

Chapter 2

A Case Study on Lean Product and Process Development

S. Vinodh and A.G. Chethan Kumar

Abstract Current products in the market are customer oriented. Customers demand for low priced products in minimum possible time of production. To achieve competitiveness and to stay ahead in the business, manufacturers adopt lean manufacturing strategies. Lean principles are focused on elimination of wastes, streamlining the processes there by reducing cost and product delivery time. Lean concepts are widely used in process perspective; there exists scope for applying lean principles for product development. Product development involves various stages associated from collection of customer requirement till the realization of products. In this context, this chapter presents a framework for Lean Product Development using a primary lean tool Value Stream Mapping. The chapter is exemplified with a case study conducted in an Indian automobile component manufacturing organization. The approach starts with the preparation of current state map indicating the details associated with each and every stage of Value Stream Map (VSM). This is followed by detailed analysis of VSM, followed by the identification of areas where improvements can be brought about. Then Quality Function Deployment (QFD) is integrated into VSM to facilitate design improvements and to achieve customer oriented products; also, elimination and integration of certain processes in process map is done to achieve stream lined process. Finally, Future state Product Development map is developed indicating the improvement proposals and possible time reduction as a result of modifications in the design process. This methodology would facilitate a framework for product development process with the incorporation of lean methodologies.

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2.1 Introduction

Lean Principles are focused on identification of wastes associated in manufacturing process and classifying them into specific categories and also eliminating these wastes by application of necessary or possible changes and thereby ensuring streamlined processes. Lean principles are widely applied in process perspective but the application of same in product design and development perspective is less. Hence, there exists vital scope to apply lean principles in the context of product development. Product development involves two major Wastes in design refer to recycling design and their testing, elimination of Non Value Added (NVA) activities that typically extend the lead time of product to market and minimal production cost and quality related issues. Lean Product Development (LPD) follows the same analogy as process based creation of value stream, determining the flow and pull and elimination of wastes. Few researchers have contributed studies in the context of Lean Product Development.

The research objective addressed in the present study is to develop a framework for Lean Product Development (LPD) coupled with Value Stream Mapping (VSM) to achieve more detailed and customer oriented products with minimum wastes.

2.2 Literature Review

The literature has been reviewed from the perspectives of lean product development and application of VSM and QFD for lean product development.

2.2.1 Review on Lean Product Development

Khan et al. (2013) explained the need for application of lean principles in product and process development. A questionnaire was developed and interviews were conducted to identify the enablers influencing product development. Walton (Walton 1999) conducted a study on LPD to spread the awareness of the same in industry. Certain tools such as Set Based Concurrent Engineering (SBCE) and metrics in Product Development are defined. Lindlöf et al. (2012) suggested the need for data exchange or knowledge transfer in LPD. They emphasized on the need for scheduled meetings at regular intervals to achieve knowledge transfer throughout the entire organization. Oppenheim (2004) explained the need for 'system engineering' for product development to achieve product quality. Cost reduction is considered as the basic need which could be achieved by reduction or elimination of wastes. The term Lean Product Development Flow (LPDF) was explained in this chapter. Pullan et al. (2013) suggested the importance of concurrent engineering in the context of product development. They also integrated

product process platform for ease of information flow, a Knowledge based decision support system was prepared using Oracle 9i.

2.2.2 Review on QFD Applications for Lean Product Development

Liu (2009) conducted a study on Product Development. For ease of Product Design, they utilized Fuzzy QFD. The prototypes are generated by the incorporation of engineering characteristics obtained from fuzzy QFD. Sakao (2007) explained the need for environmentally conscious products. The author utilized tools such as Life Cycle Assessment (LCA), Theory of Inventive Problem Solving (TRIZ). QFD is renamed as Quality Function Deployment for Environment (QFDE), with the addition of environmental aspects into the earlier one. Zhai et al. (2008) proposed a rough set theory and its use along with QFD. This Rough set QFD was used in product design to transfer customer needs to design characteristics and it was done on the case product with more imprecise and indefinite input values. Smith (2012) explained the need for development of custom products in industry. This was further elaborated by the use of lean techniques. VSM and kaizens were used to improvise the process. Chen and Chang (2009) explained the need for QFD in product development. Since this development process possessed vagueness, fuzzy logic was used to reduce it. Further, Failure Mode and Effect Analysis (FMEA) was used to identify the defect location for new product development. Kreng and Lee (2004) explained the modular product design which includes physical and functional features of a product. QFD was deployed to enhance modular product design and hence to achieve enhanced product characteristics.

2.2.3 Review on VSM Applications for Lean Product Development

Fritzell (2012) presented a case study utilizing concept maps and Design Structure Matrix (DSM) for better understanding of process. A VSM was developed as per the literature and certain modifications were incorporated to enhance product development process. Kumar et al. (2009) developed Advanced Dual Stage Performance (ADSP), which included both current state as well as future state. This VSM was developed for new product development and feedback loops were utilized to check the product. The best article was selected among various available articles and it was done using ADSP. Smith (2012) identified product development activities and classified them based on associated similarities. These activities

extended the study to high-volume low-mix product development process. The entire product development process was mapped using VSM, Bill of Materials (BoM), Check sheets, kaizen bursts were used to enhance process understanding. Haque and James-Moore (2004) classified product development into concept generation, detailed design and customer delivery. More focus was directed towards new product introduction with the utilization of techniques such as Concurrent Engineering and SBCE. Finally a VSM was developed incorporating details such as key characteristics, detailed characteristics and enabling tool. McIvor (2001) explained the need for cost reduction associated with product development process. A supply chain network was developed with addition of both customer and supplier into product development process; this facilitated the development of lean supply model. This organized supply chain would result in satisfaction among suppliers and customers as well as proper information flow amongst them. Schulze et al. (2013) incorporated a lean tool VSM to facilitate NPD process and also explained knowledge transfer in product development using 4Is (Intuiting, Interpreting, Integrating, and Institutionalizing) in the organization. These 4Is include the classification of product development processes and this classification would enable Organization Learning (OL) and help in managerial decision making.

2.2.4 Research Gap

There exists a need for designing Lean Product Development (LPD) framework. In this context, wastes in the context of Product Development needs to be emphasized and also improvement locations are to be identified. Improvements which could reduce or eliminate wastes associated with product development process needs to be proposed. Finally, future state is to be mapped with the incorporation of proposals and necessary improvements.

2.3 Methodology

The methodology is presented in the following section. This section also includes details related to various tools and techniques used in this chapter.

The detailed steps followed in this chapter are shown in Fig. 2.1.

The steps include the collection of details from industry relating to the case product, followed by categorization of development process into different categories. These categories can further be divided into two groups which include the design process and manufacturing process followed by the identification of improvement locations for application of lean improvements. Finally both product design and process development process are integrated into single map, with inclusion of improvements.

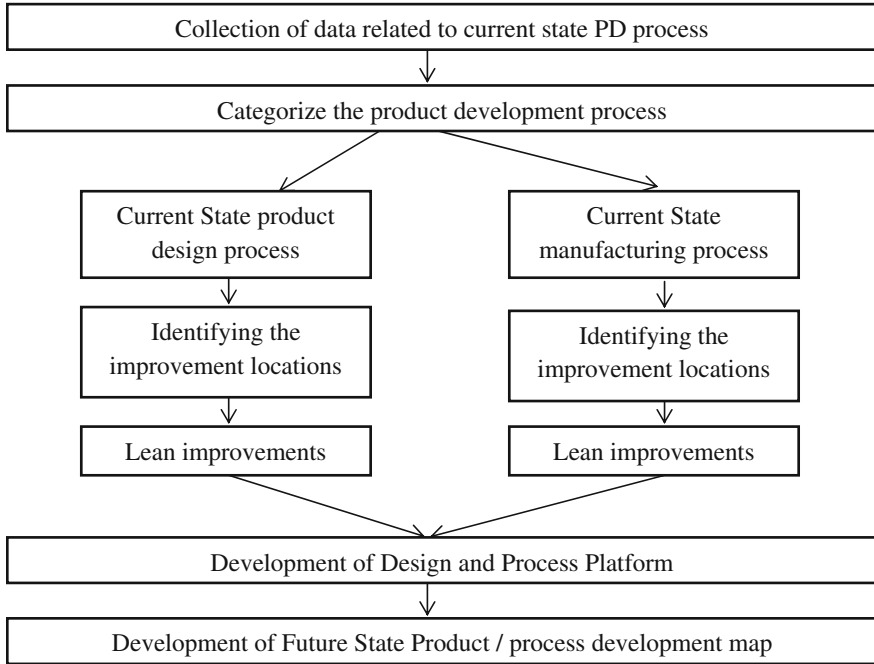


Fig. 2.1 Detailed scheme of the chapter

2.3.1 Tools and Techniques

The tools and techniques used in this chapter are discussed in this section.

2.3.1.1 Value Stream Mapping

Value Stream Mapping (VSM) is a method used by industry to take a product or service from its start till it reaches the customer. VSM is one of the lean manufacturing methodology indicating all value adding and non-value adding activities associated with entire manufacturing process. It also indicates inventory associated with process.

$$\text{Uptime} = (\text{Net Available Time} - \text{Cycle Time}) / \text{Net Available Time}$$

$$\text{Takt time} = \text{Net Available Time} / \text{Demand per day}$$

In this study, VSM is modified for Product Development application called PDVSM. The entire product development process is mapped using VSM. The current Product Development process for the industry indicates the time associated

such as Total time (TT) Change Over time (C/O) and is mapped using Current state PDVSM. This product development process can be categorized into design and production stages.

2.4 Case Study

The case study is conducted in an automotive component manufacturing organization situated in Tamil Nadu state of India. The implementation of lean principles in product development process was necessary. In this context, a critical product in the automotive system was considered for mapping the development process. Also there exist a need for modification of design process and reduction of time associated with product development process.

2.4.1 Current State Design VSM

Current state design VSM is mapping of the entire product design process of the case component. It involves grouping the stages associated with design process and collection of cycle time, changeover time associated with the each process. Also, it involves data indicating available time and uptime. Finally, the total cycle time associated with the development process is found to be 29.4 h. The current state design VSM involves four stages which include collection of customer voice, generation of three dimensional sketch, detailed drawing and finite element analysis (Fig. 2.2).

After the detailed analysis of Current state design VSM, it was found that there were certain locations where improvements can be initiated.

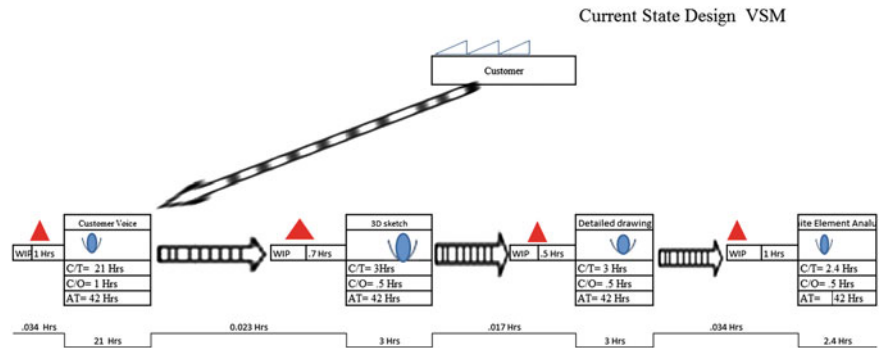


Fig. 2.2 Current state design VSM for case component

2.4.2 Current State Process VSM

Current state process VSM involves mapping entire product manufacturing process of the case product. It involves various stages such as drilling and milling, drilling and reaming, broaching (Seration), drifting, phase I milling and phase II milling. A daily demand of 45 products is to be produced, while time associated with each process is indicated below each process. Also the current state process map involves other two rows indicating available time and uptime. The work in process (WIP) inventory is indicated intermediate to each process.

With the detailed analysis of process VSM, certain regions are identified where excess time is consumed and regions which could be integrated or run simultaneously to reduce total manufacturing time. In this perspective, the following changes were suggested for implementation. Categorization of processes which are done by drilling machine could be done in a single stretch, which would in turn reduce the time associated for change over as set ups. Similar grouping can be done for milling process; this would consume little extra time for setup, but could reduce change over and total time associated with the process. Further, lean improvements such as 5S could be implemented to reduce work in process by properly organizing the entire process and allocating the time accordingly.

2.4.3 Future State Design VSM

The future state map involves the following stages.

2.4.3.1 Customer Voice

Customer voice is collected using both quantitative and qualitative terms. The quantitative values for the case product could be organized in the form of a questionnaire. The questionnaire which used is shown in Fig. 2.3. Generally for design of case component, dimension values are prefixed. But in order to accommodate the changes of design of automotive component, the following values are varied accordingly with the need of particular model. In this case, the earlier basic

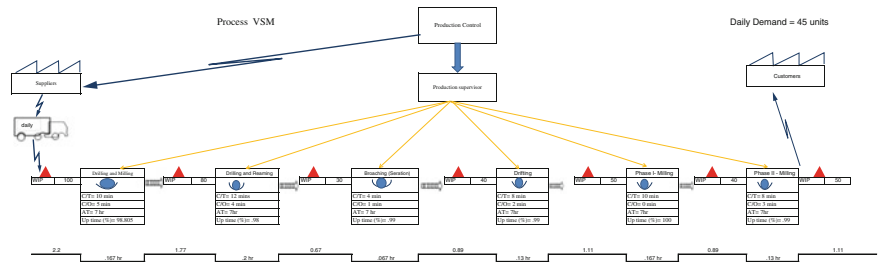


Fig. 2.3 Current state case component manufacturing process VSM

Questionnaire

General requirements

1. Case component center distance	
2. Offset distance positive	

Taper requirements

3. Major/ Minor diameter	
4. Taper designation	
5. Taper length	

Fig. 2.4 Detailed questionnaire used to collect customer voice customer voice

designs are retained whereas new variants are added to component. In the case of case component, the center distance and offset length are varied. The details related to quantitative terms are logically taken from customer (Fig. 2.4).

Questionnaire

The time associated with collection of these requirements would vary as per the response from the customer whereas the time consumed to prepare questionnaire and analyze the same could be noted. In the case of automotive component, the time consumed was around two days considering the discussions amongst workers and also considering approvals from superiors.

2.4.3.2 QFD for Case Component

In order to generate customer oriented products, the data obtained as customer voice is to be transferred into part characteristics. To achieve this, Quality Function Deployment (QFD) can be utilized. Here in QFD, the rows are taken as customer requirements, which are further categorized into primary and secondary requirements. The primary requirements include: safety, reliability, durability, performance and service of case component and associated secondary requirements include: no breakage, high speed sensitivity, flexible steering, works in all operating conditions, usage, steering rotation, output torque, serviceability, easy to lift/compact, fitment. These horizontal requirements are to be transferred as part characteristics; hence part characteristics are considered along vertical column which are as follows: Case product material, diameter at both ends, Offset length, Distance between two centers, Thickness of flange, Bend radius of flange.

The following are the scale associated with QFD:

The relationship between customer requirements and design characteristics are depicted using symbols: Strong (S), Medium (M) and Weak (W) with ratings 1, 3

and 9 respectively. The importance to customer is rated using 1–10 scale (1—least important and 10—most important). The target value is required to decide whether the product remains unchanged, improve the product, or make the product better than competitor and is rated using a scale of 1–5 (5 to keep product unchanged and 1 to discard the product). Scale up value indicates the ratio between target value and product rating. Sales point indicated how well the customer requirement will sell and value is assigned between 1 and 2. Degree of technical difficulty indicates the difficulty associated with the implementation of certain quality related improvements using 1–10 scale (1—least difficult and 10—highly difficult).

The equations used for computing absolute weight and relative weight in prioritizing product characteristics are presented as follows (Besterfield et al. 2003)

$$\text{Absolute weight, } (a_{ij}) = \sum_{i=1}^n Rij * Ci \quad (2.1)$$

where, a_j is row vector denoting absolute weights corresponding to case component part characteristics ($j = 1 \dots m$), Rij is a square matrix where weights are assigned to relate product characteristics and customer requirements ($i = 1 \dots n, j = 1 \dots m$); C_i is a column vector of importance to customer ($i = 1 \dots n$).

The relative weight of j th product characteristic is determined by replacing the importance to customer in the previous stage with absolute weight for prioritizing the part characteristics.

$$\text{Relative weight}(b_{ij}) = \sum_{i=1}^n Rij * Di \quad (2.2)$$

where b_j , row vector of relative weights for part characteristic ($j = 1 \dots m$); D_i column vector of absolute weights for part characteristics ($i = 1 \dots n$).

From the obtained values, it has been found that offset length and distance between centers of case product are inferred to possess highest relative and absolute weights; hence these are to be given highest priority while designing products. The time associated with the collection of these data and calculation is around 3 h where as to develop a HOQ it may take around 2 h while the time taken for modification, verification and approval which would take around 1 h are also being considered.

2.4.3.3 Conceptual Design and Detailed Design of Case Product

The conceptual model is generated using CAD tool. This would facilitate easy understanding of conceptual design. Conceptual design is generated as per the specifications provided by the customer while the rest of the dimensions are selected accordingly. The time consumed for each step is noted during the generation of conceptual model in the CAD software. While the detailed design shows the material used as well as heat treatment process used for production. The detailed

drawing is generated using the same steps followed as in the conceptual model. The material is selected as per standards based on load capacity requirement. Whereas material to be quenched also would consume certain amount of time which is considered with earlier detailed design generation.

2.4.3.4 Load Calculation and Engineering Analysis

Following are load calculations done for the case product. The case component specifications are as follows: Material used—Mg cu alloy, Density $\rho = 7900 \text{ kg/m}^3$, Poisson's ratio $\gamma = 0.28$, Young's modulus $E = 210 \times 10^3 \text{ Mpa}$.

The load acting on the case product is obtained from the customer which is further categorized into horizontal and vertical component as: Case Product force = 1377.8 kg, Horizontal force at smaller dia $F_H = 1.205 \times 10^3 \text{ kgf}$, Vertical force at smaller dia $F_v = -668 \text{ kgf}$.

The resultant force obtained at the smaller end of the case product is found to be: Resultant force $F_{\text{resultant}}$ is given by Eq. (2.3)

$$F_{\text{resultant}}^2 = Fh^2 + Fb^2 \quad (2.3)$$

$$F_{\text{resultant}}^2 = 1452025 + 446224$$

$$F_{\text{resultant}} = 1377.77 \text{ N}$$

This is the total load which can be applied on the case product the smaller end. With the availability of the following inputs, Finite Element analysis is done to check the deformation associated with the product. While the analysis of case product is done using Abaqus software. The inputs involve the model sketch which was developed in earlier stage followed by inputs such as material properties, displacement characteristics, applied constraints, mesh size and load applied the component in specific direction. Further these inputs are saved and executed to achieve necessary displacement associated with part and also indicate critical locations with maximum stress.

With the available data, the entire design stage is mapped using VSM as shown in Fig. 2.5. The future state map involves the following stages: collection of customer voice, transfer of customer voice into product characteristics, development of conceptual design, and development of detailed design followed by load calculation and finally engineering analysis. Future state map is more elaborate and detailed with the addition of stages such as inclusion of QFD and load calculation before engineering analysis. Future state map also indicates the cycle time and change over time associated with each stage. The improvements are indicated using kaizen bursts: generation of customer oriented products using QFD which would translate customer voice into part characteristics. The use of 5S would facilitate the process to be more ordered and hence can be recorded and same can be reused for future purpose. The use of Failure Mode and Effect Analysis (FMEA) facilitated the identification of failure location regions. Finally, the use of Poka Yoke also called

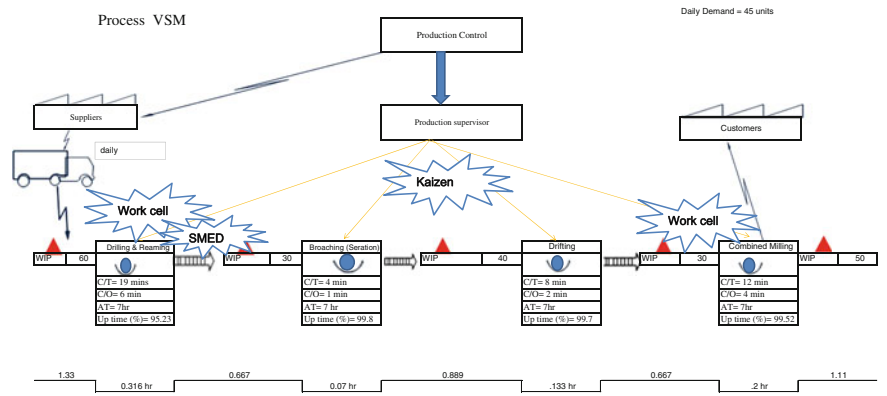


Fig. 2.7 Future state manufacturing process VSM

2.5 Results and Discussions

After detailed analysis of current study, certain suggestions were derived and the resulting improvements are listed in Table 2.1.

Detailed questionnaire in future state map facilitates the collection of both quantitative and qualitative values from the customer, compared to earlier stage where only few dimensions were collected. Also the use of QFD enhance product development process by producing more customer oriented products, since the customer voice is directly transferred into part characteristics (Fig. 2.8).

The cycle time for current state is found to be 29.8 h while after modifications in future state the cycle time is reduced to 24.5 h. A reduction of **17.75 %** is achieved despite having a descriptive and more elaborate future state (Fig. 2.9).

Table 2.1 Suggestions and future state improvements

Suggestions	Improvements
Product design related	
• Need for a detailed questionnaire	Necessitates collecting all quantitative and qualitative needs of customer
• Use of QFD in product development	Helps in conversion of customer needs into part characteristics, hence results in production of more customer specific products
Manufacturing process related	
• Combination of identical processes	Process which could be done using the same machine by varying certain changes in setup would reduce change over time
• Reduction of WIP	By properly organizing process steps, in process WIP could be reduced

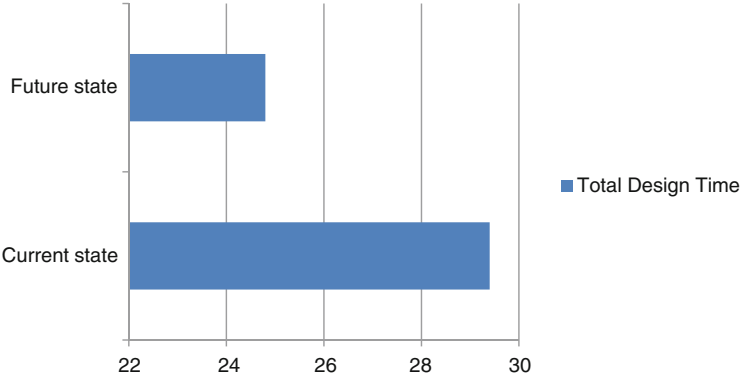


Fig. 2.8 Comparison of total design time for product design process

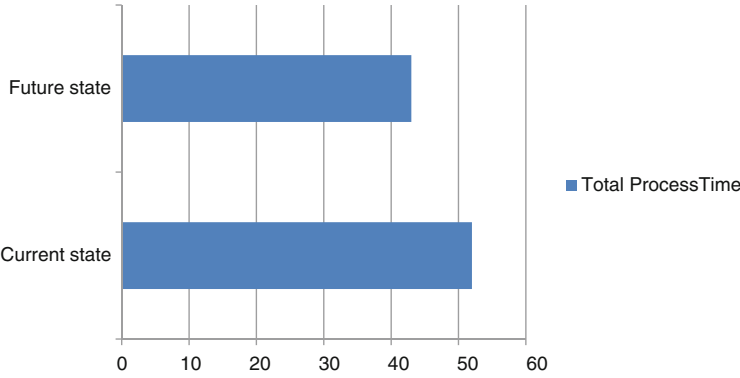


Fig. 2.9 Comparison of total process time

Based on the comparison of current state and future state, the following improvements were identified: current state process time was found to be 52 h; while in the future state, the time was around 43 h. A reduction of 9 h is achieved by making certain necessary modifications.

2.6 Conclusions

The potential of applying lean principles in the context of Product Development is explored. The case study was carried out in an automotive component organization where the scope of lean product design and development was identified. Entire product development process was mapped and wastes associated with product development process were identified. With the identified gaps, the necessary

improvement proposals were suggested. Finally, a Future state Product Development VSM was developed with the identification of necessary modifications.

The improvements achieved through this study include:

- A time reduction of **17.75 %** is achieved despite having a descriptive and more elaborate future state product design.
- A time reduction of **17.30 %** is achieved despite having a descriptive and more elaborate process design.

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