A Practical Study of the Application of Value Stream Mapping to a Pre-series Production Area

Joana Lamas, Carina M. O. Pimentel and João C. O. Matias

1 Introduction

The Lean Manufacturing (LM) system is typically recognized by its focus on cost reduction and performance improvements [6, 8]. Its applicability in repetitive production environments is well documented. However, its suitability to non-repetitive production environments, such as engineer-to-order (ETO), is sometimes questioned [3]. The ETO product development process starts with customer requests and specifications for each order and usually ends with an engineering design or manufacturing, assembly and delivery of the designed items [2]. Typical features of the customized products are defined through ongoing negotiations [4]. Because of its nature quite often the ETO product development process involves long lead times from order placement to shipment. In this type of environment, companies are constantly pushed toward fulfilling the specific requirements of customers flexibly in shorter lead times to remain competitive [9]. So, in this paper, we seek to contribute to the literature by showing the effectiveness of the application of LM VSM tool in a project manufacturing environment. In order to accomplish this objective, the following research question was considered to guide the study:

RQ 1: How can VSM be applied in an ETO environment so as to improve customer satisfaction?

J. Lamas · C. M. O. Pimentel · J. C. O. Matias (✉)
DEGEIT, University of Aveiro, 3810-193 Aveiro, Portugal
e-mail: jmatias@ua.pt

J. Lamas
e-mail: joanalamas@ua.pt

C. M. O. Pimentel
e-mail: carina.pimentel@ua.pt

C. M. O. Pimentel · J. C. O. Matias
GOVCOPP, University of Aveiro, 3810-193 Aveiro, Portugal

J. Reis et al. (eds.), *Industrial Engineering and Operations Management II*,
Springer Proceedings in Mathematics & Statistics 281,
https://doi.org/10.1007/978-3-030-14973-4_11

The study objective was reached through a project, using a case study methodology, with the active participation of one of the authors of the paper. Case study methodology was considered because as stated by Benbasat, et al. [1] it allows: (1) To study the phenomenon in its natural setting and meaningful, relevant theory generation from the understanding gained through observing actual practice; and (2) the questions of why, what and how to be answered with a relatively full understanding of the nature and complexity of the complete phenomenon.

This paper is structured in four sections. Section 2 is dedicated to a brief presentation of the case study framework. In Sect. 3 the VSM implementation and the achieved results are presented. Finally, in Sect. 4 some concluding remarks are offered.

2 Case Study Framework

This project emerged from the strategic reorganization of a successful Portuguese automotive supplier group, specialized in the production of injected plastic components. Due to the acquisition of new projects, the group decided to decentralize its pre-series area, by establishing a pre-series area in each factory of the group operating in Portugal. Previously, the projects were developed by a central department and released to each factory upon the start of serial production (phase 5 of Fig. 1). This lead to the need to implement a pre-series area in each factory of the group. So, each factory was challenged to implement a pre-series area and to organize the corresponding industrialization process of new projects. The case study described in this paper was approached in one of those factories. This company has implemented the Lean Manufacturing system and aimed to implement the new pre-series area and corresponding processes following the lean manufacturing principles and practices, so as to ensure that the standards are maintained along all the factory processes and areas. So, in the development of the new area, several lean tools were used. In this paper, in Sect. 3, we demonstrate the application of the VSM tool, as well as the benefits of using it along the project duration.

The project implementation was approached through the creation of a multidisciplinary team involving the participation of a launch leader, of a pre-series department representative and of the process engineering, production planning, logistics, and quality departments. One of the authors of this paper integrated this team since the beginning of the process.

The pre-series area is characterized by a project manufacturing environment, being each project constituted by a set of parts. Moreover, each project is supported by a file containing all relevant data about the project specifications, such as production sequences, reworking sheets, customer complaints, operators' polyvalence matrix, etc.

The pre-series area is responsible for producing, testing and controlling the first parts of a project, taking place between the prototype phase and the series phase (Fig. 1). The main productive processes occurring in this area are plastic injection,

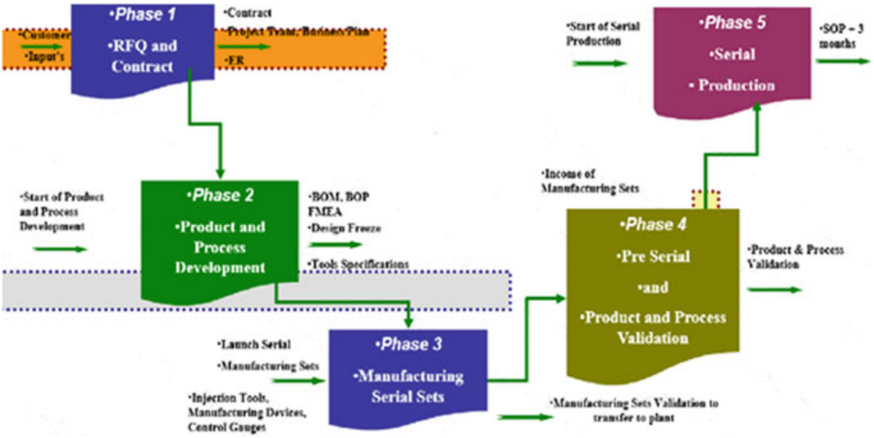

Fig. 1 Project phases in the case study company

manual assembly, and painting. Moreover, two additional operations exist related to quality assurance: parts reworking (the parts in the first test runs typically have not an appropriate quality level, requiring small reworks) and quality control (quality wall). The parts manufactured are then sent to the customer and to equipment suppliers to conduct tests. In brief, the process flow is the following: materials reception; production order emission and materials release; mold testing; storage of injected parts; standard parts production; assembly planning; assembly; quality wall; storage of final parts; dispatching and invoicing.

3 VSM Implementation

Value stream mapping is a lean manufacturing tool that is used to map every step involved in the material and information flows need to bring a product from order to delivery [5] helping to see and understand both flows. Values stream maps are typically drawn for different points in time as a way to raise consciousness of opportunities for improvement [5] by wastes identification. A current state map follows a product's path from order to delivery to determine the current conditions. Afterwards, a future state map deploys the opportunities for improvement identified in the current state map to achieve a higher level of performance at some future point [5]. Both the current state and future state maps are established using diagrams and a particular symbology [7]. According to Liker and Meier [6]. VSM is more than a neat tool to draw pictures that highlight waste, though that is certainly valuable. The same authors argue that it also helps to see linked chains of processes and to envision future lean value streams. In our case study, VSM was used in order to map the current state of the pre-series area. Through the current state map analysis, a set of wastes were identified. In the subsequent step, a future state map was projected, representing the ideal state after the wastes elimination or improvement. A detailed description of these steps is presented in the following sections.

3.1 Selection of a Project

In a typical VSM implementation the process starts with the selection of a representative product family [7]. In our case study, the project team decided to choose project XYZ because it involves a comprehensive production process and was considered demonstrative of the pre-series flows.

3.2 Current State Map

In the first stage, the pre-series area was installed in a small area outside the factory, although within its limits. The area was established with three workstations with two operators fully committed to the pre-series process. Moreover, this area worked in one five-day shift plan. The two operators were responsible for the production/assembly, some logistics, and quality assurance processes. Also, some logistics processes are tackled by the logistics personal of the series area. The current state map was devised under these conditions.

The boundaries of the current state map range from the supply of the main raw materials (plastic injection materials) to the delivery of the parts to the customer. The mapping started with the characterization of the customer orders (upper right corner) and with the calculation of the customers' takt time, through the ratio between the available working time per month over the average customer demand rate per month. The resultant takt time value was equal to 1172.7 s per part, meaning that the pre-series area would have to guarantee that approximately every 1172.7 s a new part of project XYZ is ready to be sent to the customer. The average customer demand rate per month was determined considering the customer demand over a period of 5 months. Also, in order to evaluate the consistency of the demand profile along the 5 months the coefficient of variation (CV) was also calculated. The CV is a standardized measure of dispersion being a dimensionless number that is calculated as the standard deviation divided by the mean. The achieved value was equal to 22.3%. In the next step, the supplier information was organized. The main raw materials used in project XYZ are plastic materials. This is the main sourcing material of the factory with regular deliveries of huge amounts to the factory. Considering this, a variable X was included in the current state map that corresponds to the number of days of raw material inventory assigned to project XYZ. Afterwards, the internal material flows associated to project XYZ were included in the current state map. The next step was the mapping of the information flows, from the customer through the central logistics department until the supplier. Finally, the total processing time and total

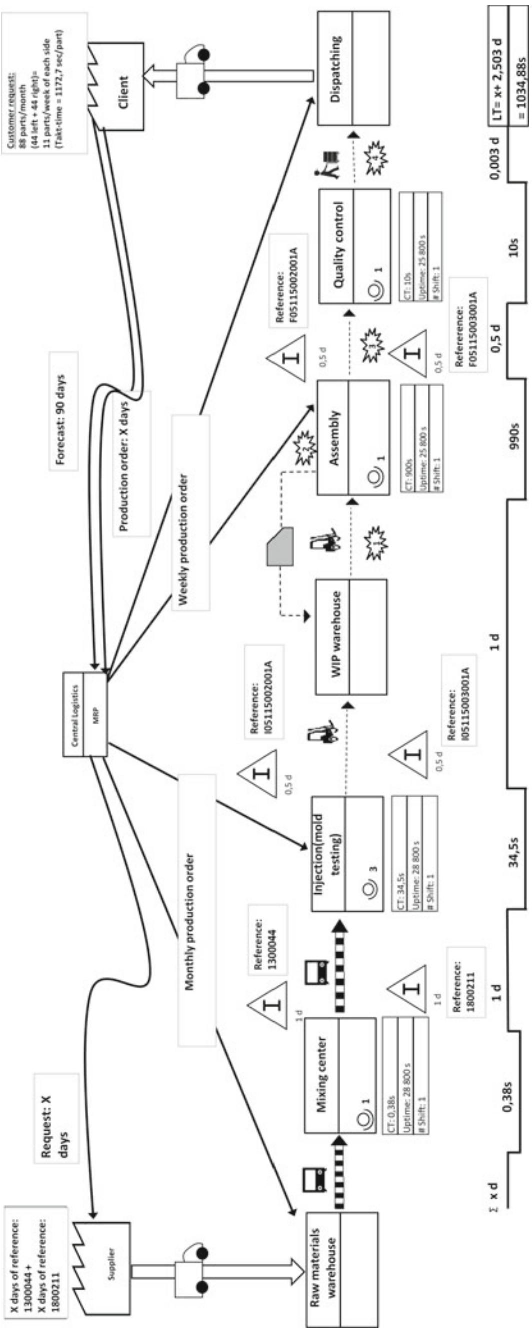

Fig. 2 VSM—current state map

Table 1 Wastes identification

Waste number	Waste
1	High parts waiting time until the start of processing and transportation time between the WIP warehouse and the assembly process
2	Manual assembly of parts increasing significantly cycle time
3	High inventory of finished parts upstream the quality control process
4	High transportation/waiting time between the pre-series area and the dispatching process

lead time were determined and represented through the timeline under the diagram. This timeline represents the total time it takes one part to make its way through the pre-series process, beginning with the arrivals of raw materials through to shipment to the customer. The current state map can be found in Fig. 2.

Four main wastes were identified from the current state map (see Table 1).

3.3 Future State Map

Grounded in the current state map and the main sources of wastes that derived from it, the project team defined a new value stream, reproduced in a future state map (Fig. 3), aimed to be achieved in a short-term. The main goals were: (1) to approximate processes thus reducing movement and transportation wastes; (2) to reduce WIP inventories; and (3) to reduce lead times.

The following three questions helped to guide the development of the future state map:

(1) How to reduce WIP waiting times/levels?
(2) Is there any task that can be eliminated?
(3) How can the assembly cycle time be improved?

The following four main changes were implemented in order to improve the pre-series process:

(1) Change the location of the pre-series area: the pre-series area was installed inside the factory, resulting in a reduction of the distances and times to perform

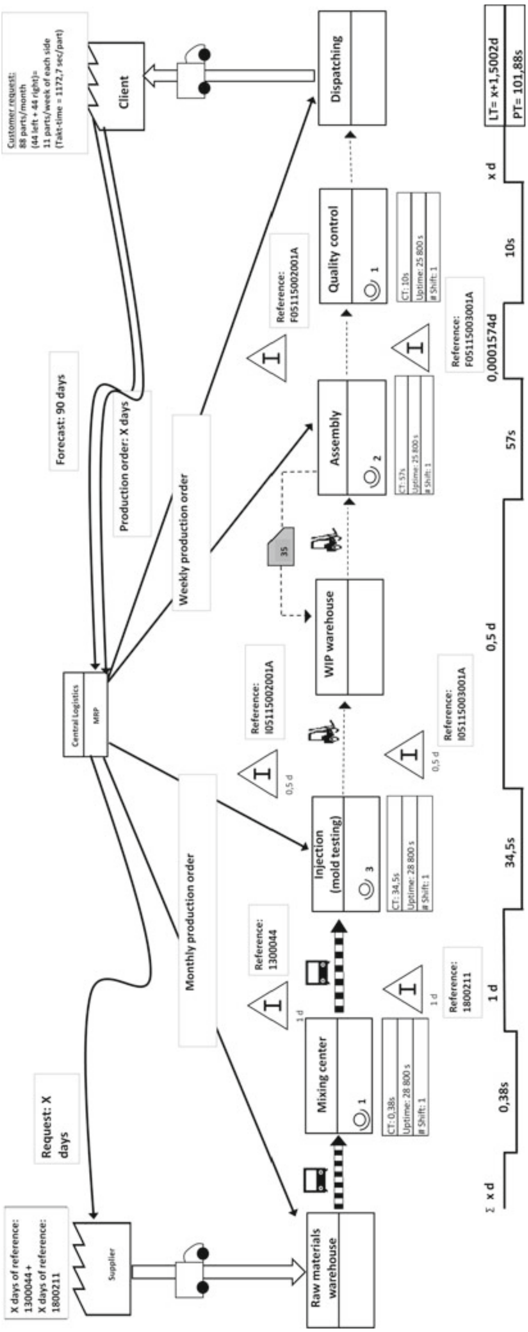

Fig. 3 VSM—future state map

the logistics operations, such as an example the distance/time from the quality control process to the dispatching area, and in a better area organization.

(2) Introduction of a logistics operator: with dedicated logistics operators in this area the dependence of the pre-series production operators on the series logistics operators was eliminated and thus the waiting times.
(3) Introduction of a quality control operator: the high level of inventory between the assembly and quality control processes occurs because the production operators are also responsible for quality control. In the new situation, the operator after finishing the assembly process moves the part(s) to the quality control process, taking in average 10 s. The part(s) is(are) placed in a queue and controlled as soon as possible, depending on the quality control workstation load and dispatching priorities.
(4) Introduction of an assembly equipment: the automatization of the assembly process allowed a considerable reduction of the assembly time.

3.4 Results

After the implementation of the improvement opportunities, identified through the VSM analysis, a reduction equal to 933 s was achieved in the total processing time of project XYZ. The huge reduction of the total processing time was mostly due to the automatization of the assembly process. Moreover, the pre-series lead time reduced from 2.5 to 1.5 days, mainly due to: WIP elimination between the assembly and quality control processes; introduction of dedicated resources that allowed the reduction of the production operators overburden, resulting in production delays; change in the location of the pre-series area that approximated the processes and resources. Other improvements resulting from the above-presented changes were: better organization of the working space and workstations; significantly improvement of the production and assembly processes; reduction of the customers' complaints; reduction in late deliveries and in the need to use express transportation services.

4 Final Considerations

Based on a theoretical background about VSM tool, we used it to analyze the material and information flows of a pre-series area through the selection of a representative project. Our aim was to show the effectiveness of this tool in a project manufacturing context. The achieved results proved that this tool, with proven results in repetitive environments, could also be of great interest to the identification of improvement opportunities in an alternative context, such ETO. As a suggestion of future work, it would be interesting to use other lean management tools, as a continuous improvement process, namely, to improve the area organization and the area layout.

Acknowledgements This work was financially supported by the research unit on Governance, Competitiveness and Public Policy (project POCI-01-0145-FEDER-006939), funded by FEDER funds through COMPETE2020—POCI and by national funds through FCT—Fundação para a Ciência e a Tecnologia.

References

1. Benbasat, I., Goldstein, D.K., Mead, M.: The case research strategy in studies of information systems. MIS Q. **11**(3), 369–386 (1987)
2. Chen, C.S.: Concurrent engineer-to-order operation in the manufacturing engineering contracting industries. Int. J. Ind. Syst. Eng. **1**(1/2), 37–58 (2006)
3. Cooney, R.: Is 'lean' a universal production system? Int. J. Oper. Prod. Manag. **22**(10), 1130–1147 (2002). https://www.emeraldinsight.com/doi/10.1108/01443570210446342
4. Gosling, J., Naim, M.M.: Engineer-to-order supply chain management: a literature review and research agenda. Int. J. Prod. Econ. **122**(2), 741–754 (2009). https://www.sciencedirect.com/science/article/pii/S0925527309002394 (April 4, 2018)
5. LEI: Lean Lexicon: A Graphical Glossary for Lean Thinkers. 4th edn. Lean Enterprise Institute (2008)
6. Liker, J., Meier, D.: The Toyota Way Fieldbook: A Practical Guide for Implementing Toyota's 4Ps. Mc-Graw-Hill, New York (2006)
7. Rother, M., Shook, J.: Learning to See: Value Stream Mapping to Add Value and Eliminate Muda. The Lean Enterprise Institute (1999)
8. Womack, J., Jones, D.: Lean Thinking: Banish Waste and Create Wealth in Your Corporation. Simon & Schuster (2003)
9. Zorzini, M., Corti, D., Pozzetti, A.: Due date (DD) quotation and capacity planning in make-to-order companies: results from an empirical analysis. Int. J. Prod. Econ. **112**(2), 919–933 (2008)