of resources as well as different solutions could be assessed to see whether they are possible to implement, use and bring required results. This could also confirm whether the created framework can work for project level or if Resource Based View should stay a theory for a company level.

The issue of non-physical waste could also be explored more by looking into more reasons behind such problem. As this project mostly focused on optimization of Resource Management due to its' large impact on non-physical waste, less important causes were not analysed. For that reason, the further investigations could make a deeper analysis of different factors influencing occurrence of non-physical waste and propose different solutions to minimize it, which are not part of Resource Management. An open questionnaire about reasons for that in Danish construction industry could take place, allowing project managers to share their insight in this matter and evaluate their proposed causes without having predefined problem areas.

All in all, the project has been completed with satisfactory results, answering the problem question, and confirming ideas stated in problem area. Besides that, based on a thorough analysis, it offered solutions for solving majority of the issues and achieving the goal of the report. As everything can always be improved, this project is no exception and has areas that could have been done better, yet they did not lower the quality of the report and are possible to be done in the future in case the project had a follow up.

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12. Appendices

Appendix 1. Relative Importance Index calculations

RII for Labour management and productivity

Management factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Planning and sequencing	0.87	5	0	3	23	43	321	5	74
2	Coordination and collaboration	0.86	2	3	5	25	39	318	5	74
3	Competency of project manager	0.84	1	4	4	34	31	312	5	74
4	Competency of foremen	0.83	2	2	8	33	29	307	5	74
5	Site layout	0.74	0	8	22	29	15	273	5	74
6	Safety and work environment	0.72	1	8	27	21	17	267	5	74
7	Congestion and overmanning	0.72	2	6	27	22	17	268	5	74
8	Supervision and inspections	0.70	1	13	21	25	14	260	5	74
	Average	0.79								

Project factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Rework and delay	0.75	2	6	17	31	18	279	5	74
2	Construction method	0.74	3	9	14	31	17	272	5	74
3	Project characteristics	0.73	1	10	19	28	16	270	5	74
4	Financial capability	0.73	1	9	22	24	18	271	5	74
5	Subcontracting	0.72	2	13	16	26	17	265	5	74
6	Contracts and procurement	0.65	8	14	17	23	12	239	5	74
7	Location	0.50	19	19	19	13	4	186	5	74
	Average	0.69								

Labor factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Motivation	0.80	3	1	10	40	20	295	5	74
2	Labour work facilities and satisfaction	0.77	2	6	10	38	18	286	5	74
3	Skill and experience	0.76	1	6	17	32	18	282	5	74
4	Crew composition	0.76	1	8	17	27	21	281	5	74
5	Personal issues and disputes	0.66	1	16	28	19	10	243	5	74
6	Absenteeism	0.65	4	18	18	22	12	242	5	74
7	Labour fatigue	0.62	6	19	21	16	12	231	5	74
	Average	0.72								

Technical factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Incomplete specification or design	0.82	2	4	9	28	31	304	5	74
2	Information	0.82	2	4	10	26	32	304	5	74
3	Materials	0.77	3	6	14	27	24	285	5	74
4	Design changes	0.74	1	11	17	27	18	272	5	74
5	Client and consultants	0.73	2	9	19	26	18	271	5	74
6	Tools and equipment	0.69	3	11	23	24	13	255	5	74
7	Technology and culture	0.69	3	9	25	27	10	254	5	74
	Average	0.75								

External factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Legislation	0.62	5	18	21	23	7	231	5	74
2	Permits	0.61	11	12	24	16	11	226	5	74
3	Weather	0.61	4	18	30	15	7	225	5	74
4	Financial stability	0.59	6	19	26	17	6	220	5	74
	Average	0.61								

RII for Space management

Management factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Supervision and inspections	0.69	2	9	22	21	10	220	5	64
2	Planning and sequencing	0.85	2	0	6	27	29	273	5	64
3	Competency of project manager	0.83	0	3	11	25	25	264	5	64
4	Site layout	0.72	0	8	24	18	14	230	5	64
5	Competency of foremen	0.82	0	2	14	25	23	261	5	64
6	Coordination and collaboration	0.84	1	3	10	18	32	269	5	64
7	Safety and work environment	0.73	0	8	24	15	17	233	5	64
8	Congestion and overmanning	0.70	1	10	24	15	14	223	5	64
	Average	**0.77**								

Project factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Execution method	0.79	0	4	13	29	18	253	5	64
2	Defects	0.71	1	7	23	21	12	228	5	64
3	Project characteristics (size, buildability, complexity)	0.74	0	5	23	22	14	237	5	64
4	Project location	0.62	6	11	27	12	8	197	5	64
5	Client, project and own finances	0.70	1	6	28	18	11	224	5	64
	Average	**0.71**								

Labor factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Motivation	0.76	0	8	15	22	19	244	5	64
2	Culture	0.70	1	8	23	22	10	224	5	64
3	Tidiness	0.81	0	2	15	25	22	259	5	64
4	Number of workers	0.70	0	7	25	26	6	223	5	64
5	Composition of work crew	0.72	1	4	25	23	11	231	5	64
	Average	**0.74**								

Technical factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Materials and logistics	0.75	1	8	13	25	17	241	5	64
2	Equipment and tools	0.70	1	12	20	16	15	224	5	64
3	Technology and culture	0.67	2	9	25	21	7	214	5	64
4	Design changes	0.72	1	4	27	19	13	231	5	64
5	Unfinished design or specifications	0.77	0	6	17	23	18	245	5	64
6	Dissemination of information	0.81	1	3	11	26	23	259	5	64
7	Interference from the client and consultant	0.68	0	12	22	21	9	219	5	64
	Average	**0.73**								

External factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Weather	0.63	6	10	29	7	12	201	5	64
2	Economic stability, including crises and inflation	0.60	5	15	25	13	6	192	5	64
3	Building permit and other permit	0.62	6	15	19	16	8	197	5	64
4	Construction law and other legal regulations	0.59	9	12	20	19	4	189	5	64
	Average	**0.61**								

RII for Material management

Management factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Competency of foreman	0.80	1	3	15	23	25	269	5	67
2	Planning and sequencing	0.86	3	1	3	25	35	289	5	67
3	Competency of project manager	0.82	0	4	11	25	27	276	5	67
4	Poor site layout	0.69	1	9	28	17	12	231	5	67
5	Inspections	0.69	1	14	19	20	13	231	5	67
6	Coordination and collaboration	0.81	2	4	10	24	27	271	5	67
7	Safety and work environment	0.68	2	13	23	15	14	227	5	67
8	Congestion and overmanning	0.72	0	10	21	22	14	241	5	67
9	Waste on construction site	0.77	1	4	15	31	16	258	5	67
10	Storage facilities	0.73	0	7	22	26	12	244	5	67
	Average	**0.76**								

Project factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Contracts with suppliers	0.71	5	8	18	20	18	245	5	69
2	Construction method	0.78	2	6	10	29	22	270	5	69
3	Rework and delay	0.73	0	9	25	17	18	251	5	69
4	Project characteristics	0.75	0	7	18	28	14	250	5	67
5	Location	0.53	9	21	24	9	4	179	5	67
6	Financial capability of client and the project	0.72	1	7	24	21	14	241	5	67
	Average	**0.70**								

Labor factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Motivation	0.76	1	11	10	25	20	253	5	67
2	Skills and experience (Improper handling of materials)	0.75	0	6	21	24	16	251	5	67
3	Number of workers	0.70	0	13	19	25	10	233	5	67
4	Crew composition	0.73	0	10	19	24	14	243	5	67
	Average	**0.73**								

Technical factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Materials and logistic	0.78	2	4	16	22	23	261	5	67
2	Tools and equipment	0.72	2	7	21	23	14	241	5	67
3	Technology and culture	0.66	2	9	30	19	7	221	5	67
4	Design changes	0.74	1	4	24	24	14	247	5	67
5	Incomplete specification or design	0.81	0	7	9	26	25	270	5	67
6	Dissemination of information	0.80	2	1	17	21	26	269	5	67
7	Approval of materials by client and consultants	0.79	0	5	15	26	21	264	5	67
8	Deliveries of defected/wrong materials	0.69	1	13	24	12	17	232	5	67
	Average	**0.75**								

External factors										
Nr	Sub-factor	RII	1	2	3	4	5	Sum of W (all points)	A (highest weight)	N (number of respondents)
1	Weather	0.60	6	14	28	12	7	201	5	67
2	Financial stability, crisis and inflation	0.60	6	13	28	14	6	202	5	67
3	Building permits and other permits	0.58	11	15	19	13	9	195	5	67
4	Construction law and legal regulations	0.59	12	14	16	16	9	197	5	67
5	Lack of security personnel	0.57	13	12	22	13	7	190	5	67
	Average	**0.59**								

Appendix 2. Factor identification and selection

Factor research of Resource Management areas done to identify, select and categorize them according to literature.

RM area	Used factors	Factors suggested by literature/studies
Labour management	• **Management** ○ Planning and sequencing ○ Coordination and collaboration ○ Competency of project manager ○ Competency of foremen ○ Site layout ○ Safety and work environment ○ Congestion and overmanning ○ Supervision and inspections • **Project** ○ Rework and delay ○ Construction method ○ Project characteristics ○ Financial capability ○ Subcontracting ○ Contracts and procurement ○ Location • **Labour** ○ Motivation ○ Labour work facilities and satisfaction ○ Skill and experience ○ Crew composition ○ Personal issues and disputes ○ Absenteeism ○ Labour fatigue • **Technical** ○ Incomplete specification or design ○ Information ○ Materials ○ Design changes ○ Client and consultants ○ Tools and equipment ○ Technology and culture • **External** ○ Legislation ○ Permits ○ Weather ○ Financial stability	(Lindhard, 2020)*:* • **Management** ○ Supervision ○ Planning and sequencing ○ Competency of project manager ○ Poor site layout ○ Inspections ○ Information ○ Coordination and collaboration ○ Safety and work environment ○ Congestion and overmanning • **Project** ○ Contracts and procurement ○ Construction method ○ Subcontracting ○ Rework and delay ○ Project characteristics ○ Location ○ Financial capability • **Labour** ○ Motivation ○ Skill and experience ○ Absenteeism ○ Labour work facilities and satisfaction ○ Labour shortage ○ Labour fatigue ○ Crew composition ○ Personal issues and disputes • **Technical** ○ Materials ○ Tools and equipment ○ Technology and culture ○ Design changes ○ Incomplete specification or design ○ Information ○ Client and consultants • **External** ○ Weather ○ Financial stability ○ Permits ○ Legislation (Alaghbari, et al., 2017)*:* • Management

		• Human/labour factors • Technical and technological factors • External factors (Kadir, et al., 2005): • Material shortage at project site • Non-payment (financial problem) to suppliers causing the stoppage of material • Delivery to site • Change order by consultants causing project delay • Late issuance of construction drawing by consultants • Incapability of contractor's site management to organise site activities • Late issuance of progress payment by client to contractor • Late supply of materials in the market • Lack of foreign and local workers in the market • Coordination problem with subcontractor • Equipment shortage
Space management	• **Management** o Planning and sequencing o Coordination and collaboration o Competency of project manager o Competency of foremen o Safety and work environment o Site layout o Congestion and overmanning o Supervision and inspections • **Project** o Execution method o Project characteristics (size, buildability, complexity) o Defects o Client, project and own finances o Project location • **Labour** o Tidiness o Motivation o Composition of work crew o Number of workers	(Lindhard, 2020): • **Management** o Supervision o Planning and sequencing o Competency of project manager o Poor site layout o Inspections o Information o Coordination and collaboration o Safety and work environment o Congestion and overmanning • **Project** o Contracts and procurement o Construction method o Subcontracting o Rework and delay o Project characteristics o Location o Financial capability • **Labour** o Motivation o Skill and experience o Absenteeism o Labour work facilities and satisfaction o Labour shortage

	o Culture • **Technical** o Misinformation o Unfinished design or specifications o Materials and logistics o Design changes o Equipment and tools o Interference from the client and consultant o Technology and culture • **External** o Weather o Building permit and other permits o Economic stability, including crises and inflation o Construction law and other legal regulations	o Labour fatigue o Crew composition o Personal issues and disputes • **Technical** o Materials o Tools and equipment o Technology and culture o Design changes o Incomplete specification or design o Information o Client and consultants • **External** o Weather o Financial stability o Permits o Legislation
Material management	• **Management** o Planning and sequencing o Competency of project manager o Coordination and collaboration o Competency of foremen o Waste on construction site o Storage facilities o Congestion and overmanning o Supervision and inspections o Poor site layout o Safety and work environment • **Project** o Execution method o Project characteristics (size, buildability, complexity) o Defects o Client, project and own finances o Contracts with suppliers o Project location • **Labour** o Motivation o Skills and experience (Improper handling of materials) o Composition of work crew o Number of workers • **Technical**	(Lindhard, 2020)*:* • **Management** o Supervision o Planning and sequencing o Competency of project manager o Poor site layout o Inspections o Information o Coordination and collaboration o Safety and work environment o Congestion and overmanning • **Project** o Contracts and procurement o Construction method o Subcontracting o Rework and delay o Project characteristics o Location o Financial capability • **Labour** o Motivation o Skill and experience o Absenteeism o Labour work facilities and satisfaction o Labour shortage o Labour fatigue o Crew composition o Personal issues and disputes • **Technical** o Materials o Tools and equipment

	○ Unfinished design or specifications ○ Misinformation ○ Approval of materials by client and consultants ○ Materials and logistic ○ Design changes ○ Equipment and tools ○ Deliveries of defected/wrong materials ○ Technology and culture • **External** ○ Weather ○ Economic stability, including crises and inflation ○ Construction law and other legal regulations ○ Building permit and other permits ○ Lack of security personnel	○ Technology and culture ○ Design changes ○ Incomplete specification or design ○ Information ○ Client and consultants • **External** ○ Weather ○ Financial stability ○ Permits ○ Legislation (Kulkarni, et al., 2017)*:* • Delay due to rejection of materials from quality control team • Transportation problems • Seasonal problems • Labour strikes • Communication problems • Hike in material prices • Lack of material management • Improper material handling (Ayegba, 2013)*:* • Design changes • Lack of proper work planning and scheduling • Inefficient workforce • Fraudulent practices/negligence and corrupt practices • Lack of security personnel • Waste on construction site • Storage facility
All areas/general project success	• **Management** • **Project** • **Labour** • **Technical** • **External**	(Chan, et al., 2004): • Project Management actions • Project-related factors • Human-related factors • Project procedures • External environment

Appendix 3. Factors influencing RM areas

Labour management and productivity

The following literature and factor identification and categorization were researched by Lindhard (2020) and has been provided to the research group for usage in this paper. An overview is shown below:

Reference	Country	Method	Factors included	Participants
(Durdyev, Ismail, & Bakar, 2013)	Turkmenistan	Survey	23	124
(Jang, Kim, Kim, & Kim, 2011)	South Korea	Survey	25	-
(Thomas, Anu V. & Sudhakumar, 2013)	India	Survey	44	185
(Karthik & Kameswara Rao, 2019)	India	Survey	38	120
(Soham, 2013)	India	Survey	27	51
(Rao, 2015)	India	Survey	15	45
(Dixit, 2018)	India	Survey	24	140
(Thomas, A. V., 2014)	India	Survey	44	185
(Muzamil & Khushid, 2014)	Pakistan	Survey	20	164
(Durdyev & Ismail, 2016)	Malaysia	Survey	39	171
(Manoharan, 2017)	Malaysia	Survey	19	170
(Hwang, Zhu, & Ming, 2017)	Singapore	Survey	26	32
(Tam, Huong, & Ngoc, 2018)	Vietnam	Survey	39	185
(Kaming, Olomolaiye, Holt, & Harris, 1997)	Indonesia	Survey	11	243
(Soekiman, Pribadi, Soemardi, & Wirahadikusumah, 2011)	Indonesia	Survey	11	63
(Hanafi, Khalid, Razak, & Abdullah, 2010)	Malaysia	Survey	41	43
(Muhammad et al., 2015)	Malaysia	Survey	15	44
(Pornthepkasemsant & Charoenpornpattana, 2019)	Thailand	Survey	16	128
(Makulsawatudom, Emsley, & Sinthawanarong, 2004)	Thailand	Survey	23	34
(Durdyev & Mbachu, 2018)	Cambodia	Survey	36	73
(Lim & Alum, 1995)	Singapore	Survey	17	67
(Abdul Kadir, Lee, Jaafar, Sapuan, & Ali, 2005)	Malaysia	Survey	50	100
(Zakeri, Olomolaiye, Holt, & Harris, 1996)	Iran	Survey	13	141
(Islam, 2013)	Oman	Survey	25	138

(Mahamid, I., 2013)	Israel	Survey	40	50
(Heravi & Eslamdoost, 2015)	Iran	Interview	15	85
(Ghoddousi, Poorafshar, Chileshe, & Hosseini, 2015)	Iran	Survey	32	60
(Bekr, 2016)	Jordan	Survey	14	150
(Choudhry, 2015)	Saudi Arabia	Survey	31	1454
(Ghoddousi & Hosseini, 2012)	Iran	Survey	31	82
(Jarkas, Al Balushi, & Raveendranath, 2015)	Oman	Survey	33	132
(Hiyassat, Hiyari, & Sweis, 2016)	Jordan	Survey	27	90
(Alaghbari, Al-Sakkaf, & Sultan, 2019)	Yemen	Survey	52	91
(Mahamid, Ibrahim, 2013)	Israel	Survey	31	59
(Jarkas, Radosavljevic, & Wuyi, 2014)	Qatar	Survey	38	247
(Jarkas, Kadri, & Younes, 2012)	Qatar	Survey	35	84
(Jarkas, 2015)	Bahrein	Survey	37	59
(Jarkas & Bitar, 2012)	Kuwait	Survey	45	259
(Enshassi, Mohamed, Mustafa, & Mayer, 2007)	Israel	Survey	45	76

"The factors have been structured into five factor categories: Project Factors, Labor Factors, Management Factors, Technical Factors and External Factors. The factor categories and sub-factors is based on Hwang, Zhu and Ming (Hwang, Zhu & Ming 2017). The sub-factors is created with outset in Zhu and Ming (Hwang, Zhu & Ming 2017), but the number of sub-factors have been adjusted as different factors were reviewed when examining included factors in the different studies" (Lindhard, 2020).

The sub-factors and what they cover is explained below (Lindhard, 2020):

Factor category	Sub factors	Factors include
Project Factors	Contracts and procurement	Procurement method, contract type, contract size and deadline, competition, incentive scheme
	Construction method	Construction method, alternative method
	Subcontracting	Subcontractors, proportion of work subcontracted
	Rework and delay	Rework

	Project characteristics	Size of project, complexity, buildability, design, requirements, type
	Location	Placement of building, ground conditions
	Financial capability	Reputation, Financial weakness, budget, cash flow, timely payments
Labor Factors	Motivation	Attitude, responsibility, team spirit, morale, and discipline
	Skill and experience	Education, training, capability, work experience and errors
	Absenteeism	Regular absenteeism, strikes and labor turnover
	Labor work facilities and satisfaction	Salary, recognition, influence, site facilities and working condition
	Labor shortage	Labor availability
	Labor fatigue	Fatigue, Working overtime, no holiday, 7 days a week, health and age
	Crew composition	Composition and size
	Personal issues and disputes	Religion, personal problem, disputes, and relationships amongst the labors.
Management factors	Supervision	Supervision, Interaction, relationship, recruitment, and competence
	Planning and sequencing	Planning, sequencing, scheduling, division of work, deadlines, and schedule compression
	Competency of project manager	Competence, leadership, management style, empowerment, ethics, and decision making
	Poor site layout	Site layout, storage, and access
	Inspections	Absenteeism and delay
	Information	Availability and quality
	Coordination and collaboration	Instructions, information flow, coordination, communication, language barriers, meetings, and trust
	Safety and work environment	Safety plans, accidents, safety equipment and work environment (noise, dust, light etc.)
	Congestion and overmanning	Site congestions, overmanning, fluctuations in manning, confined space, and interference
Technical factors	Materials	Logistics, availability, and quality

Technical factors	Tools and equipment	Availability, condition, suitability and breakdowns, utilization
	Technology and culture	Application of IT, technological advancements, research, development, and culture
	Design changes	Design changes
	Incomplete specification or design	Frequency, response rate, schedule, and internal coordination,
	Information	Availability, quality, consistency in contract documents
	Client and consultants	Client interference, approvals and disputes, decision making, competence
External factors	Weather	Heat, cold, rain, wind, humidity etc.
	Financial stability	Stability of country, inflation, cost of capital, financial crisis, disruption in supply of heat, water, electricity, political stability.
	Permits	Permits and approvals from government, bureaucracy
	Legislation	Government legislation and inspection

Additionally, other literature was also researched and used for factor analysis:

Labour management and productivity

Factor category	Sub factors	Reference
Management Factors	**Inadequate supervision/ management/ control/ project team**	Buli, 2017; Dai et al., 2009; Foster, et al., 2017; Jarkas & Bitar, 2012; Thomas, et al., 2003;
	Incompetent supervisors	Dai et al., 2009; Foster, et al., 2017;
	Overmanning	Dai et al., 2009; Dozzi & AbouRizk, 1993; Foster, et al., 2017; Thomas, et al., 2003;
	Scheduling issues	Dai et al., 2009; Foster, et al., 2017; Shehata & El-Gohary, 2012;
	Coordination and poor communication	Bernold & AbouRizk, 2010; Dai et al., 2009; Foster, et al., 2017; Shehata & El-Gohary, 2012;
	Safety	Foster, et al., 2017; Dai et al., 2009; Dozzi & AbouRizk, 1993;
	Leadership	Buli, 2017; Dai et al., 2009; Shehata & El-Gohary, 2012;

	Motivation	Buli, 2017; Dai et al., 2009; Shehata & El-Gohary, 2012;
	Labour aveilability	Dai et al., 2009; Dozzi & AbouRizk, 1993; Shehata & El-Gohary, 2012;
	Congestion and overmaning	Dai et al., 2009;
	Site layout	Dozzi & AbouRizk, 1993
	Inspection delays	Jarkas & Bitar, 2012;
Project Factors	**Site conditions: site access, site layout, congestion/ interferences**	Foster, et al., 2017; Dai et al., 2009;
	Project characteristics	Dai et al., 2009; Foster, et al., 2017;
	Rework	Jarkas & Bitar, 2012;
	Workspace	Dozzi & AbouRizk, 1993
Labour Factors	**Labour/worker quantity**	Dai et al., 2009; Dozzi & AbouRizk, 1993; Foster, et al., 2017;
	Quality of craftsmanship	Dai et al., 2009; Dozzi & AbouRizk, 1993; Foster, et al., 2017;
	Absenteeism	Dai et al., 2009; Dozzi & AbouRizk, 1993; Foster, et al., 2017;
	Fatigue and health issues	Dai et al., 2009; Dozzi & AbouRizk, 1993; Foster, et al., 2017;
	Skills and experience	Buli, 2017; Dai et al., 2009; Dozzi & AbouRizk, 1993; Foster, et al., 2017; Shehata & El-Gohary, 2012;
	Motivation	Dai et al., 2009; Dozzi & AbouRizk, 1993; Foster, et al., 2017; Shehata & El-Gohary, 2012;
	Non-productive activities	Dai et al., 2009; Dozzi & AbouRizk, 1993; Foster, et al., 2017;
	Physical limitations	Dozzi & AbouRizk, 1993;
	Crew composition	Dai et al., 2009; Dozzi & AbouRizk, 1993;
Technical Factors Technical Factors	**Uncoordinated, incomplete, and illegible drawings**	Dai et al., 2009; Foster, et al., 2017;
	Complex designs of unusual shapes and heights	Dai et al., 2009; Foster, et al., 2017;
	Rework and design changes	Dai et al., 2009; Foster, et al., 2017;

	Unavailability of suitable equipment, lack of tools	Dai et al., 2009; Foster, et al., 2017; Thomas, et al., 2003;
	Materials	Dai et al., 2009; Foster, et al., 2017;
External Factors	**Environmental conditions**	Dai et al., 2009; Dozzi & AbouRizk, 1993; Foster, et al., 2017; Shehata & El-Gohary, 2012; Thomas, et al., 2003;
	Project location	Dai et al., 2009; Foster, et al., 2017;
	Economic activity	Dai et al., 2009; Foster, et al., 2017;
	Availability of skilled labour and job availability	Dai et al., 2009; Foster, et al., 2017;
	Work permits	Dai et al., 2009;

Space management

Factor category	Sub-factors and reference	Reference
Management Factors	**Management factors**	Igwe, et al., 2020; Opsahl, et al., 2015;
	Planning and sequencing	Choi, et al., 2014; Wang, et al., 2004;
	Coordination and collaboration	Guevara & Boyer, 1981; Kwofie, et al., 2020; Opsahl, et al., 2015;
	Competency of project manager and foreman	Dzwigol, et al., 2020; Skjelbred, et al., 2015;
	Supervision	Skjelbred, et al., 2015;
Project Factors	**Project factors**	Dallasega, et al., 2013;
	Execution method	Koskela & Howell, 2011;
	Project characteristics	Cho, et al., 2009; Gidado, 1996; Wood & Gidado, 2008;
	Defects	Ahzahar, et al., 2011; Ali & Wen, 2011;
Labour Factors Labour Factors	**Labour factors**	Alaghbari, et al., 2017; Ghate, et al., 2016; Kadir, et al., 2005;
	Tidiness	Bajjou, et al., 2017; Cheng, et al., 2017; Choi, et al., 2014; Shazwan, et al., 2017;
	Motivation	Yeheyis, et al., 2016; Zuo, et al., 2018;

	Composition of work crew	Alaghbari, et al., 2017; Mathieu, et al., 2016; Oke, et al., 2016;
Technical Factors	**Misinformation**	Igwe, et al., 2020; Michaelian, 2013; Southwell, et al., 2019;
	Unfinished designs and specifications	Choi, et al., 2014; Skjelbred, et al., 2015;
	Materials and logistics	Kulkarni, et al., 2017; Nagapan, et al., 2012; Okorocha, 2013;
	Technology and culture	Minh, et al., 2017; Videbæk, 2018;
External Factors	**External factors**	Biswas & Zaman, 2019l Chan, et al., 2004;
	Weather	BAR Bygge & Anlæg, 2016; Josevski, 2019; Odeyinka, et al., 2008; Pan, 2005;
	Building permit and other permits	BAR Bygge & Anlæg, 2016; Chognard, et al., 2018; Frandsen, et al., 2012;
	Economic stability and construction law	BAR Bygge & Anlæg, 2016; Bivens, 2010;

Material management

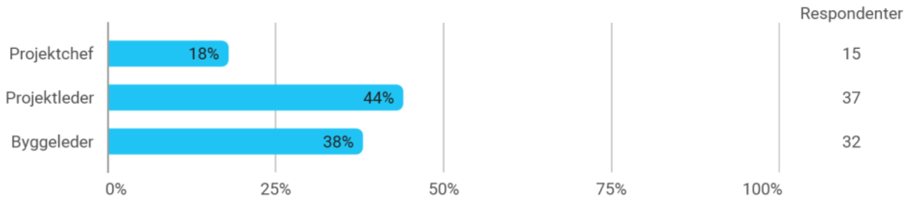
Factor category	Sub factors	Reference
Management Factors	**Competency of foreman**	Dzwigol, et al., 2020
	Poor site layout	Patel, et al., 2015; Vipin & Shabeen, 2019;
	Competency of project manager	Ayegba, 2013; Dzwigol, et al., 2020; Patel, et al., 2015; Vipin & Shabeen, 2019;
	Coordination and collaboration	Kulkarni, et al., 2017; Patel, et al., 2015; Vipin & Shabeen, 2019;
	Safety and work environment	Patel, et al., 2015;
	Waste on construction site	Ayegba, 2013; Patel, et al., 2015; Vipin & Shabeen, 2019;
	Storage facilities	Ayegba, 2013; Kulkarni, et al., 2017; Patel, et al., 2015; Vipin & Shabeen, 2019;
	Transportation method/ delays	Ayegba, 2013; Kulkarni, et al., 2017; Patel, et al., 2015;

	Inadequate supervision	Ayegba, 2013; Patel, et al., 2015;
Project Factors	**Execution method**	Koskela & Howell, 2001;
	Project characteristics (size, buildability, complexity)	Patel, et all., 2015;
	Defects	Vipin & Shabeen, 2019; Patel, et al., 2015;
	Client, project and own finances	Patel, et al., 2015;
	Contracts with suppliers	Patel, et al., 2015;
Labour factors	**Motivation**	Kulkarni, et al., 2017
	Skills and experience (Improper handling of materials)	Ayegba, 2013; Kulkarni, et al., 2017; Patel, et al., 2015; Vipin & Shabeen, 2019;
	Composition of work crew	Vipin & Shabeen, 2019;
	Number of workers	Ayegba, 2013;
Technical factors	**Unfinished design or specifications**	Ayegba, 2013; Kasim, et al., 2005; Kulkarni, et al., 2017; Varneskov, 2017; Vipin & Shabeen, 2019; Patel, et al., 2015;
	Misinformation	Awang & Fared, 2019; Chenvidyakarn, 2007; Kulkarni, et al., 2017; Vipin & Shabeen, 2019; Patel, et al., 2015; Yang, et al., 2018;
	Approval of materials by client and consultants	Johnson & Babu, 2020; Kumar, 2019; Umar, 2018;
	Materials and logistic	Ayegba, 2013; Azarova, 2015; Kulkarni, et al., 2017; Lanko, et al., 2017; Sundquist, et al., 2017; Vipin & Shabeen,2019
	Design changes	Ayegba, 2013; Patel, et al., 2015;
	Equipment and tools	Patel, et al., 2015; Pethaperumal & Sivakumar, 2017;
	Deliveries of defected/wrong materials	Ali & Wen, 2011; Kulkarni, et al., 2017; Vipin & Shabeen, 2019;
	Technology and culture	Minh, et al., 2017; Patel, et al., 2015; Vipin & Shabeen, 2019;
External factors	**Weather**	Apipattanavis, et al., 2010; Ayegba, 2013; Jung, et al., 2016; Kulkarni, et al., 2017; Patel, et all., 2015; 2016’ Vipin and Shabeen, 2019;
	Economic stability, including crises and inflation	Edwards, et al., 2010; Kulkarni, et al., 2017; Vipin and Shabeen, 2019;

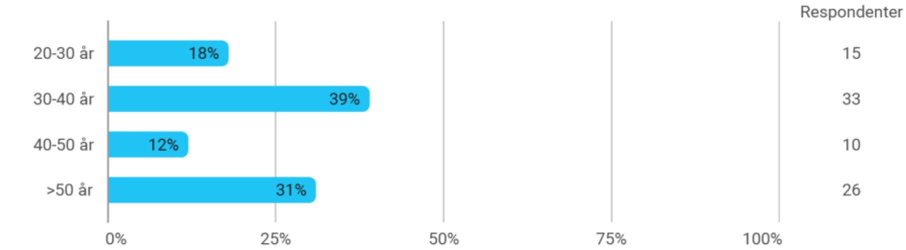
	Construction law and other legal regulations	BAR Bygge & Anlæg, 2016; Bygningsreglamentet, 2017; Miljø- og Fødevareministeriet, 2015;
	Building permit and other permits	Miljø- og Energiforvaltningen, 2019; Miljøstyrelsen, 2000; Zhang & Wang, 2017;
	Lack of security personnel	Ayegba, 2013; Patel, et al., 2015; Vipin and Shabeen, 2019; Walker, 2008;

Appendix 4. Survey answers and results

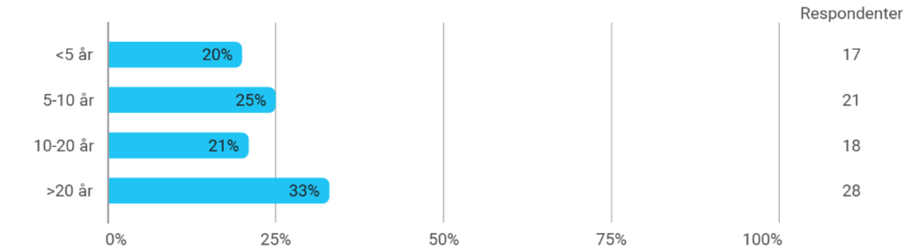
1. Hvad er din nuværende stilling?



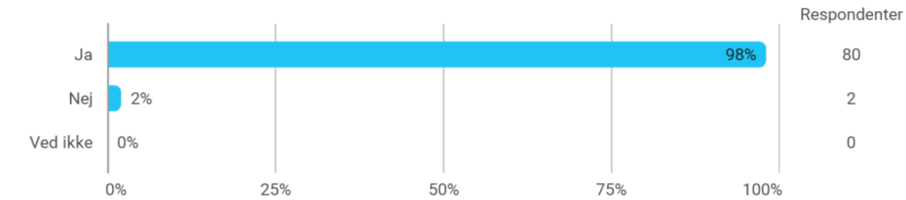
2. Hvilken aldersgruppe hører du til?



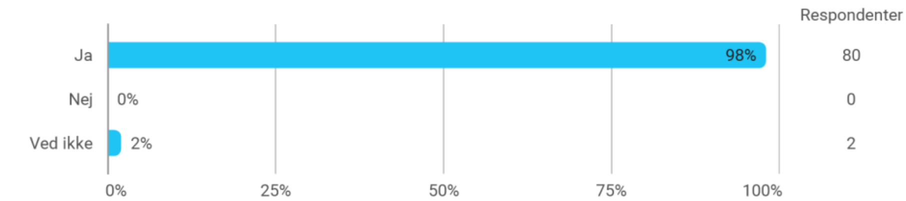
3. Hvor meget erfaring har du på byggepladser?



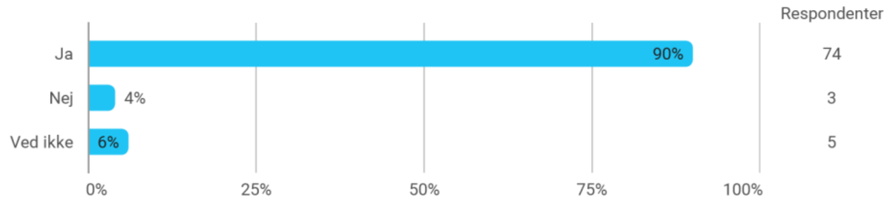
4. Er du opmærksom på ressourcespild i form af tid, omkostninger, arbejdskraft, mv på byggepladser?



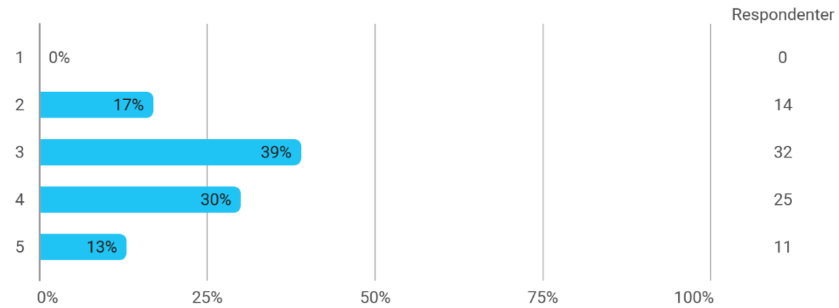
5. Tror du, det vil være nyttigt for både virksomheder og projekter at blive opmærksom på forskellige årsager til disse typer ressourcespild og handle for at minimere det?



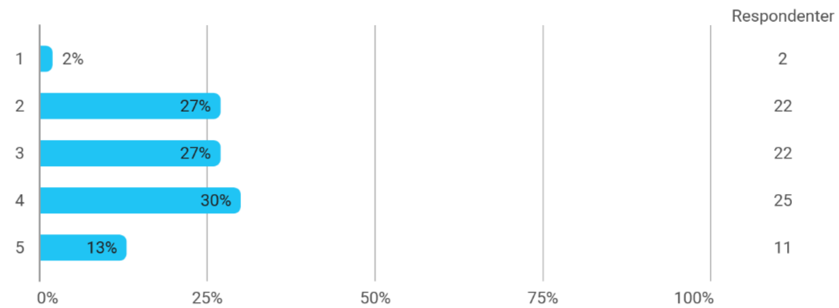
6. Er du opmærksom på den effekt, som ressourcespild har på tid og budget?



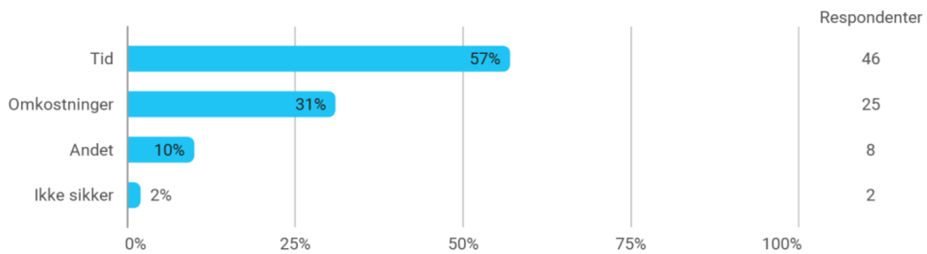
7. Hvor stor tror du den effekt, som ressourcespild har på budgettet af byggeprojekter, er? (1 svarer til ingen effekt, 5 - meget stor)



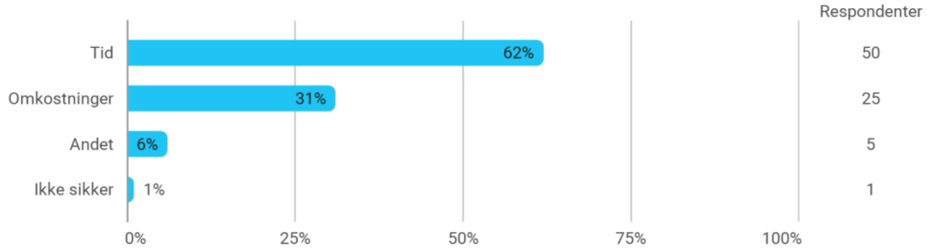
8. Hvor stor tror du den effekt, som ressourcespild har på tid af byggeprojekter, er? (1 svarer til ingen effekt, 5 - meget stor)



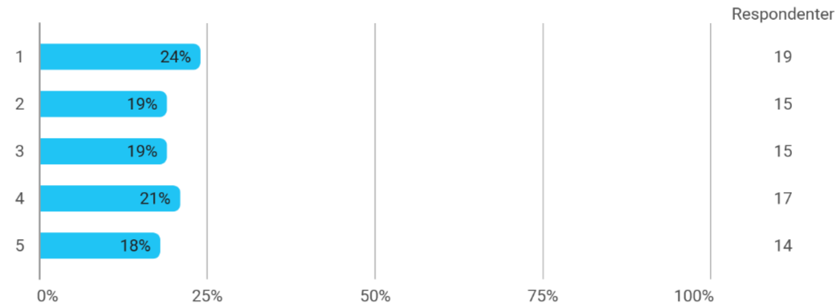
9. Hvilken type ressourcespild, tror du, har den største effekt på byggeprojekter?



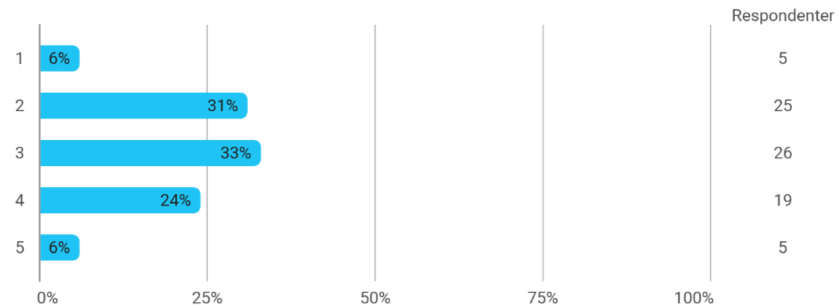
10. Hvilken type ressourcespild, tror du, er den mest almindelig på byggeprojekter?



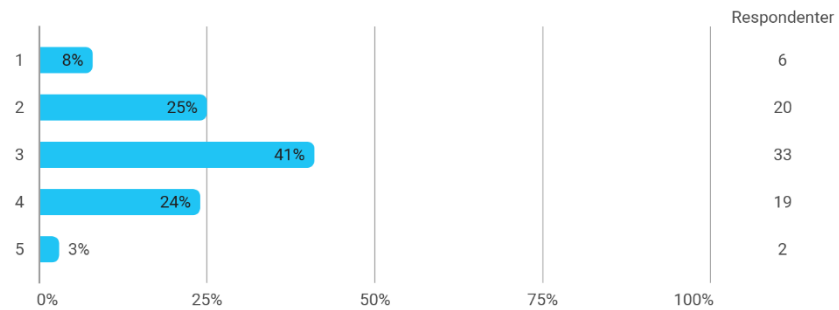
11. Hvilken faktor har mest indflydelse på ressourcespild på byggepladser? ***Fejler på grund af planlægning og design*** (1 svarer til mest indflydelse, 5 – mindst)



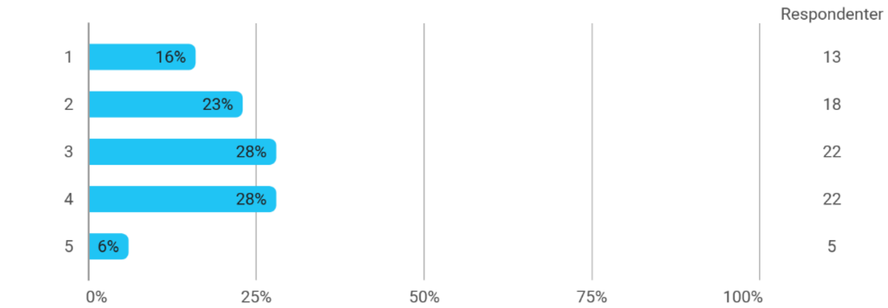
11. Hvilken faktor har mest indflydelse på ressourcespild på byggepladser? ***Organisation og ledelse*** (1 svarer til mest indflydelse, 5 – mindst)



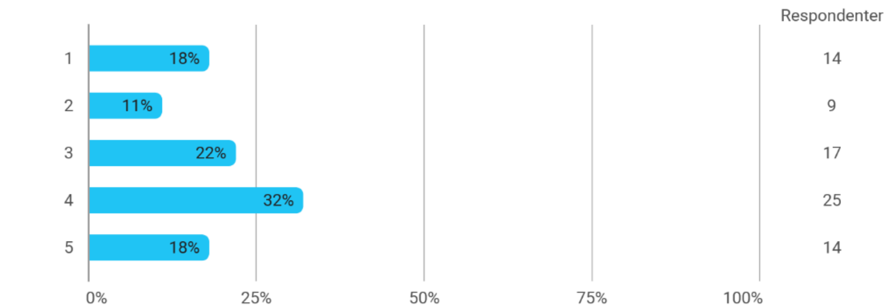
11. Hvilken faktor har mest indflydelse på ressourcespild på byggepladser? ***Viden af arbejdere og ledere*** (1 svarer til mest indflydelse, 5 – mindst)



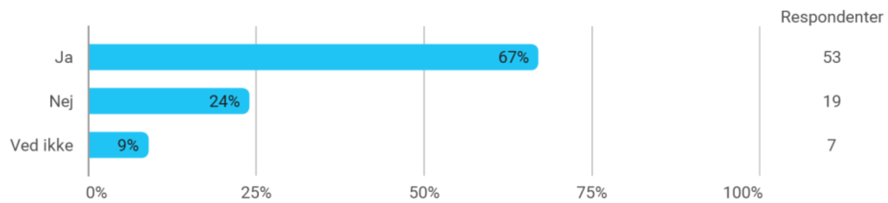
11. Hvilken faktor har mest indflydelse på ressourcespild på byggepladser? ***Dårlig kommunikation mellem medarbejdere*** (1 svarer til mest indflydelse, 5 – mindst)



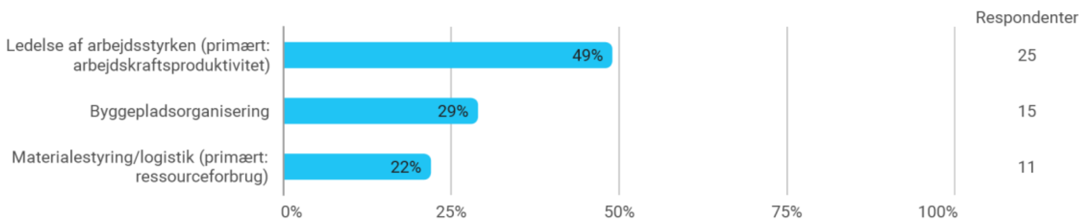
12. Hvor vigtigt er ressourcehåndtering for at reducere ressourcespild på byggepladser?



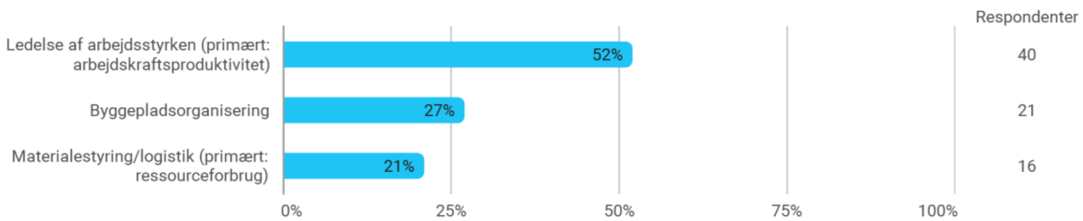
13. Bruger du ressourcehåndtering i dine projekter?



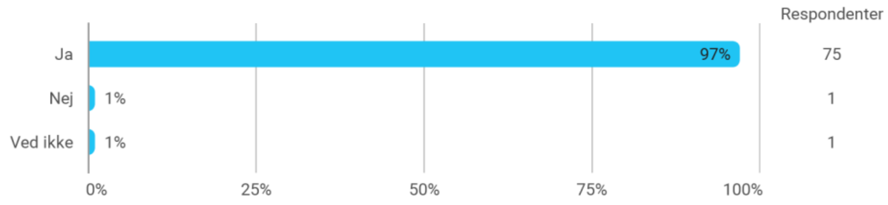
14. Hvilken type af ressourcehåndtering bruger du?



15. Hvilken type af ressourcehåndtering, tror du, er den vigtigste og har størst effekt på projekter?



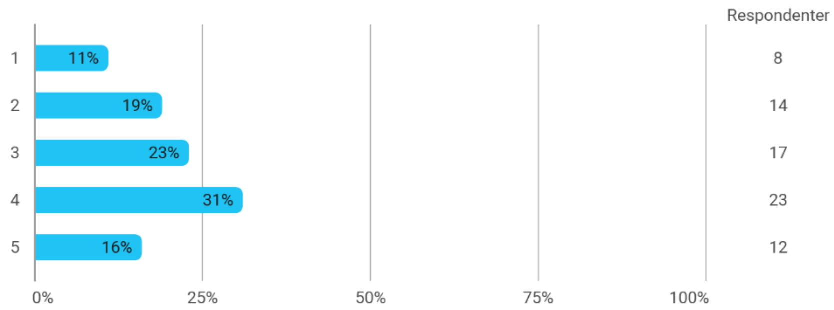
16. Tror du, at en forbedring af de tre felter inden for ressourcehåndtering under byggeprojekter vil hjælpe med at reducere ressourcespild?



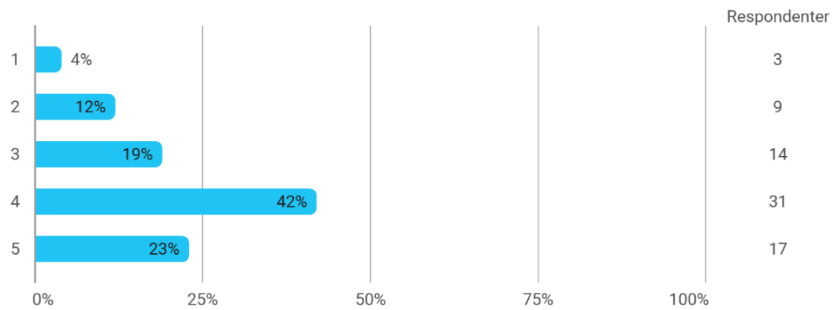
17. Bedøm vigtigheden af forskellige faktorer for ***ledelse af arbejdsstyrken*** som påvirker produktivitet af projekter fra 1 (mindst vigtig) til 5 (vigtigst).

Projektfaktorer

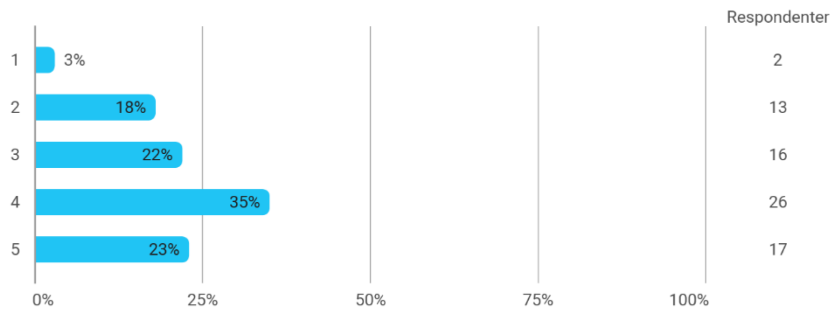
Udbudsform samt kontrakttype:



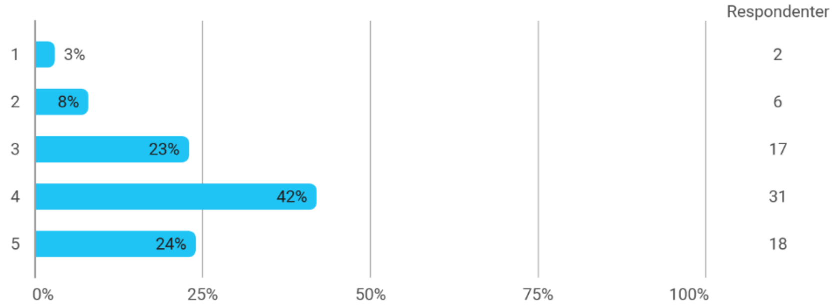
Den anvendte udførelsesmetode:



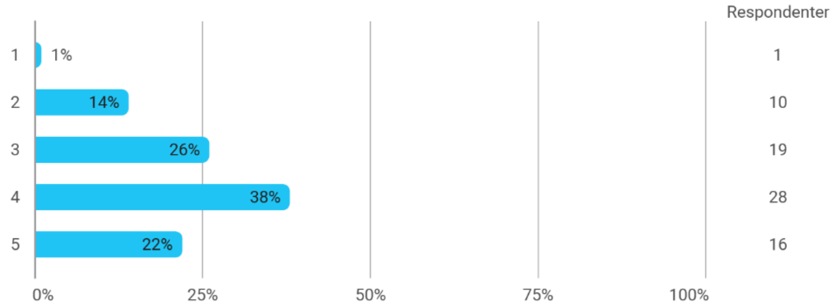
Underentreprenører:



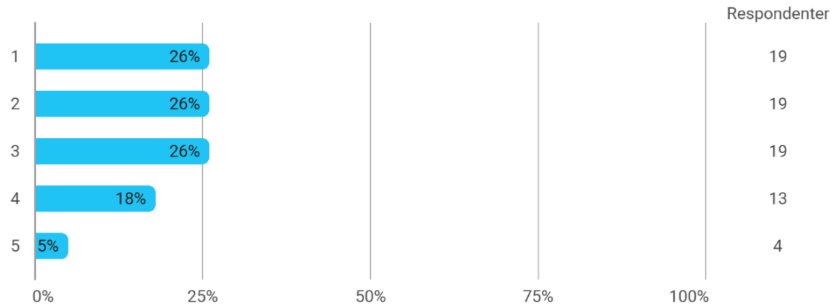
Fejl og mangler:



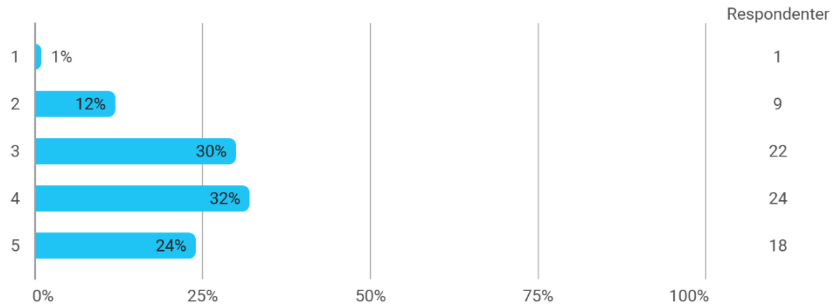
Projektkarakteristika (størrelse, bygbarhed, kompleksitet):



Projektets placering:

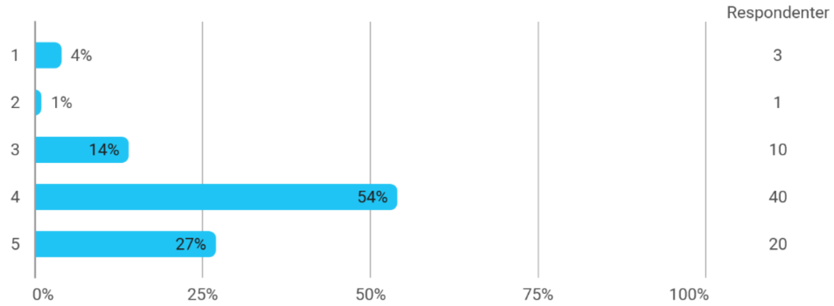


Bygherres, projektets og egen økonomi:

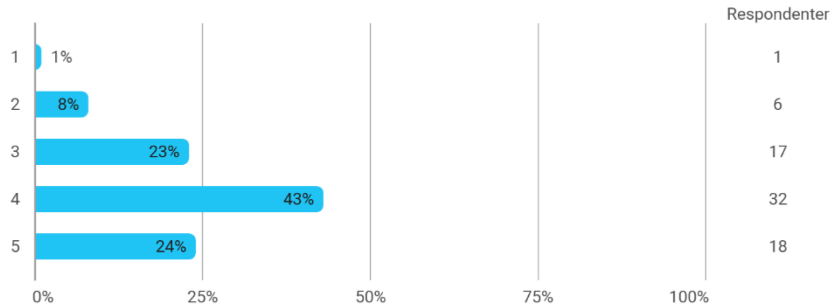


Arbejdsfaktorer

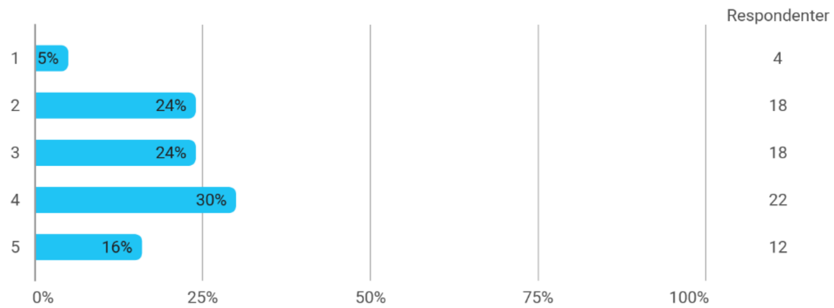
Motivation:



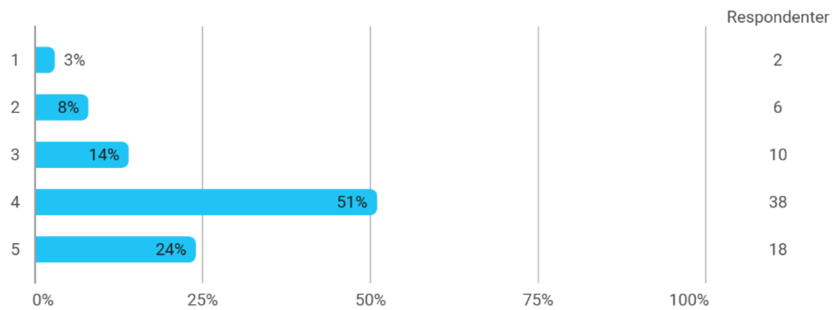
Færdighed og erfaring:



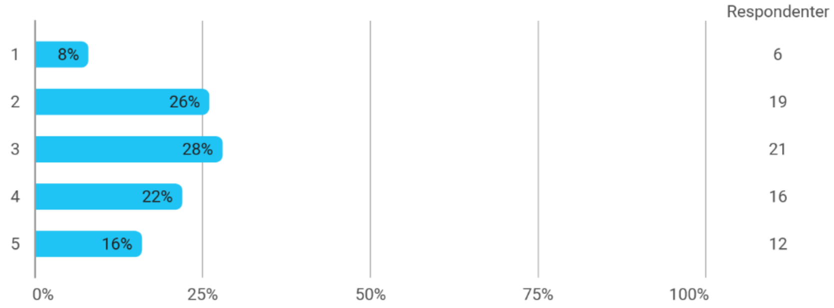
Fravær:



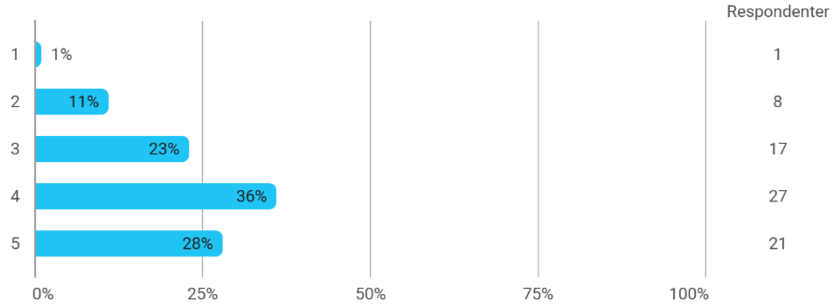
Arbejdsforhold og medarbejdertilfredshed:



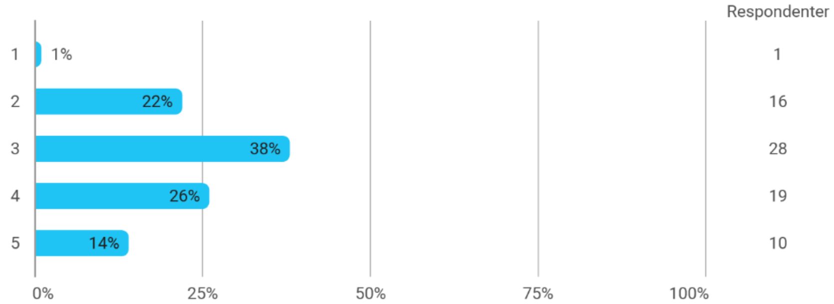
Udmattelse:



Sammensætning af arbejdssjak:

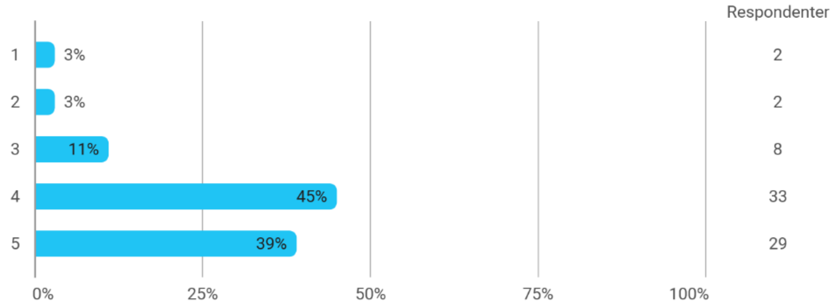


Personlige problemer og uenigheder:

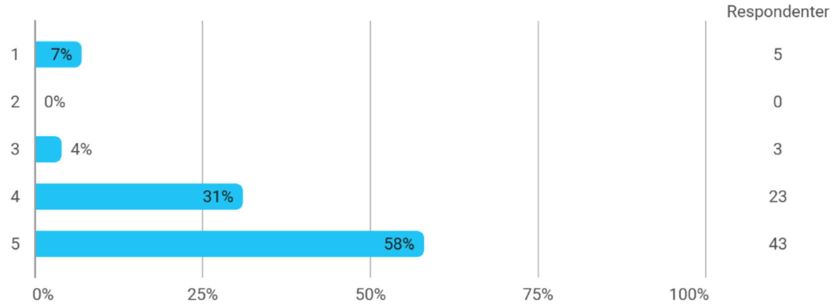


Ledelsesfaktorer

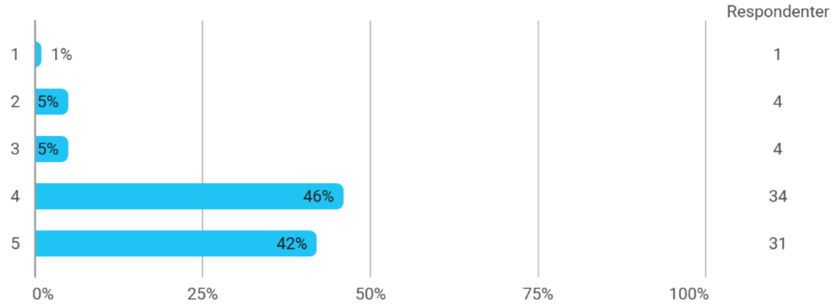
Formandens kompetence:



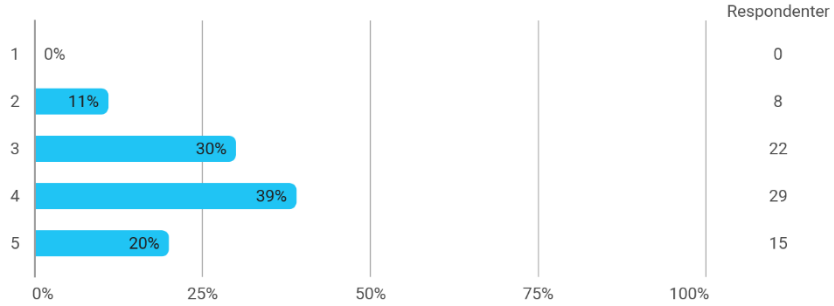
Planlægning og tidsplaner:



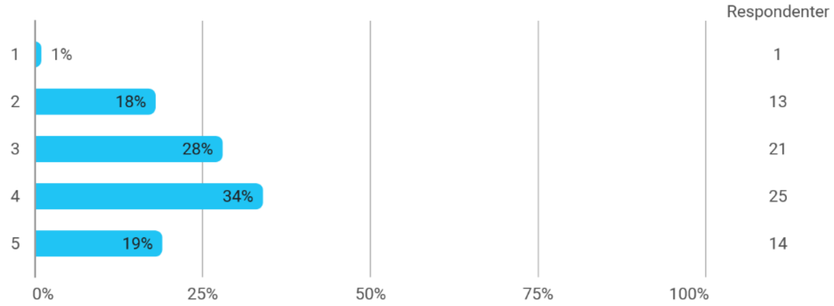
Projektlederens kompetence:



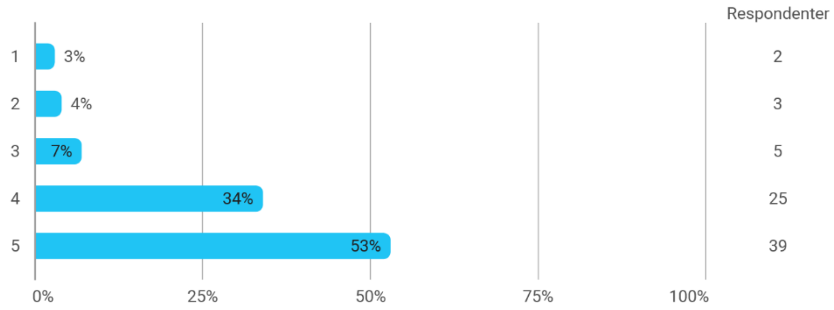
Byggepladsens layout:



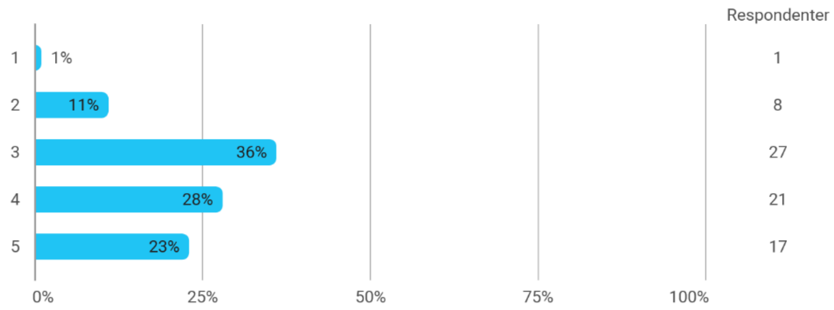
Tilsyn og kontrol:



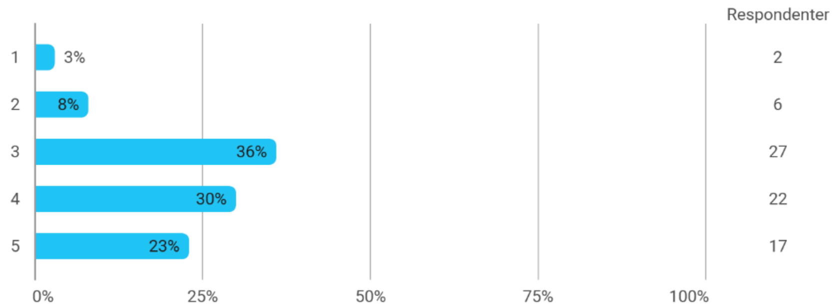
Koordinering og samarbejde:



Sikkerhed og arbejdsmiljø:

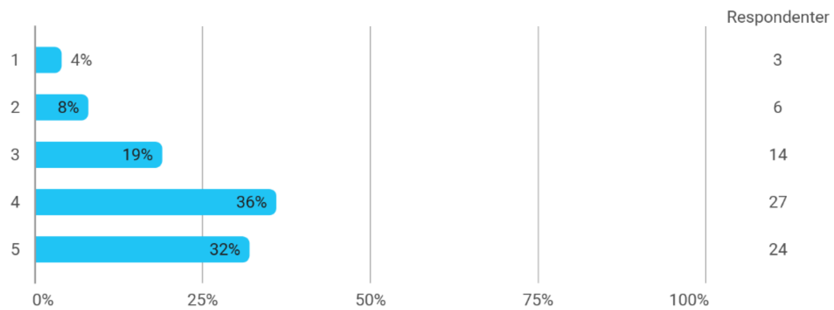


Overbemanding og manglende plads:

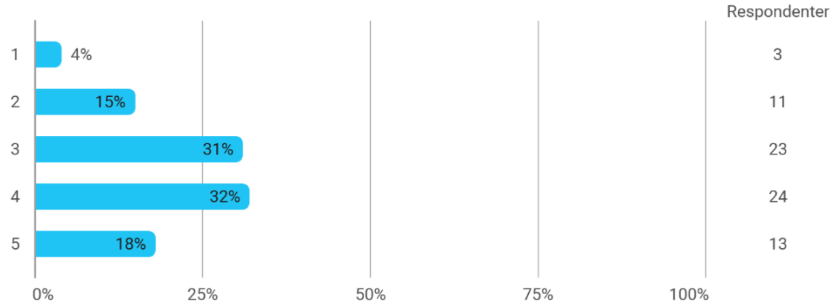


Tekniske faktorer

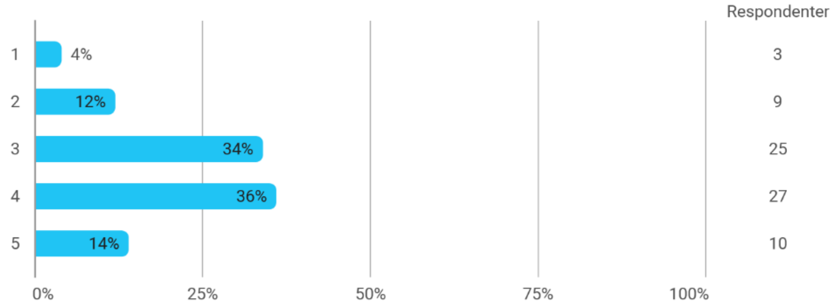
Materialer og logistik:



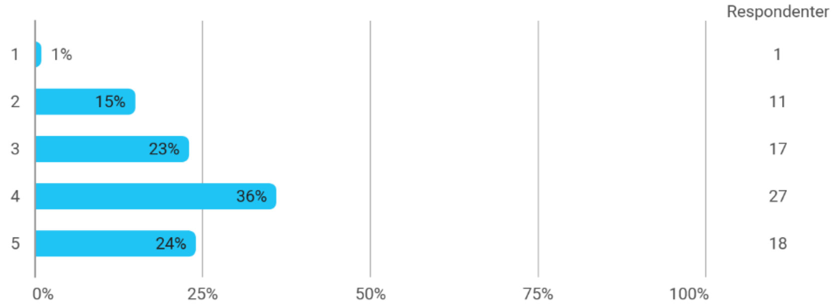
Materiel og værktøj:



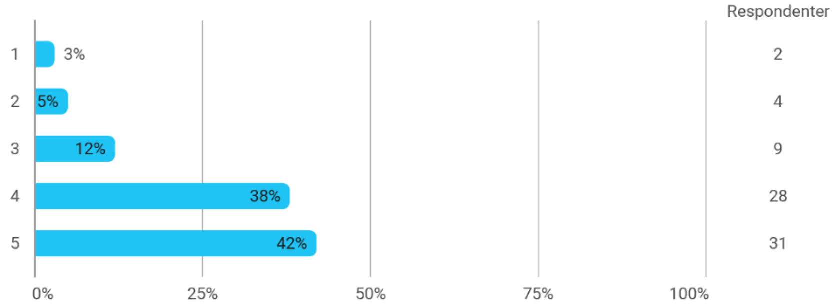
Teknologi og kultur:



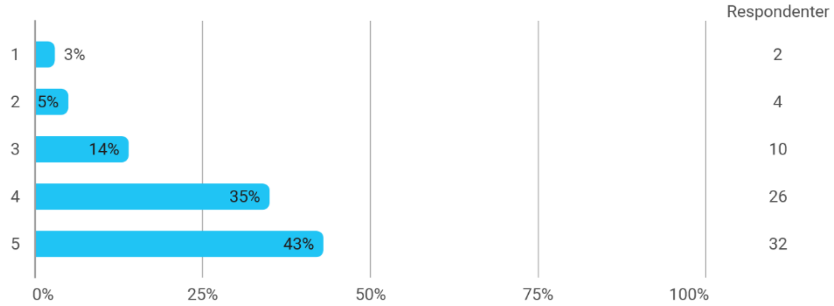
Designændringer:



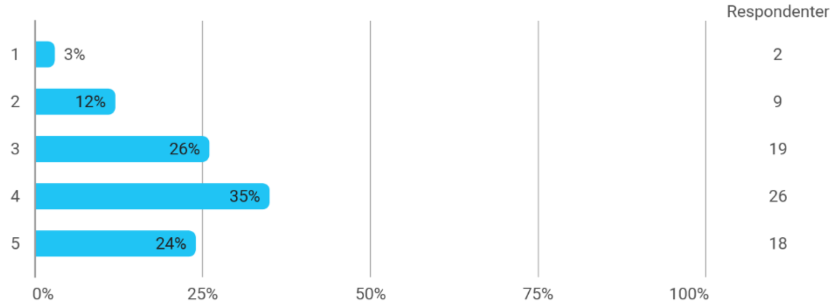
Ufærdigt design eller specifikationer:



Formidling af information:

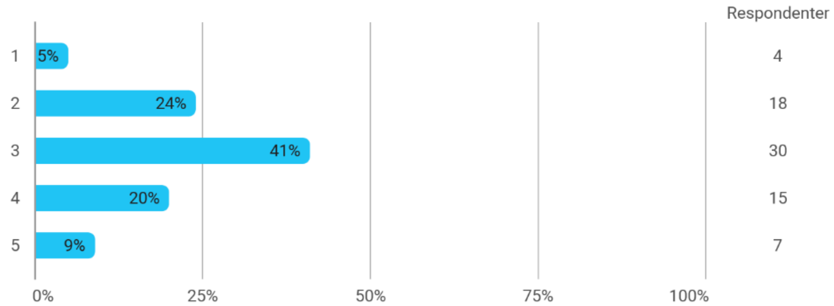


Indblanding fra bygherre og rådgiver:

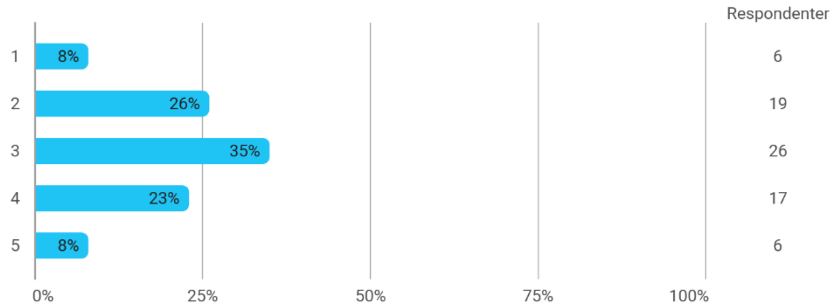


Eksterne faktorer

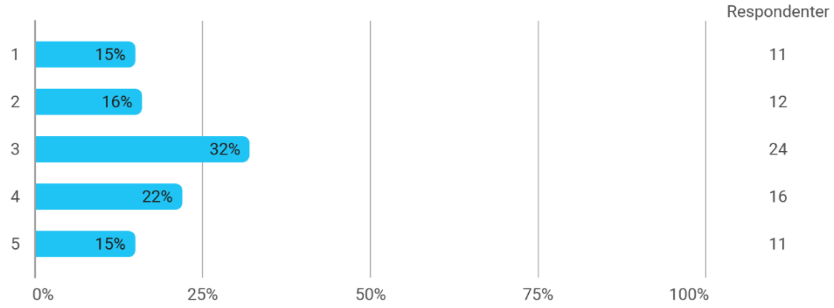
Vejr og vejrlig:



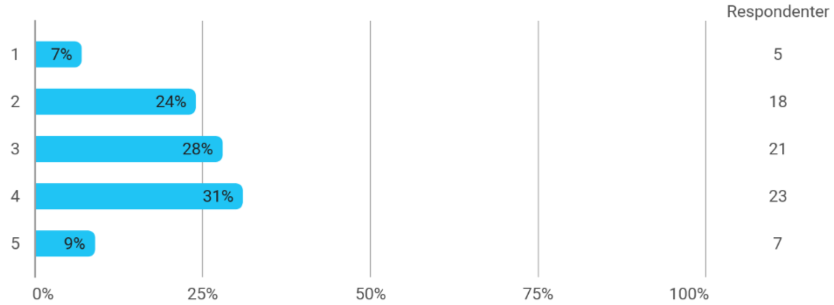
Økonomisk stabilitet, herunder kriser samt inflation:



Byggetilladelse og andre tilladelse:



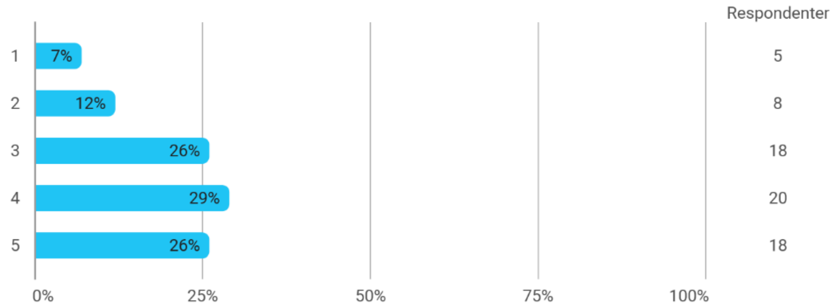
Byggejura og andre lovmæssige reguleringer:



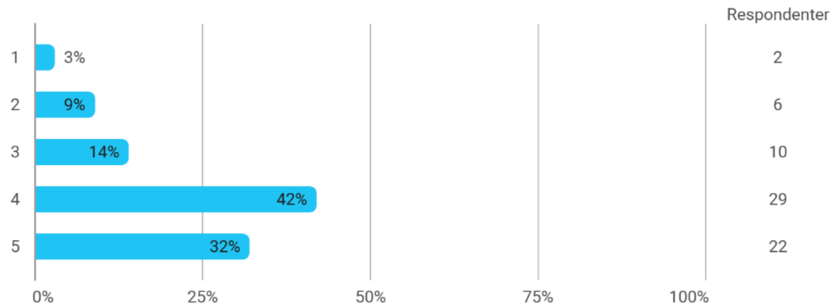
18. Bedøm vigtigheden af forskellige faktorer for ***materialestyring*** som påvirker ressourceforbruget af projekter fra 1 (mindst vigtig) til 5 (vigtigst).

Projektfaktorer

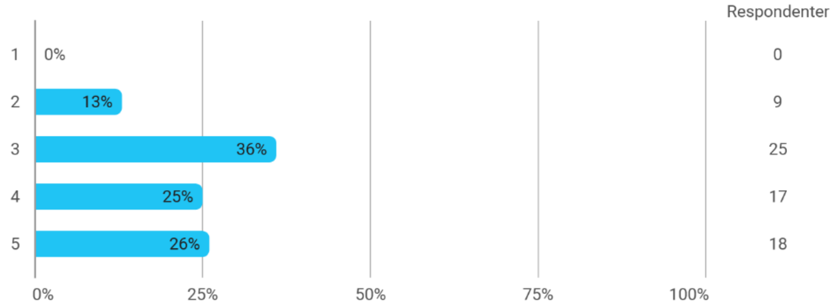
Kontrakter med leverandører:



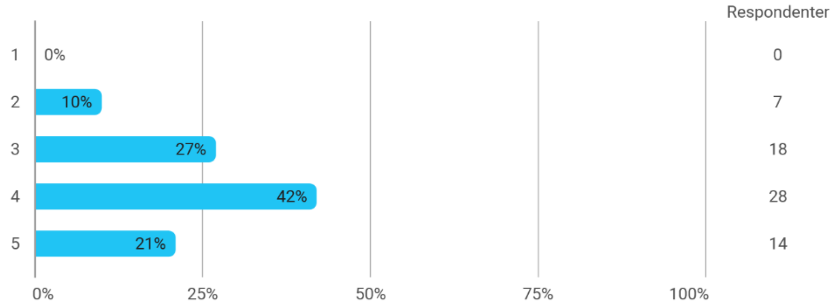
Den anvendte udførelsesmetode:



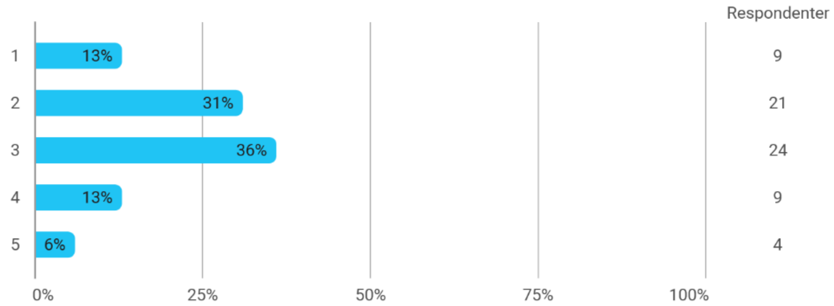
Fejl og mangler:



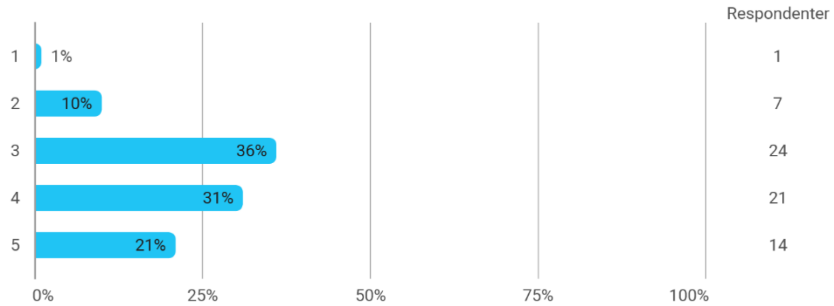
Projektkarakteristika (størrelse, bygbarhed, kompleksitet):



Projektets placering:

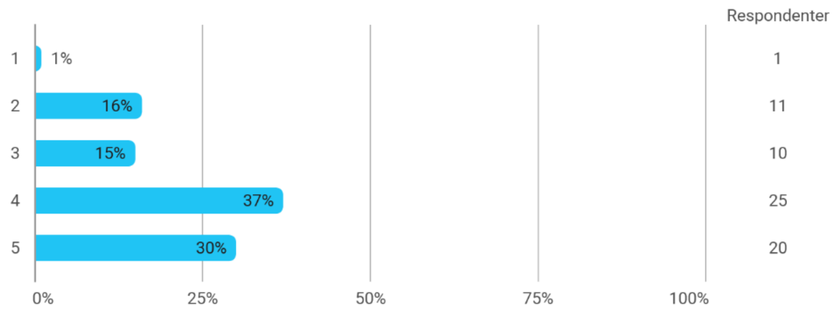


Bygherres, projektets og egen økonomi:

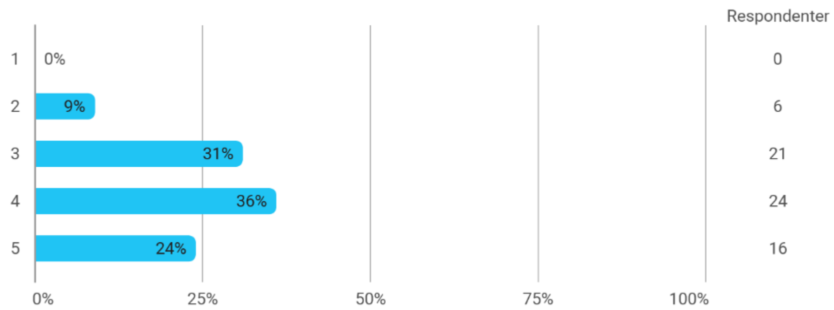


Arbejdsfaktorer

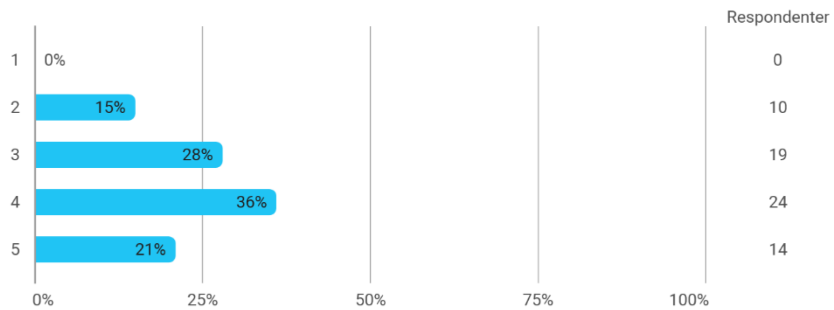
Motivation:



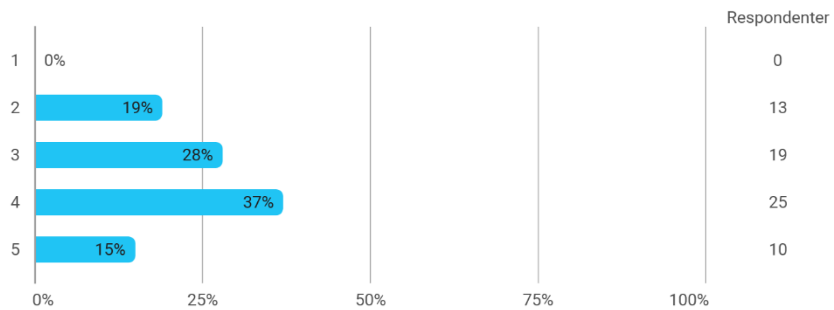
Færdighed og erfaring (forkert håndtering af materialer):



Sammensætning af arbejdssjak:

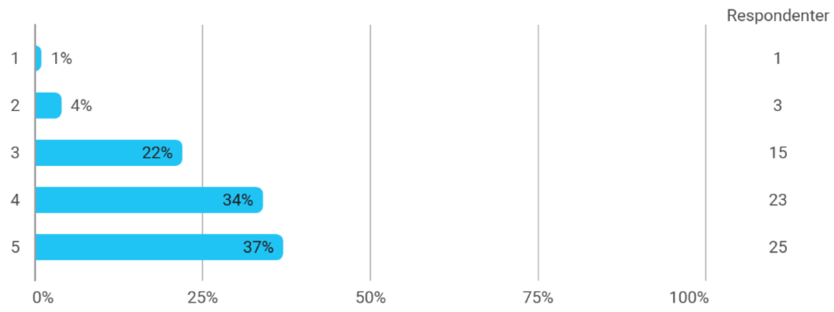


Antal arbejdere:

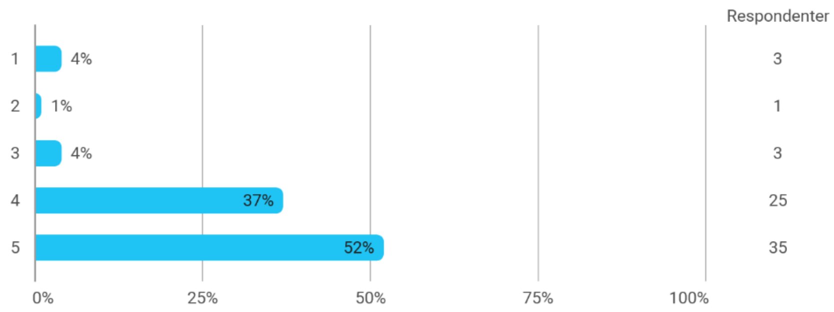


Ledelsesfaktorer

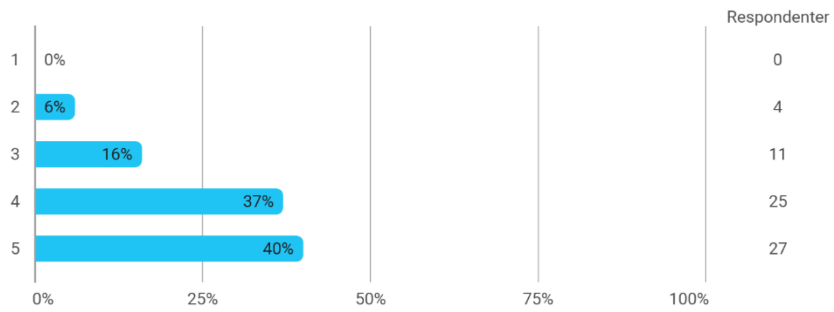
Formandens kompetence:



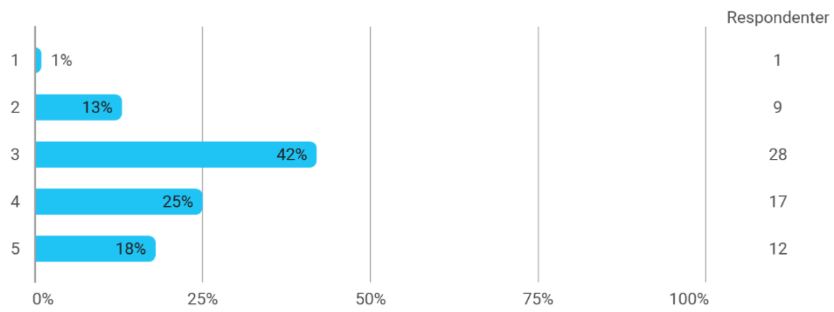
Planlægning og tidsplaner:



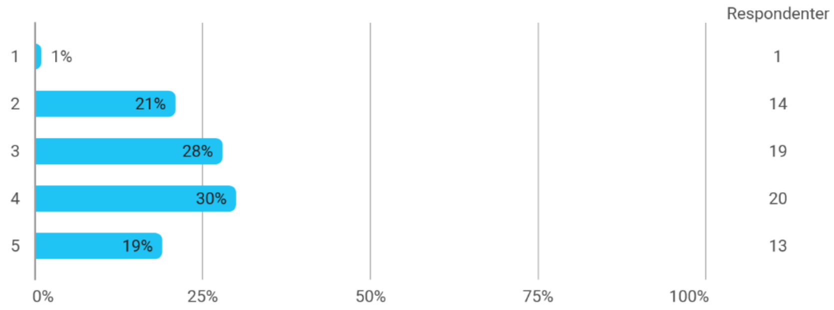
Projektlederens kompetence:



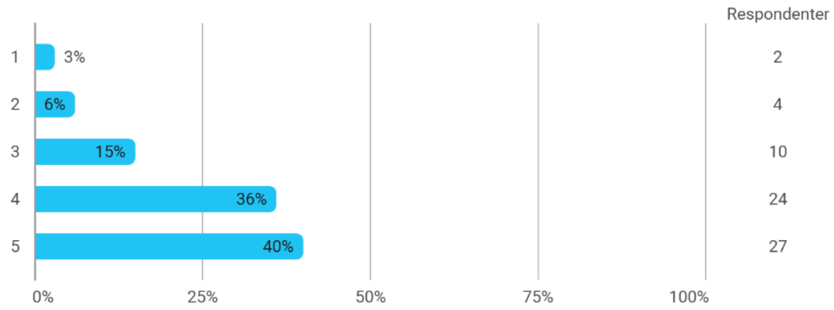
Byggepladsens layout:



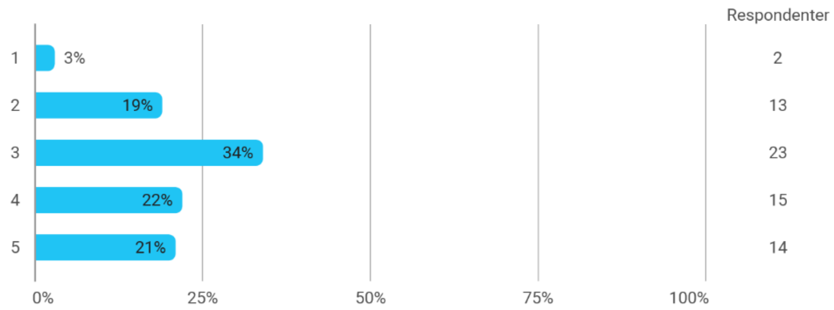
Tilsyn og kontrol:



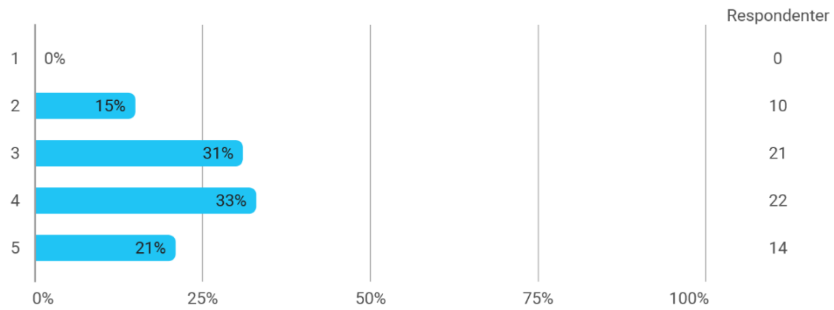
Koordinering og samarbejde:



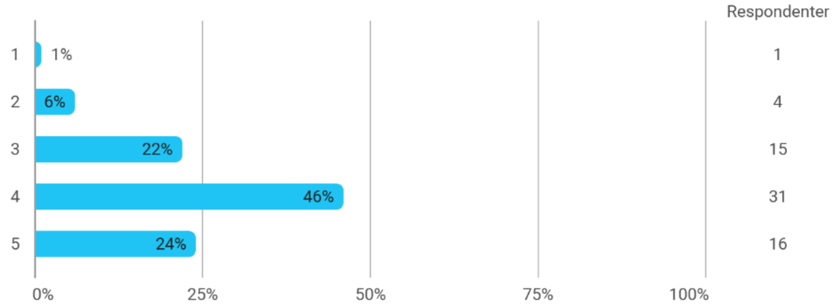
Sikkerhed og arbejdsmiljø:



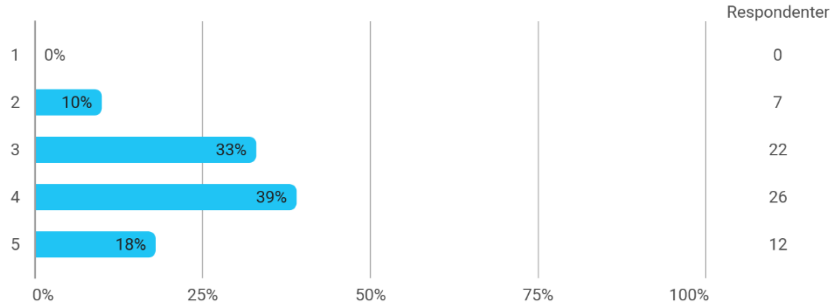
Overbemanding og manglende plads:



Affald på byggepladsen:

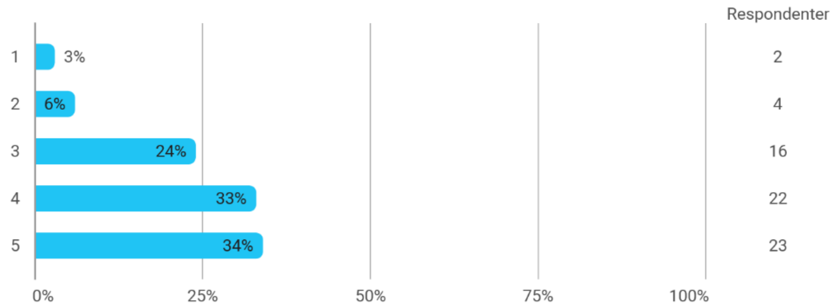


Opbevaringsfacilitet:

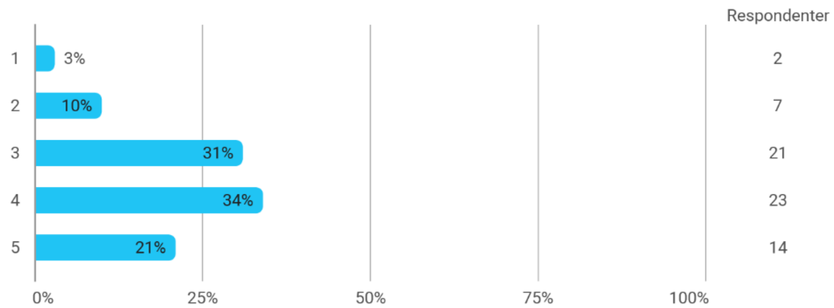


Tekniske faktorer

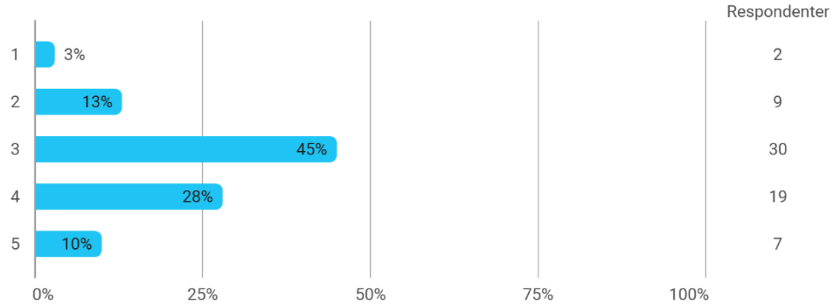
Materialer og logistic:



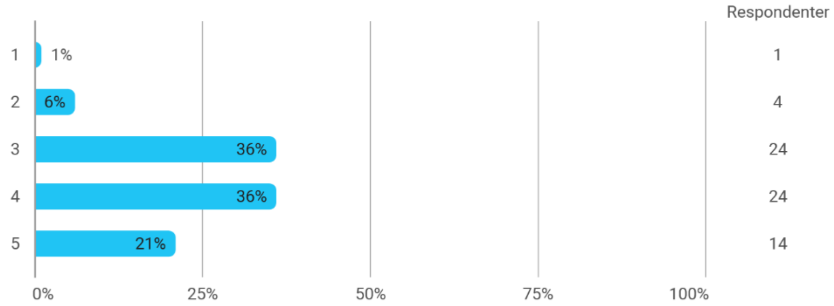
Materiel og værktøj:



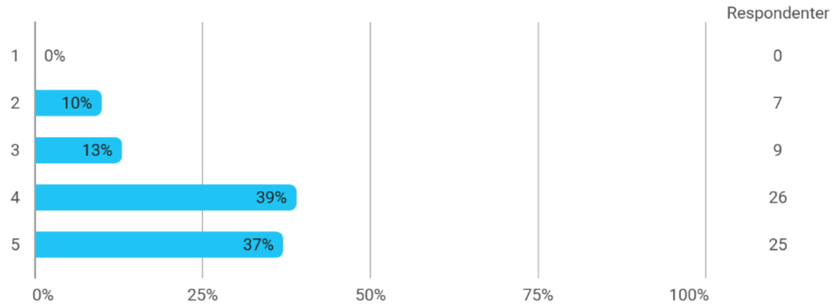
Teknologi og kultur:



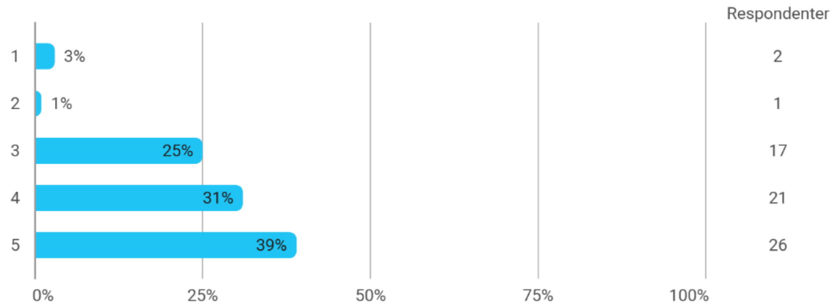
Designændringer:



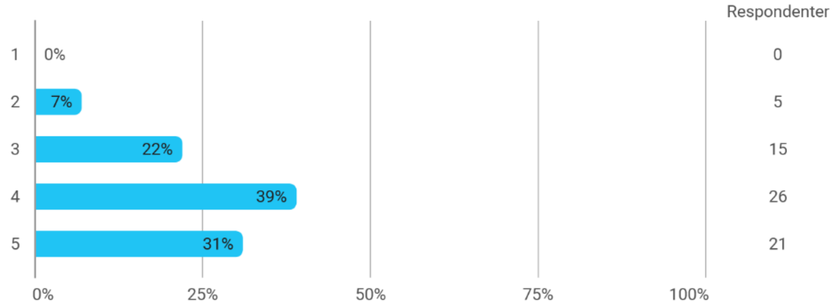
Ufærdigt design eller specifikationer:



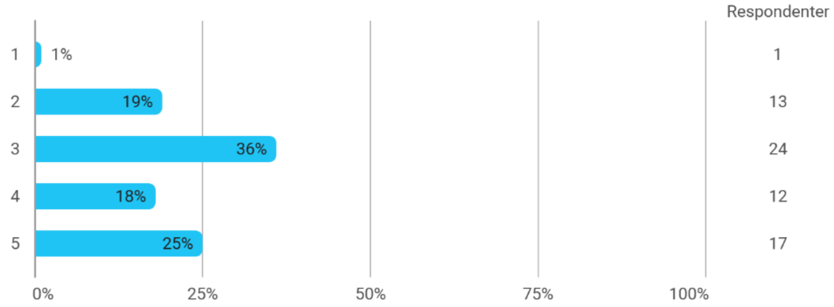
Formidling af information:



Godkendelse af materialer af bygherre og rådgiver:

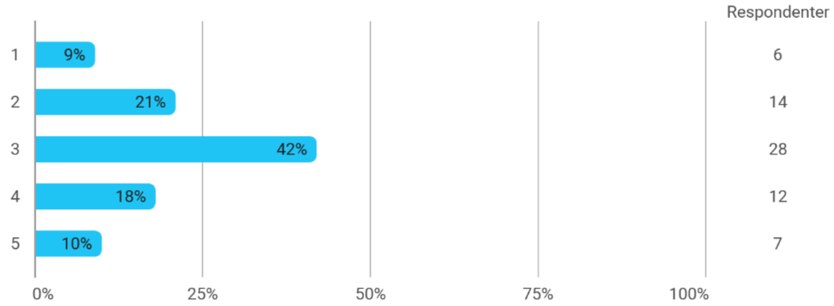


Levering af defekte/forkerte materialer:

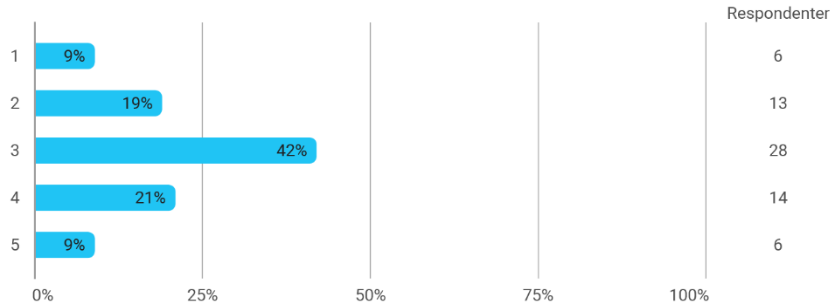


Eksterne faktorer

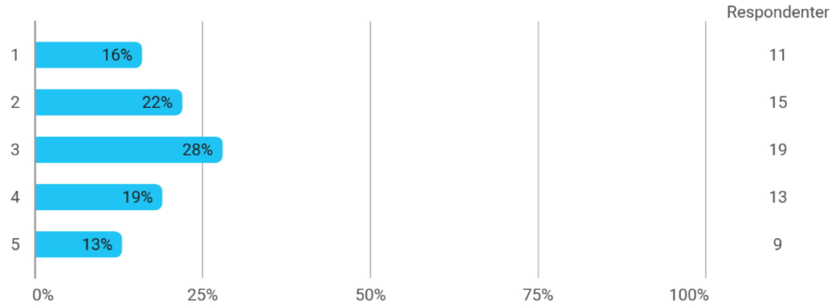
Vejr og vejrlig:



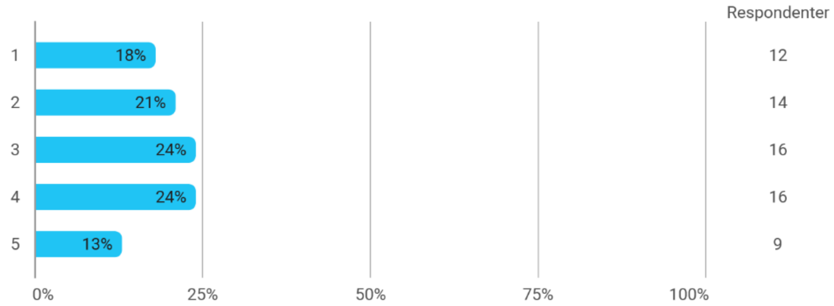
Økonomisk stabilitet, herunder kriser samt inflation:



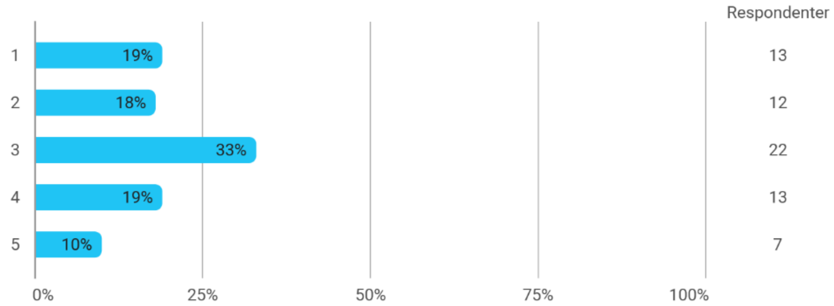
Byggetilladelse og andre tilladelse:



Byggejura og andre lovmæssige reguleringer:



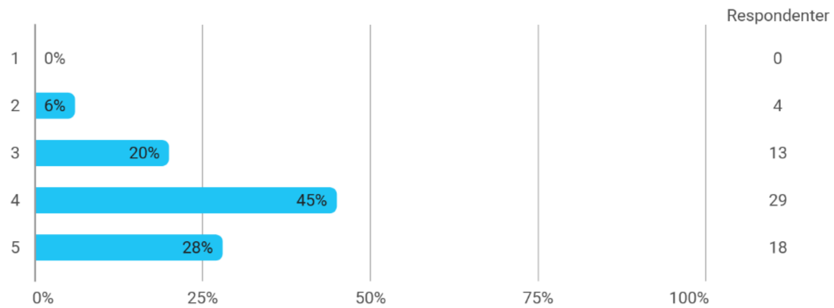
Mangel på sikkerhedspersonale:



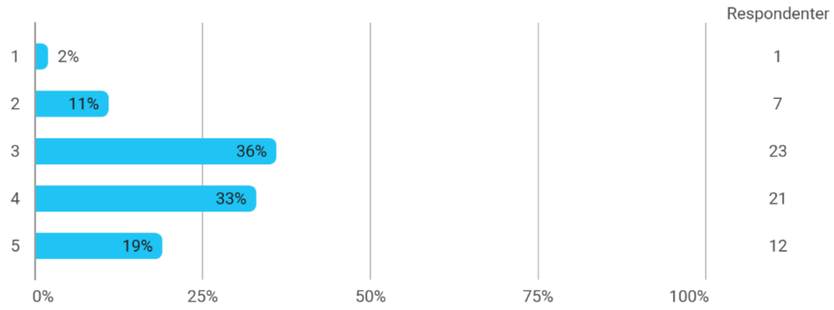
19. Bedøm vigtigheden af forskellige faktorer for ***byggepladsorganisering*** som påvirker både arbejdskraftproduktiviteten samt ressourceforbruget af projekter fra 1 (mindst vigtig) til 5 (vigtigst).

Projektfaktorer

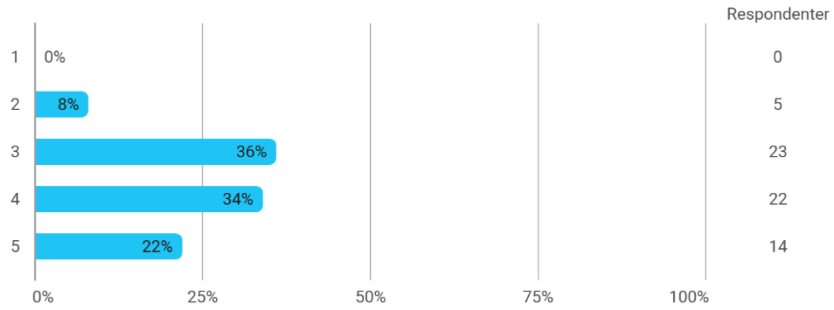
Den anvendte udførelsesmetode:



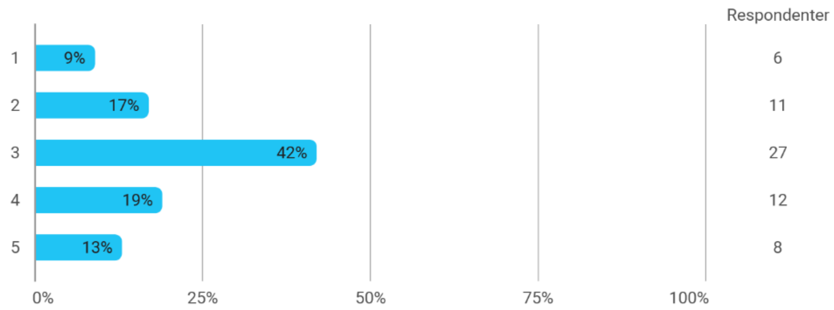
Fejl og mangler:



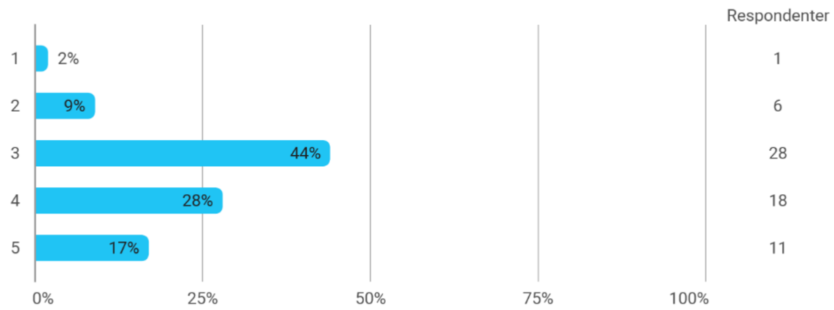
Projektkarakteristika (størrelse, bygbarhed, kompleksitet):



Projektets placering:

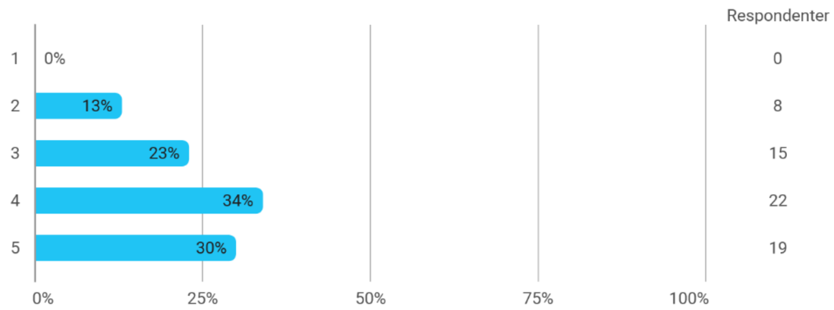


Bygherres, projektets og egen økonomi:

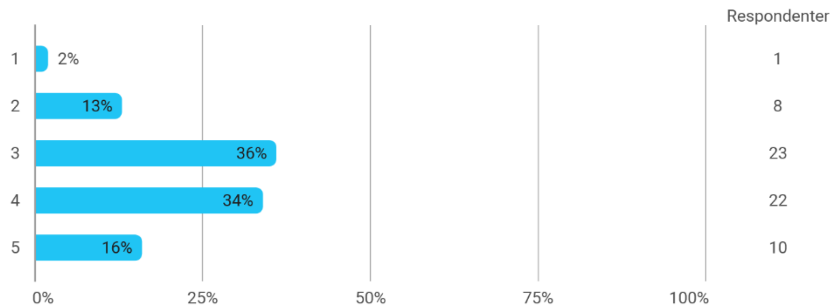


Arbejdsfaktorer

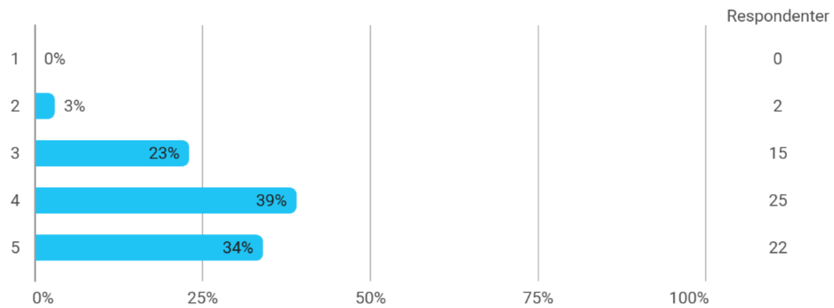
Motivation:



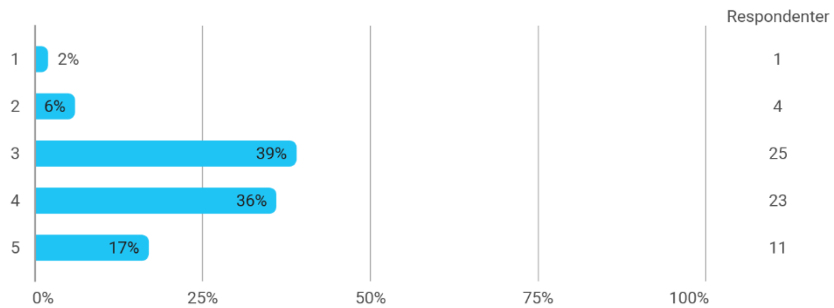
Kultur:



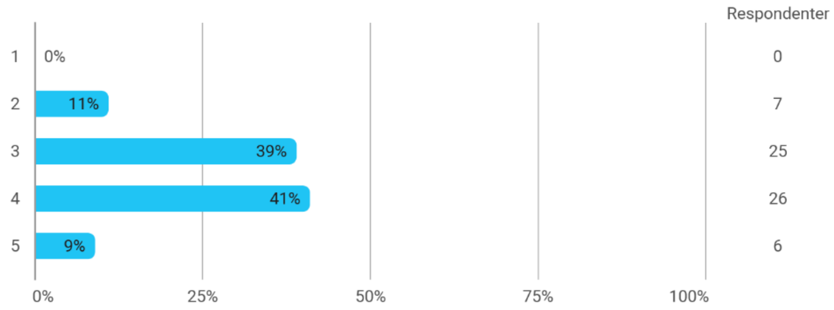
Ryddelighed:



Sammensætning af arbejdssjak:

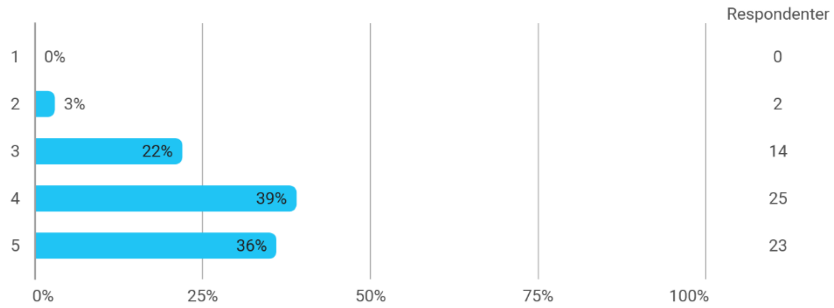


Antal arbejdere:

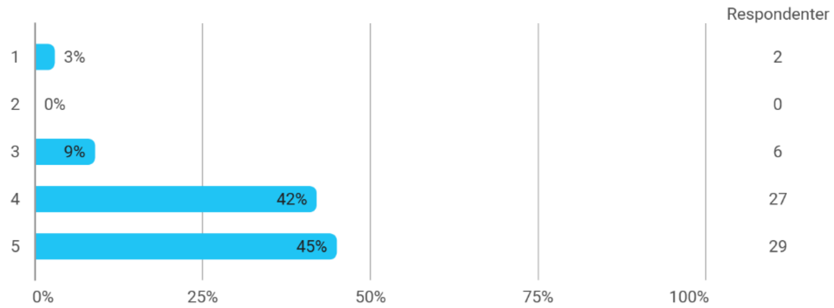


Ledelsesfaktorer

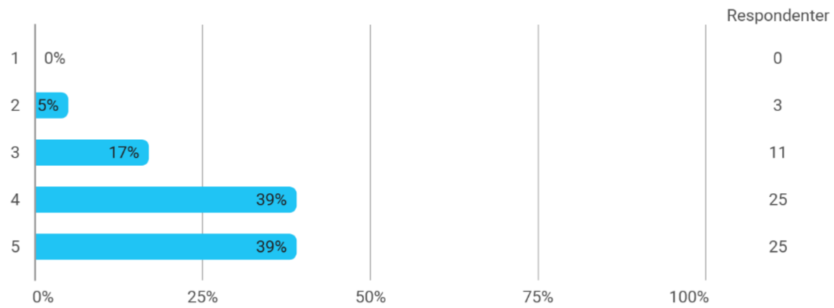
Formandens kompetence:



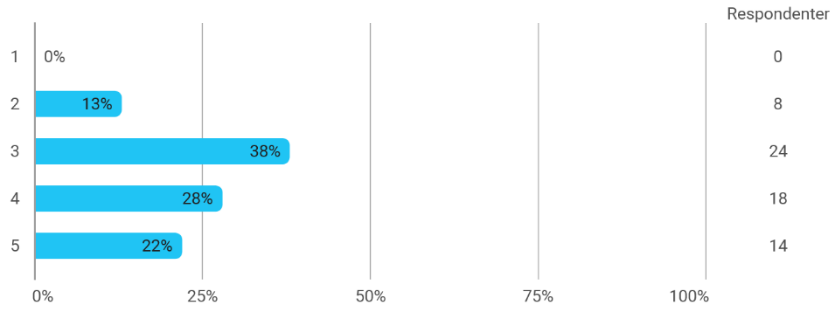
Planlægning og tidsplaner:



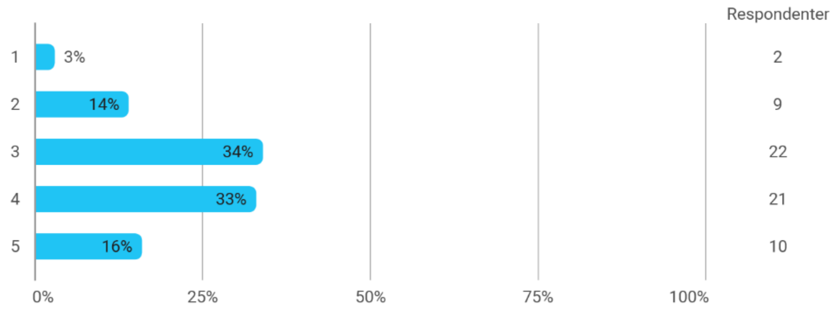
Projektlederens kompetence:



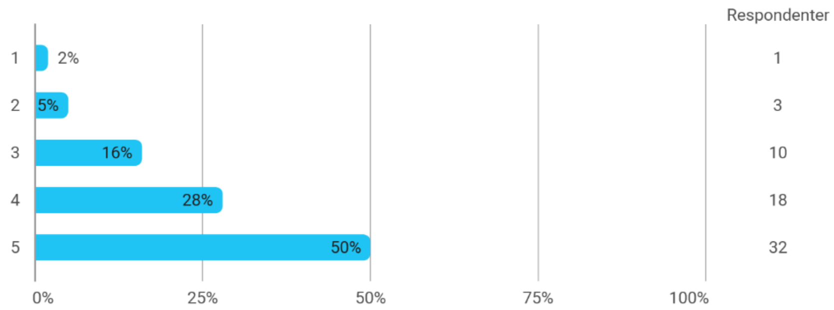
Byggepladsens layout:



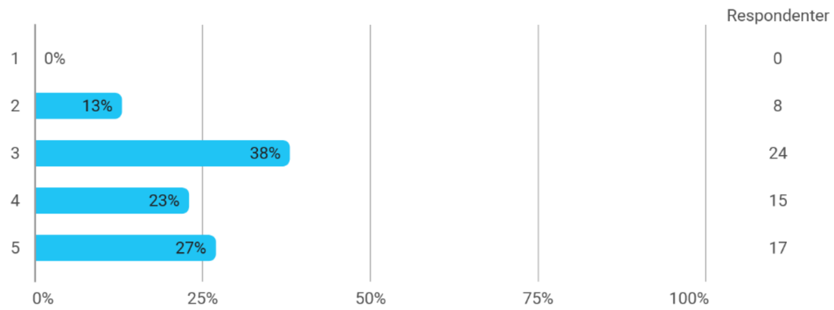
Tilsyn og kontrol:



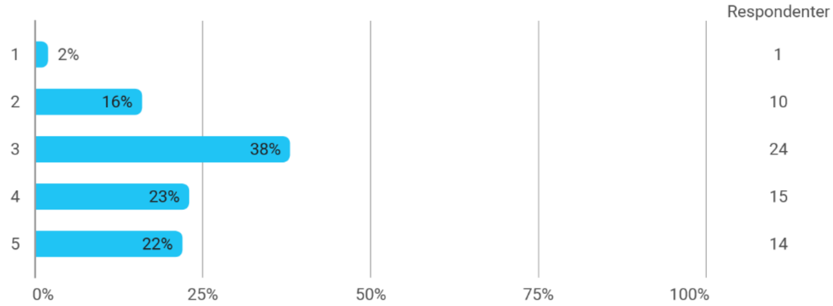
Koordinering og samarbejde:



Sikkerhed og arbejdsmiljø:

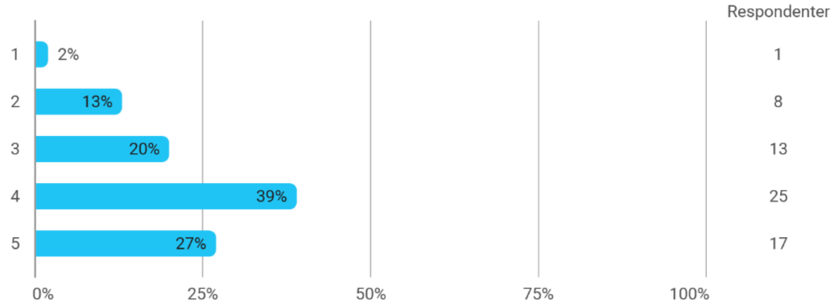


Overbemanding og manglende plads:

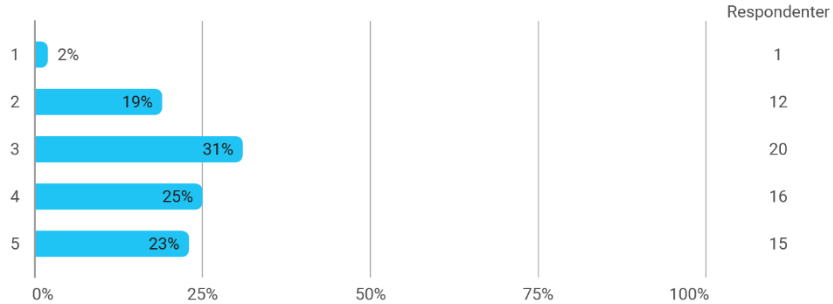


Tekniske faktorer

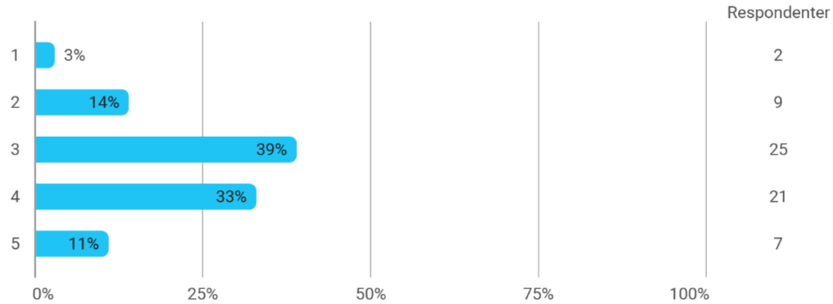
Materialer og logistik:



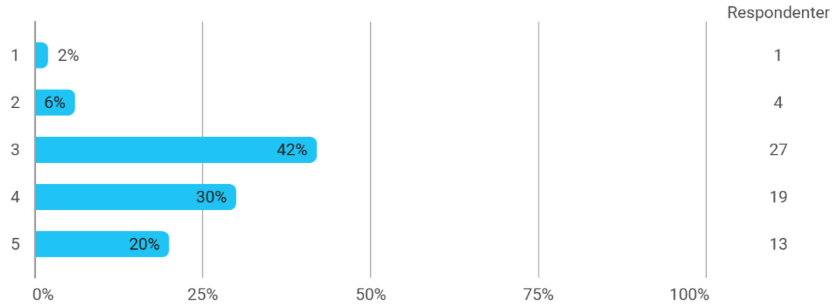
Materiel og værktøj:



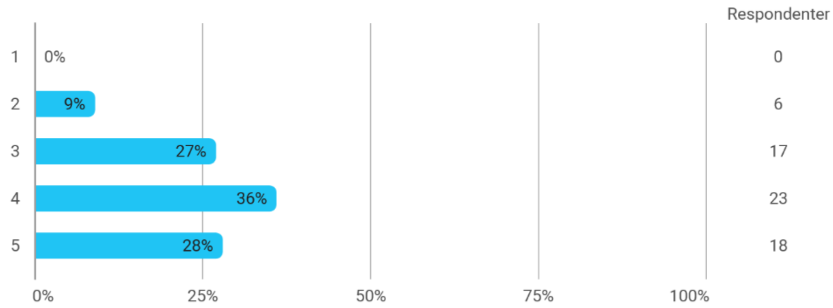
Teknologi og kultur:



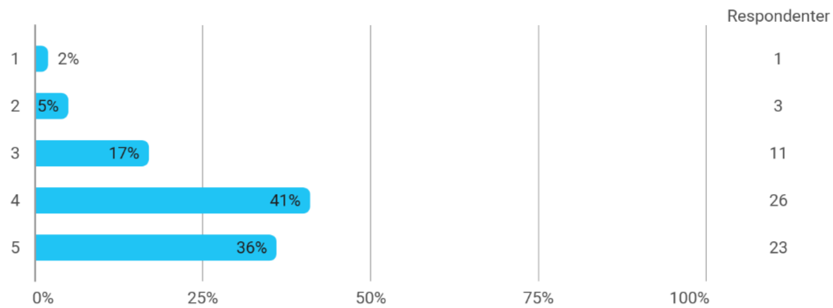
Designændringer:



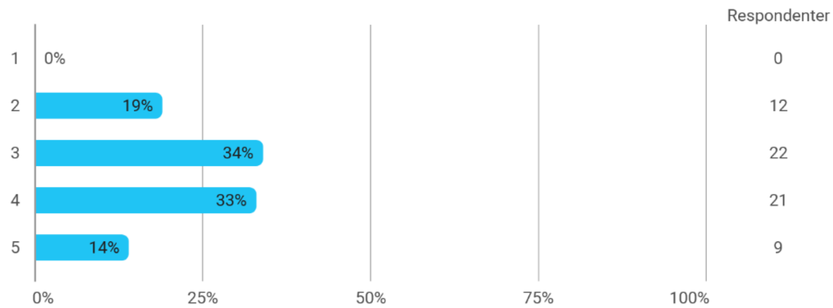
Ufærdigt design eller specifikationer:



Formidling af information:

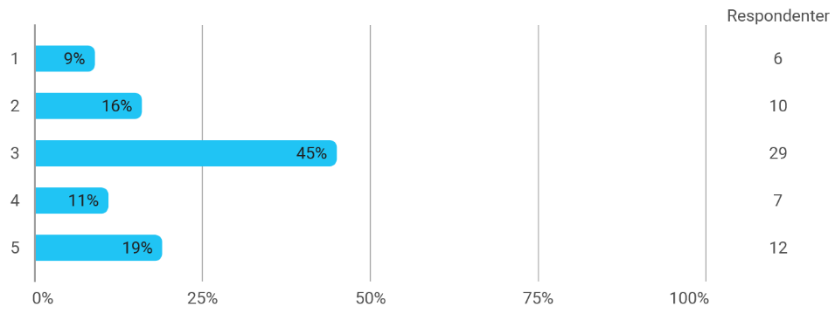


Indblanding fra bygherre og rådgiver:

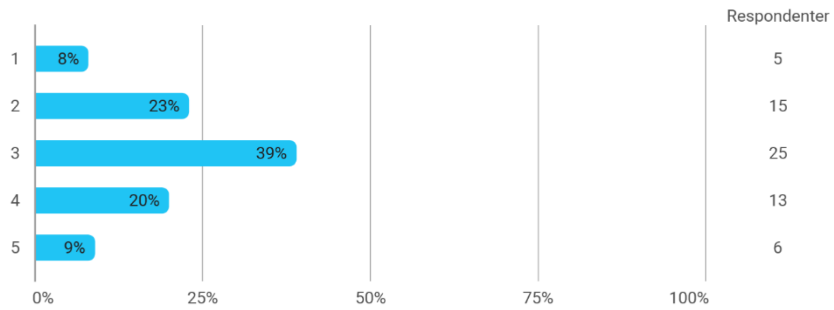


Eksterne faktorer

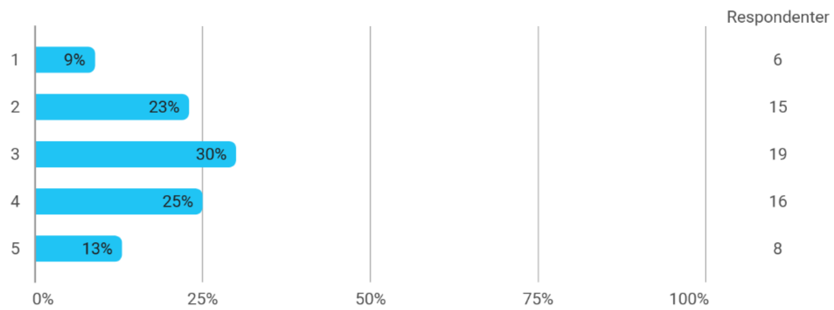
Vejr og vejrlig:



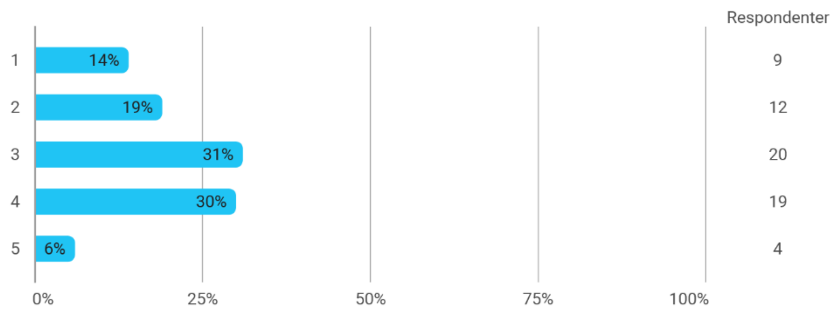
Økonomisk stabilitet, herunder kriser samt inflation:



Byggetilladelse og andre tilladelse:

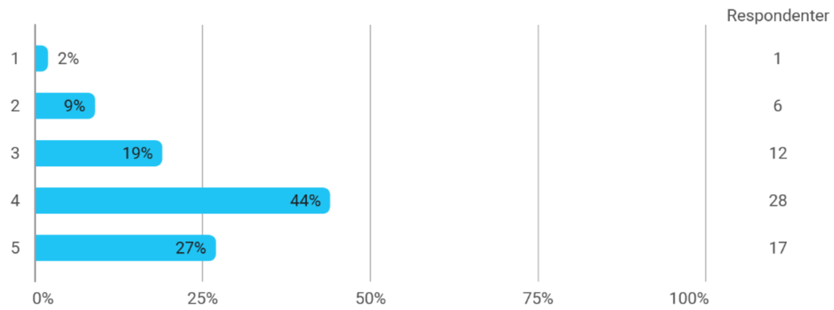


Byggejura og andre lovmæssige reguleringer:

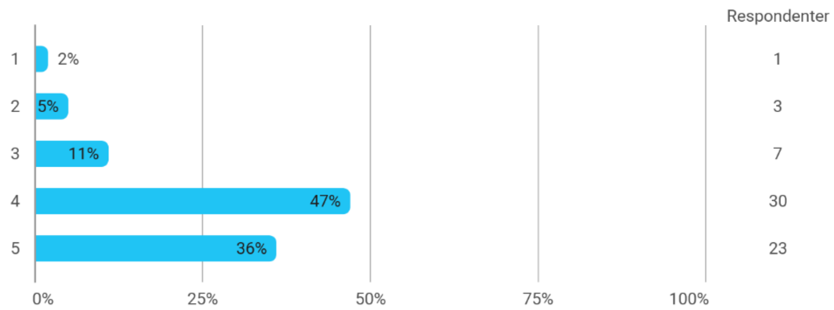


20. Hvilke faktorer påvirker arbejdsproduktiviteten mest? (1 svarer til mindst, 5 - mest)

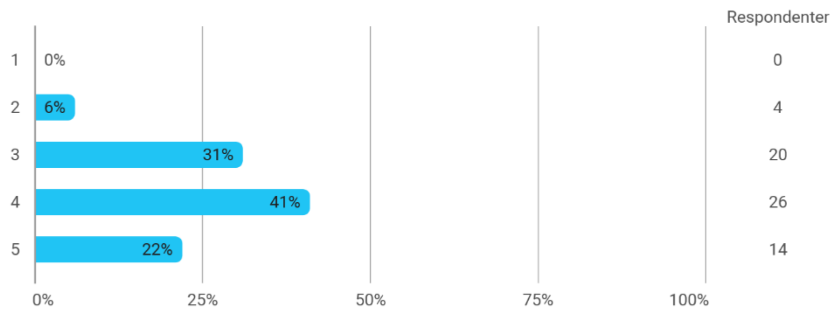
Projekt



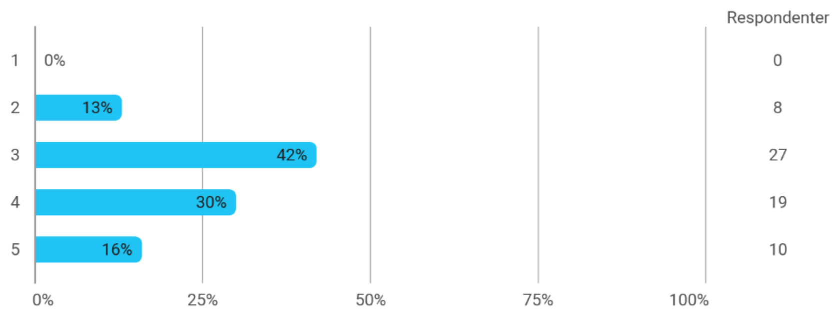
Ledelses



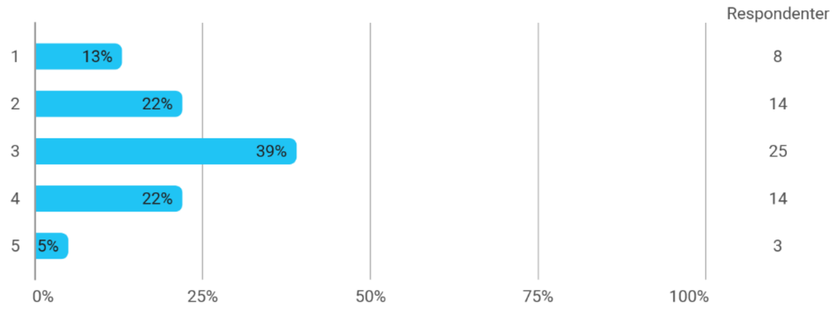
Arbejdskraft



Tekniske



Eksterne



Samlet status af spørgeskema