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Standardization in a High Mix Low Volume Company

A Case Study

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Amaresh



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Abstract

The market has been evolving from mass production towards mass customization, which has increased the complexity level for the companies. Unlike in mass production companies where the tasks are routine and standardized, the mass customization types of companies have a varied work demand which makes the work environment complex. These types of mass customization companies are known as High Mix Low Volume type of companies basically because of their characteristics of having a high mix in products and comparatively low volume production.

This thesis research was done with DEWTON INDUSTRIES, Kochi in India. Although product variety and complexity has been answered using technology development and modularization in the previous studies, there has been less focus given to reducing the complexity from the production process point of view. It is also evident that there is limited literature and research done regarding the standardization in High Mix Low Volume type companies both in the academia and in the industry. Hence, understanding the problems regarding standardization in a High Mix Low Volume company and how to handle them has been of a major importance at this point of time.

The purpose of the research is to see how standardization can be increased in HMLV companies. The research approach used here was the case study to collect the necessary data to achieve the results. The data collection techniques used were interviews, observations and literature review, which gave the guidelines and suggested solutions to the identified problems related to standardization in High Mix Low Volume company in the production department.

The findings from the research suggest that standardization in HMLV production is very important for the companies in their current market demands. This is because standardization has a major effect on the quality of end products, production lead time, working standards of employees in the production department and design department. Various problems can occur, and only standardized procedures can solve these problems. It has been well exemplified in this thesis work, how these standardized procedures can increase the quality of the products, increase production speed, and also profit for the company.

This research paper can be used as a guideline by other HMLV companies, while they plan to implement standardization in the production department. To the best of our knowledge this research was one of a kind in this particular field of study and also provides a base for in-depth research on each identified problem.

Keywords

HMLV companies, Standardization, Process standardization, Product standardization

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List of Abbreviations

5S	Sort, Stabilize, Shine, Standardize, Sustain
BOM	Bill of Material
CDA	Customer Design Adaption
DFM	Design for Manufacturing
DFA	Design for Assembly
Etc	Et cetra (And so on)
Et al.	et alia (And others)
HMLV	High Mix Low Volume
I.e.	id est (That is)
IMVP	International Motor Vehicle Programme
ISO	International Organization for Standardization
ISO 9000	Quality Management System
ISO 10013	Guidelines for Developing Quality Manuals
LMHV	Low Mix High Volume
NPD	New Product Development
QMS	Quality Management System
R&D	Research and Development
RQ	Research Question
SOP	Standard Operation Procedures

1 Introduction

This chapter introduces the background of the High Mix Low Volume companies and the importance of the standardization in such companies. This is followed by the problem description, followed by the research purpose and research questions. The delimitations of the research and also the outline of this whole thesis report has been presented at the end of this chapter.

1.1 Background

Recent market transition from mass production towards mass customization forces manufacturers to design products that meet individual requirements (Zhang et al., 2009).

While Low Mix High Volume (LMHV) is characteristic of mass production, Pandian et al., (2010) states that High Mix Low Volume (HMLV) is a main characteristic of the mass customization type organizations which can be used to manufacture products completely based on customer requirements or partially based on product variants. In customization, many products are unique or close to be that; such production is often characterized to be of a HMLV character.

HMLV refers to companies that have hundreds to thousands of active part numbers or required services for which few, if any, have ongoing forecasted demands and the work content can vary dramatically. Orders are usually not predictable and, subsequently, planning is short term, businesses are made up of many smaller orders, the overhead burden increases more than in a high-volume environment of standardized products and orders (Lane et al., 2008). Common features of HMLV are high inventories and work in progress, long lead times and low utilization. In this high transition environment, there is a huge importance for proper allocation of man, machine and material resources along with importance for attention to quality, cost and delivery (Pandian et al., 2010).

Most of the mass production companies use the traditional methods of manufacturing with standardized principles. They are bureaucratic, hierarchical, and highly standardized, workers operate under close supervision and perform highly routine, standardized, and repetitive tasks (Selladurai, 2004).

Standardization is one of the main tools for continuous improvement or kaizen that can be implemented. Although it is the most powerful tool, it is the least used lean tool. By documenting the current best practice, standardized work forms the baseline for kaizen or continuous improvement. As the standard is improved, the new standard becomes the baseline for further improvement, and so on, it is a never-ending process altogether. The process variation is reduced and also the quality of the products and processes are improved (Tamura, 2006). At the same time, to start working in a standardized way is a change that has to comply with the “normal way of working” in such a HMLV context to be possible to succeed with.

Since there is very limited literature and research done regarding standardization in HMLV Companies, this study addresses a true knowledge gap regarding

standardization in HMLV Companies. The results of this study are expected to detect weaknesses that hamper the implementation of standardized work in a HMLV context, and that give beneficial effects for the progression of lean production implementation. Such a study can also facilitate the process to implement continuous improvement and achieve change.

1.2 Problem description

Unlike the Mass production type of companies where most of the work is repeated and every work is documented in-depth to attain standardization, High Mix Low Volume type of manufacturing companies have a very vast deviation when it comes to maintaining standardization may it be with regards to documentation or the way of working.

DEWTON INDUSTRIES, Kochi in India have a large variety of lighting systems manufactured daily as per the customer demand. It is a medium scale company delivering products to all the parts of the country based on customer order. More than half of the products are standard products and the rest of them are partially customized products. To keep up with the customer demand for variety of products, they use the HMLV (High Mix Low Volume) method, the product variety is high, but the product volume is low. At present the company deals with the products based on the customer demand and they do not consider the standardization of parts and production process. Because of which they need to deal with losing a lot of time on changing tools, similar parts and so on. Hence this thesis would deal with finding solutions to the problems in standardization in the production process in a High Mix Low Volume type of company.

1.3 Purpose and research questions

In this research, our main purpose is to see how standardization can be increased in High Mix Low Volume (HMLV) production environment.

In order to answer our main aim of the thesis, we split the aim into the following two research questions:

RQ1: What are the problems faced in a High Mix Low Volume company regarding standardisation of processes and standardized work?

RQ2: How can the identified problems from RQ1 be handled or minimized?

The implications of this study work are to improve the possibility for HMLV companies to implement better standardized work in a more sustainable and efficient way, reducing the production time and increasing the quality of the products in HMLV companies.

1.4 Delimitations

This research focuses on investigating problems associated with standardization in High Mix Low Volume (HMLV) companies. The case study is conducted only in one HMLV company and this study focuses only on process standardization from the production department's point of view.

1.5 Outline

This section will briefly describe the following chapters of this thesis:

Chapter 2 – Theoretical Background

This chapter will provide the various concepts found across different literature which will be used to establish the theoretical background of this thesis work.

Chapter 3 – Method and Implementation

This chapter will give a thorough description of methods and implementation, which includes the research design, research process, the reliability and validity aspects of this thesis work.

Chapter 4 – Findings and Analysis

This chapter includes the theoretical and empirical findings that fulfils the research purpose and also addresses the research questions.

Chapter 5 – Discussion and Conclusion

This chapter includes the discussion of the study. Initially, the research findings of the two research questions are discussed, followed by the discussion of the research methods.

Chapter 6 – Reference

All the written references used in this thesis

Appendices

2 Theoretical background

In this chapter, the theoretical background of this study is presented regarding the various terminologies that have been used ahead in the whole study. The chapter covers various concepts with regards to the High Mix Low Volume and the Standardization.

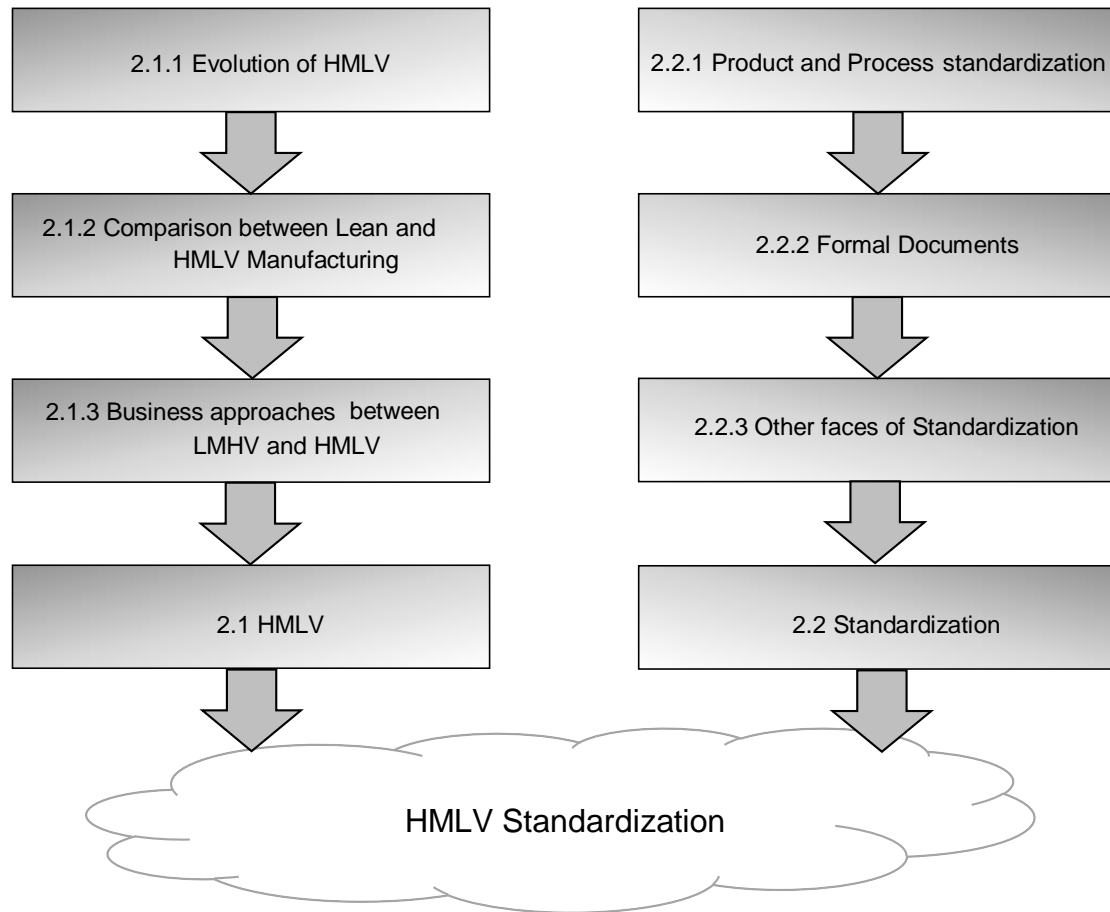


Figure 1: Structure of theoretical background

In Figure 1, the individual sections of HMLV and Standardization has been well researched which has been well explained in this section ahead. Although these sections have been researched well individually, there is not much literature available with regards to HMLV Standardization. The cloud represents the present knowledge gap in the field of research and hence this thesis will be dealing with “Standardization in a HMLV company”.

Initially in the Section 2.1, literature with regards to how a HMLV company works and their characteristics is introduced. Section 2.1.1 consists the evolution of HMLV manufacturing from the traditional manufacturing. Section 2.1.2 compares between current lean plant and HMLV plant, later in the Section 2.1.3 the difference between HMLV and LMHV companies has been put forward. Further ahead, theoretical study with regards to Standardization has been explained in Section 2.2, it consists regarding what is standardization and in Section 2.2.1. standardization of products and

standardization with regards to the process is well explained. In Section 2.2.2 standardization with regards to work documents has been spoken and finally in section 2.2.3 the other face of standardization is pinned down.

2.1 High Mix Low Volume (HMLV)

In the current world people are more into customization and uniqueness of their particular product and they are ready to pay for it too. So, in order to compensate that companies are more open to their customers and ready to meet the requirements of customers for their satisfaction. So, there comes the High Mix Low Volume (HMLV) production where the companies have a large variety of products and most of them are part sharing with each other, and these part sharing variants come under one product family (Svancara et al., 2012).

For HMLV normally, there are high varieties of end products and lots of parts are shared between most of these end products. And these companies provide partial customization to fully customization according to the customer demand (Svancara et al., 2012). Orders are usually not predictable and subsequently, planning is short term (Lane., et al 2008). Sometimes the production is based on forecasts, having ongoing forecasted demands and the work content can vary dramatically. Make to order is the best way to deal with these kinds of production. Producing products with respect to order specific needs at each stage can produce a variety of final products from the same raw material. The production quantity per period at a stage depends on the workload. To shorten lead times, it is permitted to start production at upstream stages without confirmed orders, hold semi-finished items within the system as make-to-stock, and then match orders to these items under the constraints of specifications and quantities. (Morikawa et al., 2014)

2.1.1 Evolution of HMLV

According to Sprovieri (2005), like all the other manufacturing methods HMLV has also evolved by time and research. The different types of manufacturing methods are One-at-a-time, Mass production, Agile manufacturing and HMLV.

1. *One at a time:* It is the oldest type of manufacturing method where the production is based on one person at a time. It is like the product is manufactured by one person from the beginning to the finishing state. So, the character of the product can be changed according to the person. And the variety of the product is not restricted by any means, but the manufacturing lead time is very high, and the production starts when they get any order (Zhang et al., 2009).
2. *Mass production:* This type of production came after one at a time manufacturing system and in this they introduced interchangeable parts for the products. Then they implemented standardization to the craftsmanship due to the restriction of product variants, because their main focus was to make a large quantity of products with similar characteristics (Kotha, 1996).
3. *Agile manufacturing:* The companies become more focused into making products with high variety otherwise they may fall behind other companies in

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the competition. To support that computer aided machines and designs came into companies to meet the customer demands. At the same, time it leads to low and average craftsmanship. Also, products life cycle become very short and manufacturing lead time has also become short (Manivelmuralidaran, 2015).

4. *HMLV*: Current business environment demands the capability of producing products in smaller amounts in order to respond quickly to the changing market demands (customer demands) without suffering any large stocks, excess capacity or challenging the company's credibility to deliver. This flexibility is the crucial element of success (Fritsche, 2011). So, it requires rapid response and minimum warehouse usage because the production is based on customer order (Zhang et al., 2009).

Also, according to Zhang et al., (2009), Kotha (1996), Manivelmuralidaran, (2015), Fritsche, (2011) and Sprovieri, (2005) table 1 shows the evolution of manufacturing systems in companies from One at a time to HMLV manufacturing.

Table 1: Evolution of Manufacturing Systems

Manufacturing system	One at a Time	Mass production	Agile manufacturing	High-Mix Low-Volume
Chief characteristics	Worker-Department	Interchangeable parts	Computer-aided machines, design, information management	Rapid response, minimum warehouse
Lot size	Small	Large	Medium	Small
Worker skill	High and broad	Craftsmen with standardization	Low to medium	High and low
Product life Cycle	Varies, usually long	Varies, usually long	Short	Very short
Product variability	Infinite	Restricted	High	Very high
Manufacturing lead time	Long	Medium	Short	Very short
Work in Process	Low or none	High	Low, but Significant	Close to none
Degree of automation	None	Some	Highly automated	Mixed, with excellent data tracking

2.1.2 Comparison between Lean plant and HMLV plant

The lean manufacturing philosophy has been popularized in International Motor Vehicle Programme (IMVP) by the seminal work of Womack, Jones and Roos (1990). According to Oliver et al. (1994) and Jones (1994), Lean manufacturing is actually the overall business organized at its core, to deliver products in a greater variety and higher quality by means of less resources and in a shorter lead time than the normal or conventional mass production methods.

But their main focus was to reduce waste and use less resource in the manufacturing process that makes them so hard to change from one production to other. Jina, Bhattacharya and Walton (1997), has well explained the main difference between

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Conventional Lean plant and High Mix Low Volume plant which can be seen in table 2.

Table 2: Comparison between the typical Lean plant and a HMLV plant

Characteristic	Lean plant	High mix low volume plant
Typical annual volume	From 100,000 to 1,000,000+ units per year	From 20-500 and 5,000-20,000 units per year
Product variety and complexity	Medium, with no bespoke products. Specialist products separated into dedicated plants	Very high, though some bespoke products are delivered also. All manufacturing in the same plant
Batch size	Batch size is decided by the manufacturers	Batch size is decided by the customer
Degree of vertical integration	Medium and decreasing	Can be low, medium or high – the specialist nature of products often inhibits any increase or decrease
Demand	Demand can be planned and forecasted	Demand is forecasted after customers order
Manufacturing planning systems	Stabilized by a degree of make to stock with primarily assemble to order	Low volume with make to order
Order-winning criteria	Variety Delivery speed “All in” product features	Variety Custom bespoke product “Extra” features Delivery speed

2.1.3 Difference in the business approaches

Low Mix High Volume manufacturers do their business based on the cost and the quality of the products, to them one-time delivery and customer responsiveness are qualifiers for the business, but in the current world they are not the most important considerations. In the case of High Mix Low Volume manufacturers, they do their business primarily by how quickly they can deliver the exact product their customer wants. Cost and quality are qualifiers for business, but they are not the most important when we consider the customer needs (Kotha, 1996 and Sprovieri, 2005). Table 3 shows the different competitive approaches done by the companies (Kotha, 1996 and Sprovieri, 2005).

Table 3: What wins the business

Competitive Differentiator	High Mix Low Volume	Low Mix High Volume
Cost	Qualifier	Winner
Quality	Qualifier	Winner
Delivery	Winner	Qualifier
Responsiveness	Winner	Qualifier

2.2 Standardization

The expression ‘standardisation of work’ is derived from Taylor’s Scientific Management (Taylor, 1911). Standardization in general is the activity of standard-making and David et al. (1994) states that “Standard is a set of technical specifications adhered to by a producer, either tactically or as a result of a formal agreement” both in production process standardization as well as product development standardization.

Standard operation procedures (SOPs) can be perceived as leading to work facilitation. Imai, (1986) defines SOPs as “a set of policies, rules, directives, and procedures for all major operations, which serve as guidelines, thereby enabling employees to perform their jobs successfully.”

The lean concept has been highly spreading across the world and also influencing Sweden during the last decade (Oudhuis et al., 2013). The use of standards is one of the most important concepts of lean. A given process can be made simpler by standardization for reducing the overall process diversity/variance (Hesser et al., 2006).

As industries consolidate and competition rises, firms are increasingly pursuing process standardization to further enhance process management and reap the benefits of standards (Kauffman et al., 2010). Industry-wide process standards provide the advantages of a standardized approach to describe business processes via a common terminology and consistent measurements for determining results across various industries (Kauffman et al., 2010).

Tamura (2006) speaks about the high-level quality control in Japanese manufacturing companies. He states that standard operational control by Japanese companies has the following four characteristics:

- Detailed written information about operations is communicated to all relevant parties.
- The effectiveness of standard operations is increased by means of a system for improvement (kaizen).
- The work-group responsible for a task is responsible for defining and modifying the standard operation for that task.
- There is strict separation within the factory between personnel with and without the authority to define and modify standard operations.

Adding on more points to the above characteristics Košturiak, (2006) states that the standard must have the following characteristics:

- Maximum brevity – all the necessary instructions to the operator process,
- Simplicity and visualization, so that the operator immediately and easily finds and understands the necessary instructions,
- The possibility of rapid changes in process parameters,
- Clarity which ensures that every worker has all relevant activities in the process as well,
- The ability to monitor the implementation of standards and their impact on the process parameters,

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Standardization is one of the 5S as shown in figure 2 which forms the major factors for achieving continuous improvement (Košturiak, 2006). The 5S's being Seiri (Sort), Seiton (Stabilize), Seiso (Shine), Seiketsu (Standardize) Shitsuke (Sustain).

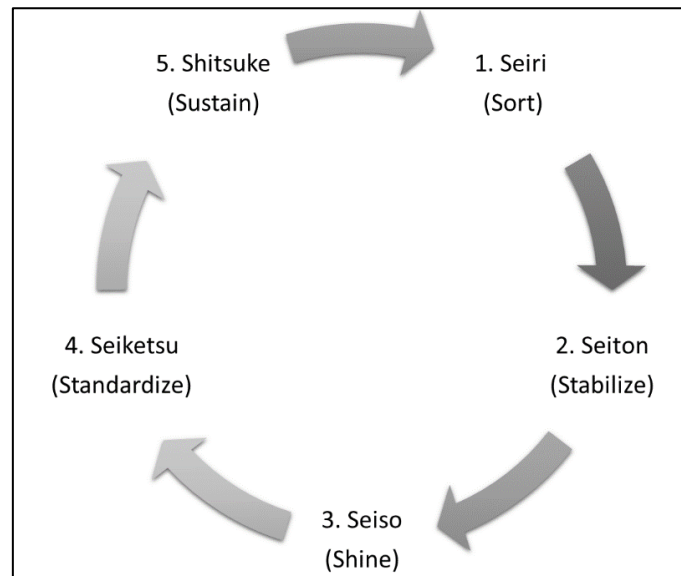


Figure 2: 5S cycle

Košturiak (2006), explains that there are two types of standards: Management standards and Operating Standards. The first one for management of staff and administrative purposes and the later for how the particular task needs to be executed.

2.2.1 Standardization of product and processes

Ulrich,1995 says that in the past years the number of optional features provided by companies is extremely high today in terms of possible product variants, especially in automotive sector. With lots of varied demands from the customers, customization is the only way the companies can answer to that demand. To these Ulrich,1995 explains that “Modularization” is one method to achieve product variety. If the components implement common function then standardization can be implemented and also the interface to the component is identical to more than one product (Ulrich, 1995). There is an improved possibility by the use of modular architecture that components would be useful for a group of products. By product standardization there is a huge gain in the manufacturing segment in terms of cost, performance and product development. And also, if the products are standardized manufacturing processes can also be standardized which can be seen as the greatest enabler of consistent performance.

Standardization is mainly dependent on the possibility to modularize its products and processes (Swaminathan, 2001). Also, Nix (2001) has spoken about the same, where he lists 8 attributes for global integration where one of them is defined as standardization of product and processes. With high market fluctuations, standardization of the product and the process will also lead to low adjustment costs, thereby affecting the company less as a whole.

2.2.2 Formal documents

In Tamura (2006) it is stated that the aim of a formal document is that the operations planned by relevant managers and engineers can be transmitted to all operatives of the shop floor. By transferring information in the written form, precise operational information can be defined.

The document names would vary from one company to the other, although their content of information is almost similar. Firstly, according to Tamura (2006) in general there are two formal documents for production process the “Quality Control Sheet” and the “Production Standard Sheet”.

1. “Quality Control Sheet”

This particular sheet contains information about the product to be manufactured, including plans and blueprints of the product, with all relevant internal and external measurements, details about external appearance and acceptable tolerance for divergence from these specifications (Tamura, 2006).

2. “Production Standard Sheet”

This provides information on the equipment and facilities to be used in the manufacturing process, and the time and number of operators needed per unit for production. This formal document enables an overall statement of the status of the equipment and also facilities and provides an approximation of their process capacity (Tamura, 2006). The standard production processes are formed on the basis of this capacity of equipment and facilities, and the number of specified process steps needed with each item of equipment, taking into account even minor changes in processing or construction.

Tamura (2006) also explains about the other two formal documents which are based on the information on the tasks to be carried out, the ‘Work standard sheet’ and the ‘Work procedure sheet’.

3. “Work standard sheet”

In this, the details of the flow of operations, with separate items in order of sequence are present. If one of the production processes involves physically cutting the product, it may be necessary to include numeric values for this and it may then include both product and quality information and details of the tasks to be carried out (Tamura, 2006).

This document should mainly include the following:

- Plans and diagrams of the product.
- The acceptable range of specifications for completion.
- Work elements (i.e. steps that must be carried out) in the process, and the sequence in which these are carried out.
- The quality characteristics of the product.
- Information about the equipment used.

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Although in this case the work elements in the manufacturing process, and the sequence in which these are carried out, are the same as those in a standard ‘Work standard sheet’, the operational details and times required are more defined in-depth (Tamura, 2006). The stipulated times are the time needed for each work station, the time needed to put the product together, the time needed for transfer to the next work station, and the handling time (the time that the operative needs to obtain the materials), the sum of which is termed the cycle time (Tamura, 2006).

Tamura (2006) also states that the ‘Work standard sheet’, containing operational information, is defined by the manufacturing department at the relevant factory after the pre-determined information about the product, facilities and equipment have been established, and this involves preparation in accordance with a basic model, taking operatives’ opinions into consideration. When bulk manufacturing has been initiated, the operational organization can modify the contents of the ‘Work standard sheet’ while the operations stipulated in that document are in progress.

4. “Work procedure sheet”

This contains details of each work element included in the ‘Work standard sheet’, including how parts are obtained, and how equipment is set up, enabling operatives to carry out each work element without error (Tamura, 2006).

The format and content of each formal document are chosen according to the field for which they are prepared and on the basis of the information required by the users. Hence, each type of formal document has a different mode of presentation, and the role of providing all necessary information to the users (Ueno, 1999), which results in each type of document being a highly individual information medium with respect to both areas covered and constituent details.

Tamura (2006) also states that the process for transmission of operational information is as follows. Firstly, the product planning department prepares the product plans and blueprints. These documents are then received at the relevant factory, where the manufacturing department and production engineers, etc., prepare documents for each process stage, such as the ‘Manufacturing process standard sheet’, ‘Quality confirmation sheet’ and ‘Work standard sheet’, taking into consideration the details of the equipment and operations in the factory. The manufacturing operations in the factory are then carried out, primarily in accordance with the ‘Quality confirmation sheet’ and ‘Work standard sheet’.

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With respect to rewriting 'Work standard sheets', Tamura (2006) explains, the group leader first hears the opinion of the operator who encountered the problem, and then listens to opinions within the shop floor work-group. The group leader then collates and adjusts the results of these consultations together with one or more of his/her managerial supervisors, including the factory chief, after which they select the relevant information, and a new 'Work standard sheet' is decided upon, primarily by the group leader. The team leader's responsibility is preparing and revising the 'Work standard sheet' and 'Work procedure sheet', and the factory chief, who oversees all the group leaders, then verifies the contents of these documents. The operators do not have the authority to modify information in these documents. It has thus been pointed out that the actual involvement of operatives in kaizen in standard operations is limited (Asao, 2004).

Nevertheless, because the authority to prepare and modify the relevant formal documents remains within the work-group, and operator's proposals are enthusiastically received and considered, from the operator's point of view, he/she has initiated the kaizen process by which the formal documents are prepared, modified and managed, and the efficiency of the operation improved.

Tamura (2006), also speaks about the importance of partial correction of Taylor's concept, operational information can be modified by the personnel responsible for manufacturing, and these personnel have the authority to modify even the two types of predetermined information based on the actual operations. The routine process for modifying the 'Work standard sheet' at shop floor level in Japanese companies is the submission of a kaizen proposal by members of the shop-floor work-group. Fujimoto (2003) states that kaizen in Japan involves the development of industrial engineering techniques in a bottom-up manner, with the participation of all of the company's employees (Tamura, 2006).

2.2.3 Standard documents in ISO 9000

Additionally, Dunford (1998) explains that there are mainly three types of standard documents that are usually present in companies.

1. A quality manual
2. A procedures manual
3. Work instructions

Standard documents basically help at documenting standards associated with ISO 9000. The quality manual talks about the responsibilities, the procedure manual identifies who is responsible and the work instructions are approved by the managers authorized by the quality manual. These three are hierarchically related, i.e. the rules at Level I authorize and enable the operating procedures at Level II., and then operating procedures in turn authorize and enable Level III standards and work practices (Dunford,1998) as seen in table 4.

Theoretical background

Level I document would not be of any use unless they provide authoritative standards, such as dimensions, tolerances, formulas, tables, temperature ranges, surface conditions, tooling, components, raw material, and so on. People will be confident about these standards because they have come after the approval (signed and dated) of a knowledgeable manager (Dunford, 1998).

What the operators need to do, is documented and authorized as Level II, like the company's acceptance criteria for tensile tests which is based on the company standards (Dunford, 1998).

Dunford, 1998 explains that the source documents such as standards, drawings, and internal engineering specifications must be accepted by the managers, to ensure that the most up to date information available to the operator are documented and authorized as Level III work instructions.

Table 4: Quality System Documentation

ISO 9000 Document Level	Contents	Purpose
1. Quality Assurance Manual	Policies	Authorization
2. Operating Procedures	Procedures	Assign responsibility
3. Work Instructions	Source Documents	Approve standards

ISO 10013 clearly states the guidelines for developing quality manuals as "To avoid unnecessary document volume, reference to existing recognized standards or documents available to the quality-manual user should be incorporated", which means one must only refer to existing standards and documents, not rewrite them.

The work instructions can be mainly of two main types, written work instructions and visual work instructions. The written work instructions are easier to create, but not user friendly for the operators with complicated task that are normally found in complex production system. In comparison, the visual work instructions consist of pictures and videos which are easier to create and edit, as well as user friendly for operators with complicated tasks. Theoretically, according to the learning pyramid, a person remembers about twice as much of all information if it is conveyed visually (Dunford, 1998).

2.2.4 Other aspects of standardization

Production process is a combination of work between machine and humans, although machines can do repeated tasks without hindrance, humans would tend to lose motivation over the period of routine tasks. The capacity of a person to act in accordance with objective morality rather than under the influence of desires is known as Autonomy, which is highly important in production floor. Only when we humans have freedom to make decisions on what we work only then we are creative.

Theoretical background

Autonomy mainly focuses on freedom in (a) work scheduling, (b) decision-making and (c) work methods (Morgeson et al., 2006). There is surely a very large difference between the concept of freedom in carrying out the work independently and being part of a decision-making process. This difference is important for creating learning processes in work, where there is none or very little autonomy in the production work (Lantz et al., 2015). This determines that standardization would lead to lower motivation, job satisfaction, performance and innovativeness of the team, which surely is a draw back in one way. By standardizing work procedures, non-value adding activities can be reduced, which reduces autonomy. But for motivation, job satisfaction, performance and innovative teamwork autonomy has proved to be crucial (Lantz et al., 2013).

Oudhuis et al., (2013) states that minimal specifications lead to development of operators and only through experimentation and learning work is performed better. The operator's contribution to the company and the organization increases productivity, quality and efficiency through their creativity and innovative capabilities.

Standardization leads to kaizen (continuous improvement) work, but these cause extra pressure on the operators since such improvements which are documented into standard work sheets are set as a base for further improvements (Oudhuis et al., 2013). Standardization thus is also said to increase the workload of the operator.

However, Lantz et al., (2015) describes that in a standardized work environment industry, the involvement in the initial planning phase of the work procedures, i.e. the standardization process, instead of autonomy in performing work tasks, is a key prerequisite for team learning processes and team pro-activity. And as also Adler, (1993) states that SOP's increases the confidence of the workers. SOPs are also claimed to be the mechanism by which employee ideas are transformed into business practice, increasing workers' perceptions of participation (De Treville, 1987; Edelson et al., 1998). And also, the involvement in lean practices is equivalent to development of standard operating procedures (De Treville et al., 2006).

West et al., (2004) and Frese et al., (2007) describe how the link between autonomy and pro-activity is well established. However, autonomy work demands are so uncertain and dynamic and not when a team performs a set of tasks that are clearly understood and optimized or standardized (Stewart, 2006).

According to lean the use of standards is the tool behind workers taking on true responsibility (De Treville et al., 2006) and that access to accurate SOPs increases worker confidence (Adler, 1993).

3 Method and implementation

This chapter focuses on the methodology in this study, including the research design, the chosen methodological instruments, the research process and the case company as a resource for the data collection.

3.1 Research design

Initially in section 3.1.1 the type of research approach used in this thesis work has been explained and further ahead in section 3.1.3 different research techniques selected to gain the information for the research questions has been well explained.

3.1.1 A case study approach

The whole research design has been well depicted using the flow diagram as shown below in Figure 3. The main purpose of the research has been depicted in the “Purpose” section, which has been tried to answer framing two research questions as seen in “Research Question 1” and “Research Question 2” section. These two research questions have been answered with the help of different research techniques which can be seen in the “Techniques” section with regards to the different techniques used for respective research questions.

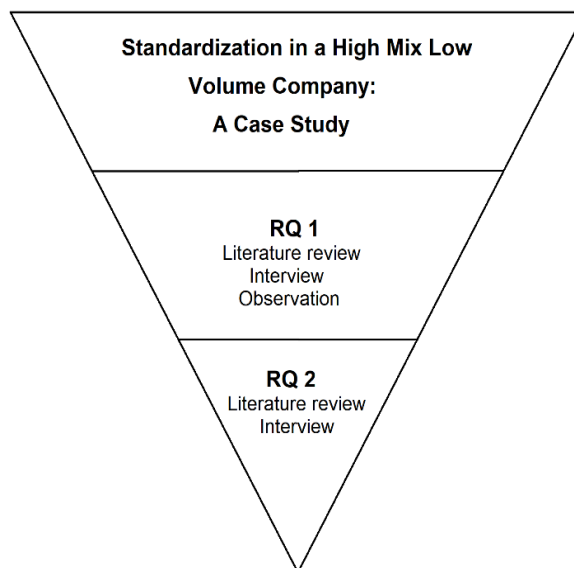


Figure 3: Visualization of the relation between purpose, research questions and data collection techniques

For the thesis purpose, we have used case study approach in order to understand the work procedures in its natural settings (Williamson, 2002; Yin, 2003). The case study was done in a company that had a High Mix Low Volume production and followed lean concepts. It gave a clear view about the problems they face in production process with regards to standardization in the real-life context. The research questions framed investigated the mainly affected problem in the company and the ways to handle the identified problems with the help of standardization.

After having identified the main problems with regards to standardization in research question one, we have answered how we can handle these identified problems in research question two. For the collection of data, we have made use of interviews, observations and literature review.

3.1.2 Case Company

For this thesis subject, we have chosen Dewton Industries located in Kochi, India after having researched on their wide variants in product range. It was observed that they manufacture a wide range of variants with a quite small variation regarding the functionalities or appearance. This study is focused only on the problems faced in the production department on the topic of standardization of manufacturing procedures.

3.1.3 Selection of research techniques

For the case study, we have acquired data from multiple sources, because these can be combined to strengthen the logic and also minimize the weakness of each technique (Williamson, 2002). For this thesis, the data collection techniques are literature review, interview and observations. To answer each research question, we have selected the techniques as shown in figure 3.

a) Literature review

The literature used consisted of books, articles, research reports and conference papers and other similar material. It provided a better and broader understanding of the research topic. This process simplifies the researcher in understanding the underlying problems of the research. Literature review lets the researcher choose a correct research method for the study (Williamson, 2002).

To cover the theoretical background and to answer research questions we made use of the literature. This was mainly to find more details about standardization, especially the problems faced while standardization and the benefits of standardization in production process.

To answer the research purpose, it was important to know whether there were any formal documents used in the production process by the operators and if they could make any changes to it. Besides, it's important to know which communication mode is used for all the documents (whether hardcopy or softcopy), since it is a highly changing work environment, there is a need for proper information available throughout the process that leads to the product and production standardization. The literatures also help us in gathering more data for the interview at the case company and also for the research questions.

In the Initial stage literature review was done by exploring the concepts like "Standardization in production department" and "High Mix Low Volume (HMLV) in a manufacturing company" which gives the basic data for the theoretical background. The keywords used to gather data in the advance search are "Standardization" AND "High Mix Low Volume (HMLV)" AND "Production process" AND "Production department" but the result was very low like in primo 3, Google scholar 2 and scopus3.

Method and implementation

With the usage of different databases, the following outputs were found with regards to different key words individually as seen in table 5. Although there were many literatures available individually with respect to the key words “Standardization” and “High Mix Low Volume” there were hardly any papers that spoke about how standardization can be achieved and improved in a HMLV company, and hence we decided to base our thesis on this particular topic of “Standardization in a High Mix Low Volume company”.

Table 5: Documents found in database

Keywords	Primo	Google scholar	Scopus
Standardization	190831	220000	249922
High Mix Low Volume (HMLV)	44	306	293
Production process	561064	647000	35507
Production department	508373	890000	8430

-These keywords are basic for the background concept, which helps us in finding the articles to support our research. So, as a researcher we select the articles as per relevancy of the research based on criteria like engineering and selected articles by the year its been published. For example, authors select the articles from 2000 to 2018 which are relevant for the validity and reliability of the research. But since there were less articles found, we have expanded the search from 1990 to 2019.

For the next stage of literature review to gather more in-depth data we have used the concept like “history of HMLV”, “standardization and innovation”, “hindrance in standardization”, “innovation vs standardization” and “production process techniques”. Also, the authors excluded subjects like business Management, social science, computer science, mathematics, and documents types like reviews, book chapter, magazine. Then the authors included the main area as engineering and document types as peer reviewed articles, books and journals. Most of all only articles in English were included and all the other languages were excluded. The table 6 depicts the filters that has been included and excluded for better understanding.

Table 6: Literature search filters (Included and Excluded)

Included	Excluded
Keywords: History of HMLV, standardization and innovation, hindrance in standardization, innovation vs standardization and production process techniques	Keywords: Lean, Mass Production, LMHV (Low Mix High Volume)
Subject area: Engineering	Subject area: Computer science, business management, environmental science, Mathematical.
Source type: Articles, Journal, books	Source type: Book section, magazine. Conference paper.
Language: English	All the other languages

b) Interview

For our research purpose, we have used unstructured interview and semi structured interview (Williamson, 2002). Initially, we have done an unstructured interview with the white-collar employees linked to the production area to know more about the company and to understand the production process.

After the initial unstructured interview, the semi structured interview was followed with the managers, the supervisors and the operators after giving them a brief introduction about the topic standardization in HMLV companies and the purpose of the interview. At the same time, we have also given more focus to the formal documents in the company related to the production process. Personnel have been selected based on the roles in the organization and their involvement in the processes like production manager, planning and scheduling manager, supervisors and operators from the production department.

To increase the reliability and validity of the theoretical findings of research question two, we have done a semi-structured interview with people who are well knowledgeable in the field of production systems. For this purpose, we have selected the employees from the case company.

c) Observation

For the research, observation was needed for a better understanding of the organization and the production processes. As it would give us a good understanding of production department and the problems they are facing and what are the things they do to manage that situation. By observation we would get a better real-time overview of the situation rather than from word of mouth. The observation was done on employees and their working patterns.

3.2 Research process

The research process was conducted in 5 different stages: Planning, Interviews, Observation, systematic literature review and Analysis. The research process was initiated on 10th October 2019 until 18th May 2020.

3.2.1 Initial Planning

At the beginning of the thesis it was important to find relevant literature in order to form the proper purpose and research questions. After defining these, we started working on theoretical background. Literature was collected using Google Scholar, Scopus and Jönköping University Library (primo). The collected literature is in the form of peer reviewed, scientific articles, conference paper and textbook. To search these literatures, we used keywords like “standardization”, “High Mix Low Volume (HMLV)”, “production process”, and “production department”. After that to gather more data we widened the search with more advanced and additional keywords like “History of HMLV”, “standardization and innovation”, “hindrance in standardization”, “innovation vs standardization” and “production process techniques”. After collecting the required data on the topic, the work on theoretical background progressed. The work was

continued throughout the process of findings because of the need for additional data in the thesis.

In order to prepare a proper semi structured interview questions, we used the data collected from the literature and also from the unstructured interviews with the managers of the company.

3.2.2 Interviews

The main purpose of the interview was to collect data from both white collar as well as blue collared employees' point of view. At the same time to gather their experiences within the company and to identify the potential areas for improvements. A total of 8 employees were interviewed at the case company, 2 managers, 1 production engineer, 2 supervisors and 3 operators, all being male employees. The experience of the employees had varied from a minimum of 2 years to a maximum of 9 years at the case company. Besides, the respondents were from all the three management levels (Upper, middle and lower) of the company as this would give us more in-depth view from different management system regarding the present scenario of their standardized system as well as the problems they see with regards to standardization. The overview of the respondent's designation, experience in the company and the interview time duration has been well shown in table 7.

Table 7: An overview of semi-structured interviews

Designation		Years in the company (Years)	Number of semi- structured interviews	Time Duration of the interview (min/person)
Managers	Production Manager	9 Years	1	30
	Planning and scheduling	5 Years	1	30
Production Engineer	Production Engineer	4 Years	1	30
Supervisor	Supervisor 1	7 Years	2	30
	Supervisor 2	2 Years		
Operators	Operator 1	7 Years	3	20
	Operator 2	8 Years		
	Operator 3	2 Years		
Total			8	3 hours 30 min

The interview was conducted in the company's production department. The initial contact was made through the telephone with the production manager, explaining the process and background of the thesis and what we need to do in the company while we visit them. Then the manager instructed us to give them a brief idea about the people that we need to interview. The procedure of the interview was that we had a face to face interview with each person in the allotted time period. First, we started with an

introduction about the purpose and background of the research. For their convenience, we handed out a printed introduction to them regarding our thesis topic which was in English and whoever had difficulties understanding English we explained them in their local language which is Malayalam. Even the interview questions were prepared in English and explained to them in Malayalam language to make them more understandable, the introduction and interview questions can be found in appendix 1 and appendix 2.

3.2.3 Observation

The observation was conducted in the workplace of the production department, where we observed the employees working patterns and the way they handle the work. By observing each station from close, we found different data that gives more aspects for the future use. And some of them were more supportive to the interview, we had conducted.

3.2.4 Literature review

In order to cover the second research question (Still under progress) and to answer the theoretical findings we have used literature review. In order to answer research question two, we need to know how the identified problems from the research question one could be handled without affecting the productivity.

3.2.5 Analysis

The analysis of the data was conducted in three stages. The first stage, after finishing the initial semi structured interview, we just transcribed the recorded interview for more understanding. The second stage, we compared it with the data collected through literature study. Third stage, all collected data from the research techniques were used to answer the research questions.

The data collected with the help of interviewing employees was qualitative and transcribed them to make it more accessible and easier to analyse (Williamson, 2002). The transcribed data later was put up in the section 4.2. An analysis was made which leads to a general conclusion, patterns and important comments were noted down from it. From the observation the majority of collected data was qualitative, this data was then put up in the section 4.2.2. The results are presented in the section 4.2.3. Then a literature review was conducted along with interviews to support the collected data and it is been put forward in the section 4.3.

3.3 Reliability and Validity

In order to achieve the required reliability, the methods and techniques were applied with respect to support of literature. To get a better validity, we used triangulation of findings using several sources of evidence (Yin, 2009) and a well-planned stage for better data collection. The methodological part has been explained in chapter 3 with complete transparency in order to enable to conduct the study under similar conditions, thereby improving the reliability.

4 Findings and analysis

In this chapter, the theoretical and empirical findings are presented with regards to the two research questions, which were collected from the literature review, interviews and observations.

4.1 Present working scenario

The following section speaks with regards to the present company working scenario with respect to the documents, process and work environment which was acquired from the semi-structured interviews.

The case company uses software platforms to share the information with regards to quality, production and production methods.

The same kind of documents are available to everyone, right from the operators to senior managers in the form of a soft copy (electronic media).

The production engineers make use of the platform known as DEWTON Project system which consists of time planning, standard protocol measuring time, production checklist and standard documents for new products. Since the initial decision of the production methods are decided by the production engineers, they have three internal separations based on the product categories,

1. New standard product – New standard documents were made
2. Customized standard product – When the order volume was high this became the new standard product. And when the order volume was low, standard documents without customization were followed which were not always accurate.
3. Minor changes in standard product – Standard documents without the minor change were followed and were generally accurate, this was the responsibility of the Product Design department.

To tackle the demand for High Mix Low Volume production the case company makes use of two different types of assemblies the Line Assembly and Cell Assembly. Large volume small size products are produced in Line Assembly whereas larger size that cannot fit in line assembly and wiring harness are produced in Cell Assembly. Lines are standardized regarding in which line which product family needs to be produced.

4.2 Problems identified related to standardization

In the following section, initially we have summed up and categorised the findings from the semi structured interview in section 4.2.1, followed up by our observations at the case company in section 4.2.2 and section 4.2.3 gives the overall inference from both the semi structured interviews and the observations .

4.2.1 Inference from the Individual Interviews

1. *Production employees not involved in New Product Development*

It was seen from the semi structured interviews with the various employees of the case company that they were not involved right from the initial stages of a New Product Development (NPD). The middle and lower management were not involved from the initial stages of NPD, they were involved at the stage when the product had already been designed and finalised. They were only involved with the decisions regarding in which line or cell it needed to be assembled and how they were convenient to work. The percentage of involvement in NPD by various employees were as follows,

- Production Engineers – From 20% of the start of NPD
- Supervisors – At the end when 20% of NPD remaining
- Operators – At the end when 20% of NPD remaining

2. *Similar parts are not shared*

Standardization with regards to parts had not been attained in all areas; this was pointed out by two of the employees. The screws were made of different designs which made the operators change the tools to fix them each time there was a different screw to be fixed, which lead to increase lead time during the production of the product.

3. *Designers are focused on the aesthetics and not on how products are manufactured or assembled*

It was also seen from the interview with operators and supervisors that most of the products were designed based on aesthetics point of view and not from how they could be manufactured or assembled. This caused difficulties for the operators at the shop floor during the assembly of the components thereby increasing the overall lead time of the production line. Also, it effected the quality of the product with inappropriate frame and body strengthening methods. Like for example while interviewing one operator he notified that once they had a problem with the light, that was the design people only concentrated on the visual aspect and didn't consider the assembling difficulty, because of that they couldn't install nuts and bolts in the frame of the body and to compensate that drawback they were forced to put a number of screws, to balance the quality but it increased the assembly work.

4. *Parts wrongly chosen*

It was clear from both upper management and lower management employees that operators did not make use of the work instructions. It was stated during the interview that they normally followed their own way of assembling although work instructions were given. The operators mainly assembled parts based on their knowledge from experience without having gone through the work instructions, which in turn lead to picking up wrong parts by the operator and bypassing the product updates, thereby causing issues regarding quality in the product.

For example, there would be an order change for different colour outer cover of a lamp but in case if the operator had not seen the update in screen, the operator would be still assembling the previous cover on the lamp itself, thereby causing quality related issues and further leading to rework and increase in the overall lead time.

5. *Training only for completely new products*

It was seen from the interviews that the operators were trained only when the product family was completely new, and the training mainly for operators was in the form of learning by experience. If a completely new product was launched, then the operators were trained by the project engineer and employees from the production department (department who dealt with the handling of procedure and assembly standards), for minor changes no formal training was given. They had also stated that they were not trained well comparatively.

6. *Inadequate work instruction*

In case of unique products, no in-depth standard work procedure documents were available. It was clear from the interviews that, no change was made in the instructions in case of minor changes in the product. Only the important procedures were instructed in the document; every detail was not instructed in the document. However, there were standard work procedure documents available in general.

Small changes in the product family were not analysed before sending them from the design team to the production floor; only verbal instructions were given to the operators by the higher ups.

The interviews at the case company had a total of 8 respondents, out of which 50% of the respondents had stated the problem of not having involved in the initial stages of NPD process; the problem of parts not having been standardized although they were similar were stated by 25% of respondents; the designers being focused only regarding the appearance and not regarding how it was made was, this was stated by 25% of respondents; the operators did not follow the work instructions at their station and the parts too were wrongly chosen by the operators either due to operators not following the updates on the screen or because of the wrong parts present at the station, this was stated and accepted by 75% of respondents; 50% of respondents had stated that if there

Findings and analysis

were any small changes to the product there wasn't any formal training given, rather verbal instructions were given. Finally, the work instructions were not easily understood was stated by 50% of respondents.

The following table 8 shows the six main problems identified in the company according to the respective individual employee's point of view. To keep the identity of the respondents anonymous, we would name the respondents as 1 to 8.

Table 8: Problems identified with respect to employee's point of view

Sl.No.	Main Identified Problems	Respondents at the company							
		1	2	3	4	5	6	7	8
1	Production employees not involved from the initial stages of NPD	✓		✓	✓			✓	
2	Similar parts are not standardized	✓	✓						
3	Designers are focused on the aesthetics and not on how products are manufactured or assembled				✓				✓
4	Operators do not follow work instructions and follow their own way, which leads to picking up wrong parts by the operator and bypassing the product updates	✓			✓	✓	✓	✓	✓
5	Operators are only trained during completely new product launch, no training in case of slight changes in products, only verbal communication are given		✓				✓	✓	✓
6	Quality information not available in the formal documents	✓	✓	✓	✓				

4.2.2 Observations

From our overall observations at the company production segment, it was seen that following main points were highlighted:

1. Many parts are similar, but they were not standardized.
2. Operators follow their own work procedure without considering the actual instructions given by the company.
3. There was no real-time feedback system for the operators to give any feedback to the upper management or to the product development department. The information lead time was longer in this fast-moving production sector both from the upper and lower management.
4. Sometimes operators had inconvenience in assembling the parts because of the challenging designs.

Findings and analysis

4.2.3 Overall inference from the interviews and observations

After analysing the entire interview and observations, the main problems faced regarding standardisation of processes and standardized work in this High Mix Low Volume case company were highlighted as follows,

1. Employees from all the segments are not involved in early stages of New Product Development.
2. Few similar product parts are not standardized, example the screw.
3. Designers are focused on how it appears and not on how it is manufactured or assembled.
4. Operators normally followed their own way of assembling as they had enough experience, however if there were any updates the operator would miss it which would eventually lead to a quality related issue.
5. Operators get training only when a completely new product is developed.
6. In-depth detailed instructions were not available for all product families.

Based on all these aspects the six main problems that affect standardization have been well visualized using the Ishikawa diagram with cause and effect in the Figure 4. The six main identified problems have been put up in Cause boxes of a “Cause Effect diagram” and the reasons for these six identified problems has been put up in the sub sections of the Cause box.

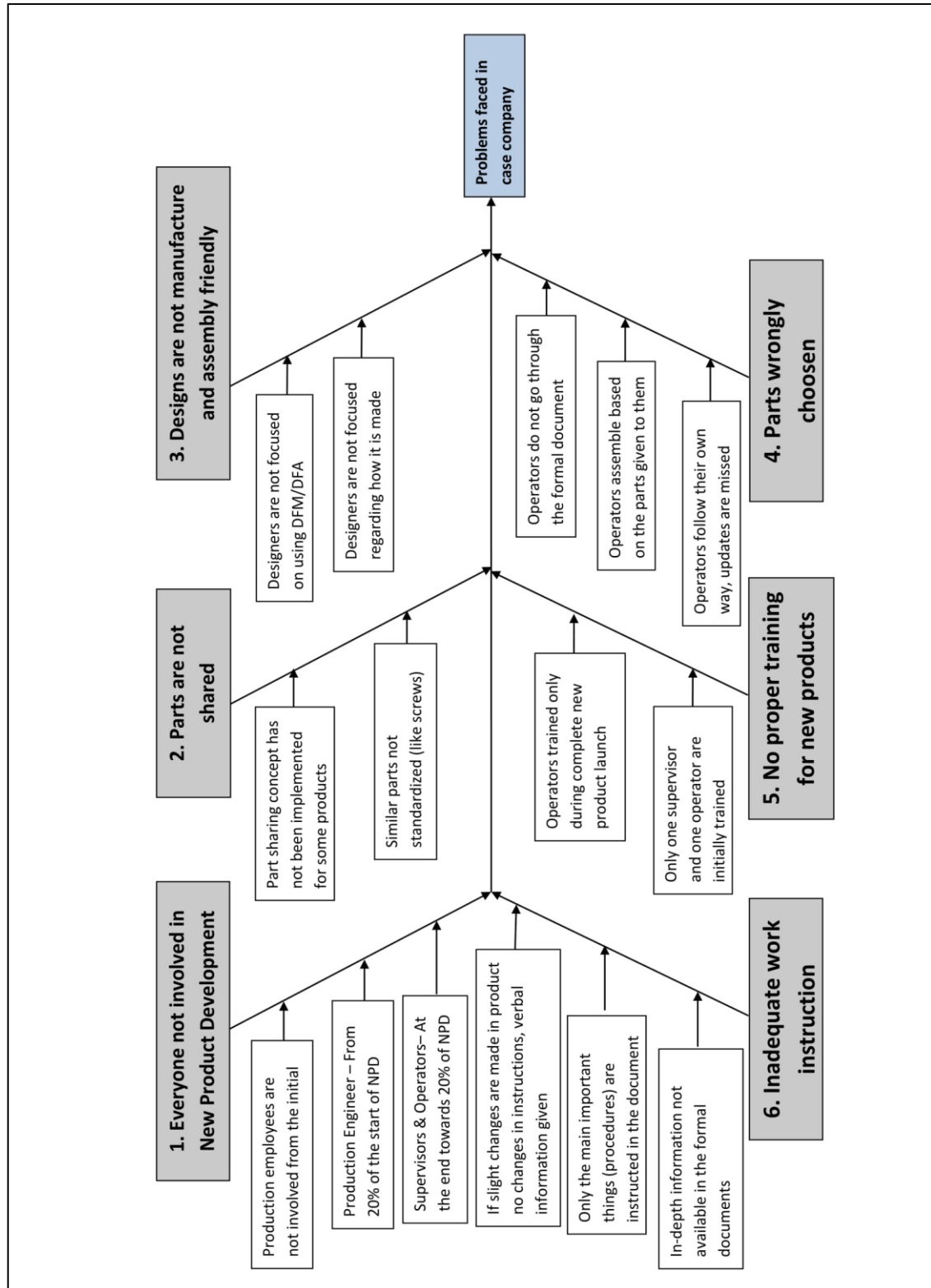


Figure 4: Ishikawa diagram representing the problems faced in standardization

4.3 Proposed solutions to handle the identified problems

In the following section from 4.3.1 to 4.3.6 we have proposed potential solutions for the identified problems in the HMLV case company with regards to standardization with the help of one more literature review, which has been backed by the second follow interview with the professionals from the case company which is put up in section 4.3.7.

4.3.1 Production integration in the early phases of NPD

Cross functional integration in the early phases of a New Product Development play a major role. The success of new product is based on the speed and flexibility of the new product development process (Nonaka et al., 1986), thereby shortening the time to market of the new products. Also, external constraints in the new product development plays a major role in later stages of production (Gerwin et al., 1996). Complexity and newness in a product might hinder production. But it can be rectified if the design team is familiar with the manufacturing and this can be achieved by integration of production people along with design team while developing new products. It is important during a new product innovation that the team has an expertise and knowledge in a variety of fields. To increase the success rate of a new product it is important for integration (including employees from all the departments) to be considered because of the interdependency of the functions and responsibilities. (Griffin et al., 1996)

Adding to the above, Ettlie (1990) formulates five main mechanisms of integration as follows: training on formal methods in Design for Manufacturing (DFM), manufacturing sign-off (confirmation) on design reviews, novel organizational structures (cross functional teams and a joint R&D-production department), job rotation in engineering functions and permanently moving personnel between design and manufacturing.

4.3.2 Implementation of Part Sharing concept

According to Meyer and Lehnerd (1997) sharing parts and production processes across a family of products leads companies to develop products faster and more cheaply, and it also increases the flexibility of their manufacturing processes. The time taken or engineering hours for these kinds of firms to develop products is comparatively less than that of firms which develops completely new products one at a time (Nobeoka et al., 1995). When a part or a component from the preceding generation is used or shared with other product lines, significant benefits from economies of scale can be gained (Ericsson et al., 1996).

McDermott and Stock (1994) states that part sharing has grown a lot from just reducing product development cost to becoming a strategic and a competitive weapon. The strategic and competitive weapon mainly enhances reducing inventory level, new product development and manufacturing. Adding to the above, McDermott and Stock (1994) states that lower stock levels of common parts is achieved by pooling of inventory, the reuse of common designs and parts shorten the new product development cycle and the set-up times and retooling time are lowered in the manufacturing process.

Not just in manufacturing sector but also from the purchasing and sales & distribution point of view, it is beneficial (Ericsson et al., 1996). Sharing parts lead to easier coordination of suppliers, lower purchasing costs per part and faster service.

To sum up, parts sharing in product development is beneficial in product development process and at the same time it reduces complexity and enhances performance throughout a manufacturing firms whole value chain (Nobelius et al., 2002).

4.3.3 Implementation of Design for Manufacturing/ Design for Assembly (DFM/DFA)

It is widely known that around 70% of the products manufacturing cost is determined by the decisions at the initial stages which is the design stage (Lai et al., 2008). The concept of Design for assembly (DFA) was initially started by Boothroyd and Dewhurst (1983) and later it was developed to Design for Manufacturing (DFM). Boothroyd introduces three basic rules that determine if a component could be eliminated or combined. These were gripping, orientation and insertion. DFA is mainly aimed at simplifying the assembly by both minimising the number of parts and ease of fitting it (Lai et al., 2008). And hence it is seen as one of the concepts to address the issue regarding the complexity of assembly of a product in the case company.

Normally product realization was not considered throughout the life cycle. Issues were normally addressed only after finishing the design, respective departments had to solve, thereby consuming time, causing inflexibility and errors at later stages (Huang et al., 2001).

Lindkvist et al., (2016) mainly describes the procedure of DFM in terms of three stages. The first stage is to find an optimal conceptual design, followed by second stage where a detailed design which completely utilizes the potential of the chosen conceptual design and in the third stage where the exact dimensions of each part is determined, and the designers focus in making “doing the right things rather than doing things right”.

Bogue, (2012) explains the benefits of DFM/DFA based on the DFM/DFA guidelines, which not only addresses the complexity of assembling a product, but many other things as follows,

1. Minimizing the parts leads to improved reliability, reduced purchase and inventory costs and simplifies assembly
2. Use of standard parts (like common fasteners) leads to reduced costs, lower purchasing lead time and potentially greater benefit, simplified repair and maintenance
3. Lesser usage of dissimilar parts leads to need for fewer manufacturing processes
4. Minimizing the usage of fragile parts leads to cost reduction due to failures, easier handling and assembly.
5. Do not over-specify tolerances or surface finish leads to easier manufacture and reduced fabrication costs
6. Design for ease of fabrication leads to cost reductions from the elimination of complex fixtures and tooling

7. Considering modular designs leads to reduced costs due to simplified assembly and test
8. Aim for mistake-proof designs leads to cost reductions by eliminating need to re-work incorrectly assembled parts
9. Design for simple part orientation and handling leads to cost reductions due to non-value-added manual effort
10. Design with predetermined assembly technique in mind leads to cost reductions from use of proven/known techniques
11. Consider design for automated/robotic assembly leads to potential cost reduction over manual methods

4.3.4 Usage of “Right” parts

An information system can be described as something, “to get the right information to the right people at the right time in the right amount and in the right format” (Johansson, 2016). Most often the operator has most of the information needed to perform the operation at his workplace. Despite knowing this fact, manual assembly errors are common, especially when product variants are high.

In general, the operator most often has the amount of needed information available (Johansson, 2016). To solve this problem of picking the “right” parts, it is important to improve the information seeking process. It is suggested that the information presented to the operator is improved in such a way that it activates attention (Backstrand, 2009).

The objective of cognitive support is, if better support and all the information regarding the task to be done is made available to the operator, it can decrease the complexity level in the shop floor work station, thereby increasing the overall productivity of the company (Ashmore, 1992). There are basically two topics within cognition i.e. automation and ergonomics. Cognition automation is mainly categorised based on skill, rule and knowledge (Fasth et al., 2009). When an operator responds based on sensor inputs such as signals and acts in automated manner without conscious control, it is mainly based on skill of the operator. In rule-based responses, the operator is already familiar with the work situation and he acts based on the already instructions known by them (reacting to sign). And in the knowledge-based response, the operator reacts to symbols during occasions when know-how is missing. Based on functional (tasks) properties respective symbols is highlighted and a certain decision is taken by the operator (Rasmussen, 1983).

Additionally, for the operator to pick the right parts the light guide could be made in use (pick-by-light, put-to-light) or search-guided (pick-by-voice) about removal or storage locations (Reif, 2009), these kinds of systems are used for manual assembly work stations. These can be characterized by different concepts of implementation, such as signal lights and / or laser projections in the case of pick-by-light or are complemented by implementing new principles (pick-by-shutter, motion control, etc.). Due to higher demand of information in manual assembly these are normally present along with the screen guided work instructions (Reif, 2009).

4.3.5 Adequate training for employees

Automation of machines improve the quality and productivity in the companies, however, there are places and tasks in the companies that need the human operator's assistance. So, there is a huge need of highly skilled operators, and in some places shortage of manual skill is seen in the manufacturing industries (Katz, 2008).

Frost, 2014 explains that, in the present world managers are more focused on hiring experienced employees. During the recruitment most of them are disqualified; it is not because the people are underqualified, it is because technology has been developing day by day. So, to compensate this, we need to give ongoing training to employees for the betterment of the company and for better customer satisfaction. The training can enhance the knowledge of the employees, but many employees in the current state, find it difficult and it is so expensive for the companies to provide training, that sometimes they need to hire external trainers for this job. Even though these are potential drawbacks, training and development can provide both the individual and organization benefits in terms of the cost and time, which is worth the investment (Frost, 2014).

In the workplace different operator support parameters are identified; some of them are work instruction, training seminar, monitoring and learning by experience. Dehnbostel, (2003) categorized them as formal training and informal training. The formal training is nothing but the training that has been given by the company in the forms of documents, seminars and instructions in the case of informal documents it is nothing, but the knowledge gained by the experience at work or learned by the new product order or by communication with other workers (Dehnbostel, 2003).

The different approaches for the training can be mentioned as on the job training, face to face training and computerised training (Dalle et al., 2016). The training is one of the main factors for the success of the company and for the new production development units. So, to achieve that we need a good infrastructure of information and communication (Johansson et al., 2016).

A) Benefits of trained employees

Frost, 2014 explains the benefits of trained employees with eight main points as seen below,

1. Improves employee's performance
The employees who are trained are more capable and can perform better on their job. Training gives the employees a better understanding and responsibilities of their role. It can also help to increase the confidence level of employees, thereby increasing their overall performance in the company.
2. Improves employee satisfaction and morale
The training can provide more supportive environment at the workplace and gives the employees more attachment to the company because more consideration is given to them by the company. Thereby increasing the employee satisfaction level towards the job and meanwhile increasing the overall productivity
3. Addresses weakness

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When we consider employees, most of them have some weaknesses related to skills at their workplace. Training program helps them to strengthen those skills that they lack; this will also help the employees if they have any other weakness within the company. It also reduces weak links in the company who rely on others to complete the basic tasks.

4. Increases consistency
A good training and development program ensure employees have good experience and background knowledge, all the employees need to know the various procedures of the company, and this increases the efficiency. This increase in efficiency will increase the financial gain of the company.
5. Increases productivity and maintains quality standards
Productivity will increase when the employees are well trained, besides they will also maintain the quality of the product.
6. Increases innovation in new strategies and products
Better training and development skills will increase the employee's innovative skills. New ideas can be developed from the employees itself rather than outsourcing them.
7. Reduces employee's turnover
Employees feel secure if they are trained and developed better and they may not lose value in the work this can benefit the company by not wasting money on recruitment.
8. Enhances company reputation and profile
Having a strong and good training at the company will help develop the employees and the company brand name, thereby becoming a reason for prime selection among the customers, new graduates and job seekers.

B) Draw backs of untrained employees

The draw backs of untrained employees has been well explained by Bercu, 2017 as follows,

1. Untrained employees = unhappy employees
They might not be satisfied with their job; unsupportiveness from the company may cause them to underperform, make mistakes and don't-care attitude about the product they are making, thereby effecting the performance of the company.
2. Untrained workers have a low production value
The quality of their work and performance become lower and less valuable.
3. Untrained workers are inefficient
When the employees are not properly trained, they need to spend more time and effort to perform the required tasks and responsibilities.
4. Lost time/money due to mistakes
Untrained workers often tend to make mistakes which leads to time and wastage of materials, which further leads to rework or scrap. Sometimes these products may be sent to some unlucky clients without knowledge.
5. An increase in miscellaneous expenses
Making unnecessary mistakes, for example making a mistake in the CAD drawing leads to reprinting of the corrected one. This may cost money, time,

waste of paper, ink and so on. If it had been done correctly at the beginning, this could have saved all losses.

6. Insufficient staff training means lost customers

Under trained or untrained employees can make any mistakes mentioned above and can have a negative impact on customer satisfaction about the company, thereby leading to downfall of the company.

4.3.6 Detailed work Instructions

At present most of the research is focused on cognitive support to operators in manual assembly thinking that high quality work instructions would decrease the difficulty level at shop floor workstations (Fast et al., 2013). To standardize the procedures and to provide knowledge about production process in organization, tools like work instructions are used. The global setting and increased product variants diversify the process of creating work instruction.

For a fluent material flow in a production line, there is a requirement for effectiveness and reliability of humans working in the production line. And one of the important factors for this is to have a very good work instructions sheets for standard operation procedures. When creating this work instructions sheet it is important that we mirror the specific standard operating procedure. This implies that we need to understand the specific steps of the procedure, its phases or the tasks and its duties, which has been well explained by Olson et al., (2012).

The work instructions might differ from one file to other but normally in one company the standard template is the same throughout for all working instructions such as manufacturing, material handling, welding and others, not only to achieve high effectiveness but also to speed up their development (Mourgues et al., 2008).

There is so much of information transfer in manufacturing sector by word of mouth, but the oral information transfer has a higher rate of error and inefficiency. Although there is higher training period, the failures have never reduced. Hence the usage of documents has come to one's rescue. They mostly contain one-half of the words contained in typical documents: simple sentence structures and basic English skills and in the respective language for ease of use (Beluško et al., 2016).

According to Beluško et al., (2016) the usage of Work instructions leads to

- Quality of the finished product
- Consistency of the finished product
- Increase in throughput of the process
- Safety of the operator

Mainly standardized work instructions are made to ensure that the process is consistent, timely and repeatable. This is normally present near the operators for their use and also for the team leaders and managers to follow up, if the operator can use the instruction.

Beluško et al., (2016) describes the following steps regarding how to make a work instruction:

1. Understand the work that needs to be documented.
2. Understand the educational and skill level of the operator who will be accessing the instructions.
3. Prepare a format for the work instructions. This may include the name of the author, the name of the document, the date of the document, the purpose of the instruction, and related references and forms.
4. Prepare the work instructions. Ensure proper flow and use clear language and/or pictures.
5. Pre-check the work instructions by allowing someone who is unfamiliar with the task, but has the level of knowledge of the operator, perform the activity by using the work instructions.

Also, Dunford, (1998) speaks of the importance of what needs to be in a work instruction. According to him the thinking of every stage of the production process being documented in the procedure manual has complicated the quality systems documentation process. It is a general belief that the more information an operator has about a task, the better the decision. But it is hardly true, because it is the quality of data that is present for the operator, that makes them to take the right decision. Such information needs to be accurate, complete, current, timely, relevant and should be transmitted in a proper information carrier so that it is correct and present in detail, so that the operator finds it clear and easy. This information, if present in a correct detailed simplified manner would reduce the complexity in the production sector.

Documenting work instructions isn't a burden as it seems to be. As other quality systems documentation, work instructions should focus on control factors, not on detailing operations.

Dunford, (1998) explains what work instructions should contain very well. According to him they should contain conditions and standards, "Rather than asking employees to detail operations, ask them to write down when operations take place and how they know what they are doing is correct". Document the conditions and standards of an operation in other way means the following:

1. Conditions
What is the occasion or trigger that starts an operation? What initiates and authorizes the operation?
2. Standards
What standards (e.g., ranges, limits) conduct the operation so the employee knows that he or she is on track?

4.3.7 Inference from the semi structured interview addressing the possible solutions for the identified issues

Following section sums up the responses from the follow up semi structured interviews held with the production manager and the production engineer from the case company.

Findings and analysis

1. Integration of production team from the initial stages of New Product Development (NPD)

From the semi structured interview, it was seen that involvement of operators and supervisors in NPD process from the initial stages wasn't much of a common trend in companies, however there are few companies that have been integrating operators in NPD process recently. Based on the interviews and findings from studying the above literature, it is important for the design team to include professionals from all expertise in it so as to take wise decisions, based on this team they need to decide if the design of the product is manufacturing and assembly friendly.

2. Implementation of parts standardization or part sharing concept

Respondents from the interview proposed that part sharing was a beneficial idea. They said that since there would not be wide variety of parts the inventory management would be easier. They also said that it would reduce the pressure on the supplier side and also reduce supplier lead time to supply the product to the focal company. They also said that the tool change time would be nullified with part standardization. On a holistic view part sharing concept would clearly reduce the production lead time.

3. Implementation of Design for Manufacture/Assembly concept

The respondents view from the interview was in line with the theoretical findings. The respondents felt that implementation of design for manufacturing and assembly concept is surely an advantage to the operators for manufacturing and assembly, as it can reduce the unwanted wastage of resources related to over all time, redesign, design printed paper, ink and manhours.

4. Parts wrongly chosen

Respondents from the interview agreed that in order for the operators to be aware of the change in parts the usage of light-guided and laser guided system could be of great help. They added a point that, to help the operators in choosing the right parts the alert system could also be used as an extra added solution but not always the best solution.

5. Inadequate training

It was suggested by the respondents from the interview that sometimes training is not needed in case if the operators were experienced professionals for every small change done in a product. Training is important but it could be costlier and hence not always a good idea until and unless, it is important for the company.

6. Detailed work instruction

It was seen from the semi structured interview that the usage of pictorial work instructions is surely a plus point for operators to grasp information at a faster rate in order to work quickly in the production line. Too much text instructions on the work instruction sheet increases the workload to read texts along with the assembling work.

4.4 Summary of proposed solutions to the identified problems

The following table 9 sums up the possible solutions for the identified problems regarding standardization in HMLV Company, respectively.

Table 9: Summary of possible solutions for the identified problems

	Identified problems	Possible solutions
1	Production employees not involved from the initial stages of NPD.	Integration of production employees in the early phases of NPD: It was seen that integration of production employees in the early phases of NPD eased the later stages as the design would be based on the available facilities in the production line. And also, previous errors and any suggestions from the production team would be a great value reducing further errors in the product development chain.
2	Similar parts are not standardized or shared.	Implementation of Part sharing concept: Part sharing would lead to standardizing parts, thereby reducing the tool change times and also lesser pressure on supplier with regards to delivering variety of parts and also eventually lead to better inventory control.
3	Designers are focused on the aesthetics and not on how products are manufactured or assembled.	Implementation of Design for Manufacturing/ Design for Assembly (DFM/DFA) concepts: DFM/DFA concepts would ease the pressure on the assembly line operators with regards to manufacturing and assembly processes as the products would be designed with lesser complexity.
4	Operators do not follow work instructions and follow their own way, which leads to picking up wrong parts by the operator and bypassing the product updates.	Usage of light-guided and laser-guided systems: These systems increased in picking right parts by the operators in the production line and reduced the errors increasing the quality of product.
5	Operators are only trained during completely new product launch, no training in case of slight changes in products, only verbal communication are given.	Adequate training of personnel's during new product launch: Proper training to employees during new product launch was essential because if they weren't updated about new product the product would be assembled wrongly thereby reducing the quality of product and also increasing the lead time because of the product rejections and rework.
6	Quality information not available in the formal documents.	Availability of proper work Instructions for operators in shop floor: A detailed work instruction or a pictorial instructions was important in production line as this would increase the quality of the product as the operator will be having all the required information at his hand. And also, when a new operator comes to a new work place, he can easily understand his job process.

Findings and analysis

From a holistic angle, it is seen that that these solutions not only lead to standardization but also leads to improve the various performance factors such as the Time, Cost and Quality, which has been represented using figure 5.

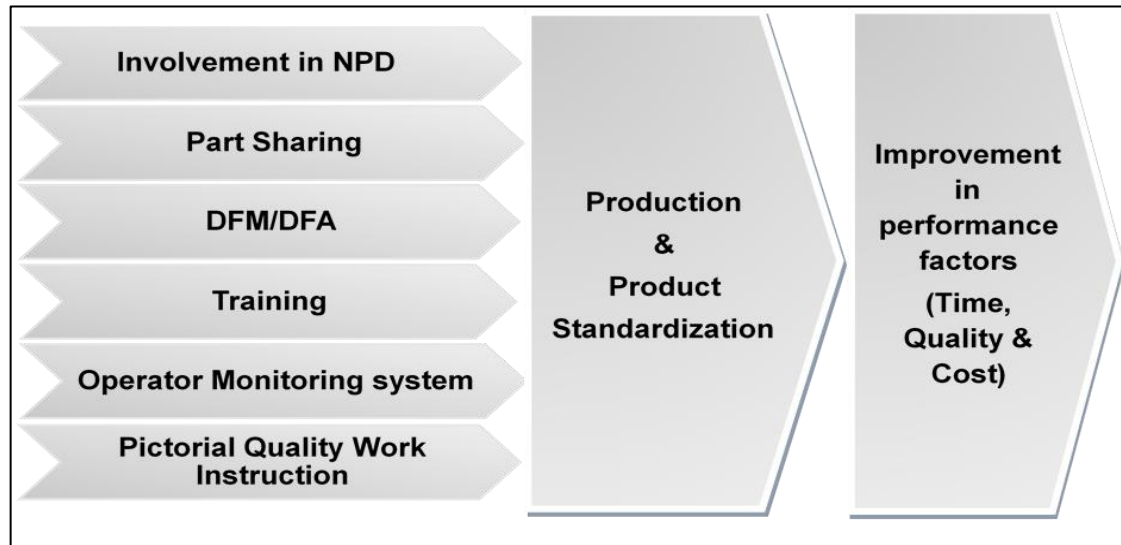


Figure 5: Interlink between the solutions, standardization and performance factors

5 Discussion and conclusions

In this chapter, at first the discussions regarding findings are presented with the purpose of answering the two research questions and there by fulfilling the purpose of the research, which is followed by the discussion of methods and ended with the conclusions and further study section.

5.1 Discussion of findings

5.1.1 Overview

The purpose of the thesis was to investigate how standardization in High Mix Low Volume (HMLV) production environment can be done.

So, to accomplish the purpose of the thesis, the following research questions were formulated and anticipated to be answered,

1. What are the problems faced in a High Mix Low Volume company regarding standardisation of processes and standardized work?
2. How can the identified problems from RQ1 be handled or minimized?

The research approach considered to answer the research questions is the case study method. The findings and analysis have been elaborated in sections 4.2, 4.3 and 4.4 respectively.

5.1.2 Answering Research Question one

The first research question was focused to find the problems faced in a High Mix Low Volume company regarding standardisation of processes and standardized work, which was supported by the case study approach with the data collection techniques such as semi structured interviews and observations at the case company.

Since most of the answers from respondents are from their personal experiences and from their daily work life, the problems mentioned by them can be completely unique as well as like those of other respondents. The problems that were chosen as the main ones were based on their effect towards standardization based on the identified theoretical base of the thesis. Based on all these aspects the six main problems that affect standardization in an HMLV were pointed out.

The main problems identified from RQ1,

1. Production employees are not involved from the early phases of NPD
2. Similar parts are not standardized
3. Designers are not focussed on manufacturing and assembly
4. Operators follow their own method because of which product updates are missed
5. Operators are trained only during a completely new product launch
6. In-depth information is not available in formal documents

All these main problems may look very minor, but however they truly have a huge impact on the overall improvement in the production process of High Mix Low Volume.

5.1.3 Answering Research Question two

The second research question focused on identifying the solutions to the problems listed in the research question one. All these solutions were found by studying the relevant literature that has been carefully elaborated in section 4.3. Besides, to make the solutions more relevant, we had conducted some more interviews with the people who were professionals in the field of production systems, it was a follow up interview with the professionals at the case company. And that has been addressed in the section 4.3.7. The proposed solutions to the identified problems are as follows,

1. Integration of production employees in the early phases of NPD
2. Implementation of Parts sharing concept
3. Implementation of Design for manufacturing and Design for assembly concepts
4. Usage of “Operator monitoring systems” like laser guided and light guided systems
5. Training for operators
6. Usage of an adequate work instruction sheet

5.1.4 Holistic view of the solutions

It was seen from a holistic view that these solutions not led to standardization but majorly influenced the performance factors of a company which is “Time, Quality and Cost”. The lead time would be decreased in many terms such as reducing tool changing time and also reduced supplier delivery time by implementation of part sharing/part standardization concept. And thereby also reducing pressure on inventory control. The design for manufacturing and assembly concept makes it convenient for the operator to perform the task and also contributes towards reducing the lead time. The usage of operator monitoring system like light guided and laser guided improves the cognitive support to the operator there by enhancing the performance of work and reducing the lead time and also reducing the occurrence of error and ultimately increasing the quality. Training of operator leads to better quality of product and also the usage of better pictorial work instruction sheet leads to faster grasping of information by the operator and thereby also contributing toward reducing the lead time.

5.2 Discussion of method

In this thesis work case study was chosen as the research method to collect data about “Standardization in a HMLV company”. Case study was considered as the most appropriate method, as we could collect data from real time environment ourselves and it would also give a better idea about a HMLV company in terms of its working procedures in the production department. The main purpose of the study was to find the problems in the HMLV company with regards to standardization in process, the research also dealt with the solutions for the identified problems.

For the data collection techniques, we used literature review, interview and observation. During the initial phase of the literature review, it was seen that although there were many papers which dealt with the standardization and HMLV in general, there was

hardly any literature found with regards to “Standardization in HMLV companies”. The theoretical background was framed after the initial phase of literature study as it was important to understand the various terminologies used in this study. This was also the foundation of framing questions for the initial unstructured interviews at the case company. This initial unstructured interview was mainly conducted to gain insights into the existing production line at the company from different sources. It also eased the decision-making process regarding which area needed to be focused on in this study. At the same time, it also simplified the analysing and concluding process.

This was followed up by semi structured interviews, so the respondents had the freedom to freely express their ideas and feelings towards the questions. During the initial semi-structured interview, the respondents at the company were briefed with regards to the topic of our thesis work and they were also presented with the short description of the topic in English and also explained in local Malayalam language for their better understanding. There was a total of eight respondents who were selected from the upper, middle and lower management work groups which was considered good enough; that made the findings more accurate because we were getting different responses from different work groups which led to source triangulation.

The solutions for the identified problems were then tried to be rectified by exploring the available literature with regards to the various problems. After that, to make the solutions more accurate and reliable, we conducted one more semi structured interview with the people who were well versed in the field of production systems.

Throughout the various stages of thesis, work observations were done at the case company, by collecting on-site data of the operators and supervisors’ daily duties and working procedures. Moreover, we also noted whatever data that was needed to answer the research questions.

5.2.1 Reliability and Validity

The whole thesis work has been well documented and explained with regards to the case study approach, the methodology, data collection techniques and analysis. This lets anyone who reads this report easily understand every stage of this thesis work. It also lets any researcher carryout the research regarding the same subject, with same aim and research question and same research approach as mentioned in this thesis, to come up with almost same set of results under similar circumstances.

The answers to the research questions are highly internally valid as this thesis study was done only in a single case company and data collection was done only in one company. Almost 8 interviewees from three different management groups were selected and hence source triangulation was achieved, while answering research question one. In order to increase the validity of the solutions of the second research question literature study was crosschecked by interviews. However, the obtained results could have varied to some degree, if a wider set of companies had been included in this study.

5.3 Conclusions

The purpose of this thesis was to establish a steppingstone in contributing towards standardization in HMLV companies, which included investigating the problems related to the standardization in a HMLV company and studying literature in order to finding solutions to mitigate these identified problems.

The first research question proposed the problems faced in the HMLV case company that hindered the standardization in the production process and employees working procedure. From the qualitative findings it was seen that even though the company was implementing standardization concepts, there were still many places that needed standardization, like in the field of product and production process with regards to the design of products, working procedures, training of operators and work instruction documents.

Findings of the second research question provided insights into the solutions for the problems that had been found from the research question one. The main solutions found from the literature that leads to standardization in the production sector are; integration of production employees in the early phases of New Product Development, improving parts sharing concept, implementation of Design for manufacturing and Design for assembly concepts, usage of Operator monitoring systems like laser guided and light guided systems, proper training for operators and lastly the usage of an adequate work instruction sheet in the production sector. It was seen from the literature that, these solutions not only contributed towards standardization but eventually lead to increase in the overall performance factors of the company i.e. decrease in production time, decrease in cost and increase in product quality.

This thesis can be used for both academic and industrial purpose. The research can be useful for people who are interested in the field of standardization and HMLV company, as it would give a better understanding of the current HMLV companies and its working procedures. The detailed literature review gives a better list of reference and it can also be used for the future research study, the research design and research approach can be used for other researches of this same kind. The result of this thesis can be useful for companies that are planning to standardize their production department.

5.4 Future Study

The future research of this thesis work would include, considering a few more HMLV companies for the case study. A more in-depth study could be done in the future with regards to the various identified problems with respect to practical implications of standardization, depending on the available time frame.

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7 Appendices

7.1 Appendix 1: Short description of the formal documents.

(for the interview purpose only)

1. Quality control sheets

The 'Quality control sheet' contains information about the product to be manufactured, including plans and blueprints of the product, with all relevant internal and external measurements, details about external appearance and acceptable margins for divergence from these specifications.

2. Production standard sheet

Which provides information on the equipment and facilities to be used in the manufacturing process, and the time and number of employees needed per unit of production.

3. Work standard sheet

The 'Work standard sheet' details the flow of operations, which separate items in order of sequence and it may then include both product and quality information, and details of the tasks to be carried out. In details, the 'work standard sheet' for such a cutting process should include the following information:

1. 1.Plans and diagrams of the product.
2. The acceptable range of specifications for completions.
3. Work elements (i.e. steps that must be carried out) in the process, and the sequence in which these are carried out.
4. The quality characteristics of the products.
5. Information about the equipment used.

4. Work procedure sheet

The 'work procedure sheet' contains details of each work element included and also how parts are obtained, and how equipment is set up, enabling operatives to carry out each work element without error.

7.2 Appendix 2: Interview Questions for RQ. 1

(for the interview purpose only)

1. Since how long are you working here?
2. What formal documents do you use in the company to plan and control production (Drawings, BOM, Quality control sheet, Production standard sheet, Work standard sheet and Work procedure sheet etc)? Is it available for you?
3. Where are the limits for formal adherence to standard procedures?
4. What is standardized and what is not?
 - What happens if they do not follow the procedures?
 - Where is the bottleneck?
 - How do they control for quality in customized orders?
5. The documents you follow, is it similar to all employees from managers to operators?
6. In what format are the documents available for you (paper or computer)?
7. Do you suggest or make any changes to these formal documents? Do your seniors accept your suggestion?
 - If so, how often you suggest changes or make changes daily, weekly or monthly
8. Are you satisfied with the current procedures or are there any challenges faced in standardization according to you? Any suggestions to the existing methods or are there any kind of solution from your perspective and experience?
9. Since the products to be assembled changes frequently do the operators get trained (given the information of the product to be assembled), if so, how often do they get trained?
10. If any new product is developed is there a new manufacturing process?
11. Do they have any formal procedures to handle all customization?

7.3 Appendix 3: Short description of the problems

(for the interview purpose only)

The main problems faced regarding standardisation of processes and standardized work in this High Mix Low Volume case company that could be highlighted are,

1. Operators normally followed their own way as they had enough experience, however if there were any updates and the operator would miss it and there could be a quality related issue.
2. Designers are focused on how it looks not how it's made, it should be produced based on DFM/DFA.
3. Not involved in early stages of New Product Development
 - (Production Engineer – From 20% of the start of NPD)
 - (Supervisors – At the end towards 20% of NPD)
 - (Operators – At the end towards 20% of NPD)
4. Few similar product parts are not standardized, example the screw.
5. Operators get training only when a completely new product is developed.
6. In-depth instruction should be available for all product families

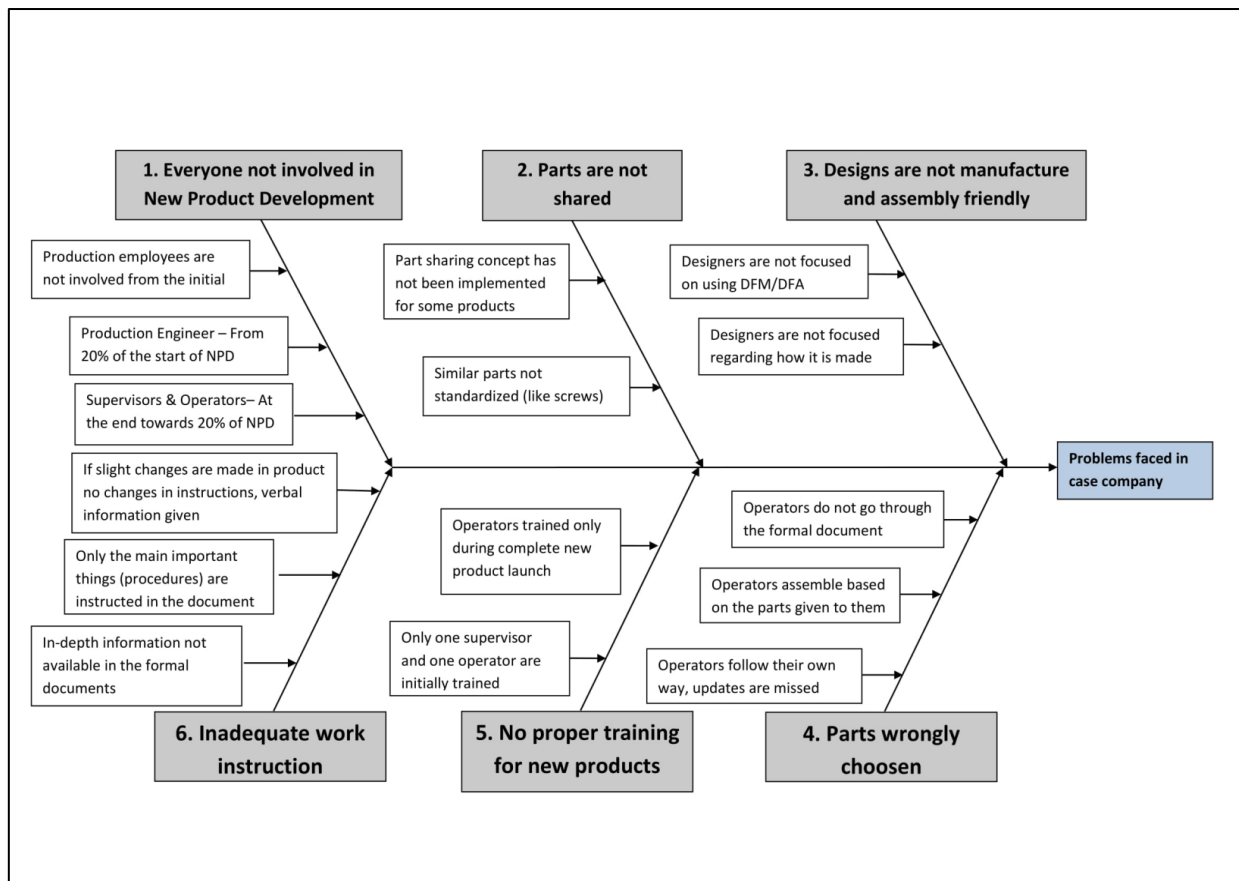


Figure : Problems faced regarding standardisation in the case Company

7.4 Appendix 4: Interview Questions for RQ. 2

(for the interview purpose only)

Parts wrongly chosen

1. Based on your experience could you suggest few concepts regarding how a right part could be chosen by an operator?
2. Can operator monitoring system be used? (Light guided or Laser guided)
3. Can this be improvised in a HMLV Company?

Design are not Manufacture/Assembly friendly

1. The product is not manufacturing friendly, so what is your opinion regarding that?
2. Can DFM/DFA concept be utilized?
3. Can this be improvised in a HMLV Company?

Production team not involved from the initial stages of New Product Development (NPD)

1. The industrialization managers, production technician, supervisors and operators are not involved from the initial stages (getting suggestions regarding production improvements) of NPD, how can this have an effect on production?
2. How important is it to involve everyone in an NPD process?
3. Can this be improvised in a HMLV Company?

Parts standardization is not followed

1. There are few parts that are not standardized (similar) what is your opinion regarding this?
2. What is your opinion regarding Part sharing? What is its benefits with respect to inventory, design, quality and work process?
3. Can this be improvised in a HMLV Company?

Inadequate training

1. Only during completely new product launch the operators are trained, but they aren't trained for minor changes in the product (they are conveyed orally), what would you say regarding this?
2. Should the employees be trained, or should they learn by experience?
3. In your opinion is training a waste of money and time?
4. Can this be beneficial in a HMLV Company?

Work instruction

1. Work instruction isn't giving all the information in-depth, so operators have the freedom to do few tasks according to their convenience, what is your opinion regarding this?
2. Which one would you prefer?
 - An in-depth or short easy to understand (quality) work instruction sheet?
 - A visualized or black and white work instruction sheet?