Implementation of 5S+S for Knowledge Work in Engineering Projects

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Abstract. The purpose of this manuscript is to propose a framework for implementing 5S+S in engineering-to-order (ETO) projects with a focus on knowledge work. The application of this framework helps to improve overall performance in companies providing knowledge work. The methodology allows transparency and control over projects in day-to-day management, through the implementation of digital tools such as visual management, 5S+S online audits, key performance indicators (KPI), dashboards, etc. This paper presents the implementation of lean management concepts in customer-specific tailor-made engineering projects, which has not been sufficiently addressed in the existing literature. The methodology used in this paper is based on the application by researchers of lean concepts in a combination of three different disciplines, namely, lean project planning and control (LPPC), lean quality management system (LQMS) and Lean Design. First, attempts at knowledge work improvement through lean are presented, based on the existing literature. Second, all three approaches: LPPC LQMS and Lean Design are explained. Third, the possibility of combining all three concepts into one framework is discussed. The use of 5S+S in knowledge work is demonstrated, and a framework is developed, based on a DMAIC (Define, Measure, Analyze, Improve, and Control) approach. The use of the framework is presented by means of an illustrative case in a small and medium size enterprise (SME) providing engineering services. The suggested methodology is applicable for engineering services-providing companies seeking overall project performance improvement. The findings are useful for project managers and engineering discipline leaders who aim to implement lean thinking in engineering projects.

Keywords: Lean, 5S+S, Knowledge Work.

1 Introduction

To compete with international corporations, it is important for small and medium-sized enterprises (SMEs) delivering engineering solutions to focus on improving efficiency

[1]. In times of highly competitive markets, it is critical that SMEs deliver high-value products at the lowest possible operating cost. This is specifically relevant for project-based organizations delivering highly customized engineering-to-order (ETO) projects [2], often experiencing project delays, budget overruns and quality defects [2]. Knowledge workers play an important role in engineering companies, as their specific skills, knowledge and creativity are the source of innovation in the workplace [3, 4]. The importance of improving knowledge work productivity has been discussed by many authors [3, 4, 5]. Lean tools and methods are a potential approach to improve the challenge of the low productivity of knowledge workers [6]. In order to support SMEs providing ETO projects, lean philosophy offers a 5S+S concept (sort, set in order, shine, safety, standardize, sustain). 5S+S principles aim to reduce inefficiencies in businesses, by identifying irregularities, eliminating performance waste, and introducing continuous standardization [7].

The number of studies related to implementing the lean concept in knowledge work has increased in recent years [8, 9]. However, there is a gap in the literature regarding detailed and consistent implementation of 5S+S in relation to knowledge work companies. Some of the lean tools are applied only in single case studies; thus, their relevancy is arguable, and more evidence is needed to prove their applicability in knowledge work [10]. The lack of clear standards and uniformity in lean methodologies' application to the knowledge-based workforce is acknowledged [10, 11]. It is from this perspective that the 5S+S framework and guidance for knowledge-providing organizations was developed and is presented in this paper. The framework, with a base concept built on 5S+S, was developed through a combination of three disciplines: lean project planning and control (LPPC), lean quality management system (LQMS) and Lean Design. The possibility of combining all three concepts into one framework offers the opportunity to develop a complete lean solution with the potential to improve overall performance in custom-specific engineering projects.

This paper is organized as follows. Section 2 introduces the literature review related to the application of lean in knowledge work, with a focus on 5S+S. Section 3 provides an overview of the methodology for developing this paper. Then, Section 4 provides a description of three concepts, which are included in the final framework: LPPC, LQMS and Lean Design. Section 5 describes the results of the case study carried out in Blueday Technology AS (BDT), where the main challenge is to improve the performance of engineering projects suffering from low project margins and exceeded engineering hours. In Section 6 the 5S+S framework is presented. Finally, Section 7 offers a discussion and conclusions, as well as introducing future research areas.

2 Background

2.1 Lean in knowledge work

Lean approach in knowledge industries. In recent years, the productivity improvement of knowledge workers has been a major challenge discussed by authors in [8 9, 12]. Understanding the mechanism that affects the productivity of white-collar workers is highly important, as it can contribute to the entire organization. A variety of

industries, in which knowledge workers play a vital role, have successfully implemented tools and methodologies with a foundation in lean philosophy, e.g., software engineering [13, 14, 15], healthcare [7], aerospace and defense [16], and construction [17, 18, 19]. In software engineering and healthcare, lean has been applied through the reduction of waste and waiting time [13, 15], contributing to improved flow and better process efficiency [7]. The reduction in waste was also a major part of changes in the construction sector, where complexity and uncertainty were minimized, while inconsistency in documentation was reduced [19]. An emphasis on transparency [16], customer requirements [19], collective commitment and a common knowledge base [16] are indicated in the literature as examples of key factors impacting value in case study organizations. However, adaptation to lean thinking and understanding the concept of waste itself seem to be the most challenging tasks during transformation into lean [7, 16]. Studies indicate that two thirds of lean implementation programs in North America fail, due to the inability of companies to achieve cultural change such as encouraging workers to adopt new behaviors or the continuous improvement of daily practices [20].

5S+S in knowledge work. The purpose of the 5S+S tool is to implement within the organization all aspects of the 5S traditional lean concept (sort, set in order, shine, standardize, sustain), with an additional focus on safety in the working area [21]. The studied cases have revealed that poorly implemented 5S undermines the safety factor [22]; therefore, an additional principle has been integrated into the 5S+S concept. So far, 5S+S has only been identified by authors as a successful lean application in manufacturing companies [23, 24]. There is an unexplored area of 5S+S in knowledge work organizations which should be investigated.

The literature has indicated a variety of approaches when it comes to lean philosophy in knowledge work [7, 13, 14, 15, 16, 17, 18, 19]. It can be observed that organizations focus on specific lean tools [13, 15, 16] and achieve effects in particular functional areas [7, 19] such as administration, manufacturing, purchase. The main challenge in studies seeking ways to improve knowledge work performance is the difficulty in defining the structure of knowledge work [12, 10], as knowledge workers are involved in many and various activities. Authors also state that, in order for the knowledge providing organization to succeed, knowledge workers must work together in collaborative ways [5, 10]. Therefore, this paper proposes a complex knowledge work and 5S+S oriented framework, which could guide several functioning areas of the organization to improve project performance.

3 Methodology

The research methodology presented in Figure 1 is a combination of action research and case study-based research. The case study research was conducted based on the collection of information from a company's internal systems, in order to verify what could possibly impact project performance. The information retrieved was related to project finances, engineering hours, reported project non-conformances, project documentation, etc. The data has been analyzed and the results presented. Simultaneously,

the literature overview was conducted, focusing on existing lean tools such as 5S+S and methodologies contributing to the improvement of engineering design routines, project execution and quality management systems. The relevant literature was studied to formulate a new approach to be carried out in a case study. DMAIC (Define, Measure, Analyze, Improve, and Control) methodology was used to develop a framework to be implemented in the organization.

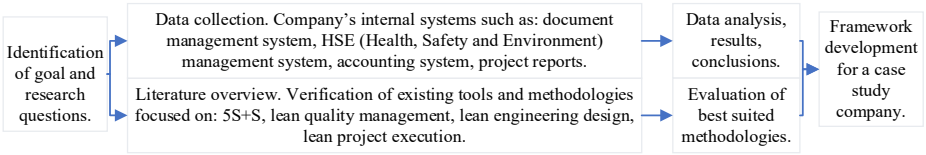

Fig. 1. Research methodology.

4 Literature overview

4.1 Lean Project Planning and Control (LPPC)

LPPC is a response to poorly planned and controlled ETO projects, caused by lack of routines, few staff members included in planning, poor monitoring, or no response to delays [2]. The model (Figure 2) was tested by several ETO manufacturing companies delivering advanced equipment to the oil and gas industry.

Planning	**Flexibility**	Updates as often as required – all levels of activities.
	Integrity	One integrated plan for all project disciplines.
	Commitment	All project disciplines commit to one common project plan.
	Participation	Regular planning meetings with formal agenda, formal reporting.
Project dedication		All project disciplines report in a standardized report.
Planning dedication		Physical progress reported by all disciplines on a standardized form (percent plan complete).
Replanning		Delayed activities are replanned (root cause analysis, discussion with the project team).
Impact awareness		Decisions taken by considering the optimization of the project processes.
Learning ability		Between all the employees and the external project partners.

Fig. 2. Lean Project Planning and Control adapted from [2].

4.2 Lean Quality Management System (LQMS)

Lean Quality Management System (LQMS) is a comprehensive approach, combining ISO (International Organization for Standardization) standards (Quality Management System) and key concepts of lean management [25]. ISO standards and lean are intended to improve organizations' production processes, but when those two concepts are not aligned, it can lead to a waste of resources [26]. The proposed framework (Figure 3) enables organizations to both develop the minimum amount of documentation required to demonstrate an effective QMS and help to organize and control internal processes.

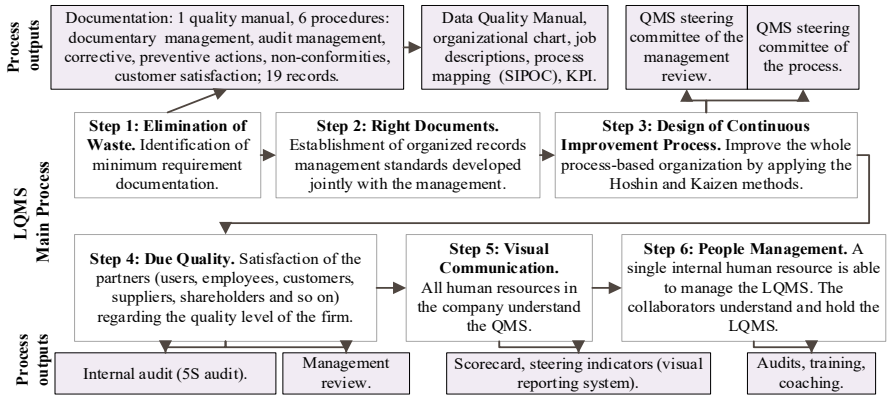

Fig. 3. Lean Quality Management System (LQMS), six-step implementation model adapted from [25].

The methodology includes several QMS templates, e.g., the lean SIPOC card (acronym of Supplier, Inputs, Processes, Outputs, Customer), which improves process mapping by adding system measures and process targets, as presented in Table 1 [25].

Table 1. SIPOC card example, Lean Quality Management System (LQMS) adapted from [25].

SIPOC		
Owner	**Processes**	**Target**
Project manager	Design of assembly drawings	Drawings according to company's standard template
Input	**Output**	
Mechanical engineer	Design completed	Focus on customer's expectation
Supplier	**System Measures**	**Customer**
Engineering	Time, quality	Warehouse

4.3 Lean Design

Lean Design is a concept developed to support engineering design through the use of tools such as pull scheduling, design structure matrix or shared geometry, in order to improve information flow, reduce negative iterations and involve all team members in all decision-making processes in the design phase [17]. The basic concept of Lean Design is illustrated in Table 2.

Table 2. Lean Design Model adapted from [17].

Lean Design	
Cross-functional teams	Involve downstream players in upstream decisions.
Set-based strategy	Create and exploit opportunities to increase value in every project phase. Select from alternatives at the last responsible moment. Share incomplete information. Share ranges of acceptable solutions.
Structure design work to approach the lean ideal	Design of product and process. Include operations, maintenance, commissioning, assembly, fabrication, purchasing, logistics, detailed engineering and design. Move detailed design to fabricators. Reduce design package sizes.
Minimize negative iteration	Pull scheduling. Design Structure Matrix (DSM). Strategies for managing irreducible loops.
Last Planner System in production control	Try to make only quality assignments. Make work ready within a lookahead period. Measure PPC (Percent Planned Complete). Identify and act on reasons for plan failure.
Technologies	Shared geometry: single model. Web-based interface.

5 Case study company

A case study was carried out in Blueday Technology AS (BDT). The company is a project-based organization handling ETO projects. BDT is a medium-sized enterprise, executing electrical engineering projects such as hybridization of ships or shore power installations. BDT provides knowledge work, service, and manufacturing. The case study scope aims to identify the reasons behind low project margins. Based on observation and collected information, it can be stated that employees are well educated, experienced, intelligent, highly motivated, and capable people. The company has approximately 35 employees, with the yearly employee turnover rate varying between 3.3% and 8.3%, at an average of 3.9%. Nineteen projects executed between February 2017 and September 2020 were included in the project portfolio investigation (excluding feed studies). It has been concluded that the company is providing services to five industry sectors: shore power, defense, marine, offshore, and aquaculture. The analyzed information revealed that planned spending for the majority of projects was significantly higher than the originally estimated budget. Of 19 analyzed projects, 13 exceeded the planned budget (Figure 4 a, b) and 14 exceeded the planned engineering hours (Figure 4 b, d). Comparisons in Figure 4 refer to marine and shore power groups, as the majority of projects executed in the company in the investigated time period belonged to the marine and shore power sectors. There is a visible pattern, suggesting that exceeded engineering hours drastically affect the project budget.

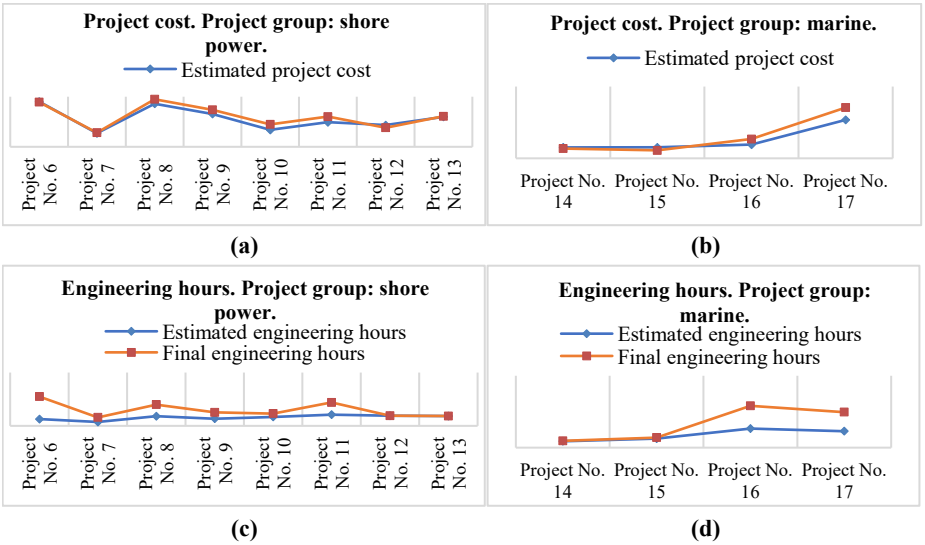

Fig. 4. Estimated project cost vs. final project cost for projects in **(a)** shore power group, **(b)** marine group. Estimated engineering hours vs. final engineering hours for projects in **(c)** shore power group, **(d)** marine group.

Analysis of several project plans indicated poor planning of engineering and pre-engineering phases, reflected in missing phase details, such as design steps, process

sequences, design milestones, master design documents, etc. Moreover, some projects' plans did not include the engineering phase at all. Additional information retrieved from the company's internal systems showed issues related to the quality of several products and low customer satisfaction related to delivery time. The discovered data was confirmed by a value stream mapping (VSM) performed as part of the case study. Future improvement actions in the company shall be focused on the following areas: engineering design, project planning, and product quality control.

6 Framework presentation

The main goal is to improve overall performance in the organization, through the implementation of all the elements of the framework, with a focus on the popularization of lean routines in the office space, waste reduction in daily practices in projects, and continuous improvement. The implementation of the framework will be introduced to the case study company in the spring of 2021. The case study is estimated to continue until spring 2023. The framework will be implemented in the case study company by the following five phases of DMAIC methodology: Define, Measure, Analyze, Improve and Control (Figure 5).

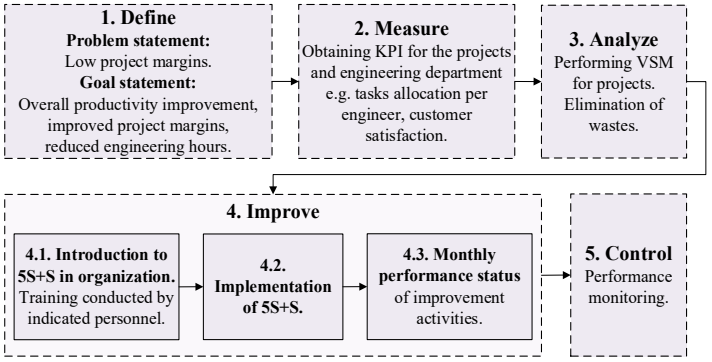

Fig. 5. Methodology and guideline for implementing 5S+S in the case study company.

Figure 6 presents the framework and guidelines for implementing 5S+S in the case study company. The framework is divided into five main sections representing areas for future improvement: physical office work, digital office, lean project planning and control, lean quality management, and lean design. Planned improvements are sequenced into six steps according to 5S+S methodology: 1. Sort (cleaning, elimination of wastes), 2. Set in order (structuring and standardizing), 3. Shine (maintaining established routines), 4. Safety (ensuring safety in the work environment), 5. Standardize (standardization and monitoring of key performance indicators (KPIs)), 6. Sustain (continuous improvement and learning). The implementation of 5S+S shall be performed simultaneously for all five improvement areas, with an introduction to 5S+S being presented to the knowledge workers before the framework is implemented, as the

implementation of lean should focus on the philosophical level before any tools and methods are applied [10].

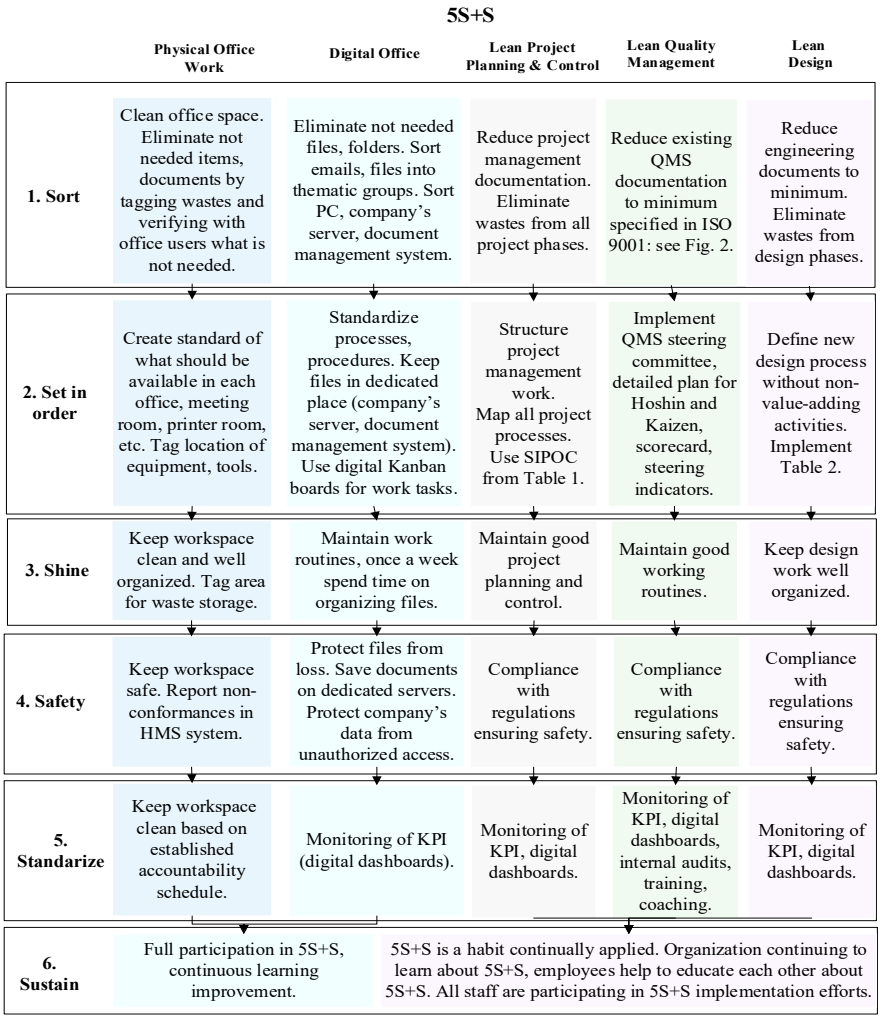

Fig. 6. Methodology and guidelines for implementing 5S+S – case study company.

7 Conclusions

This paper proposes a framework and guidance to improve overall performance in engineering-to-order (ETO) projects, with a focus on knowledge work and the 5S+S concept. In order to develop a 5S+S framework, lean approaches to knowledge work were studied. The literature refers to several attempts to implement the lean philosophy in different knowledge work related industries, such as software, healthcare, aerospace

and defense, and construction. Several authors observed that the application of the lean concept to knowledge work is challenging for various reasons, e.g., difficulties in achieving cultural change and in encouraging workers to adopt new behaviors or to establish and maintain daily practices. Attempts to implement lean described in the literature are characterized by a lack of clear standards in applying lean principles and tools to the knowledge work. Moreover, the approach of 5S+S has not been sufficiently covered within the context of knowledge work projects.

Next, the results from the case study carried out in Blueday Technology were presented. The company has struggled with exceeded engineering hours and low project margins. After analysis of the VSM and company internal systems, it was concluded that there is a clear need for overall performance improvement in the projects, specifically when it comes to engineering design, project control and monitoring, and product quality.

From this perspective, the 5S+S framework and guidance for knowledge-providing organizations was developed. The framework aims to support the organization in a cultural transformation to become lean. The 5S+S concept helps to reduce the waste and standardize the work environment, maintain the established routines, and increase the productivity of white-collar workers. The framework paid special attention to the separation between physical office work and digital office work, in order to provide separate guidance for treating digital office work waste (chats, emails, inefficient methods of storing files) and physical office work waste (unneeded physical items, e.g., binders, paper copies). The framework has the potential to provide useful methods to improve knowledge work efficiency, especially when it comes to work routines and practices. The suggested methodology is applicable for knowledge-providing companies, project managers, and team leaders who aim to improve the productivity of their project teams.

Future research shall focus more on detailed case studies where the presented 5S+S framework could be used; detailed procedures and practices enabling the identification of waste in the knowledge work environment; lean tools and methods that could support the presented 5S+S framework; and the development of tailored KPIs to monitor the transition of the company into a lean organization. Additional focus shall be directed to the applicability of lean methods to the knowledge work in order to improve customer value.

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