COMPARISON OF LEAN MANUFACTURING AND CONCURRENT ENGINEERING METHOD OF NEW PRODUCT DEVELOPMENT PRINCIPLES

Mohammad Z. Meybodi, School of Business, Indiana University Kokomo,
Kokomo, IN 46904-9003, (765) 455-9317, mmeybodi@iuk.edu

ABSTRACT

This article demonstrates the relationships between lean manufacturing (LM) principles and concurrent engineering method of new product development (CENPD). Analysis of several critical factors show high degree of similarities between LM and CENPD factors. Statistical results indicate compared with conventional companies, LM organizations are able to utilize CENPD to develop new products with 63% better quality, 52% less development time, 51% more frequency, 45% less development cost, and 36% less manufacturing cost.

Key words: Lean Manufacturing, New Product Development, Concurrent Engineering

INTRODUCTION

In today's global market; price, quality, and delivery speed are not sufficient to stay ahead of competition. To sustain their competitiveness in the market, in addition to price, quality, and delivery speed world class manufacturers must also develop competencies to innovate, design, and introduce new products to the market quickly. Creating new product ideas that are consistent with organizational strategy and moving these ideas through the stages of design, development, and introduction quickly has been the hallmark of successful world class organizations (Roulet et al. 2010; Jacobs and Chase, 2011; Ferioli et al. 2010; Marisa et al. 2008). Introducing new products to the market early has several strategic and operational advantages. It often means premium prices, building name recognition, controlling a large market share, and enjoying the bottom line profits. Better competitive position in the market makes it also difficult for competition to enter the market (Blackburn, 1991; Cooper and Kleinschmidt, 1994; Lofstrand, 2010; Zahra and Ellor, 1993). Despite its well-known strategic role, for many organizations innovation, design, and successful management of new product development (NPD) has often been a major challenge. Long development time, prohibitive development and manufacturing costs, and questionable quality have been the common result for many of these organizations (Blackburn, 1991; Jacobs and Chase, 2011; Morgan and Liker, 2006). Perhaps the primary factor contributing to such unsuccessful result is utilization of traditional sequential method of new product development by these organizations (Blackburn, 1991; Morgan and Liker, 2006). In a traditional sequential approach to NPD, different phases of NPD process are managed by personnel from different functions with little or no communication. Lack of communication and feedback among sequential stage causes the process to require too many design changes which causes the process to require too long development time which indeed causes the process to be too slow, too costly, and often of poor quality. The final product design is often rejected because it is either outdated due to long development time or it is infeasible in terms of manufacturing capability (Blackburn, 1991; Ulrich and Eppinger, 2004; Morgan and Liker, 2006). However, since early 1990's successful world class organizations such as

Toyota have recognized that introducing new products to the market quickly is a critical component of their future success. This requires drastic reduction in NPD time and traditional method of NPD will no longer be a viable option. The result of several studies for the past two decades clearly indicates through their lean manufacturing practices, some world class organizations such as Toyota have dominated competition not only in the area of manufacturing but also in the area of innovation, design, and quick commercialization of new products (Marisa et al. 2008; Blackburn, 1991; Clark and Fujimoto, 1991; Ulrich and Eppinger, 2004; Michael, 2008; Unger and Eppinger 2009). A successful NPD strategy employed by these organizations with the aim of cutting time-to-market is concurrent engineering method of new product development (CENPD). In CENPD, instead of traditional sequential approach, members of NPD teams work in parallel and there is an early consideration for various aspects of new product's manufacturing process. The question of interest in this article is: Are there relationships between success in lean manufacturing (LM) practices and success in CENPD?

LITERATURE REVIEW

Since mid 1980's lean manufacturing pioneered by Toyota Production System (TPS) has been a great force in the world of manufacturing. Some of the main benefits of LM such as lower inventory, quicker delivery, better quality, and lower cost have been well documented (Cook and Rogowski, 1996; Temponi and Pandya, 1995; Deshpande and Golhar, 1995; Handfield, 1993; Lawrence and Hottenstein, 1995; Moras and Dieck, 1992). In the simplest form, LM requires maximizing value added production activities by removing unnecessary wastes. Identification and elimination of wastes from all manufacturing activities is a fundamental principle of a LM system (Gargeya, and Thompson, 1994; Sohal, Ramsay, and Samson, 1993; Suzaki, 1987). Womack and Jones (2003) highlighted five core principles that every organization must understand in order to eliminate waste from their processes. (1) value, (2) identifying the value stream, (3) flow, (4) pull, and (5) perfection. A lean organization needs to understand what value means for a specific customer, knows how value streams creates that value, creates the flow of value to the customer, utilizes the power of pull system, and relentlessly pursues perfections through continuous improvement. Looking at LM as a process that utilizes these five principles to eliminate waste, its principles can be applied to other areas such as healthcare, education, government, supply chain, and NPD (Womack and Jones (2003; Davenport, 2002). Application of lean principles to NPD is a relatively new that has great opportunity to shorten development time, reduce NPD risk, improve quality, and reduce product development and manufacturing costs (Anand and Kodali, 2008). The company that originated famous LM system, TPS, also developed Toyota Product Development System (TPDS). TPDS employs LM principles and tools such as value stream mapping, 5S, Kanban, and continuous improvement to eliminate waste from product development activities and bring quality products to market faster than their leading competition (Morgan and Liker, 2006; Ward, 2007). However, lean new product development is a comprehensive strategy that involves various approaches to eliminate waste from NPD activities. The focus of this article is on concurrent engineering method of new product development which is a special form of LNPD. Organizations that have utilized CENPD have reported up to 50% reduction in product development time, improved customer satisfaction, and dramatic improvements in gross margin (Merle and Anthony, 2006). For instance, utilizing concurrent engineering method during Boeing 777 design resulted in a time reduction of 18 months as compared to its previous Boeing 767 model (Sharma and Bowonder, 2004). Concurrent engineering allowed the Boeing Company to introduce new airplane faster and stay competitive with respect to its competitor, the Airbus Industries. In two case studies Moges (2009) compared traditional sequential method of new product development versus the impact of CENPD. The study found for traditional sequential method 50 to 80 percent of the products were not delivered on time to the market. However, by employing CENPD approach the company was able to drastically reduce product development time. Application of concurrent engineering approach to NPD under various manufacturing environments in order to shorten development time, improve quality, and reduce development cost is reported by these researchers (Anderson, 2008; Skalak, 2002; Sobeck, Ward and Liker, 1999; Kowang and Rasli, 2011; Ribbens, 2000; Uptal et al. 1999). With regard to the general question stated earlier, the specific objective of this article is to answer the following questions:

1. Are there similarities between LM and CENPD practices?
2. Are NPD performances for companies using CENPD method better than the companies using traditional sequential method?

COMPARISON OF LEAN MANUFACTURING AND CENPD FACTORS

Similarities between LM and CENPD for a number of critical factors are shown in Table 1. Following is a brief comparison and analysis of a few of these critical factors:

Layout

Layout in a LM environment is often in the form of product focus and manufacturing cells. This type of layout is necessary because small lot size production requires that the layout to be compact and efficient to ensure smooth flow of materials and close communication between work stations. In CENPD, overlapping of a large number of activities requires a complete change in layout that facilitates communication and encourages team work. Instead of organizing by sequential functions, CENPD emphasizes on cross-functional integration and the formation of a design team. The design team sits together in a big room (i.e. Obeya), creating a type of project layout. A project layout creates an environment for frequent, two-way communication between team members.

Lot Size

In contrast to conventional manufacturing, LM requires production of small lot-sizes. Production of small lot-sizes is possible by drastically reducing set-up times. It is well documented that production of small lot-sizes in LM is closely associated with improved quality, reduced inventory, faster delivery, and more responsive to market demands. In CENPD communication are often conducted face to face around the table in a big room (i.e. Obeya). This method of communication has some similarities to utilization of small lot-sizes in LM. The difference is that in LM small lot sizes of goods are processed but CENPD requires small lot-sizes of information (Blackburn, 1991; Anderson, 2008).

Employee and Supplier Involvement

LM requires employee empowerment and team work. In LM environment, the responsibility for job scheduling and quality are often passed to empowered teams at the shop floor. Due to small lot size production, delegation of authority to the teams at the shop floor is essential for smooth production flow (Blackburn, 1991; Jacobs and Chase, 2011).

Similar to LM, in CENPD the responsibility for scheduling of the activities pushed down to empowered product development team at the lowest level. Passing responsibility down to the team is essential to achieve a high level of activity coordination and information sharing among team members.

Quality
In LM and CENPD environments, organizations are often proactive and quality means getting it right the first time. In LM, since batch sizes are small quality at the source and continuous improvement are the main foundations (Blackburn, 1991; Jacobs and Chase, 2011). Shop floor workers are empowered to become their own inspectors responsible for the quality of their output. In CENPD, because of the teamwork and two-way flow of information between team members, and utilization of quality improvement tool such as six sigma process quality problems are detected earlier and solved before they have a cumulative impact on the rest of the project (Chakravorty and Franza, 2009).

Technology
In a LM system, technology often comes after process simplification and understanding of the entire system. Also in LM technology is not viewed as a substitute, or shortcut to process improvement. Rather, technology has been utilized after process analysis and simplification has been performed. In CENPD, the design team utilizes appropriate technologies and tools at various stages of NPD process. Effective use of technologies and tools can dramatically shorten NPD time, reduce number of prototypes, cut costs, and improve quality of the design. The key to the success of technology in CENPD is building an effective design team with open cross-functional communication lines.

NEW PRODUCT DEVELOPMENT PERFORMANCES

Consistent with manufacturing literature, the dimensions of quality, time, competency, development cost, and manufacturing cost are used to measure the performance of NPD (Ulrich and Eppinger, 2004; Morgan and Liker, 2006; Wheelwright and Clark, 1992)

FACTOR HYPOTHESES

Comparison and analysis of factors in previous section indicates a high degree of similarities between LM and CENPD. To study further, a set of twenty hypotheses (H1-H20) that statistically test similarities between LM and CENPD will be presented. The hypotheses are shown in Table 2. Each hypothesis in Table 2 consists of two parts. In part a, the test is conducted for LM factors and the corresponding test for CENPD factors is conducted in part b. The last hypothesis examines the overall impact of LM principles on CENPD.

Hypotheses (H1-H20):
There is a high degree of similarities between LM and CENPD factors.

PERFORMANCE HYPOTHESES

In the second set of hypotheses (H21-H25), the differences between NPD performances for lean manufacturing companies and conventional companies are tested.

Hypotheses (H23-H27):

H21: By utilizing CENPD approach, LM companies are able to design new products with fewer design changes than conventional companies (better quality).

H22: By utilizing CENPD approach, LM companies are able to design new products faster than conventional companies.

H23: By utilizing CENPD approach, LM companies are able to design new products more often than conventional companies.

H24: By utilizing CENPD approach, LM companies are able to design new products with less development cost than conventional companies.

H25: By utilizing CENPD approach, LM companies are able to design new products with less manufacturing cost than conventional companies.

RESEARCH METHODOLOGY

A sample of 500 manufacturing firms with more than 50 employees was chosen from manufacturers' directories of the states of Illinois, Indiana, Ohio, Michigan, and Wisconsin. The sample covers organizations in variety of industries ranging from fabricated metal, communication, electronics, automotive, toots, chemicals, rubber, and paper products. A comprehensive survey instrument based on examination of the literature and critical factors listed in Table I was developed. A panel of practitioners and researchers with experience in LM and NPD was used to validate the survey. In addition to general organization and managerial profile items, the survey contained 40 items (20 paired) regarding similarities between LM and CENPD factors. The twenty paired questionnaire items are shown in Table 2.
Also, the survey instrument contained a number of questionnaire items on NPD performances for LM companies using CENPD and conventional companies.

RESEARCH RESULTS

In the first set of twenty hypotheses, the null hypothesis was that the mean response for LM is equal to the mean response for CENPD. The differences between the mean responses for LM and CENPD were compared using the statistical t-test. The respondents were asked to rate each element of Table 2 based on the degree of their agreement (1=strongly disagree, 5=strongly agree) to the question. Table 3 shows the result of similarities between LM and CENPD factors. As shown in Table 3, overall the respondents strongly agreed with the statements regarding similarities between LM and CENPD factors. Out of twenty hypotheses, the respondents agreed that there is a high degree of similarities between LM and CENPD for all except three hypotheses H3, H6, and H8.

For H3, the mean ratings for LM and CENPD are respectively 4.34 and 3.81. This means although the respondents understood that short set-up and fast transition time are the main requirements of successful LM and CENPD, the relationship between short set-up and LM was much stronger. This is a reasonable result because an average manufacturing manager has longer

experience with LM than CENPD. H6 hypothesizes the relationships between small lot-sizes and quality improvement for both LM and CENPD. For this test, the mean ratings for LM and CENPD are respectively 3.43 and 3.89. This indicates for an average manager it is easier to recognize the relationship between CENPD and quality improvement than the relationship between LM and quality improvement. The higher rating for CENPD is perhaps due to continuous and two way communications among design team members, which encourages early detection of the design problem. The LM result is also consistent with the literature because although total quality management and quality improvement are fundamental requirements of successful LM, an average manufacturing manager has difficulty to understand this relationship.
The relationships between small lot-size and reduced manufacturing cost in LM and the relationship between small batches of information and reduced development cost in CENPD are examined in H8. The mean ratings for LM and CENPD are respectively 3.58 and 3.94. For the same reasons as H6, this means for an average manager it is easier to understand this relationship in CENPD than LM. The LM result is interesting and also consistent with the literature because reduced manufacturing cost in LM is primarily due to elimination of wastes, a fundamental principle of LM, and an average manufacturing manager has difficulty to see this relationship.
The performance hypotheses (H21-H25) state that by utilizing CENPD approach, LM companies are able to design new products with fewer design changes, faster, more often, with less development cost, and less manufacturing cost than conventional companies.
Table 4 provides useful statistical information regarding NPD performances for LM and companies are respectively 5.36 and 3.28, a quality improvement of 63%. The average development time for conventional and LM companies are respectively 37.52 and 24.73 months, an improvement of 52%. For development competency, the average time between introduction of new products for conventional companies is 49.46 months and 32.72 months for LM companies, an improvement of 51%. Table 4 also indicates that LM organizations enjoy a 45% reduction in NPD cost and 36% reduction in manufacturing cost.

CONCLUSION

Comparison and analysis of a number of factors showed remarkable similarities between LM practices and CENPD. A set of paired hypotheses was used to test similarities between LM practices and CENPD factors. Statistical results clearly support the hypotheses regarding similarities between LM and CENPD for majority of factors. Specifically, out of twenty hypotheses, the respondents agreed that there is a high degree of similarities between LM and CENPD for all but three hypotheses. Statistical results also indicate that compared with conventional companies, LM companies are able to develop new products with 63% better quality, 52% less development time, 45% less development cost, and 36% less manufacturing cost. Also frequency of new product introduction is 51% faster than conventional companies.
Managerial implication of the research is that successful implementation of LM principles goes much beyond inventory reduction and frequent deliveries. Since LM focuses on elimination of wastes, application of the same principle to other areas of business such as NPD is natural.

(Tables and references are available from the author upon request)