CHAPTER - I
INTRODUCTION

1.1 INTRODUCTION

The last twenty years have seen a significant contribution from Lean thinking at both academic and practicing levels. Indeed, in many industries such as the automotive sector (Shingo, 1997), Lean thinking is a way of life. However, the widespread understanding of lean approaches by academicians and industrialists often lags the leading edge of lean evolution (Zayko et al., 1997).

Lean manufacturing is a business philosophy that continuously strives to shorten the time between a customer order and its shipment by eliminating all those activities that increases the cost and time (Garry Conner, 2001). The implementation of Lean manufacturing without a corresponding reduction in value addition requires that all the wastes are identified and eliminated from the system (Lauri Koskela, 2004). Anything that does not add value to the product can be considered as waste. Lean manufacturing aims to eliminate waste (John M. Nicholas, 2001). There are different types of wastages that exist during manufacturing, such as inventory (raw materials, work in process, finished goods, spares, etc.), time (poor process planning and scheduling), materials (Scrap), equipment (machine time), plant space, movement of materials and objects, labor (unnecessary actions), capital (idle times of resources) and so on (Womack J.P, et al., 1990). The primary objective of lean manufacturing is to assist manufacturers who have a desire to improve their company’s operation and become more competitive through the implementation of different lean manufacturing tools and techniques (Detty R.B, et al., 2000). For eliminating wastages many industries practice Lean tools such as Value stream mapping, 5S method, Visual management, one piece flow, Kanban, poka-yoke, changeover reduction, Kaizen, continuous flow, etc (Womak, et al., 1990). All these methods have their own merits and demerits, but Value stream is most frequently preferred tool for implementing the lean manufacturing in conventional system, this includes current state map and future state map for every activity in manufacturing. In general, for effective manufacturing and minimizing the wastages during manufacturing, design of the product as per final requirement of product properties such as quality, reliability, assembly, maintainability, etc. is important. “Design for X” is a generic name for the members
of family of methodologies, of which Design for manufacture is the oldest. Design for X (DFX) methodologies can be seen as tools to analyse designs for their suitability for identified aspect of a product’s life cycle. “X” may be Assembly, Manufacture, and assessing parameters like quality, maintainability, reliability, safety and environmental issues etc.

Similarly, the term design for lean manufacturing is employed, instead of design for manufacturing and then applying lean strategies (minimize the wastages) during design to give better results than previous one with respect to market strategy (Mcmanus, 2004) that is “time to market”. The product development process attempts to maximize customer value by ensuring that the product development subprocess work well together; that they use and produce the right information at the right time. In this way, it is easier to detect and solve problems throughout the product development process. Hence, the product design termed as Lean product design and its aim is to reduce all possible wastages during product development. Lean product development holds the promise of dramatically improving a company’s competitive position. Its implementation offers the potential for faster product development with fewer engineering hours, improved manufacturability of products, higher quality products, fewer production start-up problems, and faster time to market of course, all of which improves the likelihood of market success (Julian et al., 2002). With the sole intention of increasing manufacturing efficiency, the theories of lean manufacturing were developed. The success of Lean manufacturing was fulfilled by product design and it reduces manufacturing lead-time with product design methods (Hopp and Spearman, et al., 1996).

For success of Lean Product design, one has to minimize the following possible wastages possible during product design and development, such as waiting (idle time due to unavailable information, manpower or computing resources), transport/handoffs (inefficient transmittal of information, papers, faxes, emails, and files), movement (people often have to walk to distant central information access points to gain or access that information), over processing (includes unnecessary product features, unnecessary detail and accuracy of information,), inventory (huge amounts of heterogeneous information stored on computer drives and file folders), defects (information creating environment, the occurrence of failures, defects or
deficiencies in information), **Re-invention** (The classical symptom of this issue is the re-invention of processes, solutions, methods, and products which already exist).

**Lean product development** comprises numerous interrelated techniques, including supplier involvement, cross-functional teamwork, and integration (as opposed to coordination) of various functional aspects of each project (Christer, et al, 1996). A successful move toward lean product development requires approaching these interrelated techniques as elements of a coherent whole (Ping-Kit Lam, et al., 2005). Lean product development is in general achieved through an integrated approach that involves the customers and their preferences, suppliers involvement and cross functional design teams of the firm.

In reality, product development processes often contain a great deal of rework and iterations due to large number of causes such as poor planning, evaluation of customer preferences, control and synchronization, all resulting in relatively long cycle times and additional risks (Julian, et al., 2002). In electronic industry (Mobile phones, computers, and other durable goods) product life cycle time may be shorter than the actual product development time (Nick Oliver, er al., 2004). Hence, customer study is important for such industries, analyzing the existing product.

As per Keeney & Raiffa,(1976), the average person makes hundreds of choices each day, ranging from selecting foods for meals, clothes to wear, and people to talk to. Substantial attention has been focused in the marketing and behavioral psychology literature on how consumers make choices in their purchase decisions, of particular interest are decisions with numerous choices, each involving multiple attributes.

There is sufficient evidence to support the criticality of creating new products to meet, or sometimes to create, a customer need. The success of a new innovation is dependent on the ability of the designers to identify needs and evaluate quickly for creating the new products which minimizes the product development time than conventional method.

Thus incorporating customer preferences paves the way for lean product design and development. Understanding and fulfilling each individual customer's requirements has been recognized as pressing challenge for companies across
industries. Apart from offering market-focused products, which corresponds to an average satisfaction of customers' requirements, companies are pursuing a strategy of offering customer-focused product with large degree of individuality (Li Pheng Khoo, et al., 2002). The role, requirements and participation by customers in product development is most relevant for consumer durable goods industry (Venkatamuni & Rao, 2006). It is thus identified that incorporation of customer preferences and customers in the design and development of a product paves the way for lean product design and development.

A number of complex customer behaviors such as perceptions, motivation, attitudes and personality can be grouped under psychological factors for making rational decisions (John J. Cristiano et al., 2000). These factors influence the way in which customers select, organize and interpret a company and its product offerings. Kansei engineering (Nagamachi, et al., 1999) is a technique for the translation of customers' physical feeling about a product into perpetual design elements. Urban and Hauser (1993), apply the conjoint method and affinity diagrams as a contextual link between the initial and well understood customer requirements. As a structured questioning methodology built upon Kelly’s personal construct theory, the laddering technique has been widely used to transform customers' psychological factors into useful inputs for design applications. Customer information is collected through observation, survey, focused group, and interview. For analysis, the designers follow mostly Quality function Deployment(QFD) process of their ideas and implement for up gradation of the product, or develop a new product.

QFD is a visual, connective process that helps the product development team to focus on customer needs throughout the product development process (John J. Cristiano et al., 2000). It is normally presented as a structured planning tool to determine incorporation of an attribute, based on the customer’s expectation. QFD is usually represented as a set of matrices describing the relationship between customer requirements and engineering characteristics. But there is no option for customer to compare with existing homogeneous models or product attributes (Madeleine, et al., 2002).

As a part of wastage reduction in Lean product design, collection of preferences from the customer in structured format is more considerable tool. An
advantage of the structured task is that the obtained responses are directly in quantitative terms and require no further subjective interpretation on the part of the product designer. This in turn offers advantages like more speed in data analysis, lower costs and more convenience for respondents.

Analytical Hierarchical Process (AHP), as a methodology for comparing decision alternatives against criterion, has found immense applications. Hence, application of AHP to incorporate customer preferences could pave the way for Lean product development. However, such attempts (models) need to be validated, preferably through other models. Further, when the number of decision alternatives increases the number of pairwise comparisons required for AHP also increases drastically causing a serious limitation both in gathering data and the number of pairwise comparisons one can give accurately. It is infeasible to construct a pairwise comparison matrix with respect to each criterion when the number of decision alternatives is quite big, say more than 15 alternatives. A large number of pairwise comparisons will be difficult to analyze since comparisons bring complexity in the analysis. Too many comparisons easily lead to conflicting judgements and inconsistencies. Hence, it is necessary to reduce the number of pairwise comparison matrices.

Further, customer preferences will not always be expressed as “crisp numbers” but many a times as fuzzy and linguistic terms. Therefore developing Fuzzy AHP methodologies overcoming the limitations as stated above contributes to lean thinking in product design.

Another important issue in lean product design is the concept of team formation. The concept of multi functional teams is one of the key aspects of minimizing the product development waste. The membership of the team depends on the type of product to be developed, customer requirements, engineering characteristics and so on (Susan L Kichuk, 1997). The literature does not provide analytical solutions for forming teams. Furthermore, no comprehensive model exists to prioritize team membership based on the characteristic of the product considered. This type of problems can be solved through AHP and final efficiencies of various team members found through Data Envelopment Analysis (DEA) method.
Modularization is an important issue in Lean product design, and it refers to the opportunity for mixing-and-matching of components to produce more number of varieties with reduction of component design time. In a modular product design, the standard interfaces between components are specified to allow for a range of variation in components to be substituted in product architecture. Current literature on modularization focuses on developing mathematical models for computing modularization index and applied to a product. Application of such models and developing modularization indices for real life problems enables integration of suppliers in Lean product design.

1.2 IDENTIFICATION OF PROBLEM AND OBJECTIVES

Based on the earlier research work on customer preference incorporation methods in product design and development and also study of team formation and modularization methodologies the following issues were identified:

1. Developing methodologies that can convert customer preferences or wants quickly and in a more compact and comprehensive way is needed for Lean Product Development. The models already available uses an arbitrary ranking system to allow customers to weigh the importance and relationships between needs and engineering characteristics or features of product. QFD relies on symbolic notation to representing in picture format. The qualitative nature of this approach leaves room for large variations among rankings and relationships due to its dependence on human judgment. Not only can QFD be very tedious and time consuming, but the initial ranking of the importance of customer needs fairly is arbitrary and allows for customer contradiction.

2. In this context, the product development team collects consumer needs or wants and evaluate in lowest possible time through analytical Hierarchical Process (AHP) to solve the problem of customer contradiction. AHP provides a powerful tool that can be used to make decisions in situations involving multiple objectives. Also the Product development team determines the potential value of the updated product.

3. Customer Preferences in general will not always be expressed in crisp numbers and many a times in fuzzy and linguistic terms. Developing
Fuzzy AHP methodologies to overcome the limitations of customer preferences in terms of crisp numbers and allowed to evaluate linguistic preferences and it is a major contribution to lean thinking in product design.

4. The method that is developed should be validated preferably through another model. When large number of alternatives involved, eliciting customer information is difficult and ranking the Decision alternatives is needed.

5. Developing Integrated AHP and DEA model for computing Team member's efficiencies.

6. Design a spreadsheet for computing Modularization values in product design and development at different stages with respect to component interface constraints and supplier development index for a hypothetical system.

OBJECTIVES OF THE THESIS:

The objectives of the thesis are to:

1. Study the principles of Lean Manufacturing, different types of wastages that occur in Manufacturing and product design.

2. Study the customer preferences evaluation methods in product design and to develop Analytical Hierarchical Process as a method for incorporating structured, quantitative and qualitative preferences in product design.

3. Validate the AHP results and to overcome the limitations of AHP method through Data Envelopment Analysis approach.

4. Incorporate customer vague information through Fuzzy logic, and integrate it with AHP model for avoiding repeated data collection from the customer. Also to develop Fuzzy DEAHP for ranking alternatives.

5. Study of team formation in Product development and develop methodologies for team formation.

6. Study of Modularization and development of modularization index for a hypothetical system.
1.3 OVERVIEW OF THE RESEARCH WORK:

This report comprises seven chapters that theoretically and empirically investigate four managerial issues relevant to new product development towards Lean Product development.

The FIRST chapter is a general introduction and describes the Lean principles of manufacturing and it is narrowed down to Product design and development. Identify the significance of Product design and development before production with customer's information.

A review of literature is presented in the SECOND chapter. It includes review on Lean Manufacturing, implementation of Lean Principles in Product development, New Product development, Lean Product development, Analytical Hierarchical Process, Data Envelopment analysis, Fuzzy logic approaches in Product development, Modularization and Product design team formation.

The Chapter-III describes Customer requirements and their preferences evaluation methods, and introduces Analytical Hierarchical Process approach in Product design and development. This chapter is divided into three sections. In the first section, a study of various evaluation methods such as Quality function deployment (QFD), Conjoint analysis, Kansei engineering, Kano diagram, Random utility models, Market segmentation is presented and proposed the Analytical Hierarchical Process for evaluating customer preferences and to overcome the major problems with QFD.

It is proposed to apply the AHP to both an integral (single piece) product and also to an assembled product. Also the application of Goal Programming (GP) as an extension to AHP for inclusion of an additional layer is proposed to be discussed.

The Chapter-IV discusses Data Envelopment analysis (DEA) in Lean Product Design (LPD) as an integrating approach to Analytical Hierarchical Process (AHP). A model for validating the AHP results using DEA is proposed in this chapter. Also, to overcome major limitations of AHP, when a large number of alternatives have to be ranked, a new method that integrates both DEA and AHP is discussed.
The Chapter-V presents fuzzy based analytic hierarchical Process (Fuzzy-AHP) to efficiently tackle both quantitative and qualitative decisions involved in the selection of design of product, which satisfies customer needs. This chapter discusses in two sections viz., application of fuzzy logic approach for AHP problem with crisp data from the customer regarding his requirements of criterion and the second section is on integration of DEA with fuzzy AHP for ranking the alternatives.

The Chapter-VI discusses the problem of Team formation in Lean Product design. The application of a combined AHP and integer programming models are discussed as an alternative to existing methodologies. Also an attempt is made to compute various team members' efficiencies through DEA approach.

The Chapter-VII discusses the concepts of modularization in Lean product design. It is proposed to design a spreadsheet for computing Modularization values in product design and development at different stages with respect to component interface constraints and supplier development index for a hypothetical system.

The Chapter VIII concludes this dissertation and provides a general discussion of this study and suggestions for future research.