



AALBORG UNIVERSITET
STUDENTERRAPPORT

SUSTAINABLE BUILDING PROJECT EXECUTION

*Impact of Construction Project Management on DGNB Sustainability
Certification*



APRIL 12, 2017

AALBORG UNIVERSITY
School of Science and Technology
Sofia Fernandez Montes

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AALBORG UNIVERSITY
STUDENT REPORT

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SYNOPSIS:

This project report is focused on the analysis of the management and organization methodology applied by the building professionals within the framework of sustainable construction. Through the study and investigation of a case study, the main parameters that influence the process quality aspects of a sustainable building are established and described. With the support of literature review and interviews with professionals involved in the management and consultancy of the construction works, it is possible to discover the management strategies that have an influence on the sustainability-related targets of a project and define list of beneficial proceedings to ensure the success of a high quality sustainable building project.

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PREFACE

This master thesis report is conducted as part of the 4th semester of the Master of Science in Building Energy Design of the School of Science and Technology at Aalborg University, campus Aalborg. The period of conducting this project report is from 2nd September 2016 to 12th April 2017.

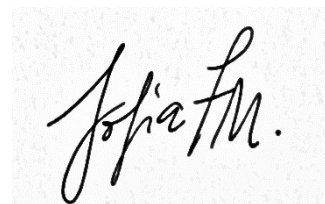
The completion and successful examination based on the report contents rewards 30 ECTS. The project supervision is held by the Associate professor Rasmus Lund Jensen and the PhD researcher Anne Nørkjær Gade.

The chapters that compound this project report are recommended to be read consequently, through the reader can easily find links to other sections of the report on the text, and because the information provided in each chapter helps for a better understanding of the following sections.

The reference method applied in this report is Harvard system, where every citation is listed with the author name, followed by the year of publication, all of it in brackets, i.e. (B. Brutland, 1987). Moreover, the bibliography can be found at the end of the report, right after the conclusion chapter, where the list of references is listed alphabetically. Additionally, the list of figures, list of tables and appendices containing additional project's information are structured in alphabetical order and they are located at the very end of this project report.

Moreover, I would like to thank my master thesis supervisors, Rasmus Lund Jensen and Anne Nørkjær Nielsen for their advice, guidance and support during the working process of this report. I would like to thank, as well, all the building industry professionals that participated in the interviews performed for this investigation, Allan Hesselholt, Bent Skararup Lindhardt and Mads Olsen.

Finally, I must thank specially Anne Hedegaard, from Region North Jutland, who provided me access to all the necessary documentation to carry on the research of this master thesis report.



Sofia Fernandez-Montes

April 2017

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ABSTRACT

Nowadays sustainability has experienced a fast growth within the building industry sector. Several sustainability certifications and rating systems have been emerging with the idea of evaluate and rate the sustainability of a construction, and its effects on the environment, providing great benefits for the building owner, stakeholders and users. Sustainable construction also brings a healthy and comfortable indoor environment, reducing the building's footprint, and increasing the quality and the property value. But, on the other hand, often, the value of a sustainable construction increases over time, causing reticence from building owners and stakeholders due to the high initial economic and resources investment.

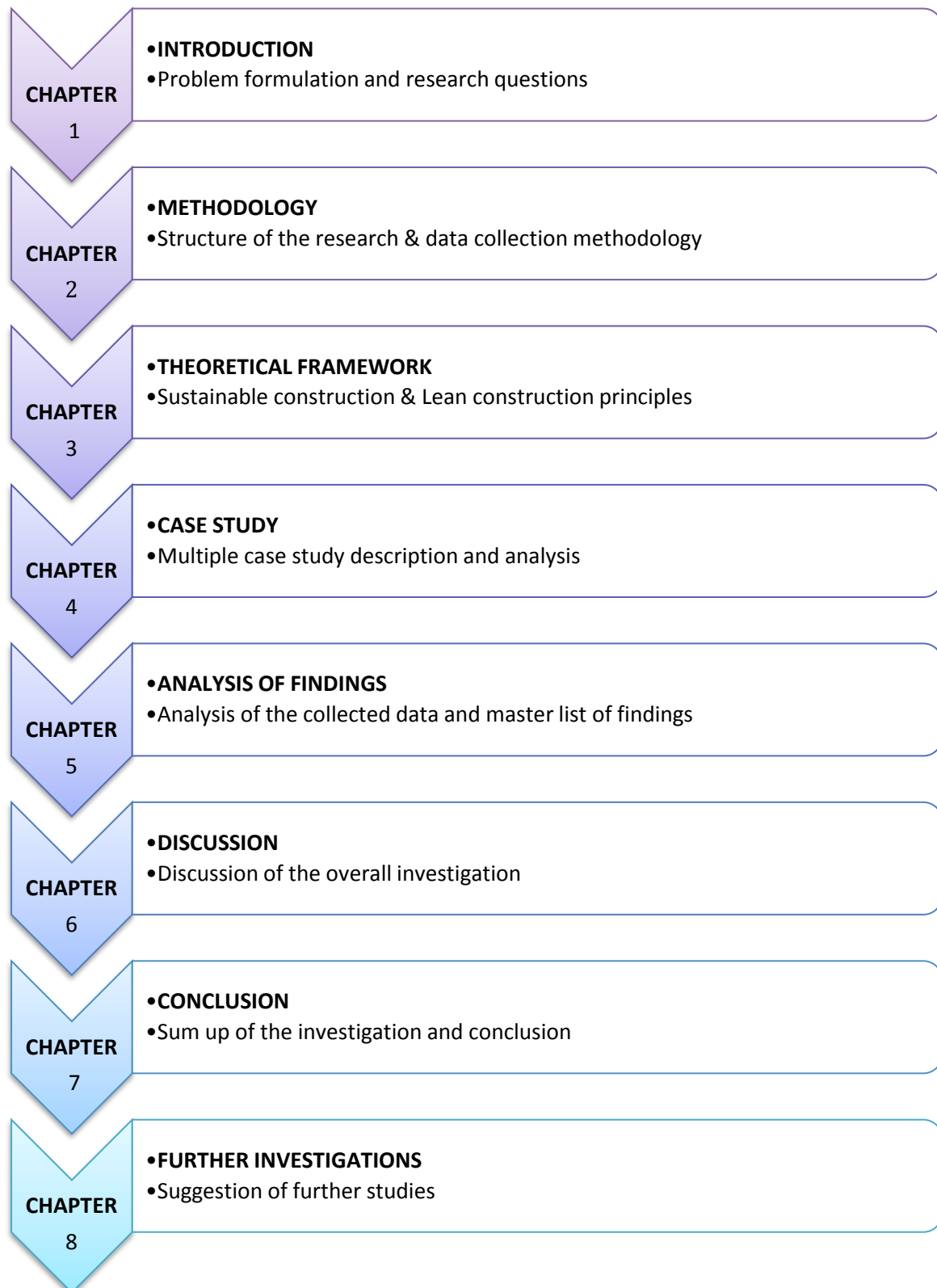
This research studies the influence of the implementation of sustainability criteria and sustainability assessment on the building's construction planning and management. A good planning and realization processes are the key concepts to achieve an enhanced property value, improving sales and renting processes of the property, and ensuring an efficient building operation. But even within the framework of a strict building process, the influence of the professional's bias and habits may interfere on the project performance, obstructing the evolution of the project work and increasing exponentially the design and construction work. Those decisions will be influenced by the traditional needs of the construction industry, the restrictions imposed by legislation and guidance, and the needs of the clients for the buildings and projects.

The investigation of this project report is based on the analysis of a case study, four healthcare buildings located in northern Denmark, which are owned by Region North Jutland. The projects represent the efforts of the Danish Government to reduce emissions and promote sustainability. Additionally, the buildings represented a big challenge for the professionals involved in the building process, due to the strict Building Owner's demands and the implementation of a new building sustainability certification, the German DGNB, which was adopted as the Danish national building certification by the Green Building Council Denmark in 2010. This unique situation brings the opportunity to overview the issues faced along the construction process and the difficulties faced by the professionals due to i.e. the lack of previous experience with sustainable construction.

Based on the analysis, it will be possible to overview the beneficial effects of sustainability certification of the building process aspects and the possible improvements that need to be implemented along the construction process to enhance the coordination, communication and planning of a sustainable building project.

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REPORT STRUCTURE



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ABBREVIATIONS

AAU	Aalborg University
BIM	Building Information
BR	Building Regulations
BREEAM	Building Research Establishment Environmental Assessment Method
CEN	European Committee for Standardization
DGNB	<i>Deutsche Gesellschaft für Nachhaltiges Bauen Ev</i> (German Sustainable Building Council)
DS	Danish Standard
EN	European Standard
EU	European Union
EVP	Evaluation point – DGNB <i>Evalueringspoint</i>
GBC	Green Building Council
GHG	Green House Gas
GWP	Global Warming Potential
IDP	Integrated Design Process
IEQ	Indoor Environmental Quality
LCC	Life Cycle Cost
LEED	Leadership in Energy and Environmental Development
LPS	Last Planner System
ODP	Ozone Depletion
PV	Photovoltaic
RH	Relative Humidity
SBi	Danish Building Research Institute <i>Statens Byggeforskningsinstitut</i>
TLP	Checklist point – DGNB <i>Tjeklistepoint</i>
TDP	Traditional Design Process

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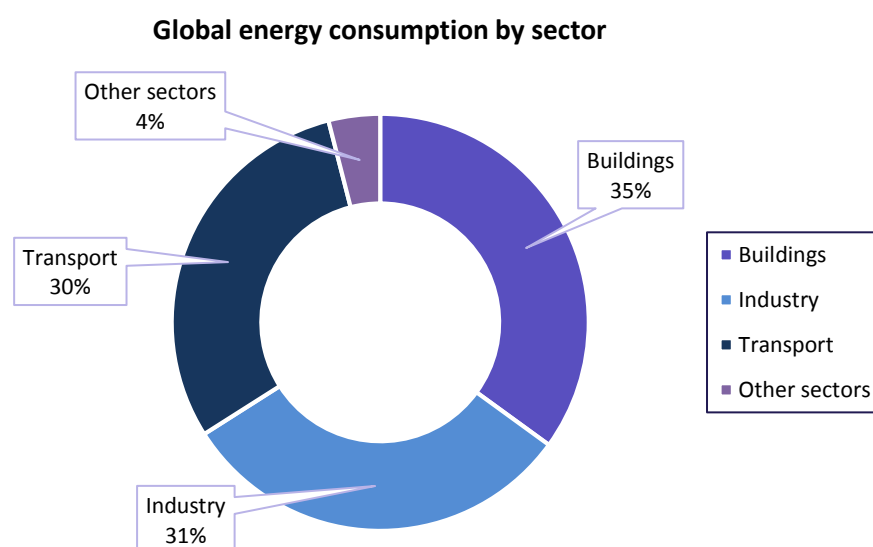
1. INTRODUCTION

The aim of the introductory chapter is to make the reader familiar with the area of research of this project report, starting from the background of the investigation, and the research aims and objectives. Also, in this chapter it is stated the problem formulation, the research questions and the scope of the project, providing a clear idea of the content of this report and the expectations of the investigation.

1.1 BACKGROUND

The social and environmental challenges faced nowadays in the everyday life are the evidence that sustainability is and will be the most constant topic along the next century between citizens, politicians, entrepreneurs, investors, business leaders, experts, auditors, etc. (Gilbert Silvius, 2011).

Buildings have extensive direct and indirect impacts on the environment. During their construction, occupancy, renovation, repurposing, and demolition, buildings use energy, water and raw materials, generate waste, and emit potentially harmful atmospheric emissions. Nowadays, buildings represent about 40% of the global energy consumption (See *Graph 1.1*), 25% of the global water consumption, 40% of the global resources, and emit approximately 1/3 of the greenhouse gas emissions (GHG) (GBC-DK, 2014). Even so, buildings also offer a great breeding ground for the achievement of a very significant reduction of the energy consumption, besides decreasing the GHG emissions to the atmosphere.



Graph 1.1 Final energy consumption by sector. Source: IEA data and analysis

These facts have promoted the creation of green building standards, voluntary certifications and rating systems aiming for the mitigation of the impact of buildings on the natural environment through a sustainable design. Sustainable assessment tools and certifications have the ultimate intention of approaching the building's performance in a more holistic way (Brophy, 2014). Thus, the implementation of sustainability guidelines and certifications could be used as a tool for the client to ensure the promotion of an integrative working environment, maintaining the focus and organization of the whole design and construction processes.

A sustainable building design requires the integration of many kinds of information, pursuing the continuous participation of users and community members, and various professionals throughout the building's life cycle. With a holistic design approach, the emphasis is focus on the functional relationship between the various building parts and the facility as a whole, increasing the complexity of the project (NIBS, 2017). The integrated working dynamic can become difficult to implement when the whole construction team is not committed to give up on following traditional working methods, where design and construction phases are understood as linear processes, and where the individual professionals, such as architects and engineers, work in their respective specialties somewhat isolated from each other. (See *Figure 1.1*).

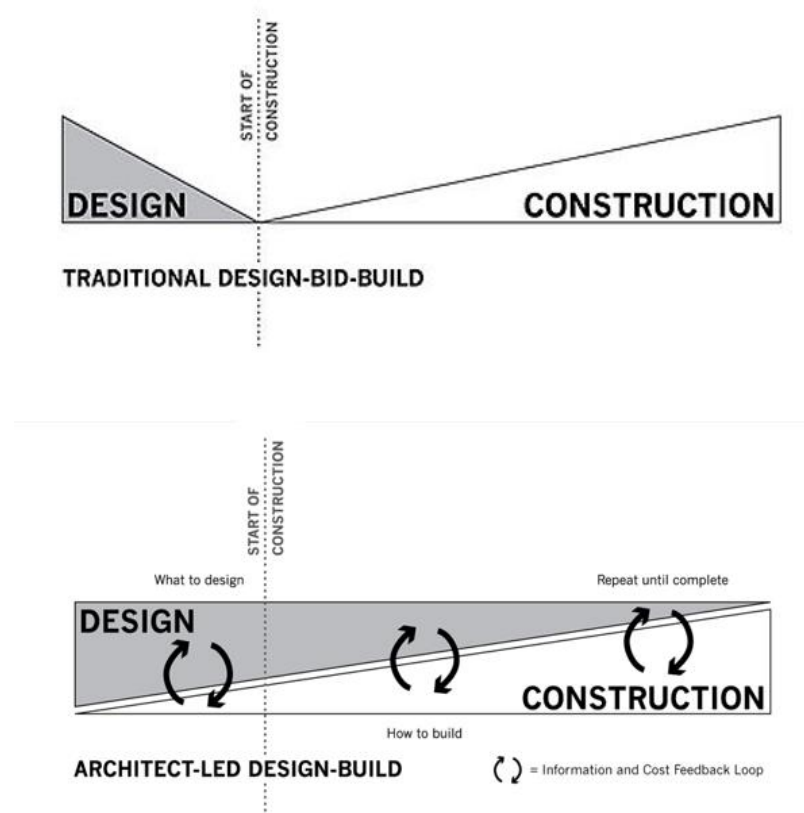


Figure 1.1 Traditional vs integrative building process (Arconic, 2017)

As key principle behind sustainable buildings is an integrated design process (IDP). This approach differs from conventional design by establishing a highly collaborative, multidisciplinary team at a project's inception and empowering this team to understand and develop all the aspects of the building, its site design, and, in some cases, its operation (Robin Guenther, 2008).

Through a traditional design process, each building professional participates when it is needed, creating operational islands, which cause ineffective coordination and poor communication, as seen in *Figure 1.2*. In contrast, an integrated design process is based on the concept that best ideas emerge when participants cross the usual boundaries (Malin, 2005) because their views are not as limited by familiarity with the way things are usually done.

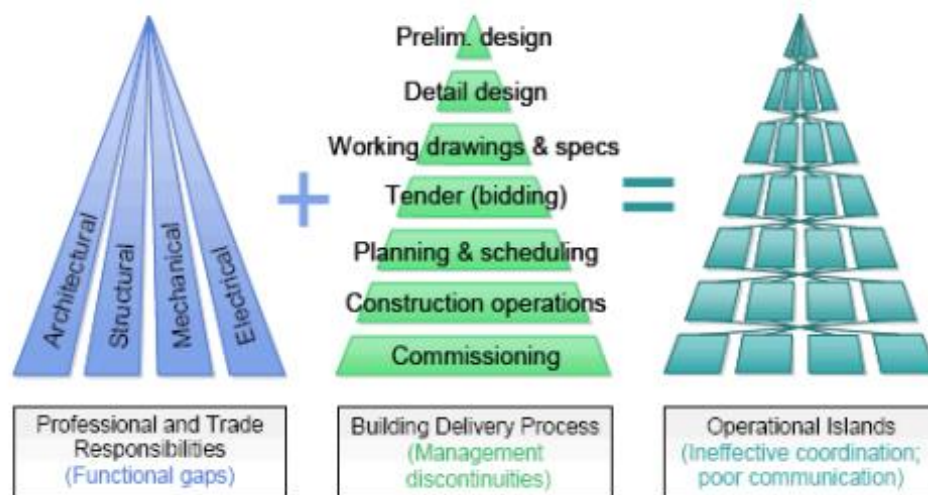


Figure 1.2 Players and practices in the building market (7006, 2012)

In a traditional building process, the constructor's role is often limited to providing input on constructability, cost and scheduling. But, sustainable design parameters increase the opportunities and responsibilities for construction professionals. An integrative design process supports the introduction of lean thinking in eliminating waste in both the design of the building and its execution process (Robin Guenther, 2008).

In this way, sustainability changes the profession of project management (Gilbert Silvius, 2011). In the past decades, the project management role is developing into the key organizational skill to execute these changes in a controlled manner (Gilbert Silvius, 2011). Project managers need to take a broad view of their role and to evolve, taking responsibility for the results of their project, including the sustainability aspects of such results. (Gilbert Silvius, 2011).

1.2 RESEARCH AIMS AND OBJECTIVES

As referred before, buildings have a great contribution to the global energy consumption and greenhouse emissions. On the other hand, buildings also offer an optimal breeding ground for the achievement of a significant reduction of their environmental impact. Buildings present levels of consumption and impact over waste generation that focus attention upon most aspects of their design, construction, operation and maintenance. From this perspective, the decisions taken by the several building professionals involved from the early stages of the project are strongly linked to the influence of the constructed environment on the energy consumption and waste generation. Therefore, sustainability certifications promote the implementation of integrative processes, where designers, planners, engineers, consultants, and project managers interact and cooperate to achieve the most holistic outcome, decreasing the negative effect of the building stock on the Earth and its population.

A good planning and realization processes are the key concepts to achieve an enhanced property value, improving sales and renting processes of the property, and ensuring an efficient building operation. But even within a strict building process, following the guidance of a sustainability certification, the influence of the professional's bias and habits may interfere on the project performance, obstructing the evolution of the project work and increasing exponentially the design and construction work. Those decisions will be influenced by the traditional needs of the construction industry, the restrictions imposed by legislation, and guidance and the needs of the clients for those building and projects. The use of voluntary sustainability certification could serve as a support tool, providing guidelines for the development of the planning process and working as a quality check over the time line of a sustainable building project.

Also, a good monitoring and management processes along the several phases of the project promote the reduction of "points of no return", maintaining the professionals informed of the performance of the building works and the possible need for improvements. During the construction phase of a project, the project manager plays an important role, being in charge i.e. activity planning and sequencing, time and cost estimation, and monitoring and reporting risks, while the number of professionals involved in the building execution compared with other stages of the project become larger. Good organization and management of the construction works benefit the process quality of a building, ensuring the implementation of the necessary sustainability criteria until completion and the availability of the necessary project documentation for further commissioning and maintenance of the project during its operation.

Additionally, the procedures and processes through which we procure our buildings and structures can have repercussions for the sustainability of a building. The implementation of i.e. lean construction principles, supplements traditional construction management approaches based on work on continuous improvement, waste elimination, strong user focus, value for money, high-quality management of projects and supply chains and improved communications. Procuring a building through a management-based system involves the main contractor in a specific management role, not as a contractor as would be traditionally recognised.

Finally, materials and their use can have one of the most profound influences upon the sustainability of a building. Despite the overall framework of sustainably procuring a building is finding more confirmed structure, built environment professionals are still left with the task of isolating the “right” products, materials and services that provide an optimal solution, including the sustainability credentials on the ground. There are number of guides and processes that can be used to isolate several different materials and products that would be suitable alternatives for use in a sustainable building. They might warrant their inclusion through good environmental credentials (in use and through production and disposal), proven durability, lower cost, ethical production, and an overall rating through life cycle analysis.

For the reasons described along the previous paragraphs, the aim of this project is focused on the planning and management methods applied through the construction phase and their influence on the achievement of a high quality sustainable building project. Also, sine materials represent a bit contribution to the energy consumption of the building and, therefore affect the operation and maintenance of it, the investigation delve into site-related materials issues and their use and special requirements, and what is the effect on the achievement of the initial goals and requirements for the sustainable building.

1.3 PROBLEM FORMULATION

As stated previously, the implementation of sustainability criteria and sustainable building certifications boost the complexity of a project. Since the sustainable certification is quite new, some professionals are still reluctant to the introduction of new working methods and approaches.

The main purpose of this study is to give answer to the following problem formulation:

- ***How do Construction Project Management methods influence the achievement of DGNB sustainability certification?***

1.4 RESEARCH QUESTIONS

To give an answer to the problem formulation of this investigation, several research questions are established:

- *What is the influence of stakeholder's working methods during the construction phase on the DGNB certification process within the four-healthcare centre projects?*
- *To which extent does tender phase affect the progress of a DGNB certified building project? Are the companies involved in the tender completely aware of the high sustainability requirements for the four buildings?*
- *Which are the challenges faced by the project managers and DGNB consultants through the construction phase of the four healthcare buildings?*
- *What are the changes faced during the communication and collaboration of the main constructor and subcontractors?*

In the questions stated above, the main possible factors that influence the organization and planning methods of a design team will be investigated.

1.5 SCOPE AND DELIMITATION

The scope of this study is limited to the public building sector within the northern municipalities of Denmark; Region North Jutland. It should have been ideal to cover all the regions of Denmark, however, the study opted to restrict the scope to North Denmark because the study of the entire country would make conclusions unnecessarily wide and incapable of clear interpretations. This a study restricted to Region North Jutland, gives the opportunity to analyse the conversion from traditional working methods to integrative design approaches for the professionals involved in the building industry, besides the fact that Region North Jutland has been deeply involved in environmental friendly strategies to reduce the energy consumption and emissions of the region starting from the public buildings.

The problem is perceived due to the increased popularity of voluntary sustainability certifications between the building owners, even though the construction industry it is still implementing traditional methods of work. The problem is relevant for the professionals involved in the design and construction stages of a sustainable building, since it is common to arise differences between professionals due to their different approaches to sustainability, which slows down the work flow of the team and their coordination.

With the purpose of perform a relevant investigation, the areas of study of this report are narrowed, focusing on the management of the building execution process and DGNB sustainability certification.

First, even though all the diverse phases of the building process and the interconnection between the several professionals involved in them would affect the outcome the project, the focus of this investigation is on the study of the impact of the tender and construction phases, within the framework of a design-bid-build delivery method. This is due to the relevance of the work dynamic and information sharing during those phases and the big impact that they have on the achievement of a high-quality edification. *Figure 1.3* below presents the several phases of the building process, in which the focus of this study, tender and execution phases, are marked in red.

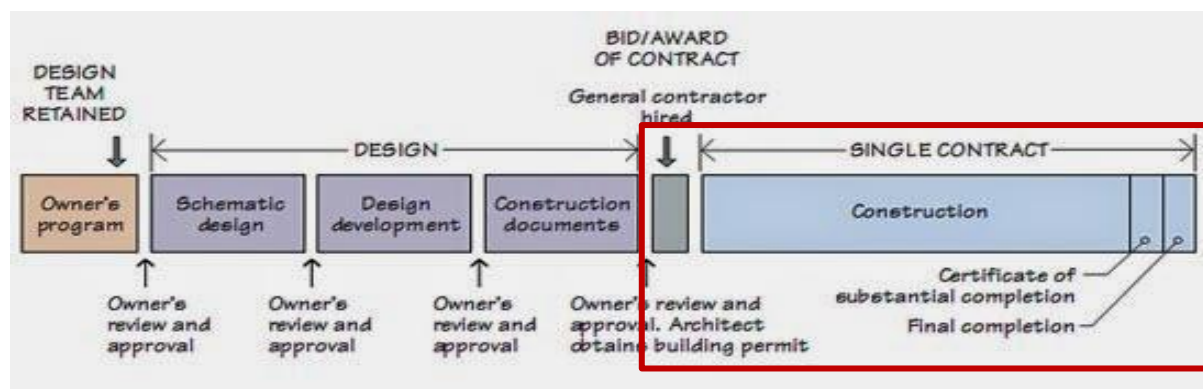


Figure 1.3 Sequence of operations in the Design-Bid-Build (DBB, 2014)

Second, since the idea is to analyse the influence of the construction management process influence on the sustainability targets of a building project, the study is based on the first-four DGNB certified buildings owned by a public institution in whole Denmark. The study of the first project certified by DGNB brings the opportunity to study the influence of inexperience and habits on the achievement of the Building Owner's requirements and how the professionals overcame the obstacles during the construction phase of the projects.

Finally, sustainability assessment tools and certifications are in constant evolution. DGNB certification emerged as part of the second generation of building sustainability certifications, which based on BREEAM and LEED certifications, approaches the sustainability of the constructions in a more holistic way, focusing on the functionality and flexibility of the building. Consequently, DGNB certification is perceived as a complex certification scheme, due to the high number of criteria and sub criteria that contains and the subjectivity of the parameters to fulfil.

2. METHODOLOGY

As the title indicates, along this section, it is presented the research methods applied for the core of the investigation of this report, together with the data collection methodology, where the documentation sources are presented and described.

2.1 RESEARCH METHODS

To perform the investigation contained in this project report, it is applied the triangulation research method (see *Figure 2.1*). The triangulation method of analysis involves the use of multiple sources for an investigation to produce understanding, since a weakness in one source will be compensated by another source (Cohen D., 2006). Rather than seeing triangulation as a method for validation or verification, qualitative research generally use this technique to ensure that an account is rich, robust, comprehensive and well-developed.

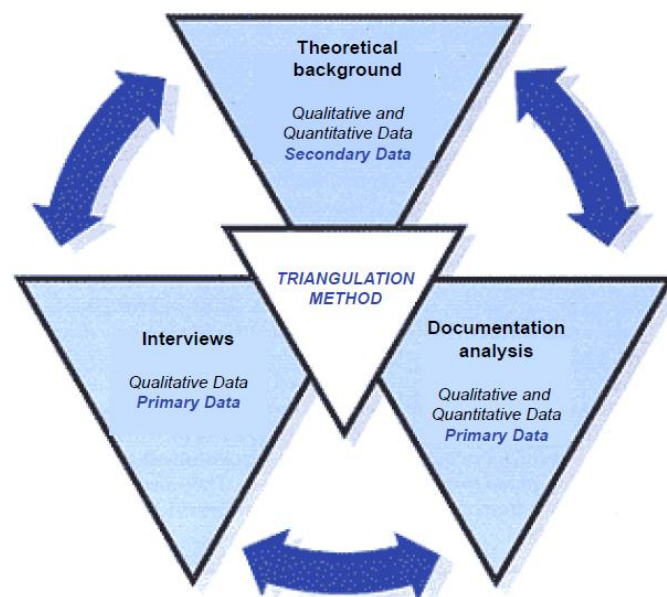


Figure 2.1 Triangulation research method (Jackson, 2013)

The research method applied for this project report is a combination of both qualitative research and document analysis. Qualitative research is designed to help researchers understand people, and their social and cultural contexts within which they live. Moreover, qualitative data sources can include participant's observation (fieldwork), interviews and questionnaires, documents and texts, and the researcher's impressions and reactions (Myers, 2009).

The documentation analysis in this project is carried out through a case study research method. A case study allows for in-depth review on an unclear phenomenon “retailing the holistic and meaningful characteristics of real-life events” (Yin, 2009). Since the research field of this report is very broad, the use of a case study method provides the opportunity to narrow down the research field into a more simple and easy research topic.

The case study research complies several steps that conform the contents’ structure in this project report. An initial introduction of the background and purpose of the focus of the investigation provides the ground for the establishment of the problem formulation and the subsequent research questions.

Additionally, relevant theory is reviewed with the purpose of gaining a better understanding of sustainability assessment, and the planning and construction process considerations in it, the barriers faced by sustainability in the building industry, and tools that can enhance the management of sustainable building projects.

The following step is a description of the case study and its relevance for the investigation. The case study used is a building portfolio, owned by a public institution, it is composed of four different buildings located in various municipalities of northern Denmark. The four buildings are awarded with DGNB silver certification, and they represent the first certificated sustainable buildings in North Jutland Region. This situation allows an analysis of the influence of certain parameters, such as the experience with sustainability and environmental friendly constructions of the professionals involved in the projects. Also, it can be determined the influence of the coordination and communication of the building industry professionals, as well as their commitment for the achievement of the sustainability goals stated by the building owner.

Since the main objective of the project is the study of the planning and management methods applied during the construction phase of the projects and their possible beneficial and negative consequences, the process quality aspects contained in the DGNB assessment are taken into consideration. Also, the main targets for this investigation are the professionals that perform the most relevant roles during the construction phase. In this case, the main contractors and sustainability consultants/advisors, are invited for semi-structured interviews with the purpose of gaining a better understanding of their personal experiences and points of view.

The final step of the case study research is the analysis of the results, discussion and conclusion. At this point, the findings of the research are established and discussed to set up a guidance for the improvement of the management and planning of the execution process of a sustainable project, and present future research work that can help clarify the topic.

2.2 DATA COLLECTION METHODOLOGY

The materials necessary for the triangulation method are collected from several sources and sites, described in the following paragraphs. The research is composed by several research components, such as DGNB assessment documentation and management tools, a case study and various interviews to professionals from the field. The research is performed with the purpose of gaining understanding of the theoretical and practical approach of the planning and management methods applied during the execution phase of a sustainable building project, and their consequences on the achievement of the building owner's requirements.

2.2.1 LITERATURE REVIEW

The problem was identified based on literature review. The existing literature on the topic of sustainable building design and the significance of sustainable development of the building industry were studied. The focus of the literature research was on the possible issues that arise due to the new working methodologies that need to be implemented for sustainable construction.

The literature review helped making a general observation of the current problems within the topic. This research work helped identify and formulate the problem statement, together with the research questions, all which have been adjust under way.

2.2.2 INTERVIEWS

The Grounded Theory is a research tool which enables you to seek out and conceptualise the latent social patterns and structures of your area of interest through the process of constant comparison (Scott, 2009). Several methods are used in Grounded Theory, such as participant observation, interviewing and collection of artefacts and texts.

The process begins with the researcher asking a question or series of questions designed to lead to the development or generation of a theory regarding some aspect of social life (Cohen D., 2006). This process helps the researcher to identify an initial sample of people to observe to obtain sampling data to begin the development of a theory. Afterwards, the data gathered is analysed following three levels of coding (Cohen D., 2006):

- Open coding: where the researcher begins to segment the data into similar grouping and forms preliminary categories of information.
- Axial coding: in which the researcher begins to bring together the categories (create themes)
- Selective coding: the researcher organizes and integrates the categories and themes in a way that articulates a coherent understanding of the phenomenon of study.

For this project, the interviews were conducted as semi-structured life-world interview, defined as the interview with the purpose of obtaining descriptions of the interviewee, with respect to interpreting the meaning of the described phenomena (Kvale, 2007). To achieve a high-quality interview, certain parameters should be taken into consideration:

- Use of semi-structured interviews with a sequence of themes to be covered and already prepared questions
- The questions should be brief and simple, to obtain longer answers from the interviewee
- Avoid the interference of personal opinions during the interviews.

To perform the investigation, several interviews were performed to gather qualitative data and to gain a better understanding of the experience from professionals involved in the management and consultancy throughout the execution phase of a sustainable building project.

To achieve a good overview of the construction management of a sustainable building project, several professionals involved in the Integrated Design Team, project management and tender phase were interviewed, which are presented in *Table 2.1* below. Also, the representative of Region North Jutland in the four healthcare centres was interviewed, since it provides a broader overview of the project portfolio and the reasons why the client chose the specific requirements for all the projects.

INTERVIEWEE	COMPANY	POSSITION	PROJECT
Allan Hesselholt	Cowi A/S	DGNB consultant (IDT)	Sæby & Brønderslev
Mads Olsen	MT Højgaard A/S	Project manager	Hurup
Bent Skararup	Lund og Staun A/S	Marketing and sales	Pandrup
Anne Hedegaard	Region North Jutland	Project manager	Pandrup, Hurup Sæby & Brønderslev

Table 2.1 Building industry professionals interviewed

The four interviews structure and transcription can be found at the end of this project report, inside Appendix C, page 86.

2.2.3 DOCUMENT ANALYSIS

The investigation is performed based on the documentation gathered from a case study. The project's documentation, provided by Region North Jutland, contains information about the project management, team's organization and collaboration, efficient information sharing and project scheduling and project delivery.

By the analysis and comparison of the documentation provided for the criteria contained in the process quality aspects of the DGNB assessment, it is possible to define the benefits and drawbacks faced for each project, together with their possible causes. Also, the documentation from the sustainability assessment of the four projects give an overview of the management and collaboration methods applied throughout the project's execution, helping to determine a guidance for good practices to fulfil the strict requirements of a sustainable building project without increasing expenses or reduce the quality of the construction.

3. THEORETICAL FRAMEWORK

This section provides a theoretical review of the key concepts that are relevant for the study of the problem. The section presents information about sustainability assessment, DGNB certification, management tools, such as LEAN construction, and describes the barriers that sustainable construction must overcome.

3.1 SUSTAINABLE BUILDING CONSTRUCTION

The way buildings are designed, constructed and operated have a profound impact on the occupant's health and the health of the environment (Kongebro, 2012). Together with the optimization of the energy systems, there are other parameters that should be taken into consideration to reduce the building's footprint.

It has been proved that construction, occupancy and demolition imply also the use of energy and resources, creating a negative environmental impact (Ullgiati, 2004). These facts have promoted the creation of green building standards, voluntary certifications and rating systems aiming for the mitigation of the impact of buildings on the natural environment through a sustainable design.

Sustainable building refers to both a structure and the using of processes that are environmentally responsible and resource-efficient throughout a building's life cycle: from sitting to design, construction, operation, maintenance, renovation, and demolition. This requires a close cooperation of the design team, the architects, the engineers, and the client at all project stages (Yang, 2006).

3.1.1 BARRIERS FOR SUSTAINABLE CONSTRUCTION

Even if sustainability has experience a great evolution in the construction sector, most the stakeholders keep reluctant to the change from conventional to integrative working methods. The level of complexity that sustainable construction makes necessary the involvement of several building professionals from the initial stages of a project until completion to ensure the achievement of the project sustainable objectives and aims (Hendrickson, 2008). Moreover, the higher initial economical investment is seen negatively by the building owners, which do not see the big advantages of a sustainable building in the long run.

A good planning and realization process are the key concepts to obtain a great property value, enhancing the sales and renting process of a building, and ensuring an efficient building operation

(Szydlík, 2014). But even within a sustainable building process, the influence of the professionals' bias and habits might interfere on the project's performance, obstructing the evolution of the project work and increasing exponentially the design and construction work and expenses.

The use of sustainable assessment tools and standards can serve as a support mechanism, providing guidelines for the development of the planning process and working as a quality control over the time line of a sustainable building project. The planning process of a sustainable project should be taken into consideration already from the pre-design phase and considered over the whole life cycle of the building. With the purpose of obtain the most holistic building design, it is crucial to have an interdisciplinary organised integral planning process, in which all professionals share their experience and knowledge. Also, a good monitoring and management process along the several stages of the project help the reduction of "points of no return", maintaining the professionals informed of the performance of the building works and possible need for improvements.

Finally, during the execution of a sustainable building, the project manager takes an important role, overseeing the management of a bigger team of professionals, due to the increased number of workers involved in this phase. A good organization and management of the construction works benefits the quality and functionality of a building, insuring the fulfilment of the necessary sustainable criteria until completion, and the availability of the fundamental building documentation for the commissioning and maintenance measures for the project during its operation.

3.1.2 DGNB SUSTAINABLE BUILDING CERTIFICATION

The German DGNB certification conforms the second generation of sustainability certifications that emerged during the 21st century. Based on the English BREEAM (intended to be an environmental assessment) and the American LEED certifications, DGNB assess buildings taking into consideration the three main pillars of sustainable development; economic, environmental and social aspects.

In 2011, Green Building Council Denmark selected as the national sustainable building certification DGNB, adjusting the system to the Danish regulations and standards, as well as i.e. the weather conditions. Additionally, DGNB-DK provides a unique opportunity for creativity and innovation, an overall economical perspective of the whole building project, through Life Cycle calculations, and promotes the functionality and flexibility of the building.

This certification is considered the most holistic voluntary sustainability certification from the most internationals, due to the sustainability assessment of the building based on the life time footprint created by the building on the close environment and resources. This analysis is made based

on the materials and appliances used for the building and the contribution of the edification to the greenhouse gas emissions.

DGNB-DK can be implemented in the construction industry from buildings to urban districts, with the purpose of obtain the certification or just use the manual as a support tool to create a more energy efficient and environmental friendly construction. The certification has six schemas translated and adapted to Danish, from which 5 are referred to new commercial and residential buildings, and urban districts, while the last one, released in December 2016, asses existing office and administrative buildings.

The assessment tool includes six key aspects to evaluate of the sustainable construction: environmental, socio-cultural, economic, technical, process and site qualities. In the specific case of buildings, the environmental, socio-cultural, economic and technical qualities represent 25% of the final score of the project, while process quality accounts for 10%, and the site quality id evaluated separately. But, it is important to remind that even if the different qualities are evaluated separately, all have interconnections and depend and affect each other.

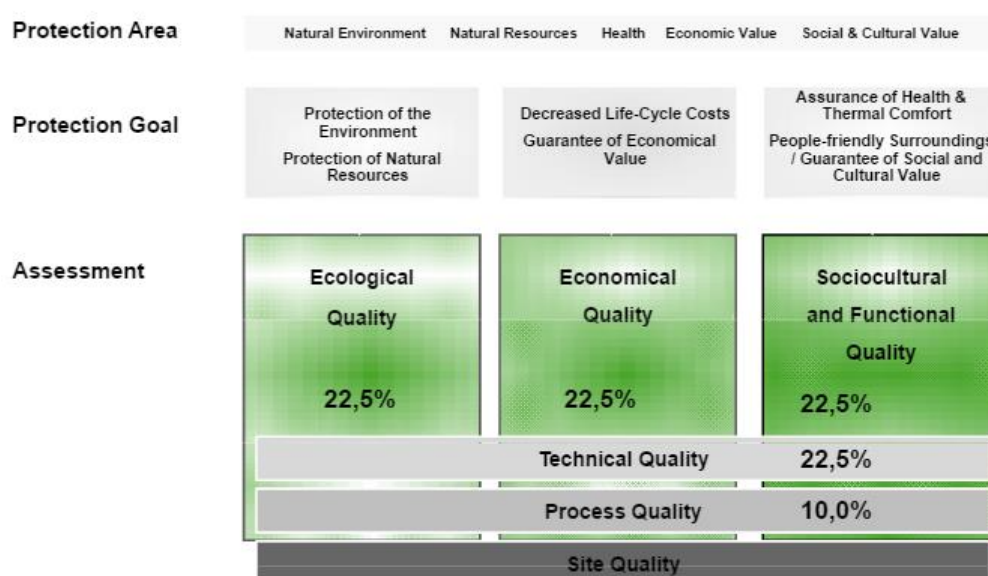


Figure 3.1 DGNB assessment quality groups

The schema is composed by 40 assessment criteria, divided between the 6 quality groups described previously. Like in the case of the quality groups, the assessment criteria and sub criteria present different weights and influence on the final award score. At the same time, each criterion contains sub criteria that are evaluated with check list points (DGNB, 2013). That through a linear interpolation can be transformed into evaluation points. *Figure 3.2* below in the text present the weighting value of the several assessment criteria, in a range from 1 to 7.

Temaområde	Kriteriegruppe	Nr.	Kriterium	Vægtning	Gruppe vægtning	Performance index samlet score
Miljø	Livscyklus vurdering (LCA)	ENV1.1	Livscyklusvurdering (LCA) - Miljøpåvirkninger	7	22,5%	100,0%
	Globalt og lokalt miljø	ENV1.2	Miljørisici relateret til byggevarer	3		
		ENV1.3	Miljøvenlig indvinding af materialer	1		
		ENV2.1	Livscyklusvurdering (LCA) - Primærenergi	5		
	Ressourceforbrug og affald	ENV2.2	Drikkevandsforbrug og spildevandsudledning	2		
		ENV2.3	Effektiv arealanvendelse	2		
Økonomi		Totaløkonomi	ECO1.1	Bygningsrelaterede levetidsomkostninger	3	
	Økonomisk fremtidssikring	ECO2.1	Fleksibilitet og tilpasningsevne	3		
		ECO2.2	Robusthed	1		
Social	Sundhed, komfort og brugertilfredshed	SOC1.1	Termisk komfort	5	22,5%	
		SOC1.2	Indendørs luftkvalitet	3		
		SOC1.3	Akustisk komfort	3		
		SOC1.4	Visuel komfort	3		
		SOC1.5	Brugernes muligheder for styring af indeklimaet	2		
		SOC1.6	Kvalitet af udedørs friarealer	2		
		SOC1.7	Tryghed og sikkerhed	1		
	Funktionalitet	SOC2.1	Tilgængelighed	2	22,5%	
		SOC2.2	Offentlig adgang	1		
		SOC2.3	Forhold for cyklister	1		
	Æstetik	SOC3.1	Tiltag til at sikre arkitektonisk kvalitet	3	22,5%	
		SOC3.2	Bygningsintegreret kunst	1		
	Plandisponering	SOC3.3	Plandisponering	1	22,5%	
Teknisk	Teknisk udførelse	TEC1.1	Brandsikring	2	22,5%	
		TEC1.2	Lydforhold	2		
		TEC1.3	Klimaskærmens kvalitet	2		
		TEC1.4	De tekniske systemers tilpasningsevne	1		
		TEC1.5	Bygningens vedligehold og rengøringsvenlighed	2		
		TEC1.6	Egnethed med henblik på nedtagning og genanvendelse	2		
Proces	Planlægning	PRO1.1	Kvalitet i forberedelsen af projektet	3	10,0%	
		PRO1.2	Integreret design proces	3		
		PRO1.3	Vurdering og optimering af kompleksitet i planlægningen	3		
		PRO1.4	Sikring af bæredygtighedsaspekter i forbindelse med udbudsmateriale og ordretildeling	2		
		PRO1.5	Vejledning om vedligehold og brug af bygningen	2		
	Udførelse	PRO2.1	Byggeplads/Byggeproces	2		
		PRO2.2	Dokumentation af kvalitet i udførelsen	3		
		PRO2.3	Commissioning	3		
Område	Område	SITE1.1	Mikroområde	2	0,0%	
		SITE1.2	Områdets og kvarterets image og tilstand	2		
		SITE1.3	Trafikforbindelser	3		
		SITE1.4	Adgang til faciliteter i nærområdet	2		

Figure 3.2 DGNB-DK evaluation matrix (DK-GBC, 2014)

When the evaluation points for each category are established, the score is multiplied by the weighting factor, to sum them up and determine the final score of the building. The DGNB certification systems is divided on four awards: Bronze, Silver, Gold and Platinum. To obtain a certain award, the various quality groups must sum up to a minimum performance index score, and a minimum total performance index of the combined quality group scores (*Figure 3.3*).

Total-Performance Index	Minimum Performance Index	Awards	
from 35 %	— %	Bronze*	
from 50 %	35 %	Silver	
from 65 %	50 %	Gold	
from 80 %	65 %	Platinum	

*This award is valid only for existing buildings

Figure 3.3 DGNB-DK certification awards per the score of the project (DGNB, 2013)

During the sustainability assessment for DGNB certification, there are various steps that need to be follow. First, during the design phase of the project, a pre-certification is performed to state the needs for the achievement of the sustainability goals and aims established in the client's requirements.

Through the pre-certification, the DGNB auditor and the consultant provide the necessary information to achieve the objectives and help the professionals to comprehend the complexity of the sustainability assessment and the great relevance of a holistic approach for the design. Several drafts of the assessment matrices are carried out to determine the responsibilities and duties of each building industry professional involved in the projects (DGNB, 2013).

As soon as the tender phase is completed, the focus starts on the final certification award of the buildings. Right after the beginning of the construction phase, a workshop is carried out by the DGNB auditor to describe in detail the actual workload that the new parties involved in the projects should overcome and to provide an overview of the actual needs of the buildings and follow up the previous work carried out by the design team.

Even if an initial design concept is already developed, along the construction phase, a project can overcome diverse adjustments to solve problems with the Building Regulations or with the accomplishment of the requirements stated on the DGNB certification applied. Due to that, the

construction phase is a good background for possible improvements of the DGNB assessment process, to increase the quality of the planning and construction criteria and sub-criteria involved in the process quality.

3.2 CONSTRUCTION PROJECT MANAGEMENT

Construction project management consists on the direction, regulation and supervision of a project from the early development until completion and hand in. The final goal of construction management is the full achievement of the client's demands for a viable project in both terms of functionality and budget (Bjeirmi, 1996).

The main concept of construction project management is closely connected to technical parameters like budget and execution but it also requires solid communication between all the agents (stakeholders, contractors and community). The primary challenge of project management is to achieve all the project goals within the given constraints (Phillips, 2003). The primary constraints are scope, time, quality, and budget (PMI, 2010). The secondary challenge is to optimize the allocation of necessary inputs and integrate them to meet pre-defined objectives.

Figure 3.4 presents the construction project management considerations, such as Building Owner's requirements, quality assurance of the construction works and program and milestone deliveries.

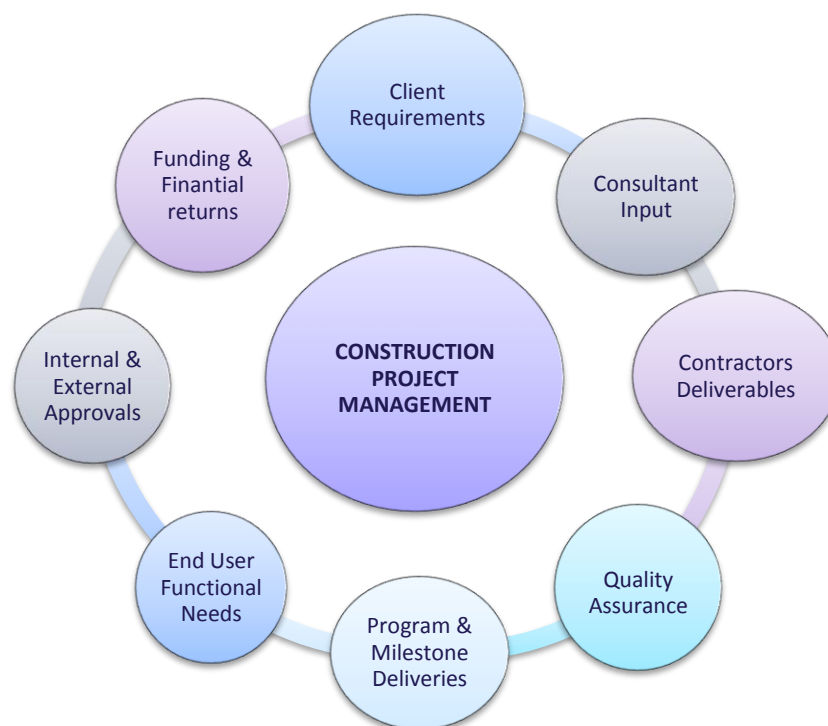


Figure 3.4 Construction project management considerations (Source: Own)

3.2.1 LEAN CONSTRUCTION

LEAN construction is a broad concept that targets the entire building process. Born in manufacturing, the goals demand a new way to coordinate action, one that is applicable to industries far removed from manufacturing. The main ideas behind LEAN thinking are defined by: stopping the line, pulling product forward, one-piece flow, synchronize and align, and transparency (G. Howell, 1998).

LEAN construction approach has been defined as *“the continuous process of eliminating waste, meeting or exceeding all customer requirements, focusing on the entire value stream, and pursuing perfection in the execution of the constructed product”* (L. H. Forbes, 2010). This approach intends to manage and improve the construction process reducing costs and maximizing the value of the building by considering the customer needs and aims.

With the challenges experimented by the building industry, such as an increasing interest on the implementation of sustainability, the conventional working methods should be supplemented for a more holistic approach, as an integrated design process. Due to that, LEAN construction is a good asset for the enhancement of the construction process. The key concepts that constitute LEAN construction are the following: six-sigma, which are the techniques and practices to improve the quality of the output, health and safety within the construction work, maximum value and minimum waste, and environmental management (Figure 3.5).

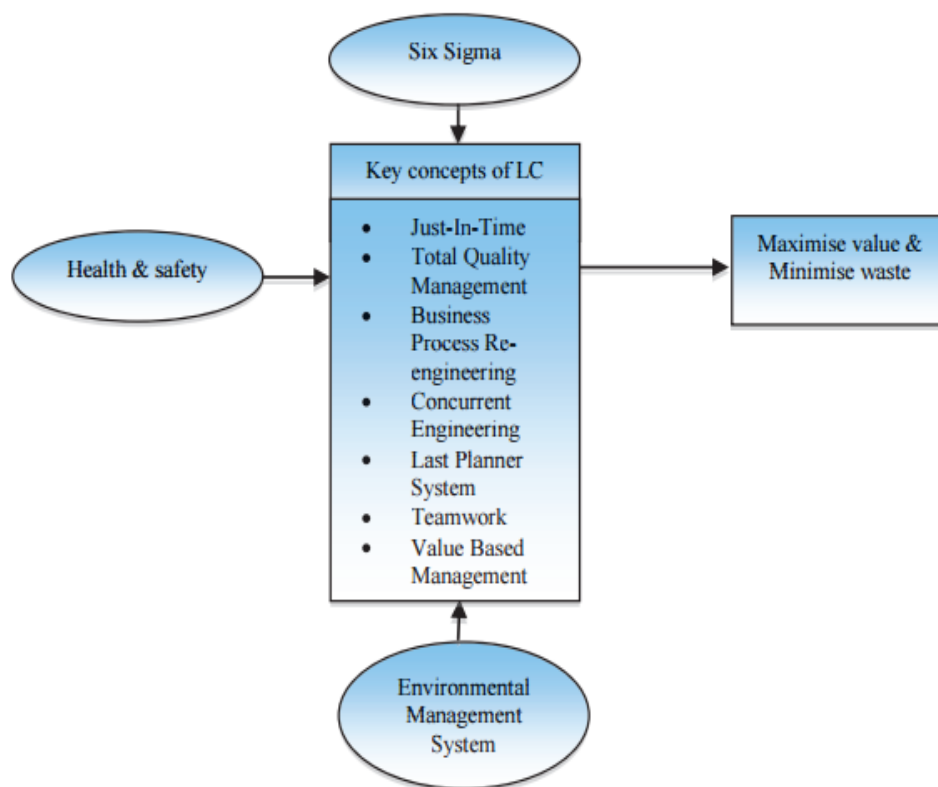


Figure 3.5 Key concepts of LEAN construction. Source: (O. Ogunbiyi, 2004)

LEAN construction affect the three aspects of sustainable construction: environmental, social and economic. Waste reduction, health and safety enhancement at the construction site and the reduction of the environmental impact of the building, enhances the productivity and process flow and generates value. However, the most used LEAN techniques for enabling sustainability are Just-In-Time tool (JIT tool), increased visualization tool, value analysis, daily meetings and value stream mapping (O. Ogunbiyi, 2004).

The implementation of work flow visualization tools provides process product and method visualization, which benefits the planning and management of the construction process of a building minimizing waste and work time (Aziz, 2013). Last Planner System is a planning system which has the intent of improve the construction process while increasing the cooperation between the craftsmen ((Patel, 2011)). By an active involvement of the craftsmen in the planning, management and organization of the building project execution, there reliability and flow of the planning are improved, because of better overview and coordination between the subjects. Also, last Planner System divides the planning of the construction process into three levels: process plan, period plan, and weekly plan (Ballard, 2000).

Last Planner system can be considered as one of the most important parts of LEAN construction. Also, it is one of the most successful principles to put in practice, where subcontractors get a large ownership plan, and it is seen more as an agreement than an order, making them bind together (collaboration and cooperation between the subcontractors) (Zettel, 2013). It also enhances the cooperation, helping to plan together, creating a better work environment.

Just-In Time tool (JIT) is intended to improve the production process through an efficient handling of the construction materials, with the control of materials provision, in the right quality, quantity and moment. The main idea is to reduce waste from over-production, delays, transportation, unnecessary processing, excess inventory, unnecessary motion and defects (G. Howell, 1998).

Moreover, Value Stream Mapping (VMS) purpose is to observe every step of the construction process and identify ideas where improvements can be made to try to eliminate waste generation. The main idea behind VSM is to enable the implementation of LEAN principles using flow diagram that documents in high detail every step of the construction process (Aziz, 2013).

Finally, the use of daily huddle meetings promotes the involvement of the employees. Through a brief daily start-up meeting conducted at the construction site, the building industry professionals

give the status of their work and what they had been working with the day before. This method ensures a fast response in case of the appearance of problems (O. Salem, 2005)

Figure 3.6 presents the LEAN principles with examples of LEAN tools application and suggestions for a wider integration of the tools.

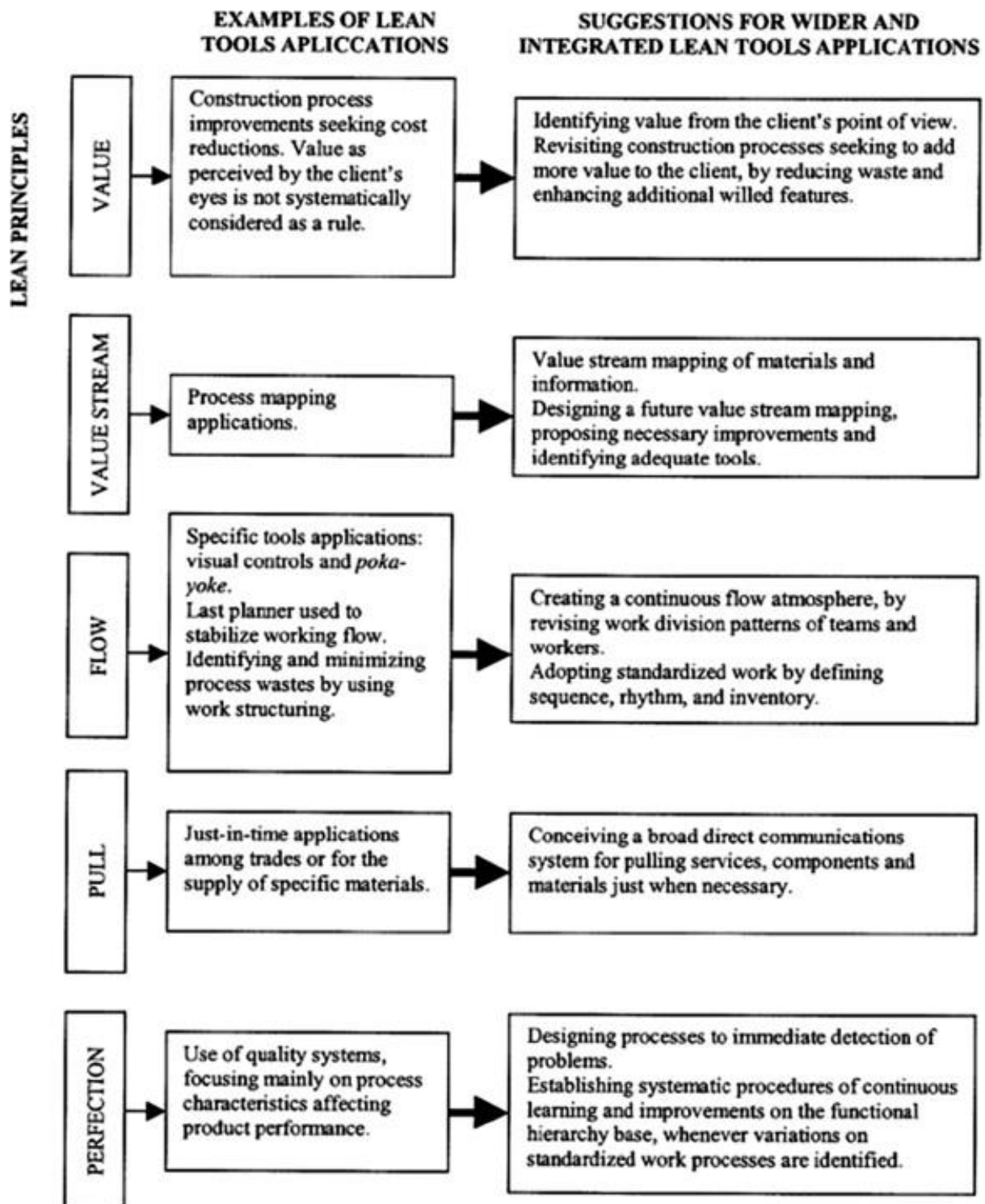


Figure 3.6 Examples of LEAN tools in construction implementation and suggestion (Granja, 2004)

4. CASE STUDY

Through the following paragraphs, the case study selected for the investigation is presented, establishing the reasons why it is chosen. Furthermore, the buildings contained in the project portfolio are presented and described, so the reader can have an overview of the characteristics and singularities of the buildings, followed by the building owner's requirements and the main issues and accomplishments of the project portfolio.

4.1 CHOICE OF PROJECT

For the investigation included in this report, it becomes necessary to analyse buildings that have achieved a sustainability certification, due to the integrative working methods and strategies applied, that differ from the conventional linear work flow usually applied in very traditional building sector. Sustainability certifications, like DGNB, assess, among other parameters, the quality of the building process through the evaluation of the planning and management aspects of the project, rating the level of detail and quality of the building documentation, which allows a better maintenance, operation and functionality of the construction.

To perform a reliable and accurate investigation, the case study used for this master thesis report is a project compound by four DGNB certified buildings, which have been build following different time lines and where various main contractors have overseen each building project. The four buildings are owned by Region North Jutland, which intended to create an attractive and healthy working environment, from which healthcare professionals and users could benefit.

Moreover, the healthcare projects represent the first DGNB certified buildings in northern Denmark, and are among the first sustainability certified buildings in the whole country. This situation provides a unique opportunity for the study of the issues and challenges faced during the execution process, which arise due to the recent adjustment of the German DGNB certification to the Danish building industry laws and regulations.

Additionally, the background and knowledge of the diverse design and construction teams involved in the projects provides the opportunity to evaluate the influence of the company's culture on the final building quality, investigating the working methods and the outcome achieved for each building. Also, as referred in previous paragraphs, the buildings are built following several timelines, which provides an overview of the improvements achieved along the projects and the influence of the experience of the professionals on the result accomplished.

Finally, the projects have as an asset the similarities on the design and distribution of the buildings, which as well follow the same requirements from the client, providing a good foundation for the comparison and verification of the findings.

4.2 PROJECT BACKGROUND

In 2008, Region North Jutland signed an agreement with The Danish Society of Nature Conservation to become a Climate Region, and therefore, it has been strongly utilising the position to pro-actively pursue action within the climate protection. North Jutland became the first Climate Region of Denmark, where nowadays, 68 out of 98 Danish municipalities have concluded, as well, into an agreement with The Danish Society of Nature Conservation, being one of the requirements to reduce the CO₂ emissions by a minimum of 2% per year.

Later, in 2010, Region North Jutland came to an agreement with several municipalities to establish healthcare facilities in peripheral areas of the Danish northern region. The applicants were supported by PLO-North Jutland (*Praktiserende Lægers Organisation*) and the health professionals involved in the respective municipalities: Thisted, Pandrup, Frederikshavn and Brønderslev (See red marks in *Figure 4.1*).

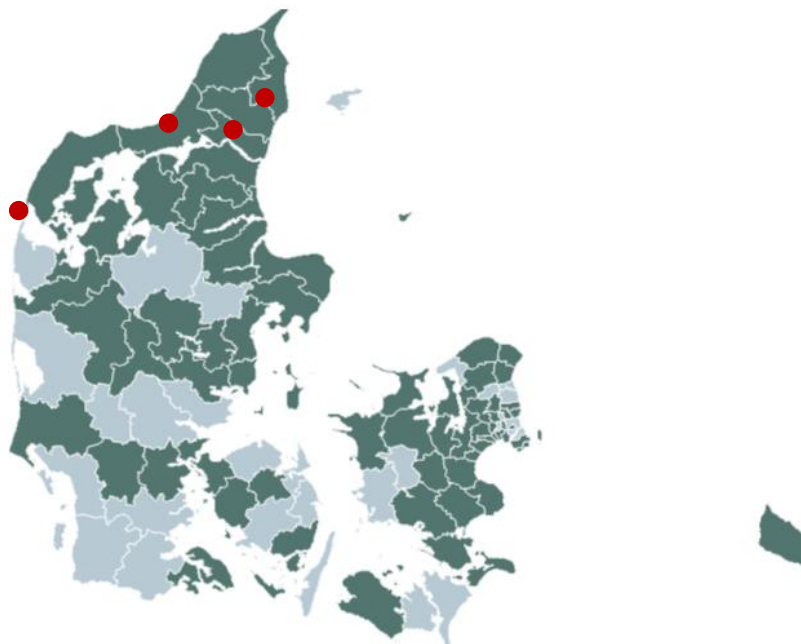


Figure 4.1 Danish Climate municipalities and healthcare centres location (DN, 2017)

There is a strong emphasis on the implementation of sustainability principles through several phases of the project. Region North Jutland wants to establish as a requirement climate labelling for the

healthcare buildings. This is important for the Region, as the country's first Climate Region, considering climate and sustainability from the start of the building projects.

Between the years 2012 and 2015, and following different time lines, the four building projects were designed, planned and constructed. The four new buildings that host healthcare facilities present diverse sizes and capacity, but bring the same content and objectives. Moreover, the projects turned out to be a complete success, even reaching completion before the programmed hand in.

The main purpose of the projects was to attract healthcare professionals towards outlying areas of northern Jutland, where the access to hospitals and certain healthcare treatments imply to travel to bigger urban areas. The four medical centres represent an essential element for the recruitment and retention plan of general practitioner (GP) in Region North Jutland.

It is important to mention that these projects have the final goal to enhance the cooperation between different fields of the healthcare sector, contributing to create strong professional environments, improving the communication, and reinforcing the quality of performance. Furthermore, the aim is to promote investigation and research work developed between professionals and the opportunity to bring closer access to special medical facilities for the locals, which represent a great development for the region.

Table 4.1 below presents the requirements established for the fulfilment of BR10 and BC 2020.

PARAMETER	BR 2010	BC 2020
Energy frame (non-residential) (kWh/m²/year)	71.3 + (1650/A)	20
Max. air leakage/second (test pressure 50 Pa)	1.5 l/m ²	0.5 l/m ²
Max. design transmission loss, single storey	5 W/m ²	3.5 l/m ²
Min. energy gain through windows/glazed walls	-33 kWh/ m ² year	0 kWh/ m ² year

Table 4.1 Energy requirements Building Regulations 2010 and Building Class 2020

Moreover, to reduce the environmental impact of the buildings and promote sustainability, the building owner aimed for the implementation of the recently adopted DGNB -DK sustainability certification. The minimum requirement established was the achievement of a total performance index of at least 65%, and a minimum performance index of at least 50%, granted at that point with silver award – since 1st July 2015, projects previously awarded with silver certification now receive a gold certificate.

4.2.1 PANDRUP SUNDHEDSHUS

Pandrup healthcare centre is placed in Bredgade 120, 9490, Pandrup. Constructed between 20 September 2012 and 23 September 2013 when it was put in operation. With a budget of 15.37 million Danish coronas, is the second completed building from the project portfolio. With a total floor area of approximately 1850 m², distributed in two floors, it hosts Nordic Medicare clinic, equipped to host 7 to 9 general practitioners (*Figure 4.2, Appendix A and Appendix B*).



Figure 4.2 Pandrup healthcare centre (Region North Jutland, 2014)

Several professionals took part in the design and execution processes of the building, as seen in *Table 4.2* below.

FIGURE	INSTITUTION/COMPANY
Building owner	Region North Jutland
Client's advisors	Arkinord A/S, Orbicon A/S, Roseel's Tegnestue ApS & Rambøll A/S
Main contractor	Lund & Staun A/S
Subcontractors	Mariendal Electrics A/S, Ventek Ventilation A/S, Buus & Co, Erling Jensen A/S, STS Støvring A/S, Vokslev Smede & Maskinværksted A/S

Table 4.2 Parties involved in Pandrup healthcare centre project

As stated in the project requirements, Pandrup healthcare centre achieved the silver DGNB certificate with a score of 76.8%. Even though it represents the first DGNB certified building from the four projects, it obtained the highest score due to the good planning and management applied through the building process.

Before the construction works started, there were several archaeological findings on the site. After the excavations performed by North Jutland Historical Museum, among other things, there were discovered archaeological remains of a farm from the Middle Ages. Even though this situation could have a negative impact on the construction process, i.e. time and work related issues, there was a

great coordination and communication between Region North Jutland and North Jutland Historical Museum. In fact, it was established an exhibition inside and outside the healthcare facilities open to the public.



Figure 4.3 Archaeological remains exposed at Pandrup Sundhedshus. Source: (NJHM)

4.2.2 HURUP SUNDHEDSHUS

Hurup healthcare centre is placed in Indrætsvej 5a, 7760 Hurup Thy (*Figure 4.4* Appendix A and Appendix B). The building construction works took place between the 8th January 2013 and 2nd September 2013, being finished before Pandrup healthcare centre. With a budget of 15.37 million Danish coronas provided by the Minister of Health, Region North Jutland and Thisted municipality.



Figure 4.4 Hurup healthcare centre (Region North Jutland, 2014)

The healthcare facilities located in Hurup have a gross area of approximately 1850 m², hosting Falck medical centre. There are 20 consulting rooms in the building, as well as changing facilities, waiting areas, canteen and meeting room. Also, the garden is provided with outdoor fitness equipment that can be used by the locals.

As in the other healthcare buildings, several stakeholders took part in the overall building process, maintaining a close communication and collaboration. *Table 4.3* presents the parties involved in Hurup project.

FIGURE	INSTITUTION/COMPANY
Building owner	Region North Jutland
Client's advisors	Christensen & Rottbøl A/S & Grøntmij A/S
Main contractor	MT Højgaars A/S
Subcontractors	Lindpro A/S, Miko Gulve A/S, Fjelsø Byg A/S, Thyholm Murer A/S, Børge Hansen VVS A/S, Nordjysk Tag ApS, EXPAN A/S, ELCON Thisted ApS, Tømrer-nes Byggeselskab A/S, Herning Kleinsmedie Aps

Table 4.3 Parties involved in Hurup healthcare centre project

During the construction phase of the building, the main contractor took emphasis on the completion of the project following the tight budget, trying to maintain the quality of the building. Moreover, the main contractor used TrimBuild concept, with the purpose of creating an efficient building management process. The idea behind it is to reduce waste, promote efficiency and increase the value of the construction.

Furthermore, as the client requirements state, Hurup healthcare centre was awarded with the silver DGNB certification, obtaining a total score of 73.2%, and fulfils the requirements for energy reduction and efficiency stated at Building Class 2020.

4.2.3 SÆBY SUNDHEDSHUS

Sæby healthcare centre was the third building taken to completion. Located at Sæbygårdvej 31, 9300 Sæby, it was constructed between August 2013 and September 2014 (Figure 4.5, Appendix A and Appendix B). This healthcare facility has a gross area of approximately 2800 m² distributed in two floors and divided in two departments, one end for health facilities (owned by Frederikshavn municipality) and the other which is used for rehabilitation (owned by Region North Jutland).



Figure 4.5 Sæby healthcare centre (Region North Jutland, 2014)

The building hosts a training hall, occupational therapy, swimming pool, study rooms, shower and changing rooms, wheelchair accessible indoor facilities and a free entrance outdoor training area, as shown in *Figure 4.6*. The building is functioning as a health, training and rehabilitation centre where 7 physiotherapists, 3 occupational therapists and 1 social and health assistant work.



Figure 4.6 Reception and training facilities at Sæby healthcare centre. Source: KPF architects

In this project, five contractors were called for tender bid, being selected HP Byg as the main contractor in charge of the management of the construction phase. *Table 4.4* shows the parties involved in the design and construction of the healthcare building.

FIGURE	INSTITUTION/COMPANY
Building owner	Region North Jutland & Frederikshavn municipality
Total advisor	Bascon A/S
Main contractor	HP Byg A/S
Architect	Arkitema Arkitekter A/S & KPF Arkitekter A/S
Engineer	Cowi A/S & Cenergia Energy Consult A/S
Subcontractors	Strandby El-teknik A/S, Møller Christensen A/S, Ousen Entreprenør, Nordjysk tag A/S, Nordjysk gulvecen-ter A/S, KBL Metalbyg ApS, Schildler A/S, Uno Koncept A/S, Colas A/S

Table 4.4 Parties involved in Sæby healthcare centre project

Sæby healthcare centre reached a final score of 76.4% on the DGNB certification, which provided it with a silver award. Among the several sustainable and environmental friendly strategies applied for the design of the building it is the use of recycle bricks for the external façade of the ground floor level. Also, as the other four buildings, it fulfils the requirements established for the strict low-energy Building Class 2020.

4.2.4 BRØNDERSLEV SUNDHEDSHUS

The last project is Brønderslev healthcare centre. Placed at Tolstrupvej 91, 9700 Brønderslev, it is the biggest building project from the building portfolio (*Figure 4.7*, Appendix A and Appendix B). The construction has a gross floor area of approximately 5060 m² divided in two floor levels.



Figure 4.7 Brønderslev healthcare centre (Region North Jutland, 2014)

The building hosts several clinics, nursing functions and staff facilities, including reception, coffee shop and roof terrace for the staff, as seen in *Figure 4.8*. The project, with a budget of 81 million Danish coronas, started the construction works on October 2013 and handed in in March 2014, ahead of schedule.

Following the client aims, the building achieved DGNB silver certification, with a final score of 76.7%, and fulfils the requirements established in the Building Regulations for Building Class 2020.



Figure 4.8 Indoor facilities Brønderslev healthcare centre. Source: C.F. Møller & KPFF Arkitekter

Brønderslev healthcare centre share the same main contractor with Sæby healthcare centre, which helped the professionals to gain experience with a similar project and improve the process to avoid previous issues. *Table 4.5* shows the companies involved in the design and execution process of the healthcare project

FIGURE	INSTITUTION/COMPANY
Building owner	Region North Jutland & Brønderslev municipality
Total advisor	
Main contractor	HP Byg A/S
Architect	C.F. Møller & KPF Arkitekter A/S
Engineer	Cowi A/S & Cenergia Energy Consult A/S
Subcontractors	Strandby El-teknik A/S, Møller Christensen A/S, Hirtshals Entreprenørforretning A/S, Vegtech A/S, Nordjysk tag A/S, Fisher Danmark A/S, Uno Koncept A/S, Schildler A/S, Colas A/S

Table 4.5 Parties involved in Brønderslev healthcare centre project. Source: Region North Jutland

4.3 DOCUMENTATION ANALYSIS

This subsection presents the findings from the document analysis performed to get a more accurate approach to the execution process of the four healthcare centres. The document analysis is based on the documentation provided for the sustainability assessment of the four healthcare centres and the minutes from the meetings between the parties. The idea is to investigate the teams involved in the four projects, the role of each professional and the process quality aspects for each building.

4.3.1 TEAMS DISTRIBUTION

As part of the same building portfolio, the four building share the same project owner Region North Jutland. Due to the ambitious requirements established by the building owner, the level of monitoring and quality control of the projects increases, in comparison with conventional construction methods. In this situation, the implementation of sustainability certifications and assessment tools becomes beneficial for the stakeholders, ensuring the implementation and compliance of the project requirements until building completion, reducing, therefore, extra investments due to inaccurate time planning or mistakes during building execution.

Through the building project process, several teams of professionals took part in the design and construction stages of the four buildings. At the design phase, four different teams of professionals oversee the goals and objectives set up, as well as outline proposal design. Later, during the construction phase, another three teams take full responsibility.

In the case of the last two project completed, Sæby and Brønderslev, the same team is on charge of the construction phase. This situation, gives the opportunity to analyse and compare the working methodology applied and the improvements of the working strategies from one project to another, together with their perception of the documentation provided for both projects during tender phase.

PHASE/BUILDING	PANDRUP	HURUP	SÆBY	BRØNDERSLEV
DESIGN	Team 1	Team 2	Team 3	Team 4
CONSTRUCTION	Team A	Team B	Team C	Team C

Table 4.6 Design and construction teams of the four projects

The projects different time lines might have influenced the level of understanding and experience of the professionals on sustainability and sustainability certification. Team A, in charge of the execution of Pandrup healthcare centre, has been led by a main contractor with no experience regarding sustainable construction. This fact could have influence the outcome of the building and the evolution of the construction process.

During the building project, several stakeholders take part along the concept design and development, tender phase and execution process. At design phase, the design team is composed by the building owner and his advisors, architects and engineers from diverse fields, in charge of the development of the building's outline proposal, together with the initial studies, such as energy and indoor climate calculations, in accordance with the project requirements and goals. Through the design phase, the number of professionals involved is limited, and they keep a close communication and cooperation with the client, providing control over the work management and progress of the accomplishment of the key ideas that define the building projects.

Together with the tender phase, new professionals take part of the design finalization and the construction process. At this point, a main contractor is selected to take over the position of project manager through a turnkey contract. The main contractor takes full responsibility of the project until is completed and handed in to the building owner. An integrated design team (IDT) works side by side with the main contractor, providing support for the sustainability assessment and to warrantee that the building design fits the prerequisites for comfort and safety of the occupants, and at the same time, fulfils the requirements for sustainability certification.

Additionally, the main contractor is responsible for the management of the subcontractors involved in the construction works, maintaining them informed of the project requirements and their duties, which contributed for an improved construction process. At this stage, due to the increase of the number of professionals involved, it is crucial to maintain a good communication and

cooperation, exchanging ideas and being fully informed and involved in the process to avoid misunderstandings that could lead to waste of time or money.

Finally, since the goal is to obtain an energy efficient and environmental friendly building, there must be a good guidance from sustainability auditors and consultants involved in each project. In most cases, the companies involved in the four buildings have very few or non-experience with sustainability certification, and with the high commitment and implication required. These situations make necessary to give a great support for the understanding of the certification criteria and how and why they need to be fulfilled.

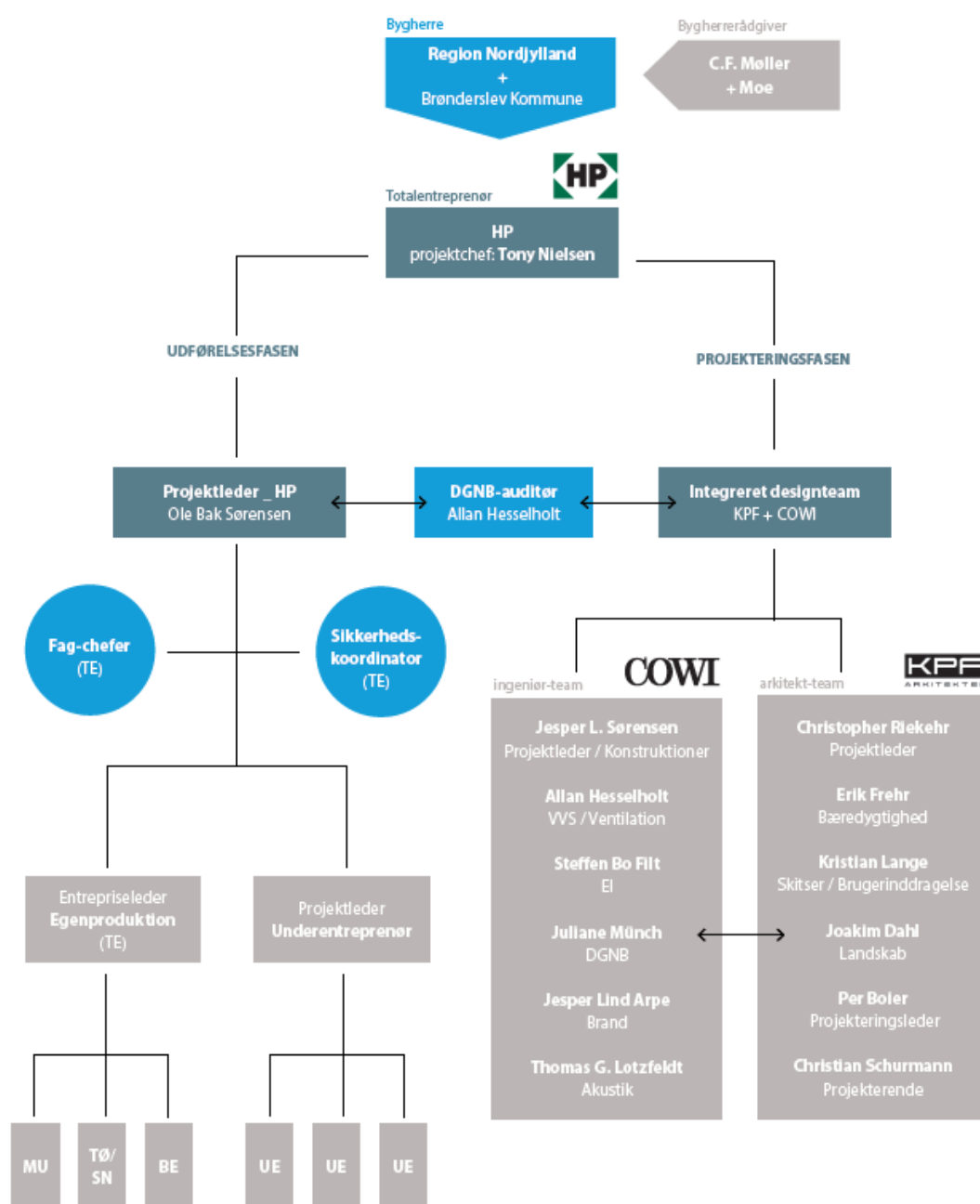


Figure 4.9 Example of organization diagram (Region North Jutland, 2013)

4.3.2 MAIN CONTRACTOR RESPONSIBILITIES

In accordance with the client aims and goals for the projects, there are several requirements for the main contractor which are listed in the tender materials provided to the bidders. The requirements are the following:

TOPIC	DESCRIPTION
RESPONSIBILITY	Execution of construction
	Execution of meetings together with building owner and advisors
	Oversee authority design and planning applications
	Gathering of any additional approvals
	Additional geotechnical studies
	Statement of environmental aspects in the project execution
	Construction management and supervision
	Quality assurance
	Services connection
	Health and safety coordination
	Registration of the project at DGNB-DK
DOCUMENTATION	Main project documentation should be used as a base for construction related work
	Quality assurance documentation
	Sustainability assessment documentation
	Operation and maintenance instructions
COSTS	Waste deposit and disposal, and cleaning of the space and roads
	Collection fees and contributions
	All weather measurements and drying costs
	DGNB registration costs
	DGNB auditor and external evaluation
PLANNING	In accordance with tender material requirements
	Extended weather and conservatory measures
	Sustainability calculations and analysis

Table 4.7 Main contractor responsibilities stated on the call for tender

4.3.3 SUSTAINABILITY ASSESSMENT

The four healthcare buildings are assessed in accordance with the DGNB sustainability scheme “*New Office and Administrative buildings*”, which is the first schema adapted to the Danish building sector. The scheme was released on 2012 by the Green Building Council Denmark (GBC-DK), and it is intended to assess buildings to be mainly used as offices and for administrative purposes. The scheme, besides considering environmental and economic aspects, focuses on the assessment of the user comfort, such as noise, temperature and appearance, affecting the performance and motivation of the workers.

The process quality contains various criteria and sub criteria regarding planning and construction aspects. The several criteria present different weighting values, providing higher relevance to the quality of project preparation, where the goals and objectives of the project are integrated from the first stages. **Error! Reference source not found.** and Table 4.8 below present the process quality criteria.

GROUP	CRITERIA
PLANNING PROCESS	(43) Quality of project preparation
	(44) Integrated planning
	(45) Optimization and complexity of planning method
	(46) Sustainability aspects in tender phase
	(47) Creation for conditions for optimal use and management
	(48) Environmental impact of construction site
	(49) Quality of the companies involved
CONSTRUCTION PROCESS	(50) Quality assurance for reconstruction
	(51) Commissioning

Table 4.8 Construction process criteria

Even if the sustainability certification is voluntary, some of the criteria follow Danish standards and regulations. On the other hand, some criteria go beyond compliance, to guarantee a long-term quality of the building. Specially criteria no. 43, 44, 45 and 47, which focus on the Life Cycle impacts. The certification needs further improvements on issues regarding more efficient flow of information, dynamic stakeholder communication strategies, a stronger involvement of executing companies onto the process from the start, and rethinking the accuracy of criteria 50, focused on the project commissioning.

Depending on the level of team's ownership to the project, it can occur a "hunting point" strategy instead of discussing what makes the most holistic sustainable building of high quality. Hopefully, the certification scheme is put together so most the projects will be holistic despite the potential "point hunting".

4.4 INTERVIEWS

This subsection presents the findings from the interviews performed to get a more accurate approach to the construction process of the four healthcare centres. Several professionals involved in the four project took part in the interviews, sharing their knowledge and experience about the sustainable assessment of the construction process and the work dynamic. The professionals chosen for the

interviews have been involved in the tender preparation, construction project management and DGNB consultancy and assessment.

TOPIC	FINDINGS	DESCRIPTION
PROFESSIONALS EXPERIENCE	<ul style="list-style-type: none"> Working culture of the subcontractors 	Use of conventional construction methods by the subcontractors and their lack of experience with sustainability certification
	<ul style="list-style-type: none"> Inexperience of the project main contractor with sustainability 	Necessary support from the DGNB auditor to provide information from the requirements of the project
PROJECT DOCUMENTATION	<ul style="list-style-type: none"> Tender invitation 	Need for implementation of information about the sustainability certification of the project in the tender invitation
	<ul style="list-style-type: none"> Construction materials 	High level of documentation about the materials installed in the building
	<ul style="list-style-type: none"> Commissioning 	Problems collecting the information about the materials and systems from the subcontractors
	<ul style="list-style-type: none"> Sustainability assessment documentation 	Need for a person appointed by the main contractor in charge of the collection of the required documentation for the sustainability assessment
COMMUNICATION	<ul style="list-style-type: none"> Follow up meetings 	Need for the implementation of follow up meetings with the DGNB auditor to get information about the performance of the sustainable assessment
	<ul style="list-style-type: none"> On site meetings 	Implementation of site meetings once or twice a day to keep track of the working process and possible issues
	<ul style="list-style-type: none"> Meetings with the client 	At least once a month there should be a meeting with the client to analyse the state of the project
	<ul style="list-style-type: none"> Meetings with subcontractors 	Every two weeks there should be schedule a meeting with the subcontractors to analyse the status of the working process
ORGANIZATION AND PLANNING	<ul style="list-style-type: none"> Implementation of support tools 	Use of LEAN construction principles within a sustainable project gives the chance to ensure the high quality of the building and enhance the organization and planning
	<ul style="list-style-type: none"> Monitoring sustainability goals 	Need for increased awareness of the performance of the analysis of the energy and comfort of the building through the construction phase

Table 4.9 Findings from the interviews

5. ANALYSIS OF THE FINDINGS

This section presents the analysis of the findings from the quantitative research, interviews, and the document analysis of the case study. The issues faced during the planning and management of the construction phase of the four-sustainable building projects are described and studied. At the end of the section it is presented a master list of findings, where the discoveries are summarized.

5.1 PROFESSIONALS BACKGROUND

5.1.1 COMPANIES CULTURE

The company's culture is defined as the values, practices and beliefs shared by the company's employees (Reh, 2016). From the case study, the companies' culture and working methodology involved in each project must be analysed separately. As described in Chapter 4.3.1, several teams took part on the construction phase of the four healthcare centres. The teams were composed by the main contractor, sub consultants and subcontractors in charge of the advice and execution of the project construction work.

One of the main points to take into consideration when analysing the culture of the companies involved in the four healthcare centre projects is the location of the buildings. The intention of the buildings' owner is to promote the engagement of local companies on the construction of the four buildings, on an attempt to promote the integration of sustainability in the new building projects owned by Region North Jutland.

The strict requirements of DGNB certification promote the use of local resources, such as construction materials, increasing the documentation demand from the providers to ensure a health and safe environment for the users and workers. The high documentation demand entered in conflict with the conventional working methods applied by the subcontractors and with their lack of experience with the sustainability assessment of buildings.

The role of the main contractor becomes more complex with the implementation of sustainability in the building industry. In charge of the project management, the main contractor takes over the project for its execution and hand it in to the building owner after completion. In this situation, the company's culture has a significant impact when it comes to the delimitation of the responsibilities that each subcontractor has for the achievement of the sustainability certification. For that reason, DGNB sustainability assessment scheme takes into consideration the analysis and evaluation of the companies' sustainability qualification, from main contractor to subcontractors.

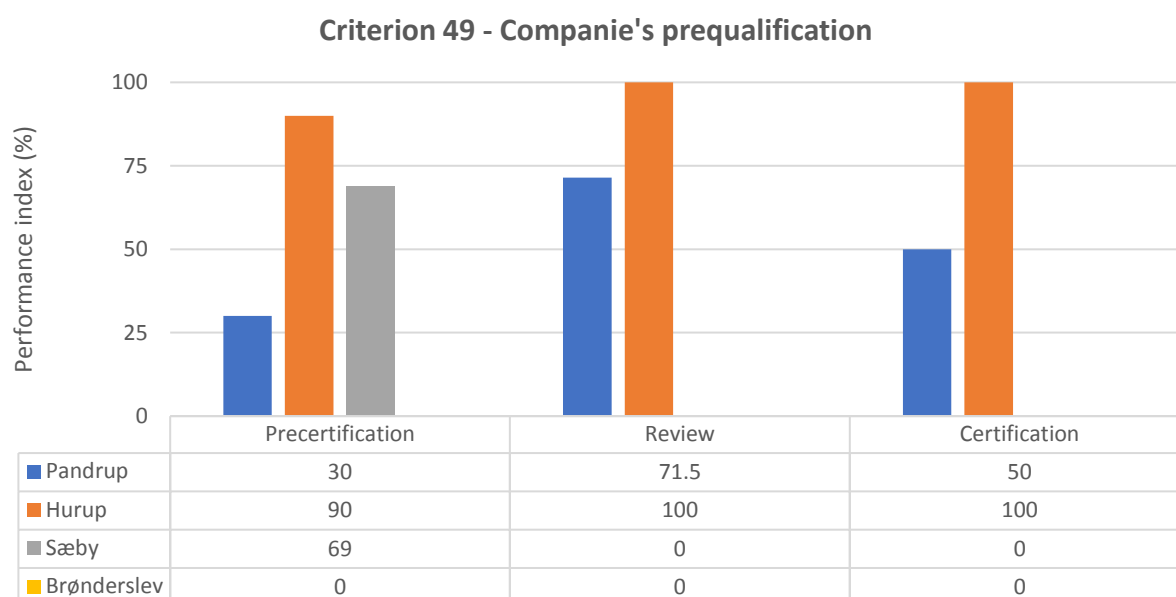
The contractors' pre-qualification is evaluated through the fulfilment of the following Danish and international certifications and requirements:

CERTIFICATION	NAME	DESCRIPTION
ISO 14001	Environmental management system	Through this certification, the companies can prove that they are fully aware of their environmental obligations and the reduction of their environmental impact.
OHSAS 18001	Occupational Health and Safety	To achieve this certification, a company must have a health and safety management system following the requirements of OHSAS 18001 Standard.
BEC	The Benchmark for the Danish Construction Sector	BEC is a business foundation with the purpose of promote quality and efficiency in the construction sector. The companies involved in the four projects must have achieved quality group B at BEC system, which corresponds to projects delivered with typical defects
ISO 9001	Quality Management	To achieve ISO 9001, a company must implement Quality Management System requirements in the following areas: <ul style="list-style-type: none"> - Facilities - People - Training - Services - Equipment
DWEA	Danish Working Environmental Authority	The companies must have obtained a Green Smiley from the Working Environment Authority, which indicates that the companies have no issues in terms of health and safety.
Other		Documentation of participation in a sustainability certified project.

Table 5.1 certifications of pre-qualification from DGNB assessment scheme

Criterion 49, from the DGNB scheme for new office and administrative buildings (2012), evaluates and rates the quality of the contractors and subcontractors. Depending on the level of qualification, the criteria will be awarded with different score, from 0 to 10 evaluation points. To obtain a score, it is necessary that the companies provide justified and documented information that proofs the expertise, reliability and productivity of the firms.

As presented in *Graph 5.1* below, the documentation analysis shows a generally low pre-qualification of the companies involved in the four-sustainable building projects. Just two of the projects have justified the pre-qualification of the contractors and subcontractors,



Graph 5.1 Criterion 49 performance index analysis

Pandrup healthcare centre had fulfil partially the requirements for pre-qualification, in which only the main contractor, Lund og Staun, was evaluated. The information provided about the main contractor shows that the company has achieved BKNi certification, a system that equals to The Benchmark for Danish Construction Sector (BEC). The idea behind Bülow Management, is to evaluate several indicators after the construction phase of a project, to provide information about the work on the site and the companies who have executed a building.

Furthermore, Pandrup's main contractor fulfils another requirement from the pre-qualification. Even though the company did not achieve the project execution, Lund & Staun took part on the pre-certification and call for tender at Hurup healthcare centre, which together with Bülow Management certification, gave the final score of 3 evaluation points.

On the other hand, the main contractor involved in Hurup healthcare centre execution obtain the highest score. The main contractor, MT Højgaard is certified with DS/EN ISO 9001:2008, DS/OHSAS 18001:2008, Bülow Management, and has provided documentation about previous experience as main contractor for KPMG's new office building, which achieved as well as Hurup healthcare centre, a silver award at DGNB certification.

Finally, Sæby and Brønderslev projects share the same main contractor, which at the time did not justify the fulfilment of the minimal requirements from certifications or previous experience stated at DGNB scheme, even though, at Brønderslev project, HP Byg presented BEC rating documentation, not being enough to achieve any score of the criterion.

5.1.2 TEAMS EXPERIENCE

The professionals experience may cause impacts on the construction process of a sustainable building. Due to the complexity of a sustainable building project, the professionals must make clear their tasks and expectations, to provide value to the project and reduce the possibility of interferences in the achievement of the project objectives and requirements.

In all the projects appears the figure of the main contractor, which takes full responsibility for the construction phase of the project. This can represent a hard task when the professionals have no background working with sustainability, due to the increased number of professionals involved in this stage of the project, and because of the complexity of sustainability, which contains very abstract parameters.

From the previous section, it has been proven that not all the main contractors had some previous experience with sustainable building projects. Also, through the interviews, it has been found out that for most of the professionals, the four-health centres were the first experience with the new DGNB certification at the time:

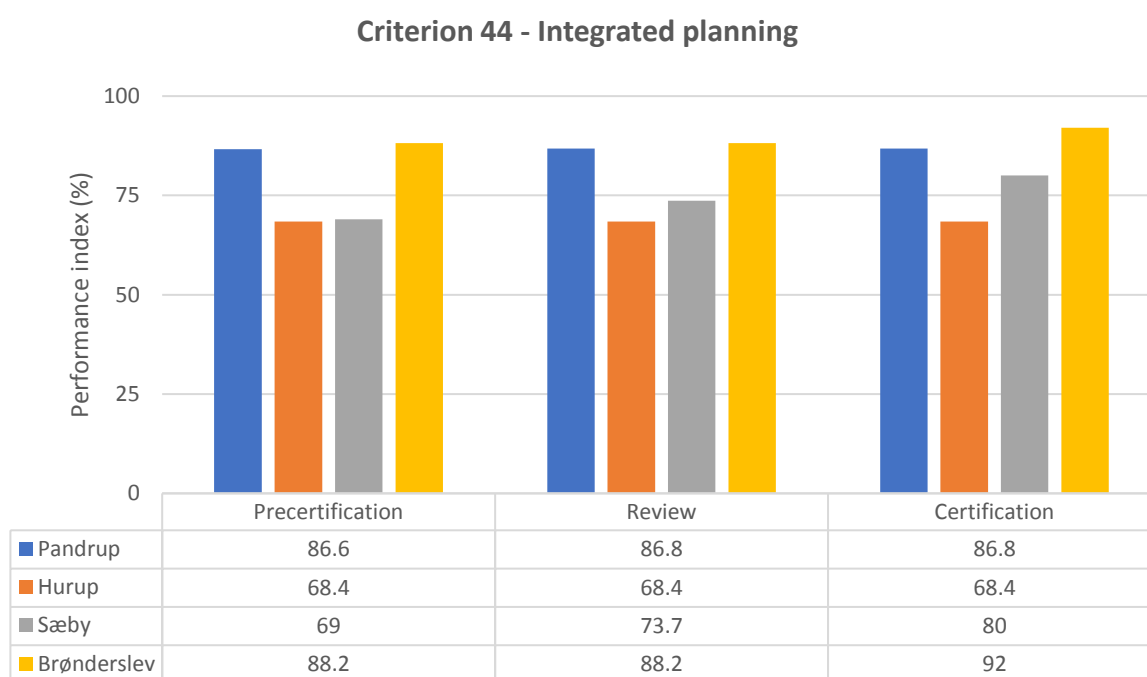
“Pandrup project was the first time that we worked in the company with DGNB, it was completely new for us ... We worked together with the engineers of Rambøll, because they have their own DGNB auditor who guided us through the tender phase” (Lund & Staun A/S)

Even though the main contractor had no previous experience with DGNB sustainability certification, the integrated design team, composed by sub consultants, provided support and guidance for the integration of the sustainability considerations already from the start of the construction phase. Additionally, the DGNB auditor has the task to inform of the sustainability requirements of the project.

“Even though, as a public developer we still set the demand for the achievement of DGNB for all our new projects, some professionals think that it does not concern them. The main contractors just use consultants who bring them the necessary knowledge about sustainability certification. But, from my point of view, I find that the best team is the one that has experienced interdisciplinary professionals who share their knowledge between each other, so the whole team brings a lot of knowledge to the project.” (Anne Hedegaard, Region North Jutland)

Criteria 44 analyses the integrated design team quality, to improve the coordination among the parties involved, aiming to ensure an optimal planning process and high quality of the building in all life cycle phases. In this subsection, the focus is on the qualification of the team members, which is evaluated through the qualification of the integrated design team process quality sub criteria.

Reviewing the sustainability assessment documentation, it is visible that in all the projects, the integrated design team includes at least 75% of the professionals with at least two previous experiences with sustainable building projects or an integrated design process. This situation benefits the construction process of the four buildings, providing the projects with interdisciplinary planning team that worked with the building owner to develop a high-quality planning that enhanced the quality of the projects and the health and comfort of the users.



Graph 5.2 Criterion 44 performance index analysis

Even if Pandrup healthcare building was one of the first buildings taken to completion, the integrated design team had the enough experience and knowledge to integrate the sustainability considerations from the very beginning of the construction phase of the project, providing the main contractor the support and guidance necessary to obtain a high-quality edification.

On the other hand, Hurup healthcare centre suffered complications during the design phase. The architect firm working as client's advisor had no previous experience with DGNB certification or with the integrated design process, complicating the implementation of all the sustainability criteria on the design of the building.

Sæby and Brønderslev projects share the same main contractor and integrated design team in charge of the execution process. This situation gave the opportunity to enhance the work on the last project, Brønderslev, based on the issues and mistakes faced on the first healthcare project.

5.2 PROJECT DOCUMENTATION

5.2.1 CALL FOR TENDER

After the design development and the drawings were ready for the execution of the four healthcare centre projects, it was hold the tender phase, consisting on a close bid where several contractors were invited. Through the restricted calls for tender, Region North Jutland opened the offer on only for selected prequalified contractors. The tenders for the buildings were hold in two separated groups, Pandrup and Hurup, and Sæby and Brønderslev together.

After receiving all the bids for the projects, the owner proceeded to the selection of the main contractor through Best value selection method. This evaluation method puts weight on both contractor qualification and price of the offer, basing the selection in terms of quality and money.

“At the beginning the idea was to hold the tender of the four buildings ate the same time, but due to delays on some of the projects, we divided the projects in two groups. Thanks to that, we had some time to analyse the first two projects, which helped us to adjust the weighing of the tender offers evaluation of the last two projects.” (Anne Hedegaard, Region North Jutland)

During the tender phase, the main contractors were chosen based on the qualification overview of their experience, management plans, project organization, budget and schedule performance, specified in APPENDIX D – TENDER PHASE. Each evaluation criteria had different weight, providing a higher value to the considerations that were more relevant for the projects, ad described in the project documentation and interview with the building owner project manager.

“We also found out that a lot of companies were willing to participate in the projects, so, due to the concerns from the first two projects, we changed the tender evaluation weighing, giving higher score for the sustainability considerations of the offers from 20% to 25%, reducing the weighing of the process aspects.” (Anne Hedegaard, Region North Jutland)

As shown in Table 5.2, in Pandrup and Hurup healthcare centres the price and quality of the tender offer had more relevance, dividing the rest of the score between the sustainability and process aspects equally.

CRITERIA	VALUE (%)
Quality	25
Price	35
Sustainability/DGNB	20
Process	20

Table 5.2 Evaluation criteria of Pandrup healthcare centre

In contrast, at Sæby and Brønderslev healthcare building projects, the evaluation of the tender offers does not follow the same weighting as initially. Here, the building owner decided to give a higher relevance to the sustainability considerations of the offer, decreasing the value of the process quality, that rates the description of the process of implementation of planning and construction phase, such as team's organization and LEAN construction principles implementation. This change was done due to the issues observed by the building owner during the first two projects, reaching the conclusion that the sustainability aspects had to have a higher relevance on the offer evaluations.

CRITERIA	VALUE (%)
Quality	25
Price	35
Sustainability/DGNB	25
Process	15

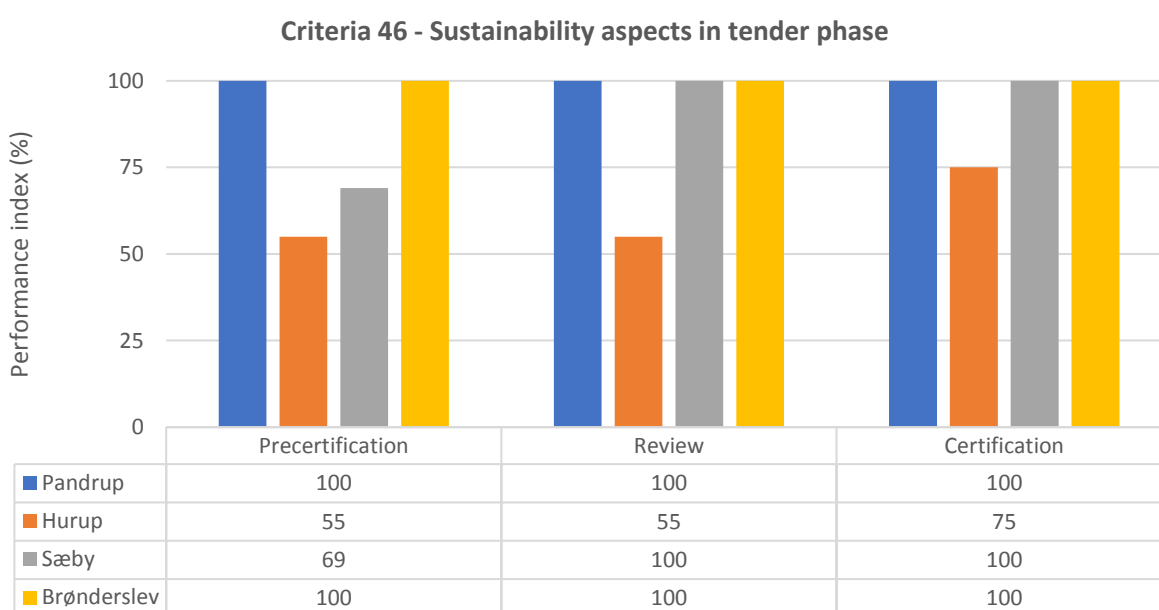
Table 5.3 Evaluation criteria of Sæby healthcare centre

Together with the tender documentation, the contractors received the project requirements in which the prerequisites for the project and the material necessary for the evaluation of their offers, as refereed in previous paragraphs. Since the four projects are part of the same building portfolio, the requisites and expectation for the four healthcare centres were the same.

The building owner requisites and aims for each project since the start of the project do not suffer any changes, but when it comes to the additional material necessary for the bidders to create an offer and understand the project itself, the quality of the documentation could vary. The documentation analysis and interviews' data showed that the information and documentation provided by the designers to the possible main contractors differ from project to project. But, once the construction of the project has been awarded to the main contractor, the bid documents (i.e. approved construction drawings and technical specifications) might not be altered.

Moreover, the implementation of the sustainability requirements and expectations for a project at tender phase has a profound impact on the construction process. If the companies involved in the bidding are not fully aware of the high responsibilities and strong commitment that a sustainable certification or sustainable criteria implies, it may cause a long learning and adjustment process for the new contractors and subcontractors, what will influence the time planning management and on the fulfilment of the building owner requirements. Also, if the companies involved in the construction phase are familiar with the sustainability assessment process, most of the mistakes and misunderstandings could be avoided.

The DGNB criterion 46, Sustainability aspects in tender phase, evaluated the integration of sustainability aspects in the call for tender and when choosing companies. The required documentation for call for tenders include specification of services, additional technical preliminary comments, and special contractual terms. *Graph 5.3* shows the performance of the quality of the sustainability aspects integration in the tender invitation and the consideration of sustainability aspects in the selection of the companies in charge of the buildings execution.



Graph 5.3 Criterion 46 performance index analysis

In Pandrup healthcare centre the client selected a small contractor company which did not have a previous direct experience with sustainability certified buildings. This situation could have influence negatively the quality of the building and risk the achievement of the strict sustainability requirements. On the contrary, the information and documentation that the main contractor received, as well as the support provided by the DGNB auditor and the subadvisors in terms of DGNB assessment created a great work environment.

“We also saw that sustainability was expanding and we wanted to have the chance to work with it ... Also for our company was new to participate in a project as a total entrepreneur, so it was a learning process for us”. (Lund & Staun A/S)

At Hurup healthcare centre project, there is a failure on the implementation of the sustainability considerations at the tender phase. The team of architects involved in the design process of the building did not have any previous experience with DGNB sustainability certification, not being aware of the high demands implied in it. This situation lead to poor quality tender documentation, unbalancing the level of information of every party involved in the project.

As presented before, the main contractor in charge of the execution of the healthcare building located in Hurup, faced issues with the lack of documentation of the design of the building. The architect in charge of the design did not fulfil the necessary minimum daylight requirement, of minimum 2% DF in most of the working floor area, as established on the Building Class 2020 and DGNB certification, which forced the team to correct the design. This situation created some issues for the main contractor, which, even though the project was finish ahead of time and with the expected quality, unbalance the level of information about the project between the before and after tender teams.

“At Hurup project, the team had problems fulfilling the requirements stablished on Building Class 2020 regarding the daylight demands, when calculating the daylight factor. Since the building is used for medical care, we could not get as much flexibility in the rooms as we wanted, due to the daylight requirements, so the design team was not sure about which parameter had to be prioritized, the flexibility of the building or the daylight factor of the working spaces.” (Anne Hedegaard, Region North Jutland)

“We had some issues with the building documentation through the tender phase. The architect company is title of the design did not have any previous experience with DGNB sustainability requirements, which made them correct certain parameters of the building design”. (HT Højgaard A/S).

“The tender documents did not say other than DGNB silver certification was a requirement, so we based the workload estimation on our company internal knowledge from previous projects”. (Cowi A/S)

For Sæby and Brønderslev projects, since the buildings share big similarities and have the same main contractor and integrated design team, the document sharing during the project bidding had the same quality. The main contractor and integrated design team during the first project had to face a period of learning of the criteria contained in the sustainability assessment scheme and provide a good guidance to the subcontractors involved in the project execution. Due to the first experience with Sæby healthcare centre, the construction and certification process of the second building, Brønderslev, became easier tasks that could be based on the previous work, being ahead of the possible issues and barriers for the successful completion of the healthcare centre.

5.2.2 SUSTAINABILITY CERTIFICATION

As stated at the building owner requirements, the project should achieve the silver award for DGNB certification. Region North Jutland, as building owner, defined the minimum criteria that need to be fulfilled by the construction team, which was described and explained to the professionals through the performance of a workshop at the beginning of the construction phase. **Table 5.4** below presents the minimum process quality criteria that had to be achieved and the required checklist points of each sub criteria.

CRITERIA	No.	INDICATOR	REQUIRED CHECKLIST POINTS	TOTAL CHECKLIST POINTS
QUALITY OF PROJECT PREPARATION	43.2	Agreement on objectives	25	25
OPTIMIZATION AND COMPLEXITY OF PROJECT PREPARATION	45.1	H&S (Health and safety) plan	10	10
	45.6	Measurement concept	5	10
CREATION OF CONDITIONS FOR OPTIMAL USE AND MANAGEMENT	47.1	Project documentation	25	25
	47.2	Instructions for servicing, inspection, operation and care	25	25
	47.3	Adaptation of plans, verifications, and calculations for the finished building	25	25
	47.4	Compilation of user manual	25	25
QUALITY ASSURANCE	50.1	Documentation of materials, auxiliary materials and data safety sheets	50	50
	50.2	Measurements for quality control	50	50

Table 5.4 Minimum project requirements for DGNB process quality aspects

“At the beginning, due to inexperience, we chose silver certification because it was a middle ground award, so the demands were not that tight and the cost of the certification was not as high as gold certification. We also found out that silver certification was matching the requirements from Building Class 2020.” (Anne Hedegaard, Region North Jutland)

During the construction phase the architect also acts as the owner's agent to review the progress of the work as it relates to pay requests from the contractor, and to issue site instructions, change orders (or field orders), or other documentation necessary to facilitate the construction process and certify that the project is built to the approved construction drawings. To improve the sustainability assessment process, the main contractor should appoint a person in charge of the sustainability assessment documentation, taking full responsibility of the delivery and availability of the necessary building information.

Even though the projects are part of the same portfolio, the companies involved in the design and construction stages are different. The collaboration and organization methods applied in each project have an influence on the quality level, affecting the functionality and flexibility of the building and defining the maintenance and commissioning processes.

“When it comes to the entrepreneurs, it is necessary to explain what are the aspects that need to be taken into consideration, and what work is already done for the sustainability certification. Also, there are certain requirements for materials, i.e. wood, in which it is necessary to make sure that all the documentation is available, such as the chain of custody. That was the more difficult part.” (Anne Hedegaard, Region North Jutland)

To ensure an optimal use and management of the buildings, it is necessary to provide project documentation, which defines the quality of the building. The project documentation that need to be available should contain project general description, project planning, building description, information about inspection, servicing and management, and project costs. The documentation necessary for the achievement of a sustainability certification could represent a big problem in certain areas of the building execution. As described previously, the conventional working methods applied by subcontractors put in risk the good performance of the project work.

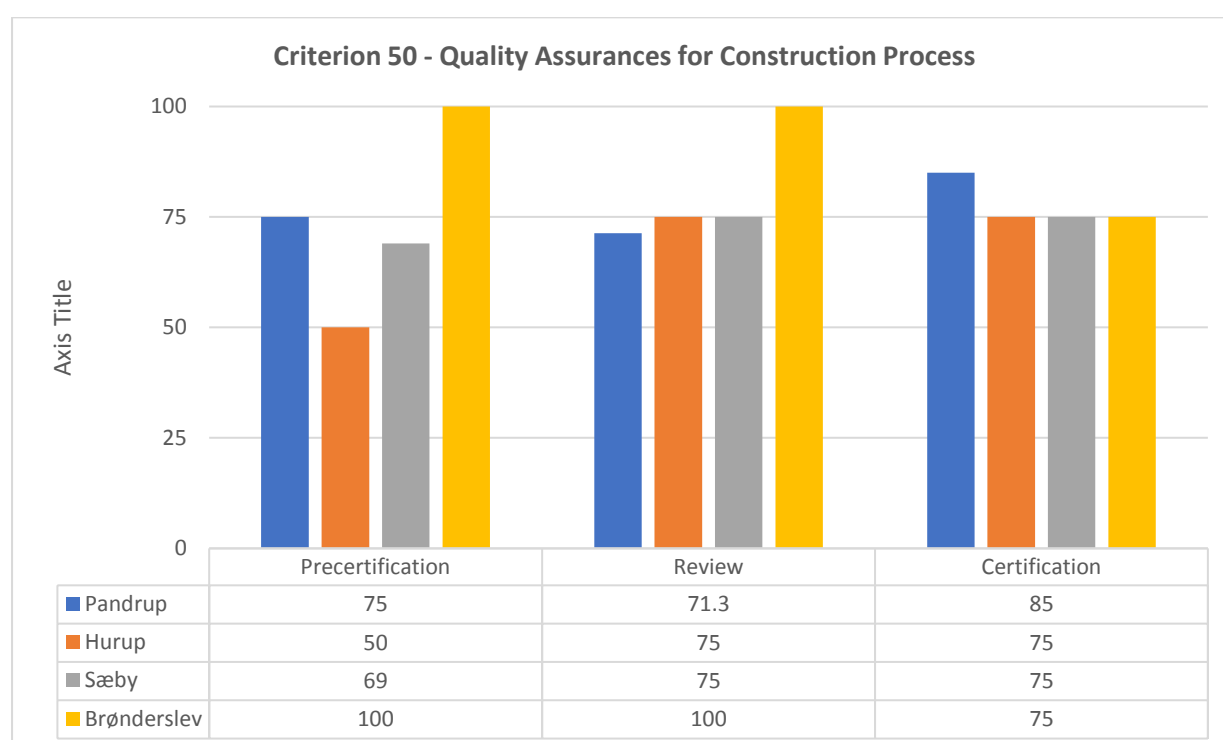
High level of documentation about the materials installed in the building. The contractors in charge of the materials provision present the same issue regarding the materials security data sheets. A possible reason might be the young age of DGNB certification, which did not leave room for the evolution of the company's culture, to meet the strict documentation requirements.

“The inexperience of the main contractor and subcontractor affected the most when it comes to the construction materials. the main contractor had to go until the end of the chain, to make sure that subcontractors were informed of the high requirements for the materials disposal and documentation.” (Anne Hedegaard, Region North Jutland)

Criterion 50, Quality assurance for construction process, takes into consideration the quality of the construction phase, through the detailed building documentation provided by the main contractor (Graph 5.4). This criterion requires documentation of materials, auxiliary materials and safety data sheets, besides the documentation of the measurements for quality control.

Safety data sheet is a document regarding the identification, hazard, handling, storage, transportation, waste disposal and the safe work conditions of a given chemical substance/mixture. The requirements for the format and content of the safety data sheet is available in Annex II of Regulation 1907/2006/EC. In compliance with Article 31 of the regulation.

In case of mixture, the Annex will be modified by CLP regulation (1272/2008/EC) on 1 June 2015, therefore the safety data sheets must be modified and parallel with the labelling and the packaging of the substances as well.



Graph 5.4 Criterion 50 performance index analysis

From the four projects process quality assessment, it is possible to gain an overview of the different level of project documentation delivered. In example, Pandrup healthcare centre presents high quality building documentation, which indicates the importance of information sharing and communication between the different contractors and subcontractors involved in the construction process.

“We also had a meeting with the subcontractors before the start of the project execution where we explained the DGNB certification requirements and each professional’s tasks.” (Lund & Staun A/S)

In the specific case of the building materials and systems used for the project, the high complexity of the documentation that is required for submission and the impossibility of the subcontractors to obtain it creates big impacts on the functionality and flexibility of a building.

“I believe that the subcontractors were willing to collaborate, but it should be taken into consideration the working culture of the companies. So, from some of the subcontractors it was easier to get the necessary documentation for the DGNB assessment, but i.e. the electrician was more familiar with traditional construction methods, so it was not possible to obtain certain data sheets, not because they did not want to, but because they were not used to these requirements.” (Lund & Staun A/S)

“It is common that arise problems with subcontractors due to lack of material’s security data sheets, while, on the other hand, the main contractor usually has all the necessary documentation required, because of the direct contact with the building owner. It is a more difficult task when it comes to the subcontractors because they are not in direct contact with the building owner and they normally leave the site before the project is completed.” (Cowi A/S)

“In example, with the paint, it was difficult to obtain the security data sheets required by the process quality criteria of DGNB. We really tried to get the documentation, but it was really complicated to obtain it. That is the problem of DGNB, if you use a certain type of, as an example, wood, you need to give prove through the documentation.” (HT Højgaard A/S)

From all the interviews performed with the professionals involved in the management and consultancy of the construction phase of the four projects, it arises the difficulty of the fulfilment of certain criteria from DGNB, such as criterion 50. The main barriers faced by the construction team where related to the inexperience with the DGNB documentation of the materials suppliers, which were not able to provide all the necessary documentation to prove the precedence and quality of the materials implemented in the four healthcare buildings.

5.2.3 COMMISSIONING

Dynamic systems and equipment tend to migrate from their as-installed conditions over time. The needs and demands of facility users also typically change as the building is used. Therefore, periodic verification of systems, assemblies, component condition and operation are essential (WBDG, 2017).

Building commissioning is a quality assurance process which begins at project inception (Pre-design phase) and continues throughout the life time of a building (through the occupancy and operation phase). The objective of commissioning process is to ensure, by verifying and documenting that the building operates as intended by the building owner and that the staff is prepared to operate and maintain the systems and equipment in the building (ASHRAE, 2005). In accordance with ASHARE Guideline 0-205, during the construction phase of a building project, the commission process has certain objectives:

- Update the Owner's Project Requirements
- Update the Commissioning Plan
- Verify that submittals meet the Owner's Project Requirements
- Develop detailed test procedures and data forms
- Verify that systems and assemblies comply with the Owner's Project Requirements
- Develop the Systems Manual
- Verify training of the Owner's operation and maintenance personnel and occupants
- Acceptance of Construction Phase Commissioning Process activities

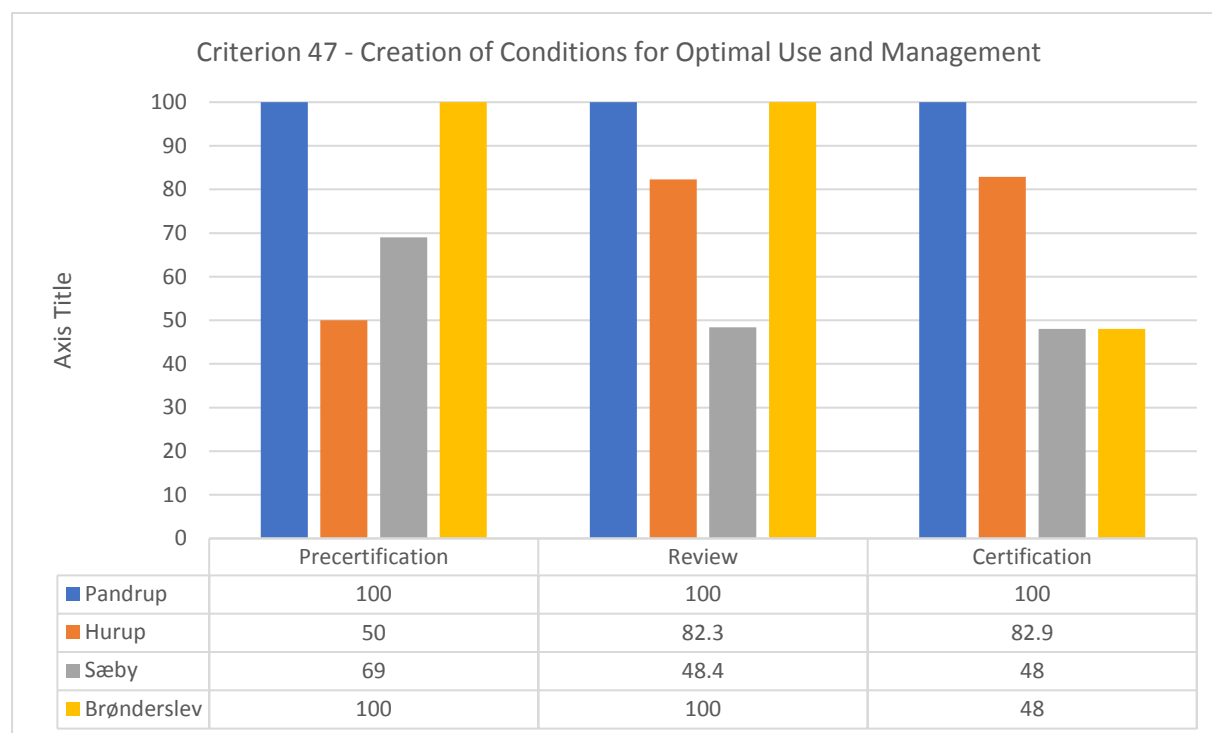
Often, the building industry professionals understand the commissioning process as a specific and independent discipline, not taking into consideration the necessary application, not only to new projects but also existing, to ensure the optimal function of the building. But, through the construction phase there is many documentations that needs to be created to troubleshoot problems and optimize the operating strategies of the buildings.

Commissioning documentation is generated throughout the project delivery process. Key documentation includes Owner's Project Requirements, Basis of Design, Commissioning Plan, and the Final Commissioning Report (WBDG, 2017). *Table 5.5* below describes the necessary commissioning documentation and the agents in charge of each document and who will review it and use it.

PHASE	DOCUMENT	INPUT BY	PROVIDED BY	REVIEWED/ APPROVED BY	USED BY
CONSTRUCTION	Owner's Project Requirements Update	O&M, Users, Capital Projects, Design Team	CA or Designer	Owner	CA, Design Team
	Basis of Design Update	Design Team	Design Team	Owner, CA	Design Team, CA
	Commissioning Plan Update	Design Team, CA, Owner, Contractor	CA	CA, Owner, Design Team, Contractor	CA, Owner, Design Team, Contractors
	Submittal Review Comments	CA	Design Team	Design Team	Contractor
	System Coordination Plan	Contractor, Design Team	Contractor	CA, Design Team	Contractor, CA
	Inspection Checklist	CA, Contractor, Design Team.	CA	CA, Design Team	Contractor
	Inspection Reports	Contractor	CA	CA, Owner	Contractor
	Test Procedures	CA, Contractor, Design Team	CA	CA, Design Team	Contractor
	Test Data Report	Contractor	CA	CA, Owner	Contractor
	Commissioning Meeting Agenda and Minutes	CA	CA	All	All
	Training Plan	Design Team, CA, O&M, Contractor	Contractor or CA	Owner, CA	O&M, Users, Contractor
	Systems Manual	Design Team, CA, O&M, Contractor	Contractor	Owner, CA	O&M, Users
	Users Log	CA	CA	N/A	CA, Design Team, Contractor
	Issue Report	CA	CA	Owner, Design Team	Design Team, Owner, Contractor
	Preliminary Construction Commissioning Process Report	CA	CA	Owner	Owner
	Final Construction Phase Commissioning Process Report	CA	CA	Owner	Owner

Table 5.5 Commissioning documentation matrix construction phase (ASHRAE, 2005)

Criterion 47, Creation of Conditions for Optimal Use and Management, aims to ensure that the necessary project documentation is available, which makes possible the operation and maintenance of the building. According to the DGNB scheme, “New Office and Administrative Buildings” version 1.4, the conditions for an optimal use and management of the four buildings, it was necessary to present project documentation, to verify the quality of the building, instructions for servicing, inspection, operation and care, adaptation of plans, verification, and calculations to the finish building, and a user manual.



Graph 5.5 Criterion 47 performance index analysis

From the evaluation of the criterion, *Graph 5.5*, it is visible that only Pandrup healthcare centre achieved a maximum score, which ensures the quality of the building. This fact reaffirms the good implementation of Lean construction principles on Pandrup project, and the optimum working environment created by the project manager. On the other three buildings, Hurup project also presents a good quality of building documentation, instructions for operation and maintenance of the building and adaptation of plans, but it does not present a complete user manual, what conditions the good operation of the building, because of the disinformation of the users.

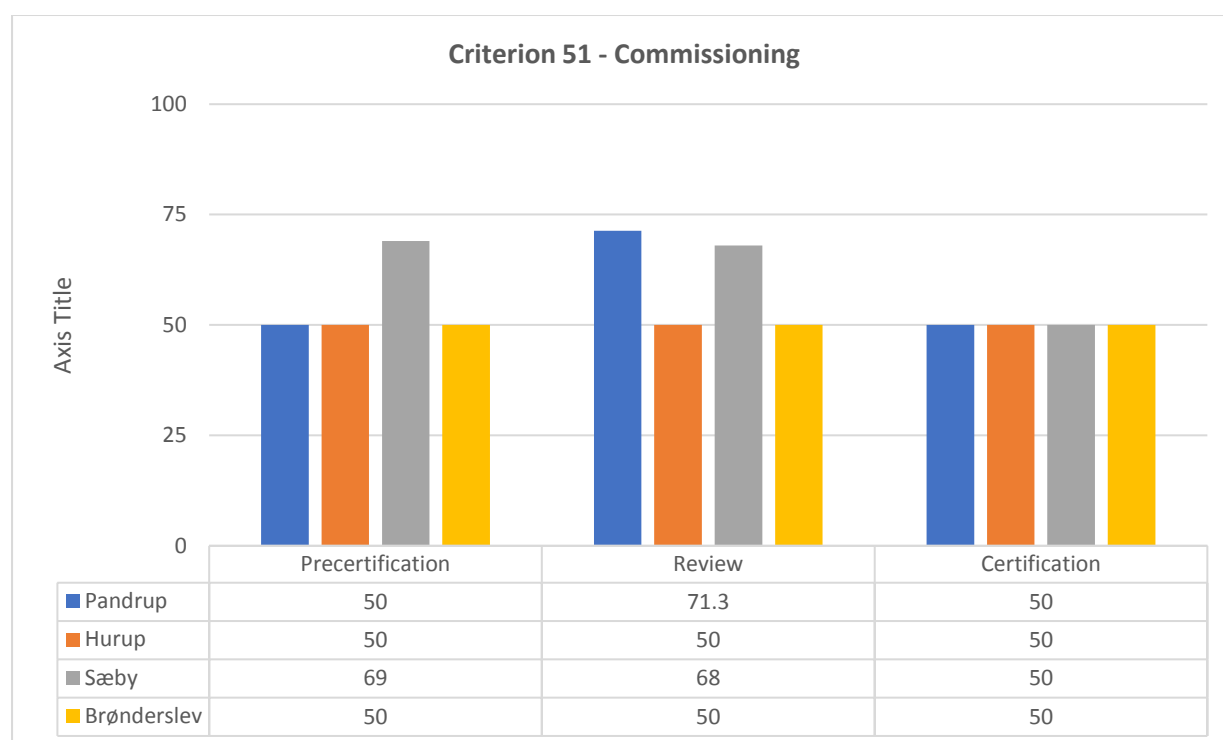
Criterion 51, from DGNB certification, assess the systematic initiation of operation, where the individual components of the building services system are adjusted and regulated to run smoothly with each other (*Graph 5.6*). After 10 to 14 months, an operation optimization can be carried out and the system can be readjusted (DGNB, 2013).

Commissioning process will start in planning phase and will end after one year of operation. Based commissioning process is based on a commissioning plan developed during the planning phase and

functional testes for all electrical and mechanical systems in the building by independent third parties during the transition period before building starts for operation phase (DGNB, 2013) e.

There is certain documentation that needs to be provided for DGNB certification. Firstly, it is required the demonstration and documentation of commissioning for such systems as heating, ventilation, air conditioning and chilled water systems, building automation, lighting, hot water supply, sun shading systems and façade louvers for natural ventilation. Secondly, it is necessary documentation by an external third party of a functional test for all systems which underwent commissioning, such as list of functional teste conducted and logs for those tests (DGNB, 2013).

Finally, the professionals need to provide a concept for the planning expectations to the operation phase as well as for the ongoing process for energy management with reviews and optimization during the operation phase of the building.



Graph 5.6 Criterion 51 performance index analysis

As described for quality assurance criterion (Criterion 50), the documentation for the commissioning quality of the building is not complete. The four buildings miss the documentation for various quality control measurements and materials information, what influences the commissioning management. Also, some of the projects lack the creation of a user manual for the building and the collection detail information about the electrical and mechanical systems.

From the DGNB assessment documentation of the four projects, it is visible that for all the buildings, the teams only fulfilled partially the commissioning criteria, achieving the minimum score for the silver DGNB award (*Graph 5.6*). As stated in the certification documents, Pandrup, Hurup, Sæby and Brønderslev provided only documentation regarding the performance of functional tests of the single system components installed in the buildings. The lack of minimum requirements for commissioning from the Building Owner and the short experience of some of the construction teams, such as Pandrup and Hurup projects, resulted in a poor commissioning process which affected the start of the operation of the buildings and their maintenance.

“The problem is that we did not have a lot of experience with the commissioning demands of the DGNB certification. Afterwards, we found out that the commissioning is one of the most important to prioritize this criterion. Now for every new project, no matter which type of building, we require minimum of 75 points in the commissioning criteria, because we experience in the four first projects, that, even though they were a success, it was hard to start operating the buildings and maintain them as intended.” (Anne Hedegaard, Region North Jutland)

The weak commissioning planning and management of the four buildings brought certain issues when starting the operation, taking couple of months to adjust the building's systems to achieve a comfortable and healthy environment. For that reason, Region North Jutland decided to adjust the requirements for the new projects, including a minimum requirement for commissioning of 75%. This means that the new projects are required to have a commissioning with subsequent adjustments and operational optimization of the building systems within the first 14 months, avoiding issues on the optimal operation and functionality of the constructions.

From this section, it can be concluded that the commissioning process of a building project is one of the most important considerations to implement to the project from the early stages of the project. In the specific case of the four healthcare centres, the new implementation of DGNB assessment and the lack of experience with sustainable construction induced the implementation of “point hunting” in the commissioning criteria, only achieving a minimum score to obtain the required award aimed by the building owner, which will create issues in the long run related with the maintenance and functionality of the four buildings.

5.3 PROJECT COMMUNICATION

5.3.1 TEAM COLLABORATION AND COMMUNICATION

The communication and collaboration between the team members is one of the key parameters when aiming for a high-quality construction. The number of considerations and requirements when building a sustainable project requires the commitment of the professionals to exchange the project information with the intention of maintain everyone informed of the evolution of the project and help to avoid mistakes throughout the execution process.

As described before, the number of professionals involved in the execution of a building project increases exponentially, entering in the process material suppliers, sub-contractors, sub consultants and the main contractor in charge of the management of the construction phase *Figure 5.1 Project Managers communication with all stakeholders* (Figure 5.1). This situation makes necessary a good coordination and communication of the team, to ensure that all the parties understand the aims of the project and the steps that need to be follow.

But even if the design is already done, the client and the client's advisors should be in contact with the construction team, through follow up meetings, where the current state of the project is discussed, together with the following tasks that need to be performed to reach completion. At this point, the bias and habits of the professionals might interfere in the evolution of the project, not willing to maintain a close communication with the rest of the professionals and following traditional working methods.

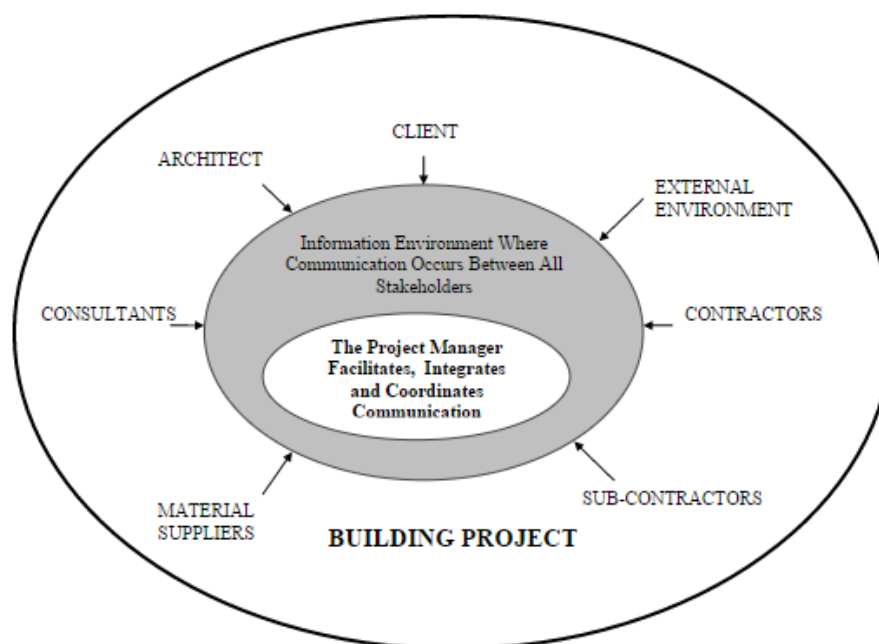


Figure 5.1 Project Managers communication with all stakeholders (Yang, 2006)

During the execution process of the four healthcare centres, each team established different requirements for the communication and collaboration. As a project requirement, it is established the requirement for the project manager to hold regular meetings together with the building owner and the building owner's advisors, which have the final decision is decisions related with the structure and installations of the four buildings. At least once a month there should be a meeting with the client to analyse the state of the project.

In accordance to the meeting minutes' documentation for the four healthcare centres, the meetings with the client and the client's advisors were held every two weeks, either at the main contractor's office, at the building's site or at the Region's headquarters located in Aalborg. At the client's meetings, corrections and discrepancies with the previous meeting are discussed, besides the next steps planned for the project and possible issues on the current ongoing work.

At Hurup, Sæby and Brønderslev projects, the meetings were attended by the building owner, the building owner's advisors, the main contractor and the subadvisors. On the other hand, at Pandrup building project, during the client meetings, only the building owner and the building owner advisors were participating, performing additional meetings with the subcontractors, approximately every 10 days. This situation benefited the evolution and quality of Pandrup project, due to the close communication and collaboration of the professionals, which enhanced the information sharing and the monitoring of the construction works.

Moreover, every 2 weeks, the main contractors of the four projects scheduled safety meetings together with the site manager and subcontractors, where all the issues related with the health and safety of the works are discussed. The safety meetings were held normally in the office of the main contractor.

Together with the client meetings, the subcontractor meetings and the safety meetings, Pandrup project also implemented on site meetings with the workers to improve the working environment and the collaboration and communication between the construction workers. These daily huddle meetings promote the involvement of the employees through brief daily start-up meetings conducted at the site. During the onsite meetings, the workers share what they had been working on the previous day, what are the plans for the day and the necessary help from the rest of the team to achieve the daily objectives.

"We often scheduled meetings on site with the workers before the actual daily work was starting, where the evolution of the project and the daily tasks were discussed, which at the end of the project paid off." (Lund & Staun A/S)

5.3.2 PROJECT INFORMATION SHARING

In most of the projects there is a high risk to face a knowledge gap between the design and construction phases of a project. This situation is caused by lack of project information sharing during the call for tender which allows the bidders to have a better overview of the workload and characteristics of a building project. The collaboration and information sharing of a team brings several benefits to the project, such as cost savings and facilities reduction.

As it shows Brønderslev project documentation, at the start of the execution phase, the DGNB auditor carried out a workshop with the project manager and the integrated design team, in which DGNB certification was presented and described, analysing the current situation of the sustainability assessment of the building, to clarify the necessary work for the certification and to discuss any question or doubt that could arise.

But the most vulnerable professionals involved in the construction phase are the subcontractors. Their disconnection from the purpose of the project and from the building owner or client makes difficult the full engagement of the subcontractors and increases the risk of not fulfilling the sustainability requirements, and therefore, the achievement of DGNB sustainability certification.

Through the data collection from interviews and document analysis, it is visible that the four projects overcame certain problems due to the lack of project ownership from the subcontractors. In most of the cases, the construction professionals do not perceive the sustainability of the building as part of their work, maybe due to lack of technology or resources for it, or simply due to the culture of the company as discussed previously in this report. However, not for all the projects the project manager took into consideration the information and communication with the subcontractors.

Pandrup's main contractor did not have an extensive experience with the implementation of sustainability in construction, therefore, the company took advantage of their deep knowledge of LEAN construction principles, to maintain a good management and planning of the project execution. The implementation of kick off meetings with the subcontractors, focused on getting to know one another better within the team and laying the ground for a successful work, helped the professionals to create an optimal work environment, where each professional share his/her knowledge and gets to know in depth the characteristics of the project and which information is required from them.

"We also had a meeting with the subcontractors before the start of the project execution where we explained the DGNB certification requirements and each professional task. So, I consider that we had a good team, where people was willing to participate." (Lund og Staun)

5.4 WORK PLANNING AND SCHEDULING

One of the main client's requirements for the four projects is the implementation of Lean construction principles, which are based on the reduction of waste and the improvement of the efficiency and quality of the final product, as described in Chapter 3. In accordance with the client requirements reflected on the tender material handed in for the main contractor, it is required that the contractor uses MS-Project 2012 for the compilation of schedules specifying interdependences, duration, start and end date, % of work completed, delay and previous assignments.

Within the building portfolio, it should be implemented the Critical Path Method (CPM) for scheduling, that is based on the calculation of the minimum completion time for a project along the only usable and practical scheduling procedure (*Figure 5.2*). The essential technique for using CPM is to construct a model of the project that includes a list of activities required to complete the project, the duration of each activity, the dependences between them and logical end points, such as milestones or deliverable items.

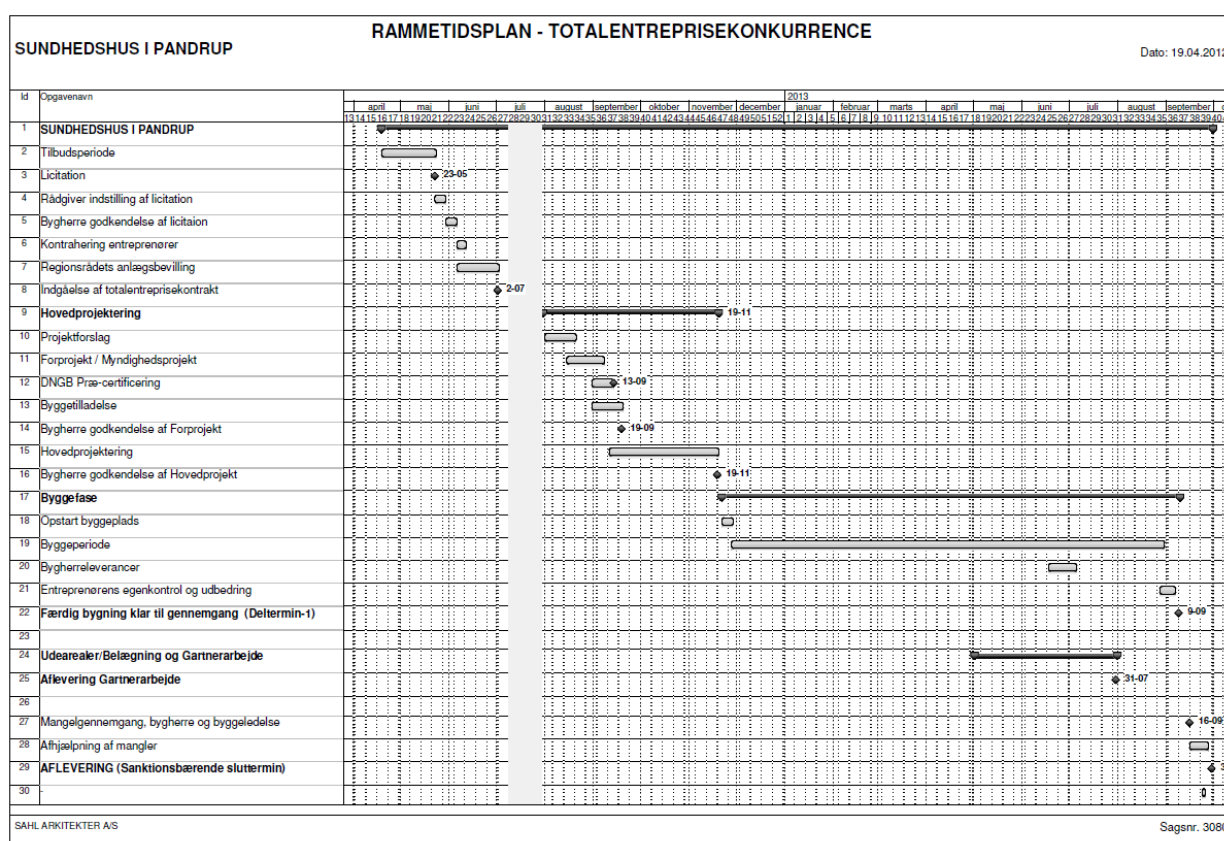


Figure 5.2 Example of time schedule Pandrup healthcare centre. Source: Region North Jutland

In addition to assigning dates to project activities, project scheduling is intended to match the resources of equipment, materials and labour with project work tasks over time. A good scheduling can eliminate problems due to production bottlenecks, facilitate the timely procurement of necessary

materials, and otherwise insure the completion of the project as soon as possible. Following the documentation provided for the sustainability assessment of the buildings, it is shown the implementation of several planning tools, such as Last Planning Tool, which were described as a requirement on the call for tender documentation (Digital Appendix 1)

A process plan was performed in the four buildings with the aim to determine the ideal building process, in terms of order and time. The focus of this plan is to address times or areas that require special coordination between the trade contractors. The plan should express agreement between all the parties, and in this way, build the best cooperation between the parties through a negotiation of which can be the best option for the building process.

Also, a periodic plan with two main objectives, manage the logistics, and as break down process plan for more specific operations, was performed throughout the construction phase. This means that the period plan was a check list or an agreement between the trade contractors to ensure healthy activities. The period plan was carried out once a week at a site meeting, in which there were six weeks represented, to examine the health of the future activities (coming activities).

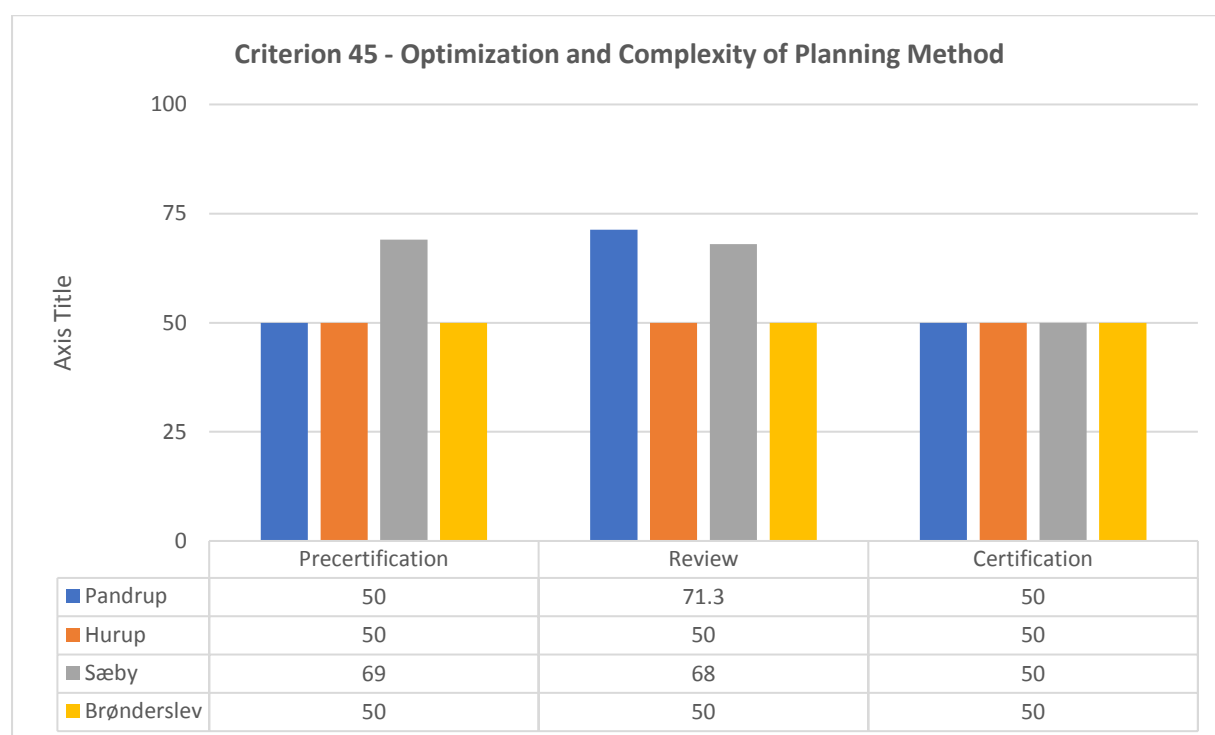
Finally, a weekly planning was designed to ensure that the upcoming week's work was done in the most appropriate way for the workers, and that all activities were healthy. The weekly plan was carried out once a week at a meeting.

In the specific case of Hurup healthcare centre, the main contractor, HT Højgaard, implemented TrimByg process management concept, which means less waste, greater efficiency and increased value. Through five steps, MT Højgaard intends to create the most efficient building process for all the parties involved. TrimByg tool is based on the following concepts:

- Organization based on the definition of the roles at the construction site early in the process and clearing responsibilities and tasks.
- Planning focussed on the requirements and following a short planning horizon on site, to increase predictability, together with health and secure activities.
- Coordination, based on collaboration across the site operators and ensuring an ongoing interdisciplinary coordination of individual activities.
- Follow-up of the site work. Through the continuous record of the construction works on site, it is possible to identify mistakes and find the cause, ensuring that the error does not occur again.
- Evaluation of the cooperation, construction process and lessons learned from each project. (Learn from experience)

This tool enhanced the construction process, allowing for an early completion of the project, and with a high-quality documentation, even though this project presented some handicaps due to problems with the daylight factor in the working areas of the building, making necessary a change in the design, what could have caused delays for the hand in of the project.

During the assessment of the buildings, another requirement from the Building Owner is the achievement of the maximum score for the Health & Safety plan and a minimum score for the measurement concept, where a measurement and monitoring concept is developed for electricity, and water consumption. This sub criteria are part of Criterion 45, Optimization and Complexity of Planning Method, *Graph 5.7*.



Graph 5.7 Criterion 45 performance index analysis

From the score obtained for criterion 45, it is visible that the four buildings just achieved the requirements established by the client, disregarding the energy, water and waste concepts to minimize the consumption and optimize the resources availability of the four buildings. Also, the conversion and dismantling of the buildings, cleaning and maintenance concepts were not taken into consideration, affecting the commissioning process of the building, as a consequence, the operation and functionality of the four buildings in the long run.

6. DISCUSSION

The implementation of sustainable building certification, like DGNB, do not ensure the success of a building project. The working methodology of the teams involved in the design and construction of a sustainable building project shape the quality of the project outcome. For that reason, one needs to be aware of the company's culture and background to avoid misunderstandings that risk the successful completion of the building project, through an optimal information sharing from the initial stages of the project and the commitment of the team members to work all together as a team.

In addition, the four healthcare centres were assessed following the DGNB scheme "New Office and Administrative Buildings" (version 1.4), released in 2012, that is the second version released of this scheme. "New Office and Administrative Buildings" scheme also is the first one adjusted to the Danish market, and, at that point, it was only translated to English, creating confusion between the professionals due to bad translations and errors of the document. For that reason, Green Building Council was open to help and support the companies through the assessment process, answering any question that was arising through the process and welcoming feedback from the building industry professionals.

Since the main objective of this project report is to study the effect of construction project management on the achievement of DGNB sustainable building certification, the analysis is based on the process quality criteria contained in the building's sustainability assessment, disregarding the performance of the rest of the assessment groups, which have a higher impact on the final score of the four buildings. Also, when assessing a public building, like the four healthcare buildings, the focus remains mainly on the indoor environmental comfort and indoor air quality parameters, intending to ensure the health and comfort of the users. This situation, combined with the lack of experience of the Building Owner, Region North Jutland, with DGNB certification, promoted the appearance of "points of no return" and "point hunting" strategies for the sustainability assessment, i.e. the commissioning criterion.

On the other hand, the Building Owner established Lean construction as project requirement, what have been proved beneficial for the construction teams, due to their previous experience with this management tool and because of the good support that LEAN construction provides to DGNB assessment, promoting the reduction of site waste, construction time and overall construction cost (Marhani, 2013). Specially in the first building, Pandrup Sundhedshus, the implementation of Lean construction was a great asset for the main contractor, which at that point had no experience with

sustainability or sustainable building certification, creating a great foundation for the construction process, which paid off with a project completion before deadline.

All professionals are required to collaborate within the whole building process, monitoring the sustainability goals and ensuring the optimal performance of the project. But, the different phases of a design-bid-build delivery method can become an issue. The participation of several professionals through the design and execution processes of a building can create an offset on the level of understanding and ownership of the project. The mistakes from the design phase have a significant impact on the construction process of a building, increasing costs creating more waste, and risking the health and comfort of the occupants. These facts must be taken into consideration when analysing the good performance of the construction project management, evaluating how the construction team reacted to the issues and how they overcame the “points of no return” of the project.

Regarding the qualitative data, it should be taken into consideration that the case study, the four healthcare buildings, were projected and executed from 2012 to 2015, following different time lines, which can affect the answers obtained at the interviews from the professionals, due to the time that has passed since the projects were completed and delivered. Moreover, each professional and company has different priorities and completely opposite perceptions about sustainability assessment, which might have interfered in the information obtained, even though the projects were executed as required by the Building Owner. For that reason, the research method applied in this report is the triangulation method, which allows to confirm the findings from the interviews performed with the DGNB assessment documentation, ensuring the quality of the investigation.

Finally, the document analysis is based on the DGNB assessment documentation provided by the project manager of Region North Jutland. The four buildings documentation is store in iBinder, a cloud storage provider that intends to simplify the construction industry’s management of documents, due to the complexity of construction projects. This tool was also new for the teams involved in the four projects, creating clear differences on the organization of each project’s folder and confusion when searching for certain documentation.

7. CONCLUSION

This project report is presenting the analysis of the effect of construction project management methodologies on the achievement of sustainability criteria, or as in the case study in which the investigation is based, the achievement of DGNB sustainability certification. The four buildings contained in the case study are four healthcare facilities located in northern Jutland, Denmark, as described in Chapter 4. In this study, the experiences with the construction project management and DGNB assessment of the four healthcare centres were reconstructed from the interviews, buildings' documentation analysis and theoretical background. As a result of the throughout analysis data, answers to the research questions were found.

The study of the four-first DGNB certified buildings in northern Jutland give the opportunity to investigate the influence of the professionals' backgrounds and previous knowledge on the construction of a sustainable building project. The inexperience of the main contractor regarding sustainability can become an issue when the team is not fully committed to put extra effort on the learning process of the certification requirements and on the implementation of integrative working methods. But, on the other hand, the experience from previous projects allows for the interference of professional's habits and bias, due to use of similar projects as a reference, disregarding the specific characteristics of each building.

The implementation of Lean construction principles on the four healthcare centres helped for the mitigation of the use of more traditional working methods, establishing strong boundaries for the management and organization of the construction process. Also, the sub consultants, which are part of the integrated design team, support and guide the main contractor throughout the sustainability assessment of the construction. From the analysis, it has been found that the experience and culture of the company is not directly related with the success of the project. In the case of the four healthcare centres, the main contractor of Pandrup project, without any experience with sustainability and being a small size company, obtained a great performance through the construction process, providing high quality building documentation and completing the project before time.

Additionally, the design-bid-build delivery method can be problematic for the progress of the sustainability assessment of a building. Through the call for tenders, the Building Owner provides the bidders the necessary information regarding the project objectives and goals, as well as the requirements from the main contractor and manager of the construction phase. If the bidders are not provided with a detailed description of the high requirements that have to be fulfilled for the successful completion of the project, it can be risked the fulfilment of the expected benchmarks and

deadlines of the project. A possible implementation of a workshop with the companies invited to tender could provide the bidders a good overview of the DGNB project's workload, making them prepared for the important role that the main contractor has during the project execution. Furthermore, the sustainability aspects of the tender offers should have a higher relevance on the evaluation, together with the project costs, to avoid misunderstandings.

The implementation of several professionals through project design and execution induce to an offset on the level of understanding and implication with the project purposes and objectives. This situation might risk the health and comfort of occupants and users, creating extra costs in the long run. The support of the DGNB consultant/auditor to the main contractor and integrated design team it is crucial to understand which work was already done through the design phase, what are the requirements for the construction phase and who is responsible of what. For that reason, it is important that the DGNB consultant/auditor creates an action list, with detailed descriptions of the several tasks and the necessary documentation for the assessment. Also, through an initial workshop and follow-up meetings with the construction team, the DGNB consultant/auditor informs about the progress of the assessment of the necessary improvements of it.

But it is also really important to take into consideration the communication and collaboration with the subcontractors and craftsmen involved in the execution of a sustainable building project. The disconnection of the subcontractors from the client and the purpose of the project, do not create a feeling of ownership from the companies, which see the sustainability assessment as a task of which they are not in charge off. Also, in the works onsite, there should be a strict monitorization of the works, trying to avoid mistakes and ensuring the successful completion of the works with the necessary documentation for the sustainability assessment and certification of the building.

Finally, the use of kick-off meetings with the subcontractors right after the tender phase, where the main contractor informs about the DGNB assessment process and about the purpose of the necessary documentation, aids the cooperation and creation of an optimal working environment. Moreover, adoption of certain Lean construction tools, such as huddle meetings with the onsite workers, enhances the information sharing and collaboration between the professionals. Through the implementation of daily huddle meetings at the beginning of the day, where the professionals inform of the work performed the previous day and what is the current status of it, which helps to avoid mistakes and delays on the site,

8. FURTHER INVESTIGATIONS

This report is presenting the investigation of the influence of the project execution on the sustainability and quality of a project. Since it is a broad field, the analysis performed is intended to give a foundation for further investigations through the establishment of the main parameters that interfere on the good planning and construction processes of a building, besides the beneficial strategies and solutions that could be implemented. The research that has been undertaken for this thesis report has highlighted several topics on which further research would be beneficial.

From the analysis of the case study, it has been found that there is a disconnection of the subcontractors from the final purpose of the project. Specially, when the Building Owner aims for the implementation of sustainability criteria or sustainable building certification, it is crucial that every member of the construction team is aware of the strict requirements that must be fulfilled and the need for exhaustive documentation of every step performed for the project execution. Due to the broad field contained in construction project management, throughout this report, it was not possible to perform a detailed investigation of the management of the subcontractors and craftsmen involved in a sustainable building project. Further investigations are needed to determine whether, and to what extent the information sharing and collaboration methods applied with the professionals located at the end of the pyramid affect the quality of the completed building project.

Additionally, it has been proved the benefits of the implementation of Lean construction principles when aiming for a sustainability certified building. The possible integration of certain parameters of Lean construction management principles, such as meeting scheduling and information sharing methods between the members of the construction team could enhance the performance of the building assessment, to guarantee an optimal communication channel, especially during the construction works.

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APPENDICES

APPENDIX A – FLOOR PLANS

Pandrup Sundhedshus

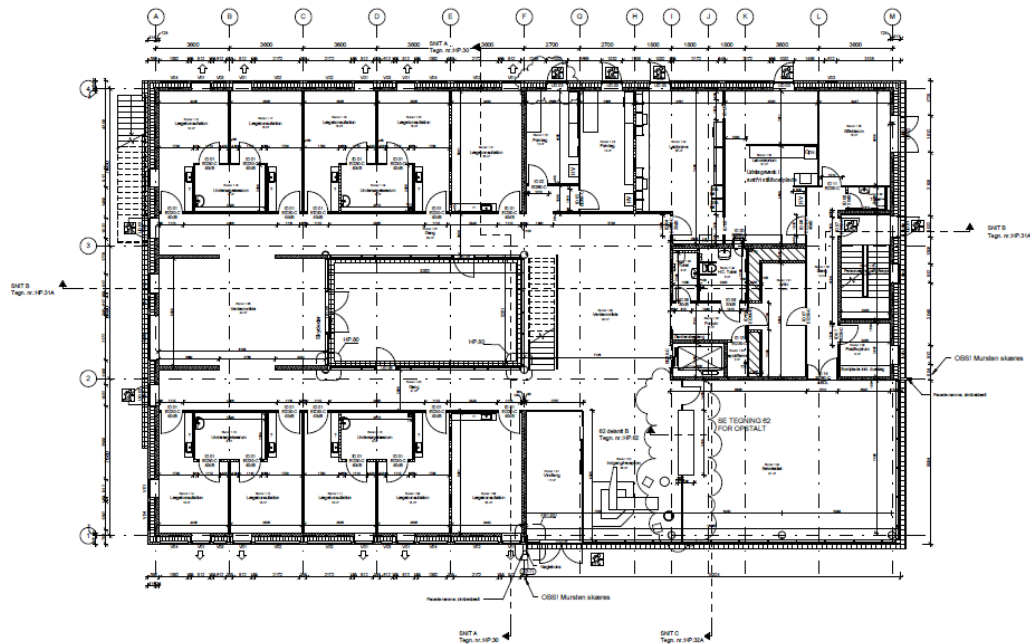


Figure 0.1 Pandrup Sundhedshus ground floor plan

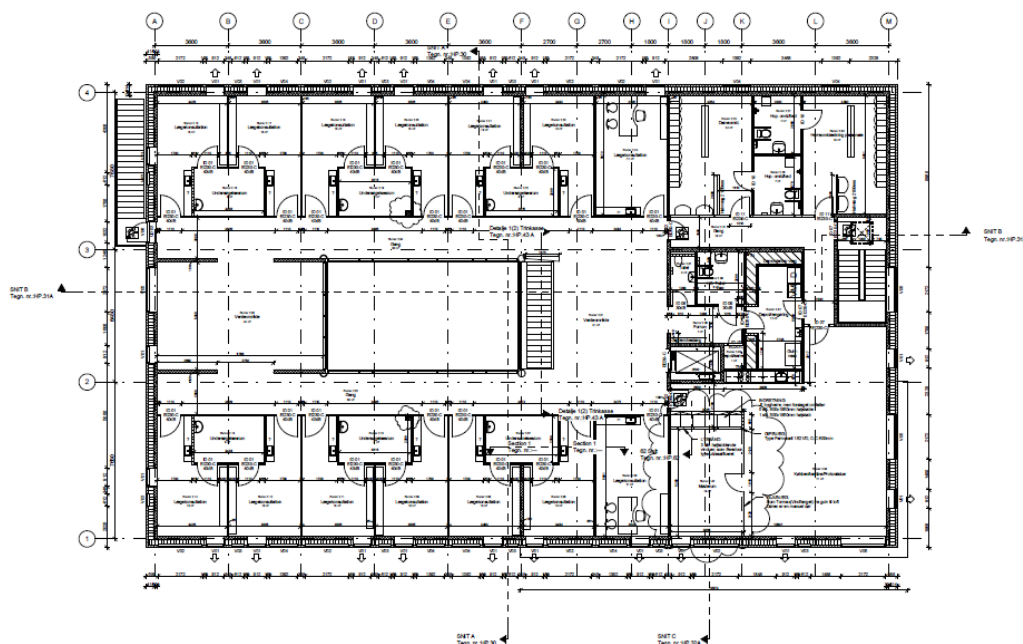


Figure 0.2 Pandrup Sundhedshus first floor plan

Hurup Sundhedshus

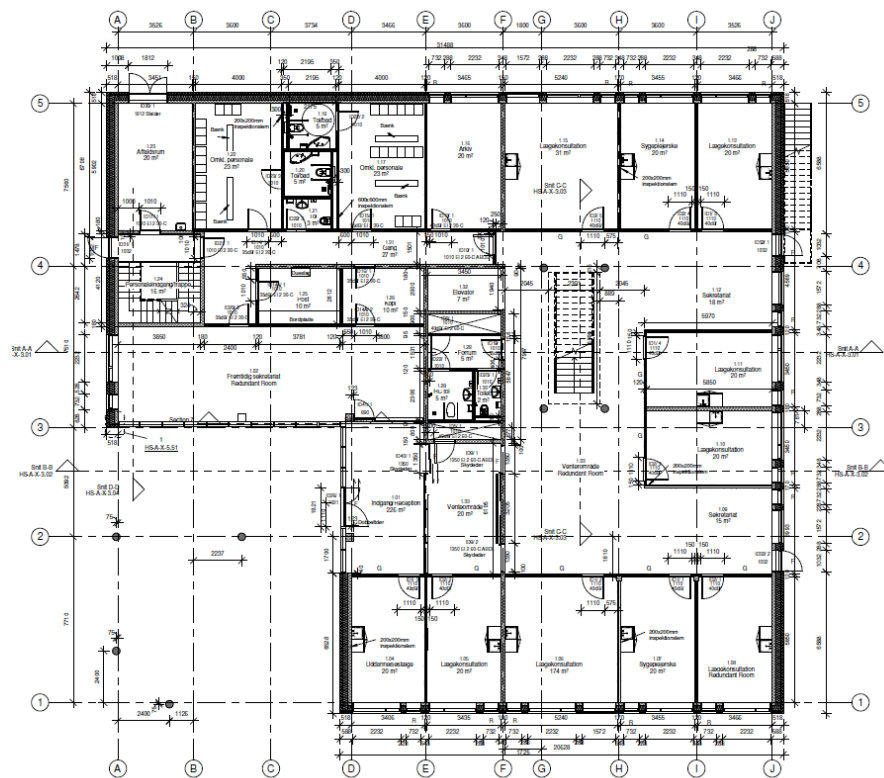


Figure 0.3 Sundhedshus Hurup ground floor plan

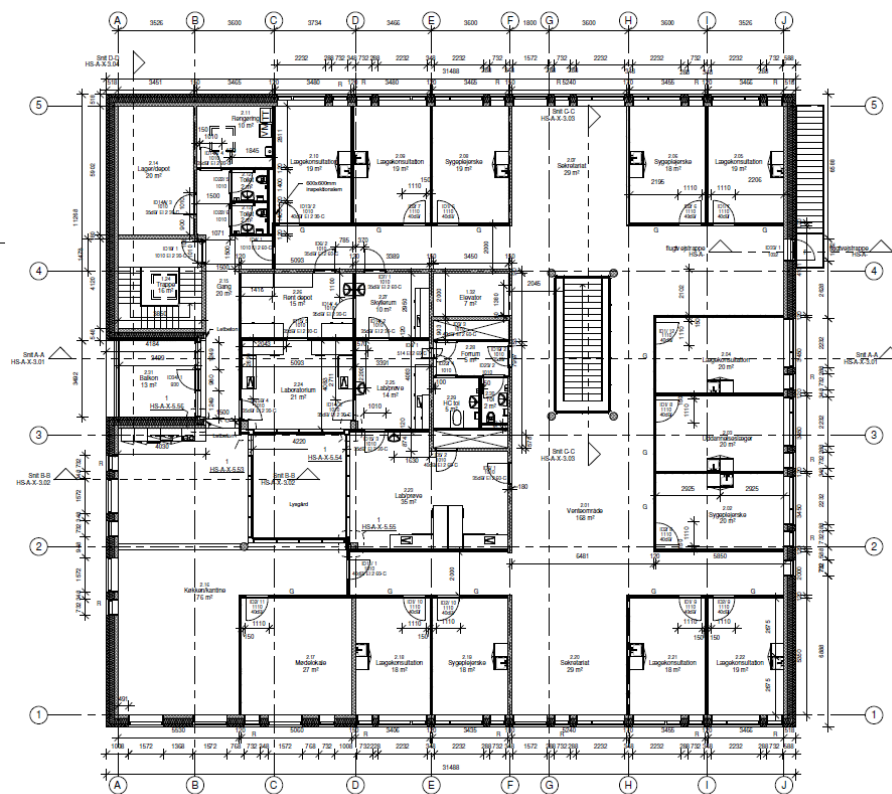


Figure 0.4 Hurup Sundhedshus first floor plan

Sæby Sundhedshus

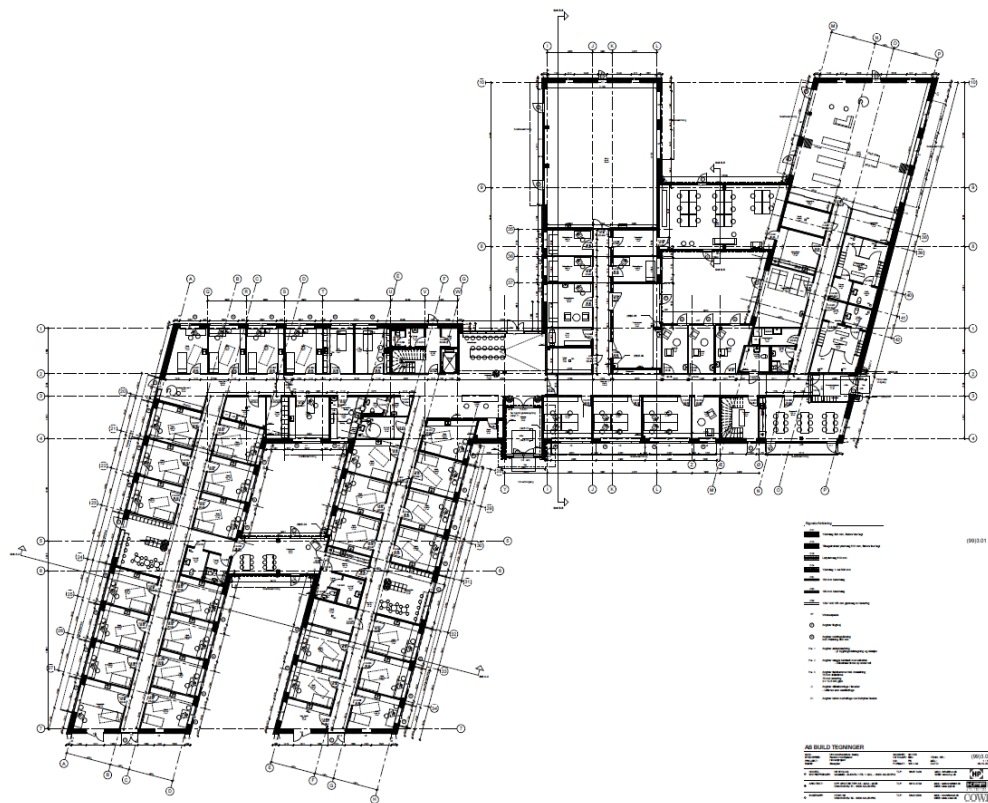


Figure 0.5 Sæby Sundhedshus ground floor plan

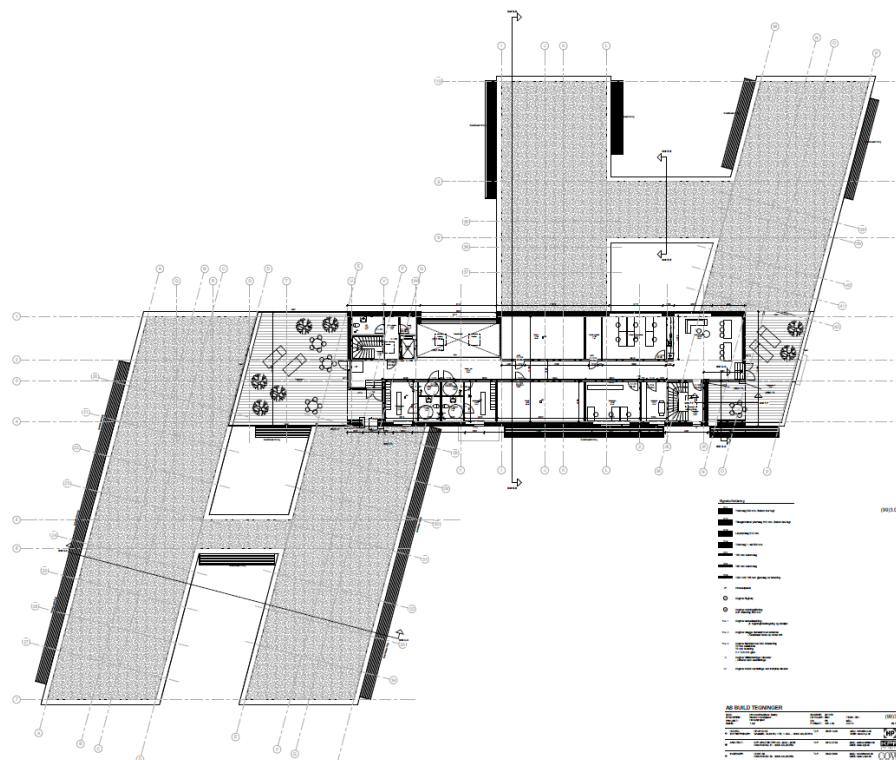
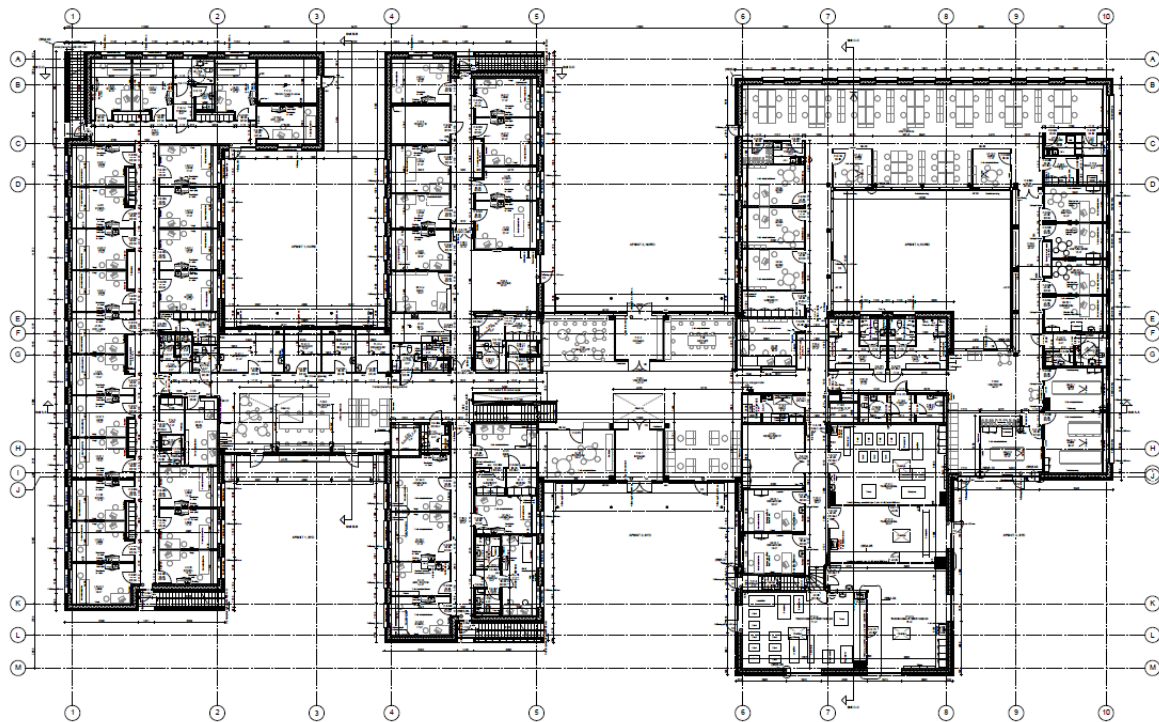
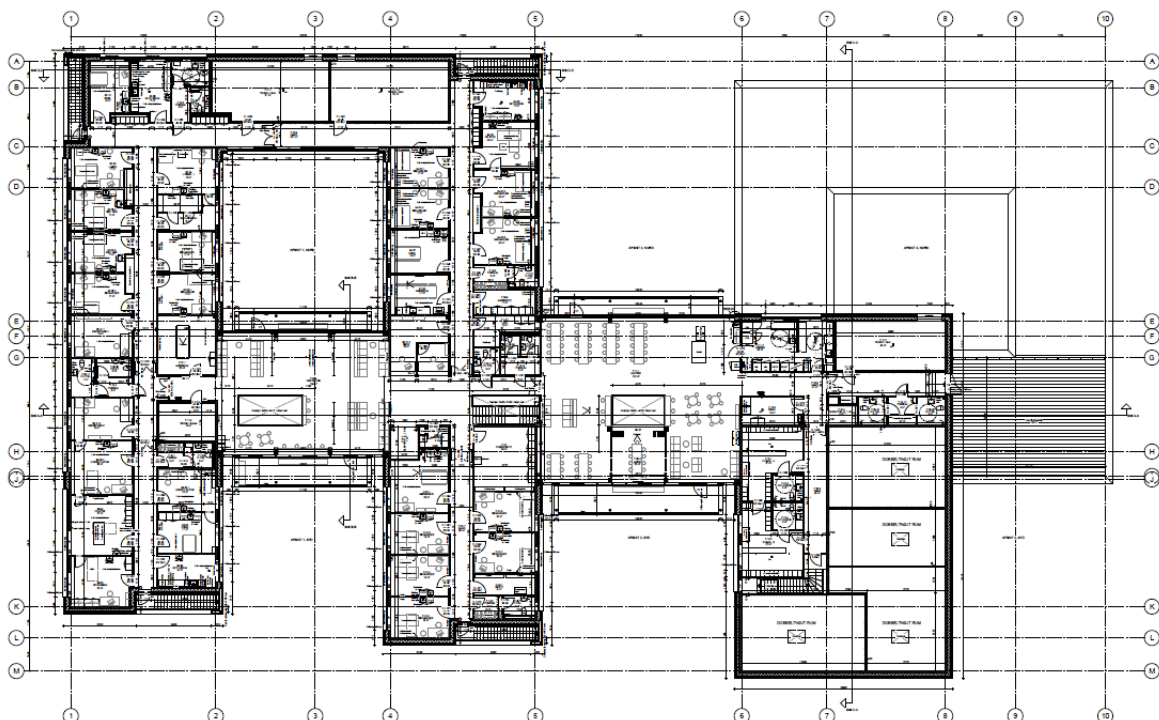


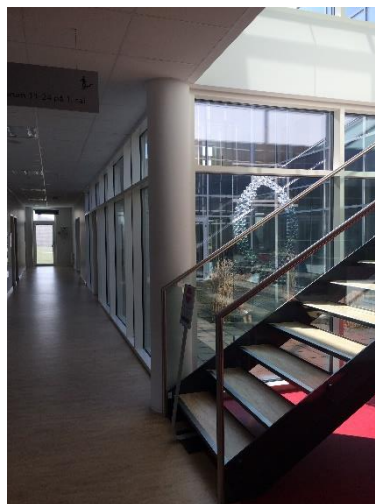
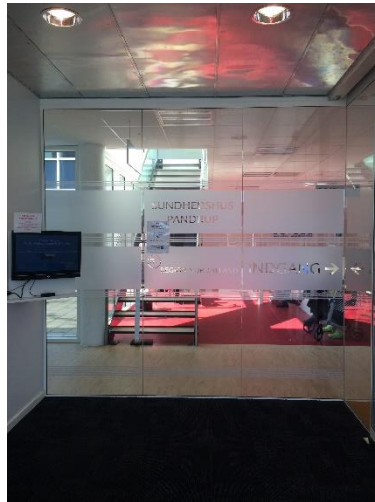
Figure 0.6 Sæby Sundhedshus first floor plan

Brønderslev Sundhedshus**Figure 0.7 Brønderslev Sundhedshus ground floor plan****Figure 0.8 Brønderslev Sundhedshus first floor plan**

APENDIX B – SITE VISIT

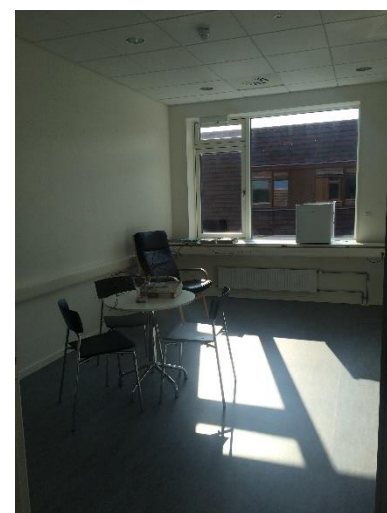
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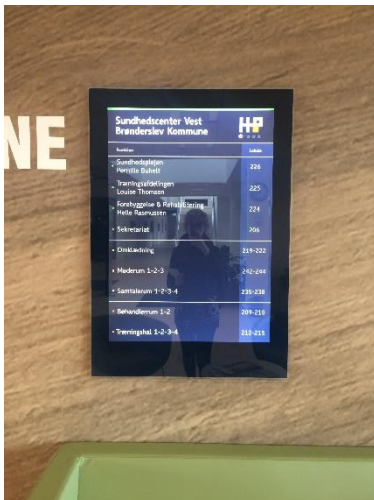
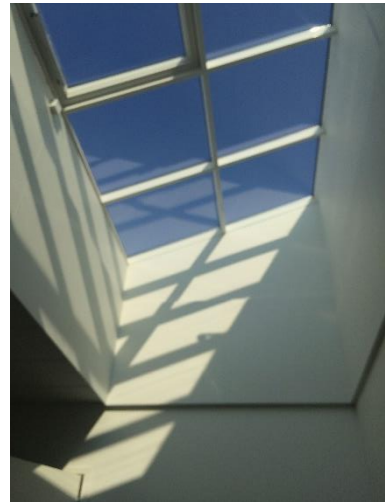
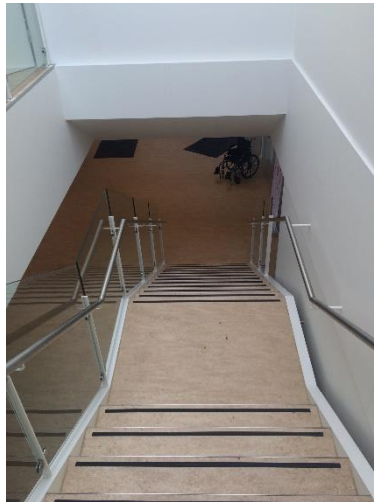




Brønderslev Sundhedshus (04.04.2017)









APPENDIX C – INTERVIEWS

RESEARCH QUESTIONS	INTERVIEW QUESTIONS	TOPIC
	<ul style="list-style-type: none"> What was your position at the healthcare centre project? 	Introduction
What is the background of the professionals involved in the four healthcare buildings construction process?	<ul style="list-style-type: none"> For how long have you been working with DGNB certification? 	Professionals background and experience
	<ul style="list-style-type: none"> What was the first DGNB certified project that you worked with? 	
	<ul style="list-style-type: none"> Did you have any previous knowledge about the sustainability assessment process? 	
How does Tender phase influence the sustainability assessment process of a project?	<ul style="list-style-type: none"> Was your workload estimation of the sustainability assessment documentation, based on the information provided through the tender invitation, reflecting the actual workload? How did it influence your work? 	Tender phase
What is the influence of the DGNB certification in the team dynamic?	<ul style="list-style-type: none"> In your opinion, how well organized were the teams involved in the construction phase? 	Organization and planning Communication
	<ul style="list-style-type: none"> In your opinion, were there enough follow up meetings with the DGNB auditor? Do you have any suggestion to improve them? 	
	<ul style="list-style-type: none"> From your perspective, to which extent were the building industry professionals involved in the construction phase willing to fully collaborate between each other? Could you give an example? 	
	<ul style="list-style-type: none"> How did you experience the interaction between the project manager and the DGNB auditor? What were the challenges faced? 	
	<ul style="list-style-type: none"> In your opinion, how well informed were the members of the integrated design team and subcontractors about the DGNB assessment progress? 	
How does DGNB certification affect the construction process?	<ul style="list-style-type: none"> From your point of view, what were the advantages and disadvantages of the implementation of DGNB certification during the planning and construction processes? What were the challenges faced? 	DGNB certification

Table 0.1 Structure interviews 1, 2 and 3

RESEARCH QUESTIONS	INTERVIEW QUESTIONS	TOPIC
	<ul style="list-style-type: none"> What was your role at the four healthcare buildings? 	Introduction
What is the background of the professionals involved in the four healthcare buildings construction process?	<ul style="list-style-type: none"> What is your experience with sustainable construction/DGNB certification? Why did Region North Jutland decided to implement DGNB certification as a requirement for the four buildings? And why a silver award? 	Professionals background and experience
What is the influence of the DGNB certification in the team dynamic?	<ul style="list-style-type: none"> Can you recall what were the mayor issues faced during the sustainability assessment of the four buildings? From your point of view, what were the advantages and disadvantages of the implementation of DGNB certification for the four healthcare centres? How did it affect the projects' execution? In your opinion, were the contracting and sub-contracting companies prepared to provide the necessary documentation for the DGNB assessment? Were there any issues with the required documentation from subcontractors? 	Organization and planning Communication
LEAN construction	<ul style="list-style-type: none"> In accordance with the projects' documentation, LEAN construction principle was a must for the management of the four projects, why did you decide to implement it? Did LEAN construction enhanced the construction process of the four buildings? In which way? Were there any handicaps due to the inexperience of the main contractor and subcontractors with sustainable construction and LEAN construction? 	
How does DGNB certification affect the construction process?	<ul style="list-style-type: none"> Did you experience an optimal information sharing between the parties involved in the buildings' execution? Did it vary in each project? How did you experience the communication between the project manager and the subcontractors? Were the subcontractors aware of the strict project requirements established by the client? What were the issues faced during the projects that might have caused more delays or increased projects' costs? 	

Table 0.2 Structure interview 4

INTERVIEW 1, LUND & STAUN A/S

S: Sofia Fernandez Montes

B: Bent Skararup Lindhardt

S: What was your position at Pandrup healthcare centre?

B: I work on sales and marketing which is a quite broad field, but at that point, I also took part on the tender phase, preparing the tender offer documentation. I was also involved in the DGNB assessment during the project execution, defining what work had to be done.

S: For how long have you been working with DGNB certification system?

B: Pandrup project was the first time that I worked with DGNB, and it was completely new for the company at that time. When we saw DGNB as a requirement, we just decided to go for it. We worked together with our engineering advisors from Rambøll, because they had their own DGNB advisor, who guided us through the tender phase.

We also participated in the tender offer for Hurup healthcare centre.

S: Did you have any previous knowledge about the sustainability assessment process?

B: No, I had no previous experience or knowledge about sustainability at the time.

S: Was your workload estimation of the sustainability assessment, based on the information provided through the tender invitation, reflecting the actual workload?

B: At that point we were waiting just to see what would happen. During the tender phase, we could not decide how many hours of work we were going to need, but we discussed it with the engineers and they gave us an estimation on an hourly basis. So, we knew that the sustainability assessment was going to take quite some time, but we were prepared to put the hours and effort needed. As I said before, we did not have the specific number of working hours.

We also saw that sustainability was expanding within the building industry and we were really interested into work with it. We saw Pandrup project as a chance to expand the company's market. Also, for our company it was new to participate in a project as total entrepreneur so it was a learning process for us.

S: In your opinion, how well organized were the teams involved in the construction phase?

B: It was an advantage that Lean construction was stated as a requirement for the project along with DGNB sustainability certification, because we already had some previous experience with Lean construction. Lean construction and DGNB certification are quite a good match.

We often scheduled meetings on site with the workers before the actual daily work was starting, were the evolution of the project and the daily tasks where discussed, which at the end of the project paid off. We also had a meeting with the subcontractors before the start of the project execution where we explained the DGNB certification requirements and each professional task. So, I consider that we had a good team, where people was willing to participate.

Moreover, the building owner established a very clear description of the project process, so everybody was well informed of the steps that had to be done.

S: In your opinion, were there enough follow up meetings together with the DGNB auditor?

B: The follow up meetings with the DGNB auditor, in my opinion, were very helpful and good. We had an action list in which it was established who oversaw what and the possible needs for improvement in the sustainability assessment criteria, as well as a review of the actual status of the DGNB certification process. This made the whole assessment process easier to follow.

S: How often were you holding follow up meetings?

B: We were having every two weeks a meeting with the subcontractors, and with the building owner once a month. The meetings schedule was set up in accordance with LEAN construction principles. Also, the onsite meetings were performed twice a day.

S: From your perspective, to which extent were the building industry professionals involved in the construction phase willing to fully collaborate between each other? Could you give me an example?

B: I believe that the subcontractors were willing to collaborate, but it should be taken into consideration the working culture of the companies. So, from some of the subcontractors it was easier to get the necessary documentation for the DGNB assessment, but i.e. the electrician was more familiar with traditional construction methods, so it was not possible to obtain certain data sheets, not because they did not want to, but because they were not used to these requirements.

S: How did you experience the interaction between the project manager and the DGNB auditor?

B: From my point of view it was fine, there was a good collaboration and communication. It was easy to work with the DGNB auditor.

S: In your opinion, how well informed about the DGNB assessment progress were the members of the integrated design team and the subcontractors involved in the construction phase?

B: *I think that there were enough meetings and everybody was updated. So, I believe that everybody was well informed and aware of what was going on. During the first meetings, everybody understood that we all had to collaborate and work with each other as a team.*

S: **From your point of view, what were the advantages and disadvantages of the implementation of DGNB sustainability certification on the planning and construction processes?**

B: *Of course, you must expend some extra time with the project documentation and trying to understand the several criteria contained in DGNB certification, but that means that every requirement is taken into consideration from the early stages of the project, avoiding surprises during the execution of the project.*

S: **Did you take part in more DGNB certified projects after Pandrup Sundhedshus?**

B: *Yes, we have worked in two other certified projects. One of the projects was completed last year and the certification award is in process. The second project is still in process, but we have already completed the pre-certification, and we aimed for platinum award.*

S: **Do you believe that it will be beneficial for DGNB certification to include certain aspects of the process and technical qualities of the building in the Danish Building Regulations?**

B: *I think that it could be beneficial for the sustainability certification of buildings, but it is difficult to find a balance, because of the continuous evolution of DGNB certification. In Denmark, Building Class 2020 has already strict requirements, which helps the fulfilment of certain parameters contained in DGNB certification, such as energy or indoor comfort requirements.*

INTERVIEW 2, COWI A/S

S: Sofia Fernandez Montes

A: Allan Hesselholt

S: What was your position at Sæby and Brønderslev healthcare centres?

A: I was responsible for the design of the mechanical installation, heating and water, sanitary installation, and ventilation system. Additionally, I oversaw the thermal comfort, indoor environmental quality and energy calculations, and finally DGNB consultation.

S: For how long have you been working with DGNB certification system?

A: Sæby Sundhedshus was the first DGNB certified project in which I took part, so since 2013.

S: What was the first DGNB certified project that you have worked with?

A: As I said before, the healthcare centre in Sæby was my first experience working with DGNB. Fortunately, the company had previous experiences with DGNB, so I used as a reference the experience from other colleges.

S: Did you have any previous knowledge about sustainable building assessment?

A: When we started working at Sæby Sundhedshus project I had no experience with sustainable building certification. But some colleges from Cowi helped me through their previous experiences, so those projects were used as a reference.

S: What was your perception of DGNB certification when you started working at Sæby project?

A: As a system is easy to understand, but at that point it became hard because the DGNB manual was written in English. The first translation was made from German to English, and it was not the best quality of translation.

Also, for some criteria it became hard to understand which documentation was necessary, but Green Building Council Denmark was very helpful and they appreciated that we asked question, which they answered every time, because they were aware that the manual needed some improvements.

I do not remember everything very well, since it was long time ago, but it was a tough start.

S: Which version of the DGNB schema did you used?

A: We worked with the second version of the schema for “New Office and Administrative buildings”, from 2012. As I said before, it was the first schema adapted to the Danish market, so it was translated to English, not in the best quality.

S: From your point of view, was your workload estimation of the sustainability assessment process, based on the information provided through the call for tender, reflecting the actual workload?

A: We did as approximative estimation of the needs for the project, and it was quite precise. As I referred before, I had some colleges who had worked before with DGNB certification, so we used them as partners to estimate the workload.

On the other hand, the tender documents did not specify anything other than the requirement for DGNB silver award, so we decided to base the workload estimation on the internal company's knowledge.

S: Did you felt that you were provided the same quality of documentation at the call for tender at Sæby and Brønderslev projects?

A: Sæby Sundhedshus was our first project, but fortunately we had the same main contractor and integrated design team in charge of the execution of Sæby and Brønderslev projects. That situation made the bidding process at Brønderslev project easy, because everybody was aware of the necessary work for the construction phase. In contrast, at Sæby project we had a lot of initial work, but luckily everybody was willing to contribute and collaborate. Probably, that is the reason why the project outcome turn out to be quite good.

S: In your opinion, how well organized were the teams involved in the construction face?

A: In my opinion, the teams were quite well organized because of the figure of the main contractor, which in charge of the construction phase and needs to appoint a person responsible for the DGNB assessment documentation.

In my case, I oversaw DGNB consultancy for the engineering subadvisor, Cowi, and there was another professional appointed for the same task working for the architecture subadvisor. I was in frequent contact with the architect, and we had several meetings along the year, both for the design and construction phase, where we went through the assessment documentation to understand what tasks were already done and what work was left.

Overall, I think that the team was well organized.

S: In your opinion, were there enough follow up meetings together with the DGNB auditor?

A: Yes, there were. Of course, at Sæby Sundhedshus project we had more follow up meetings, since it was the first project from the building portfolio in which we were involved. But when it comes to the review performed by Green Building Council of the sustainability assessment, the number of questions

or remarks received were below 20 for Sæby project, which is quite low, and around 5 for Brønderslev. I believe that the number of questions suggest that the information provided was enough, mostly due to the number of meetings performed between the professionals.

S: Do you have any suggestion for a possible improvement of the communication?

A: Of course, we learned some new things from Sæby and Brønderslev healthcare centres that nowadays we are implementing in the projects that we work. One of the things is that the main contractor needs to appoint a specific person in charge of the DGNB assessment document collection. Nowadays, when we participate in a tender process, we demand that the main contractor appoints a person for the collection of the assessment documentation and information, as well as to perform regular follow up meetings, following a regular interval. We learned that from during the two projects, and I am sure that if at the time, we would have done it, the outcome would have been even better.

S: From your perspective, to which extent were the building industry professionals involved in the construction phase willing to fully collaborate between each other?

A: I think that implementing DGNB certification in a project enhances the information sharing process. It is common that arise problems with subcontractors due to lack of material's security data sheets, while, on the other hand, the main contractor usually has all the necessary documentation required, because of the direct contact with the building owner. It is a more difficult task when it comes to the subcontractors because they are not in direct contact with the building owner and they normally leave the site before the project is completed.

Moreover, the main contractor had agreements to pull back payments for all the parties involved in the execution of the projects. So, i.e. if any of the companies did not supply the required data or information, whether we talk about engineers, architects, or subcontractors, the main contractor would not give the payments, with the intention to secure that everybody was willing to participate and collaborate.

S: How did you experience the interaction between the project manager and the DGNB auditor?

A: As a DGNB consultant, I see the assessment process as a side by side cooperation between the project manager and the DGNB auditor. This is due to the amount of common work, such as pointing out which tasks had to be performed by the engineers, architects, etc., along with the time schedule and the list of payments. So, as I referred before, all the assessment work should be carried out with a close communication and side by side participation of the main contractor and the DGNB auditor.

S: Did you experience any problem to fulfil the minimum requirements for the DGNB silver award?

A: Yes, in the version of the DGNB manual that we used, there was a criterion regarding the construction materials, which, due to the way it was formulated, it made it nearly impossible to achieve it.

From the beginning of the projects, we took the decision of not aim for this criterion, because there were some issues to gather the security data sheets for some of the materials. Also, regarding the process quality criteria, there were some other criterion that could not be fulfilled as well due to they had to be submitted.

S: In your opinion, how well informed about the DGNB assessment progress were the members of the integrated design team and the subcontractors in charge of the execution of the projects?

A: As I explained before, Sæby Sundhedshus was the first DGNB certified project in which I took part, meaning that I had previous experience with DGNB. So, I had a meeting in my company with the colleges which had previous experience with sustainability assessment of buildings. And couple of months after, I went myself to the consultant courses. But, we started from scratch, and we schedule a lot of meetings at the beginning of the construction, in which we all went through the manual and the assessment documentation material.

For Sæby Sundhedshus, the process was harder, but on the second project, since we had the exact same team, things became easier without as many meetings. Moreover, we had the advantage that a big part of the assessment documentation for one project could be used for the next one due to the similarities of the two buildings.

S: From your perspective, what were the advantages and disadvantages of the implementation of DGNB certification in the projects? What were the challenges faced?

A: One of the disadvantages is that DGNB certification demands a certified auditor, and a big economical investment. On the other hand, the advantages are mostly that, as a building owner, you have all the buildings documentation stored and connected in one place, and the assumptions made through the building process, with information about who and why they were made.

In a conventional building project, you probably could call the engineer to get some information about a certain topic, such as indoor environment, or the architect if you need to know something about the design, making you go through all the collecting data process. In the case of a DGNB certified building, all the information is available in one place, and of course, it is necessary a review from a third party (Green Building Council) to ensure the quality of the assessment.

S: Do you think that the implementation of LEAN construction in the projects execution was beneficial for the process quality aspects of the DGNB assessment?

A: *It is a side by side process, wither if we talk about DGNB or LEAN construction, both share the same values and foundation, where things should be planned up front.*

INTERVIEW 3, MT HØJGAARD

S: Sofia Fernandez Montes

M: Mads Olsen

S: What was your position at Hurup healthcare centres?

M: I was the project manager from MT Højgaard, and I oversaw the design and construction of Hurup healthcare centre.

S: For how long have you been working with DGNB certification system?

M: In MT Højgaard we had been working quite some years with sustainability, we had worked with DGNB buildings but mostly in Copenhagen area (office buildings). Hurup healthcare centre was my first DGNB project. And we did not use our resources from Copenhagen connected, but we had as engineering consultant Grontmij, and they were the ones taking care of the DGNB certification.

S: What was the first DGNB certified project that you have worked with?

M: Hurup healthcare centre was my first DGNB certified building.

S: Did you have any previous knowledge about sustainability assessment process?

M: I had some experience with international sustainability certifications like LEED and BREEAM. I knew the principals about sustainability certifications but not in detail. I had no knowledge about the criteria points from DGNB or the certification process, but, as I said before, we worked together with Grontmij, which had all the knowledge.

S: Was your workload estimation of the sustainability assessment documentation, based on the information provided through the tender material, reflecting the actual workload?

M: I think that the engineers took charge of the time estimation and they did a good job. But in the case of the architects, they faced some challenges with DGNB because they had never worked with this sustainability certification before, so we had to start all over again.

In our company, MT Højgaard since I was the responsible of the project management, I just adjust the work to my working hours. And, within a DGNB project, more parties are involved, the consultants and subcontractors, and they are in charge also to provide their part of the documentation to achieve the certification and the documentation about the quality assurance tests.

At the end, there were some final tests that needed to be performed, such as blower door test, but at the end they were not carried out.

S: Did you feel that you were provided enough information about the DGNB certification along with the tender invitation?

M: *A lot of the decisions regarding the DGNB certification were already made even before we won the tender and before the construction phases, regarding mostly the architecture of the building.*

Through the tender call documentation, we got information about the project requirements for the main contractor, of course including some information about the DGNB certification. So, we price what we were asked, taking into consideration the DGNB certification costs.

We signed contracts with our subcontractors where we specified the work and documentation that they had to provide for the DGNB assessment of the building. We also provided them with lists with descriptions of the tasks that they had to perform.

Regarding the building site, there was a requirement about the waste management, which is more work than what we normally do, but we found a company that took charge of the building site waste making the work easier.

S: In your opinion, how well organized were the teams involved in the construction phase?

M: *Not everybody in the team knew what they had to do from the beginning of the project. During the design phase the architects and engineers were very organized, and specially the architects were really open to the implementation of an integrated design process.*

I think that the team spent more hours than expected with the organization and the clarification of each professional's tasks.

S: In your opinion were there enough follow up meetings with the DGNB auditor?

M: *At Hurup project, the communication with the DGNB auditor was mostly by phone. Before the construction started we created a detailed action list where the tasks already performed during the design phase were already checked.*

We spent a lot of time collecting the documentation for the DGNB assessment of the building, mostly regarding the materials, where we had to prove their origin and the information regarding the hazardous compounds. In example, with the paintings, it was difficult to obtain the security data sheets required by the process quality criteria of DGNB. We really tried to get the documentation, but it was really complicated to obtain it. That is the problem of DGNB, if you use a certain type of, as an example, wood, you need to give prove through the documentation.

S: Do you have any suggestion for the improvement of the collaboration and communication of the project manager and the DGNB auditor?

M: Since we had a contract with the company where the DGNB consultant was working, it was easier to work all together as a team and collaborate with each other. Also, the people were very open and fully committed to collaborate.

From my point of view, I think that the communication with the DGNB auditor through the project was good. Grøntmij was very open and we were comfortable working with them.

We also applied throughout the project TrimByg, which is based on Lean Construction principles, and that helped us with the management of the subcontractors. We use it in all our projects, and we even have a consultant assigned for the implementation of this tool on the building site. We will make all together the time planning, etc.

S: From your perspective, to which extent were the building industry professionals involved in the construction phase willing to fully collaborate between each other? Could you give me an example?

M: Yes, everybody was committed to collaborate, but, of course, the lower you go down on the pyramid, it is more difficult. The subcontractors and the onsite workers are disconnected from the final purpose of DGNB, but for that we had the project manager and site manager, which made sure that the requirements were fulfilled.

But that is true that there are some issues due to their lack of information about the sustainability assessment. There are some products that you can use in a regular building project but in a DGNB certified project you need to inform about their risks. So, from my point of view, sometimes onsite the workers use products that are not supposed to, but there is no way to completely control it.

So, I believe that it should be used extra time to introduce to the subcontractors and craftsmen about DGNB certification, where the criteria are explained so they understand why certain methods or products cannot be used in the construction process.

INTERVIEW 4, BUILDING OWNER – REGION NORTH JUTLAND

S: Sofia Fernández Montes

A: Anne Hedegaard (Region North Jutland)

S: What was your role at the four healthcare centre buildings?

A: I was representing the public developer, Region North Jutland, for the four buildings projects, as a project manager, and, it was the person in charge for the tender preparation and economy aspects of the four projects.

S: What is your experience with sustainable construction/DGNB certification?

A: Well, at that time, I did not have a lot of experience, but I got to know the certification by working with it at the four healthcare centre projects. So, I have been working with DGNB system since 2011-2012.

S: Why did Region North Jutland decide to implement DGNB certification as a requirement for the four building projects? And why silver award?

A: Region North Jutland became the first Climate Region in Denmark, since 2007. A part of the deal as a Climate Region was to reduce the CO₂ emissions by 2% each year until 2025, I think. Due to that, we look at the CO₂ emissions from vehicles along the region, and the emission from our building projects. We found out that our building projects were responsible for a large amount of greenhouse emissions. That is the reason why we chose to implement DGNB to our projects, since it was a new system and we wanted to test it.

At the beginning, due to inexperience, we chose silver certification because it was a middle ground award, so the demands were not that tight and the cost of the certification was not as high as gold certification. We also found out that silver certification was matching the requirements from Building Class 2020.

S: Can you recall what were the mayor issues faced during the sustainability assessment of the four buildings?

A: We knew that most of the professionals did not have at the time much experience with sustainability, so we required that at least one person from each team had some experience with DGNB sustainability certification.

The main issue that we faced was to make the professionals understand that they had to work as a team, to understand what they had to take into consideration in each phase of the building project and that all considerations had to be rate in accordance to DGNB certification.

Also, when it comes to the entrepreneurs, it is necessary to explain what are the aspects that need to be taken into consideration, and what work is already done for the sustainability certification. Also, there are certain requirements for materials, i.e. wood, I which it is necessary to make sure that all the documentation is available, such as the chain of custody. That was the more difficult part.

S: From your point of view, what were the advantages and disadvantages of the implementation of DGNB certification for the four healthcare centres? How did it affect the projects' execution?

A: I think that the implementation of DGNB was an advantage because we obtained a high-quality building. The certification allows to control that all the considerations are integrated in the right moment of the project process.

One of the disadvantages could be the need for explanation of DGNB certification to the professionals, which we still have in our current projects because not everybody is into sustainability and sometimes not really interested.

S: Even if sustainable development has been gaining fame within the building industry, some companies maintain traditional working methods and techniques. In your opinion, were the contracting and sub-contracting companies prepared to provide the necessary documentation for the DGNB assessment? Were there any issues with the required documentation from subcontractors?

A: Well in the first two projects, I got the feeling that for the main contractors and subcontractors, it was important to deliver what was expected from the project requirements and to gain experience with sustainability certification.

On the other hand, in our latest projects, it has been a bit different, because some contractors tend to not care as much about the DGNB certification, because they think is too expensive and they need to use a lot of time to fulfil the criteria.

Even though, as a public developer we still set the demand for the achievement of DGNB for all our new projects, some professionals think that it does not concern them. The main contractors just use consultants who bring them the necessary knowledge about sustainability certification. But, from my point of view, I find that the best team is the one that has experienced interdisciplinary professionals

who share their knowledge between each other, so the whole team brings a lot of knowledge to the project.

Anyway, I think that the four healthcare buildings were not especially complicated. When you take a residential building or a hospital, the requirements are stricter, as well as the costs increase, and if the professionals are not careful with their work, the attainment of DGNB certification could be a problem.

S: In accordance with the projects' documentation, LEAN construction principle was a must for the management of the four projects, why did you decide to implement it?

A: As I learn a bit more about DGNB certification, I found out that the principles of LEAN construction could be a reference also for the building process, and that they complement each other very good. That is the reason why we established LEAN construction as a requiring, which we still do in our current projects.

S: Did LEAN construction enhanced the construction process of the four buildings? In which way?

A: At the four projects, the implementation of LEAN construction made easier the work, through the implementation, i.e. on site meetings, maintaining all the professionals informed about the evolution of the work.

S: Were there any handicaps due to the inexperience of the main contractor and subcontractors with sustainable construction and LEAN construction?

A: I think that the inexperience of the main contractor and subcontractor affected the most when it comes to the construction materials. the main contractor had to go until the end of the chain, to make sure that subcontractors were informed of the high requirements for the materials disposal and documentation.

As I referred before, when it comes to wooden materials, there are strict requirements for the disposal and storage, such as not keep certified with non-certified wooden materials.

But I cannot recall any other examples right now.

S: Where there any issues at tender phase caused by mistakes during the design proposal of the buildings? Could you give me an example?

A: The issue was due to the demands stated on Building Class 2020 from the Building Regulations and DGNB certification demand. I think that in Hurup project, the team had problems fulfilling the requirements established on Building Class 2020 regarding the daylight demands, when calculating the daylight factor. Since the building is used for medical care, we could not get as much flexibility in the

rooms as we wanted, due to the daylight requirements, so the design team was not sure about which parameter had to be prioritized, the flexibility of the building or the daylight factor of the working spaces.

S: Where there any differences on the evaluation of the tender offers from project to project?

A: At the beginning the idea was to hold the tender of the four buildings at the same time, but due to delays on some of the projects, we divided the projects in two groups. Thanks to that, we had some time to analyse the first two projects, which helped us to adjust the weighing of the tender offers evaluation of the last two projects.

We also found out that a lot of companies were willing to participate in the projects, so, due to the concerns from the first two projects, we changed the tender evaluation weighing, giving higher score for the sustainability considerations of the offers from 20% to 25%, reducing the weighing of the process aspects.

S: How did you experience the communication between the project manager and the subcontractors? Did it vary from project to project?

A: I think that the communication was enhanced due to the implementation of LEAN construction in the four projects. In example, in Hurup project, we had a very good construction site, and I knew that the main contractor, MT Højgaard, was really skill on LEAN construction, which you could notice from the beginning of the work and at the site. The site was clean and organized, and you could notice that there was a good working environment, where there was a constant communication between the workers. Also, we had a similar situation at Pandrup project, where the number of on-site accidents was reduced and the project hand in was before time.

S: Since we are talking about the projects hand in deadline, where the four buildings hand in before time?

A: No, the first two projects, Pandrup and Hurup, were hand in before time, and the last two project were just completed on the expected date.

S: What were the issues faced during the projects that might have caused more delays or increased projects' costs?

A: In example in Pandrup, we were asked if we would like to achieve a golden award instead of silver for the DGNB certification. So, the criteria requirements were evaluated as well as the extra costs, and that made slower the project process.

Nowadays, when we take our projects to tender, we have a minimum requirement for each criterion and it is up to the contractor to try to achieve more points or just our minimum requirements. Our minimum DGNB requirement remains as silver, which now corresponds to the golden award, and the contractors must present an offer where they fill in some of the points for the less relevant criteria.

S: I have noticed that some of the projects did not take it into consideration the commissioning requirements, why did it happen?

A: think that the problem is that we did not have a lot of experience with the commissioning demands of the DGNB certification. Afterwards, we found out that the commissioning is one of the most important to prioritize this criterion. Now for every new project, no matter which type of building, we require minimum of 75 points in the commissioning criteria, because we experience in the four first projects, that, even though they were a success, it was hard to start operating the buildings and maintain them as intended.

Nowadays we are aware of the relevance of the commissioning process for our new buildings.

S: Where there any DGNB criteria that gave some problems during the four first projects which help you improve the new buildings that you are working on?

As I said before, the criteria regarding materials, from the environmental quality group, and the economic criteria and water use and the reuse of rain water.

S: Did the archaeological remains found at the building site of Pandrup healthcare centre affect the building process in any way?

A: We found out that there were a lot of archaeological remains at the site, but at an early stage so it did not interfere with the project process. The building was finished first and then the work related with the remains was finished later. We made a project out of it, so we got extra money from the North Jutland Historical Museum.

APPENDIX D – TENDER PHASE

Assignment and criteria evaluation of tender offers

Quality – this criterion evaluates the completion of the quality list and offer description. Moreover, it will be weighed the suitability of the offered qualities for an optimal operation and maintenance, as well as the design suits the architectural idea (essence of the project)

Price – this criterion takes into consideration the total contractor price

Sustainability/DGNB - this criteria analyses that the building fulfils Building Regulations 2020 and DGNB silver. Since the project goals are very ambitious, and the project's success therefore depends on the experience of the construction team, sustainability assessment will be based on the fulfilment of the following requirements:

- DGNB assessment matrix (DGNB spreadsheet)
- Incorporation of DGNB into the design, construction and operation of the building
- Integrated Design Team
- Experts' experience in low energy buildings
- Experience with environmental friendly material use, LCC analysis, cradle to cradle, etc.
- DGNB Consultant/Auditor, or expert with extensive experience in building certification systems, such as LEED, BREEAM, DGNB, or passive houses

Description of the achievement of BC 2020 in accordance with the following requirements:

- Ventilation and cooling principle (if cooling is necessary)
- Heating and DHW principle
- Report of the use of renewable energy sources (solar cells, and solar collector's area and annual performance)

Process – this criterion is assessed based on the tender's description of process of implementation planning and construction phase. The emphasis is on:

- Organization, including the CV's of the professionals involved
- Tender intends to ensure no problems due to sickness, etc. (back-up)
- How is LEAN construction incorporated during the construction process?