Value Stream Mapping for Knowledge Work: A Study from Project-Based Engineering-To-Order Organization

Daria Larsson, Arne Gildseth, R. Ratnayake

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Daria Larsson[1,2], Arne Gildseth[2] and R.M. Chandima Ratnayake[1]

[1] University of Stavanger, 4036 Stavanger, Norway
[2] Blueday Technology AS, Norway
daria.larsson@blueday.no; arne.gildseth@blueday.no, chandima.ratnayake@uis.no

Abstract. This paper presents a tailor-made value stream mapping (VSM) methodology for engineering projects with a focus on knowledge work. The VSM is a lean-management method for analyzing value-adding processes through material and information flow mapping. The tool helps organizations to reduce engineering hours, lower project costs and improve project margins. A documented systematic procedure for VSM for an office environment has been identified in the literature; however, there is no universal approach regarding a VSM methodology for knowledge work, specifically engineering design. This paper addresses these issues, by proposing a systematic procedure for conducting VSM for engineering design projects, along with a case study. First, the manuscript describes the examples of VSM attempts in knowledge work reported in the literature. Next, it demonstrates a case study, conducted in a project-based engineering-to-order (ETO) organization, where the main goal was to identify waste through a current project value stream map (CPVSM). Based on the findings, a future project value stream map (FPVSM) was developed and is presented in the article.

Keywords: Lean, Value Stream Mapping, Knowledge Work.

1 Introduction

Lean philosophy had its origins in the automobile industry and was later extended to apply to various organizations; it is known for reducing waste, while adding value to products and services [1]. Lean principles have been applied in office-based functional areas such as administration, customer service, and engineering design [1, 2]. Value stream mapping (VSM) is one of the most powerful lean tools [3] that also supports organizations depending on knowledge work [4]. The tool is used to map value-adding processes [5], in order to help organizations to realize the connection between information flow and material flow [1], and to identify wasteful activities. Finally, it helps to reduce or eliminate non-value-adding activities and improve process productivity [5].

According to a review of the literature, VSM has been widely used in manufacturing, healthcare, construction, product development and service sectors [6]. The number of publications referring specifically to the approaches of VSM in engineering projects and the office work environment is limited [1, 2, 7, 8]; in addition, the literature does not adequately describe the aspect of VSM in office knowledge work. This paper fills the existing gap in the literature by providing a systematic approach to VSM for knowledge work. It presents the VSM performed for an engineering-to-order organization focusing on a selected engineering project and project stakeholders.

This paper is organized in four sections. Section 1 introduces the subject of VSM. Section 2 presents the methodology used to develop this article, while Section 3 provides the relevant literature review related to examples of VSM approaches to knowledge work. In Section 4, a VSM for the case study is provided. Finally, Section 5 summarizes the main topics discussed in the article.

2 Methodology

The research methodology (Fig. 1) consists of action research and case study-based research. A comprehensive literature review was conducted, focusing on existing examples of VSM approaches related to different industry sectors and engineering knowledge work. Established search criteria for the paper retrieval included: academic journals, books, conference papers. Oria, an academic database, was searched for relevant publications. At the same time, the case study research was conducted based on interviews with employees, performed in the company. Interviews had a standardized format, with each interviewee being asked the same questions. There was one interviewer and ten interviewees; all interviewed people were involved in one specific project selected for case study need.

The detailed methodology for the performance of VSM is presented in Fig. 3, Section 4.1 of this paper. The VSM methodology developed in this paper was adapted from the VSM model given by [9]. The basic model contains four main steps: selection of product family, current state map, future state map, and work plan for the implementation of the future state [9]. The data received from VSM has been analyzed and is presented in the graphical form of a current project value stream map (CPVSM) and a future project value stream map (FPVSM), in subsequent sections.

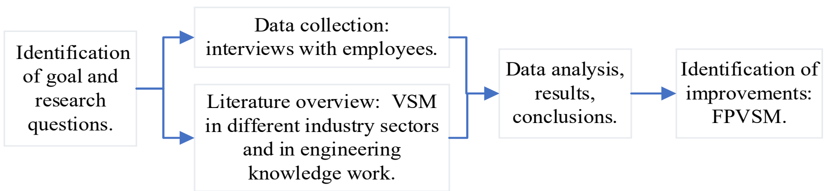

Fig. 1. Research methodology.

3 Literature overview

3.1 Value stream mapping in knowledge work

Value stream (VS) in an office environment. VS can be defined as all activities required to fulfill a customer's request, from order to delivery [10]. Depending on the type of VS, two main flows can be recognized: the flow of information and the flow of materials [10]. The information flow in engineering knowledge work is usually defined in a project management communication plan, which specifies interactions between project stakeholders. A material flow in an office environment can be represented by, for example, a digital document sent for a discipline check or an email, which is a form of corporate electronic documented information. According to the literature [11], all daily activities and processes, such as sales, customer service or engineering, can be defined as office VS (Fig. 2).

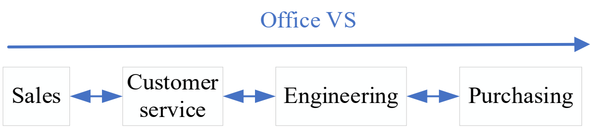

Fig. 2. Office VS adapted from [11].

While material flow is visible in a physical work environment and therefore can be observed and mapped, in the office environment, on the contrary, information and material flow might not be visible (e.g., digital transfer of a document, e-mail). A similar analogy occurs during the identification of non-value-adding activities. Typical waste in manufacturing is transportation, inventory, waiting, defects, over-processing or excessive motion [12]. In the office environment, there is a significant challenge in defining and identifying waste [1]. Tasks are assigned through emails or meetings; thus, it is challenging to track the flow of information [1]. The exact time needed to complete a task is difficult to estimate, as some tasks require confirmation by a manager or a customer [1]. The number of tasks assigned to an employee is not transparent, as some employees can perform multitasking [3]. Moreover, it is hard to tell whether the task was completed successfully or not, due to the many variables included [1].

VSM in industries. As the lean concept was originally created to support the manufacturing sector, the majority of studies related to VSM focus on the manufacturing industry [6, 13]. Several publications refer to the use of VSM in healthcare service sectors [14, 15, 16] and sales processes [17]. VSM has also been used in construction supply chains [18] and product development processes [19, 20, 21, 22, 23]. In manufacturing, VSM has contributed to reduced cycle time, reduced waste in the supply chain, increased productivity and reduced lead time [6]. In healthcare, VSM was used in conjunction with queuing modelling, to reduce patient wait time and medical errors [16]. The new process model delivered more efficient service and a reduction in non-value-added activities [16]. As also observed by other authors, the benefits of applying VSM to healthcare were reduced employee overtime and customer complaints in the administrative process, as well as reduced treatment time [6]. VSM application in the service sector contributed to eliminating delays, errors and inappropriate procedures and to improving customer satisfaction [6]. The construction sector used VSM to improve process performance [24] and enable sustainability [25]. VSM was applied to several areas within construction, such as supply chain, administrative management, construction process and designing [6]. The product development sector is the closest one to engineering knowledge work, as the development of products and design is very often included in engineering office activities. According to [26], product development value stream mapping (PDVSM) can lead to excessive complexity in a traditional process flow map, to the point where drawing a process is lost. The author proposes a tool named Design Structure Matrix (DSM), which is a visual representation of a system or project in the form of a square matrix recommended for complex projects or processes [26]. Several benefits have been obtained from using VSM in the product development process, such as reductions in waiting time and iteration [22], development costs, man hours and cycle time [23].

VSM in knowledge work. Several publications refer to approaches for using VSM in office work [1, 2, 7, 8], where authors have successfully managed to describe possible ways of conducting VSM in a knowledge work environment; however, the literature does not adequately describe the aspect of VSM in engineering projects with a focus on knowledge work and office activities. Therefore, the aim of this paper is to perform VSM for a case study company, inspired by the existing methodologies described in the literature [1, 2, 6, 7], and to support a systematic approach for the implementation of VSM in knowledge work.

4 Case study description

A case study was performed in Blueday Technology AS (BDT), which is a medium-sized engineering-to-order (ETO) organization. BDT provides knowledge work (project management, engineering), service and manufacturing to five industry sectors: shore power, defense, marine, offshore and aquaculture. This paper focuses only on knowledge work and non-manufacturing activities within the company. Based on previously performed studies, it was concluded that, for the majority of projects, final project margins were significantly lower than the estimated project margins. As concluded from earlier analyses, exceeded engineering hours were a main reason for low project margins. Through VSM, the case study aims to identify the exact reasons behind time-consuming engineering hours in projects.

4.1 Value Stream Mapping

The proposed VSM methodology (Fig. 3) provides a systematic approach for implementing lean in engineering projects with a focus on office work. First, the person responsible for VSM selected a project to analyze. The following employees were chosen to join the VSM team: project manager, Vice President (VP) project executive, mechanical engineer, electrical engineer, automation engineer, service technician, purchaser, document controller, and production technician.

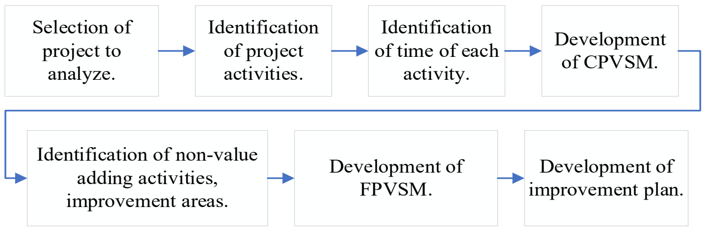

Fig. 3. Methodology for performance of VSM.

The CPVSM was developed while "walking through" the actual pathway of the material and information flow. Due to the complexity of the project, the VSM responsible person conducted separate interviews with VSM team members, in order to collect information about project activities within each discipline. The interviewed persons defined their contribution to the current state of the project process, including problems, based on their experience and improvement ideas. Once the interviews were completed, the person responsible for VSM prepared a complete CPVSM, based on collected data. Next, all improvement propositions and problems identified by team members were added to the graph, through the use of agreed symbols (Fig. 4). Finally, the overall analysis was performed, with a focus on the elimination of waste such as waiting time (Fig. 5). The challenges identified during the CPVSM were replaced by solutions and later presented in the FPVSM (Fig. 6).

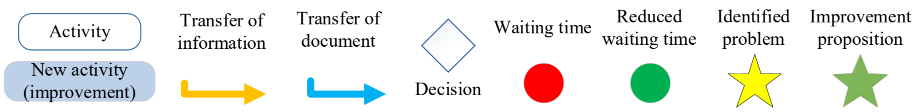

Fig. 4. Legend for VSM.

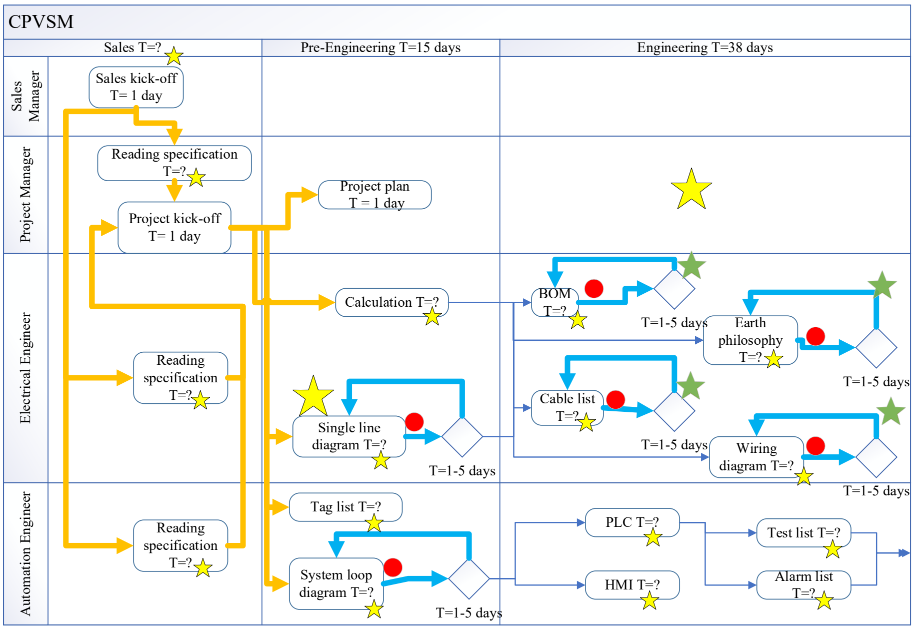

Fig. 5. CPVSM with identified problems and improvement propositions - case study. (Due to large size of the complete map, only a small section is presented.)

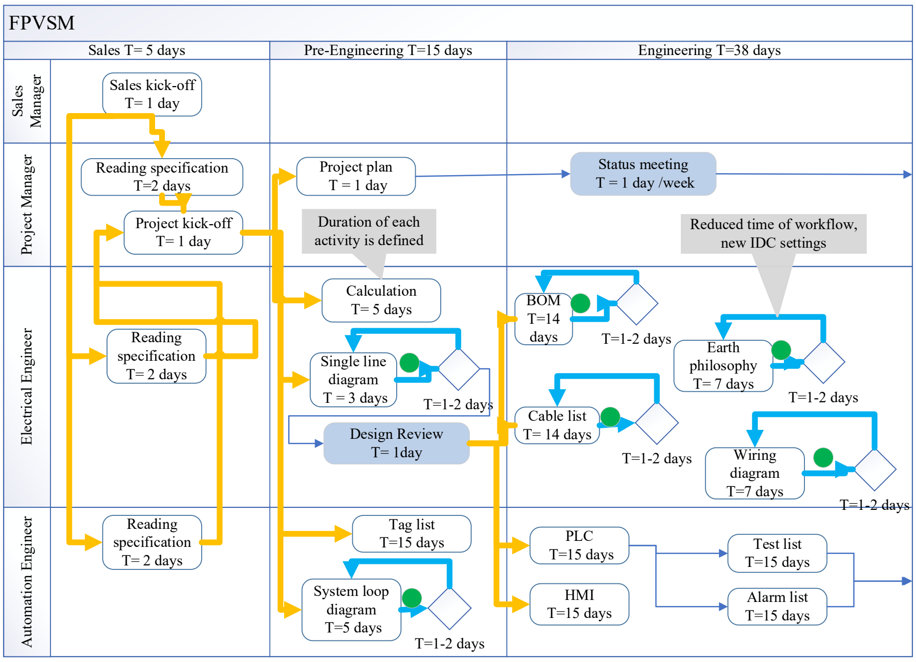

Fig. 6. FPVSM - case study. (Due to large size of the complete map, only a small section is presented.)

In order to ensure that all improvement proposals are documented and implemented, an implementation plan has been developed (Fig. 7). The execution of this plan is expected to start in the coming months in the case study company.

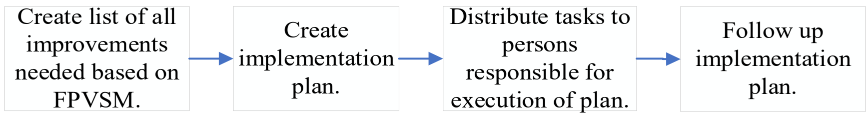

Fig. 7. Implementation plan.

VSM – findings. One of the main reasons behind the exceeded engineering hours was interviewed persons' inability to identify the exact time needed for various engineering activities. Those activities were related to the creation of design and documentation, such as designing single line diagrams, or the creation of a bill of materials (BOMs). Moreover, insufficient project management control over engineering activities and over documentation development was found to be one of the most important problems (for example, lack of documented project status meetings, lack of document status reports). Other challenges identified based on VSM were as follows: insufficient involvement of document controller in the project process (reflected in lack of control over project document list); undocumented activities related to transfer of knowledge and experience (design reviews); lack of documented project milestones such as design freeze for 3D model.

The findings suggest that improvements are required in the area of engineering control and monitoring. It is very important for the organization to define the time for each engineering activity, to meet delivery milestones. There is also a clear requirement to increase the monitoring of all activities in the pre-engineering and engineering phases (mainly activities related to recurring processes such as creation of document revisions, design changes), in order to improve control over the process.

Based on the findings, it can be concluded that future improvements can lead to reduced project time, by eliminating non-value-added activities, reduced project delays, and reduced engineering design errors. In addition, an improvement within administrative routines and the structuring of documentation could potentially improve knowledge sharing among project stakeholders. The potential improvements demonstrate similarities to those improvements achieved in other sectors such as manufacturing, construction, healthcare or product development. In each of these sectors, VSM contributed to improved productivity of lead time and improved process efficiency, by eliminating waste such as long waiting time or man hours. However, the findings and potential improvements from the case study described in this paper can be compared only to case studies related to other sectors and industries, as the literature review related to office knowledge work within engineering companies is very limited. Individual sectors have fundamental differences, and therefore the comparison of findings between different VSM approaches is limited.

5 Conclusions

The paper focuses on improving office VS in engineering knowledge work, achieved through the use of one of the most popular lean tools – VSM. The literature overview identifies several examples of the implementation of VSM in knowledge work; however, research related to the engineering office environment is limited. This article aims to fill the existing gap in the literature, by presenting an approach to VSM in an engineering office environment, based on a case study company. In the presented methodology, the information and document flows were improved by the identification of waste in various project phases such as engineering design, document control, and project management. The proposed FPVSM aims to reduce the total number of engineering hours required to accomplish the project and to lower the final project cost. As presented in the case study findings, the overall project performance can be improved by reducing non-value-adding activities, such as recurring tasks or improved control over duration of engineering assignments. The systematic approach to VSM presented in this paper could be applied to any organization, in order improve the efficiency of the office work environment.

Future research shall be focused on lean tools and techniques supporting VSM in a knowledge work environment, the identification of typical waste in office work, and factors contributing to the successful performance of CPVSM and FPVSM.

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