Strategies for Commissioning Processes to Ensure Sustainable Building Performance

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Abstract. Building commissioning has developed over the last decades starting in the US as a quality insurance methodology, but it has increasingly been applied in other countries, including Denmark where this study was undertaken. The purpose of the paper is to investigate, how commissioning can be applied – not only during the building process but also during building operation, and to develop recommendations for strategies concerning implementation of commissioning processes to ensure sustainable building performance for both new and existing buildings. The study included a number of expert interviews as well as a case study of a Facilities Management (FM) organisation and one of their new office and laboratory buildings recently occupied. The case study included both quantitative investigations of energy consumptions and qualitative investigations based on documents and interviews. The research shows that commissioning has great potential to improve the sustainable performance of buildings, but it is important for FM organisations to develop strategies for their commissioning processes for the whole building life cycle. For new buildings, it is important to have particular commissioning processes in place for trouble shooting in the period from contractors handing over the building until a steady operation is established, but an ongoing commissioning process is also important to ensure continuous sustainable performance. The paper has implications for researchers by paving the way for a new field of research focusing on how to ensure sustainable building performance by implementing commissioning processes during the whole life cycle of buildings. It also has practical implications by providing specific recommendations for building clients and FM organisation concerning strategies for commissioning process that can ensure sustainable building performance and support SDG 11 and 12.

1. Introduction
The development of new building technologies with the aim to achieve more functional and sustainable buildings has led to more complex technical installations in new buildings, which represents a challenge to manage for all parties involved. A result of this has been the appearance of performance gaps and basically implies that new buildings are not functioning as expected [1][2][3]. Building commissioning started in the US as a quality insurance methodology and research from the US shows energy saving of approximately 13% and an average payback period of 4.2 years, when implementing a commissioning process [4]. However, building commissioning is a relative new term in the Danish building industry and thus, the application has increased in recent years due to enhanced technical requirements of new buildings. The commissioning process can be defined as a quality-based management process with the aim of considering the interactions of the technical installations and the overall economy of building projects [5]. A continuation of the commissioning process is possible and can be defined in the terms
“ongoing commissioning”, and “monitoring-based commissioning”. The focus is on the last phase of a completed commissioned building and concerns sustaining the building performance throughout the building’s lifetime as well as methods for continuous optimization of building performance [6][7]. The value of implementing an ongoing commissioning process has been studied in a survey with 120 respondents from the building industry including commissioning providers, owners, managers, engineers and contractors distributed in all regions of North America. The survey results demonstrated that by implementing an ongoing commissioning process, activities related to improve operations management and drive energy optimisation, 65% of the respondents indicated an average simple payback period within the first two years of operation for the buildings [8].

This paper investigates how commissioning can be applied in the construction process and during the further building operation. Aiming to realize the UN’s ambitious Sustainable Development Goals (SDGs), this research contributes to achieving improved energy performance of buildings through management strategies, which is an important initiative in order to address the SDG 11 “Sustainable cities and communities” [9] and SDG 12 “Responsible consumption and production“ [10]. The research is based on a case study of a Facilities Management (FM) organisation combined with expert interviews within the field of building commissioning. The purpose of the research is to develop specific recommendations for commissioning strategies for new buildings and existing buildings.

2. Methodologies

The research was conducted in the spring of 2019. The study encompassed a literature review concerning the state of the art of applying a commissioning process throughout a building’s lifetime [11].

The empirical study was undertaken in a cooperation with a Danish FM organisation, which functions as both the building owner and the building operation. The organisation includes 200 employees and is responsible for operating more than 100 buildings and has many ongoing new construction projects at a university. The first author worked during the study at their office, thus, generating the possibility of ongoing knowledge sharing and dialogue with the employees together with access to internal databases and participating in relevant meetings. Furthermore, the case study concerned a recently occupied office and laboratory building. The building was evaluated on the basis of interviews with employees and internal documents. Data from energy meters were included to observe the energy consumption during the first years of operation. The aim of the case study was to gain deeper knowledge of the building’s prior commissioning process during the construction project as well as the handover process and the building’s technical functionality in operation. It was decided not to include occupants’ comfort assessments, as the scope for the case study was to seek knowledge from the technical experts of the case study building. Additionally, the investigation of the possibilities within applying data from energy meters should address how the FM organisation can work towards an increased digitalized method.

The study included 11 interviews; four individual interviews and one group interview with employees from the case organisation, one interview with an external consultant, who had been involved in the case project, and five expert interviews. The experts had years of experience concerning building operations and the commissioning process in the Danish building industry. The interviews were semi-structured, thus allowing a certain flexibility in terms of asking supplementary questions in case the interviewee demonstrated further expertise within a certain field of interest [12].

3. Key Findings

The FM organisation has had mixed experiences of involving a commissioning process in previous construction projects. The problems were almost identical, as there had not been a fixed framework for the management of commissioning activities. Hence, a hired consultant had decided the framework for commissioning, which had resulted in a lack of focus on the FM organisation’s needs. As a result, the FM organisation decided to develop their own framework for a commissioning process that must be followed for their future building projects. The construction period for the case study building was from 2014–2016, and the commissioning process was entirely handled by an external consultant, thus prior to the development of the organisation’s own framework. The building included many performance issues
at the time of handover due to a failure to complete the building’s technical systems and installations. The users moved into a building with an unsatisfying indoor climate, and the operating staff had difficulties solving the problems as the building management system (BMS) was not installed properly. The commissioning process was a relatively new concept, as the Danish Standard DS3090 was published at the time of the building project’s beginning [13] and there was a general confusion regarding the definition of a commissioning process. The application of data from the energy meters showed issues concerning acquiring valid data and the possibilities of achieving detailed data for the energy usage, as to get an accurate insight into where problems occurred.

In order to apply an ongoing commissioning process, several of the experts emphasized the importance of ensuring an "error-free" building project, and the importance of avoiding additional expenses to correct mistakes related to the construction process. Another common issue is the separation of construction budget from the operating budget in building projects, resulting in operation costs not being considered in the pricing. An efficient commissioning process is characterized by ensuring an early implementation, as the most influential decisions are made in the pre-design stage, and getting the involved stakeholders to understand that achieving a successful commissioning process requires a united effort. There was a broad consensus among the experts that continuous optimization of the technical systems will create value in the operation phase. Nevertheless, one of the main challenges among organisations is to prioritize resources for optimizing building operation, as other investments might generate a shorter payback period. Another challenge is the question of the necessary competencies related to increased technology in new buildings. The experts’ suggestions for valuable commissioning activities in the operation phase involve an increased focus on legal obligations to the building project’s stakeholders and attention to the documentation and testing process of the technical systems.

3.1. Recommendations of Strategies
The recommendations of strategies for the FM organisation are based on the researchers’ assessments from the collected data and knowledge sharing with the case organisation throughout the research period. Two strategies are presented with one strategy concerning future building projects and one strategy concerning existing buildings. Also, the theory and key findings emphasize the importance of influencing building projects at an early stage [1] and proactive actions may remedy operational issues occurring during the building’s lifetime.

3.1.1. Strategy for future building projects. The strategy is divided into five focus areas together with commissioning activities: 1) Financial incentives and milestones for building performance, 2) Testing procedure, 3) Operation & Maintenance (O&M) material, 4) Operating requirements, and 5) Planning of data application. The first focus area involves activities within defining commissioning milestones for building performance in the tender documents linked to financial rates for completion to ensure sufficient financial incentives for the stakeholders. The second focus area suggests planning of automatic test runs of the technical systems in the operations and planning of a coherent 100-day test period prior to occupancy. The third focus area includes descriptions of standard operating procedures (SOP’s) of the technical systems, containing descriptions of test procedures and revised descriptions of the technical systems. The fourth focus area refers to contractual incorporation of the commissioning process by establishing operating requirements until the 5-year inspection, including specifications of the performance level and the management procedure. The fifth focus area entails developing a training plan for the operating staff, developing a plan for application of the energy data and ensuring technical review of the data to validate the accuracy from the meters.

3.1.2. Strategy for existing buildings. This strategy is also divided into five focus areas: 1) Energy management/monitoring-based commissioning, 2) Checklists, 3) Collection of valuable O&M information, 4) The FM organisation’s standards, and 5) Training of the staff. The first focus area includes establishing a baseline for optimization, analysis of the energy consumption and planning for corrective actions. The second focus area suggests developing checklists, including the setting of
operating working time for technical systems and ensuring an update of the changes on a yearly basis. The third focus area involves a continuously update of the O&M material in order to ensure an efficient building operation. The fourth focus area refers to updating current standards for the FM organisation and includes setting increased requirements for the energy data, compromising data accessibility and level of detail. The fifth focus area proposes educational courses within building management system and data application for the staff.

4. Conclusion
The research shows a great potential for implementation of commissioning in order to achieve sustainable performance of buildings. Nevertheless, it is important for FM organisations to incorporate commissioning strategies, which consider the whole building life cycle. New building projects require specific commissioning activities for fault detection in the handover process until a steady operation is established. An ongoing commissioning process should also be considered to acquire continuous sustainable building performance. Furthermore, the research established that the commissioning process in the operation phase is at an early stage in the Danish building industry. Thus, the benefits of considering operation optimization are not integrated as an essential part of building projects today.

The paper demonstrates implications for researchers by introducing a new field of research aiming at how to achieve sustainable building performance by implementation of commissioning processes considering the whole life cycle of buildings. Thus, the research contributes to promote sustainable building operation as part of achieving sustainable cities and communities, SDG 11 [9], and adapting sustainable practices for companies in line with SDG 12 [10]. The practical implications are considered by providing specific recommendations for building clients and FM organisations in relation to strategies for commissioning process for realizing sustainable building performance.

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