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THE INFLUENCE OF LEAN MANUFACTURING PRACTICES ON JOINT PRODUCT DEVELOPMENT

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Abstract

The focus of this article is to examine potential influence of lean manufacturing (LM) practices on joint product development (JPD). Comparison of several key factors show high degree of similarities between the two methods. Several hypotheses regarding similarities between the factors for the two methods were developed and tested. Survey data from a sample of manufacturing organizations strongly supports the hypotheses regarding similarities between the factors for the two methods. Statistical results also indicate compared with conventional product development methods, organizations utilizing JPD are in a much better competitive position by being able to develop products faster with better quality, higher frequency, and lower development and manufacturing costs. Broader managerial implication of the research is that successful implementation of LM principles goes much beyond inventory reduction and frequent deliveries. For LM organizations success in JPD is the result of knowledge and technology transfer from their LM system into their new product development process.

Keywords: Joint Product Development, Lean Manufacturing Practices.

1. Introduction

Innovation and speedy new product development is crucial for companies to gain competitive advantage. Creating new product ideas that are consistent with organizational strategy and moving the ideas through the stages of design, development, testing, and deployment has been the trade mark of successful world class organizations (Jacobs and Chase, 2023; Ardakani et.al. 2023; Fatehi and Franza 2020; Johansson and Safsten 2015; Ferioli et al. 2010; Sarkar et al. 2023; Roulet et al. 2010). Introducing new products to the market early has several strategic and tactical advantages. (Sureeyatanapas et. al. 2024; Lofstrand, 2010; Kristav, 2016; Wen et.al. 2020; Sahoo, 2021; Cooper and Kleinschmidt, 1994).

Despite its strategic role, for large number of manufacturing organizations innovation, design, and successful management of new product development 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. The primary factor contributing to such unsuccessful result is perhaps the use conventional sequential approach to product development by these organizations (Ahmed et al. 2023, Shukla and Sushil, 2022; Skalak, 2002; and Morgan and Liker, 2006). However, manufacturing literature for the past three decades clearly shows that through their lean practices, world class organizations such as Toyota have dominated competition not only in the area of manufacturing but also in the area of innovation, design, development, and quick commercialization of new products (Marisa et al. 2008; Heinzen and Hoflinger 2017; Ulrich and Eppinger, 2000; Anand and Kodali 2008; Unger and Eppinger 2009; Wankhede and Vinodh, 2023; and Michael, 2008). Instead of conventional sequential approach, world class organizations utilized joint product development (JPD) method. In a benchmarking article, Meybodi (2015) showed companies utilizing JIT practices are better in the selection of benchmarking performance measures that are consistent with organizational strategy. This article is the extension of the earlier results. Our focus is to demonstrate potential relationships between success in lean manufacturing (LM) practices and success in JPD.

2. Literature Review

For the past three decades, lean manufacturing (LM) has been a great force in the world of production. Some of the main benefits of a LM such as lower inventory, quicker delivery, and lower cost have been well documented (Ahmed et. al 2023; Lawrence and Hottenstein, 1995; and McKay, et.al 2011). Identification and elimination of waste and respectful treatment of employee are the two fundamental principles of a LM system (Anderson, 2008; Hobbs, 1994; Womack and Jones, 2003). Elimination of waste is achieved by adopting practices such as quality improvement, setup time reduction, utilization of flexible resources, cellular manufacturing layout, and pull production system (Gargeya, and Thompson, 1994; Albers and Braun 2011; Sohal, Ramsay, and Samson, 1993). Respectful treatment of people often means employee empowerment by installing policies of team work, fair compensation, employee training and new positive attitude toward suppliers (Weeth et.al 2020; Arora and Mital 2012; Sohal, Ramsay, and Samson, 1993). Unfortunately, often a narrow view of LM has been accepted and utilized by western manufacturers. Application of LM to reduce inventory and increase deliveries is only a small fraction of the full potential benefits of a LM system (Kristav, 2016; and Goffin et.al., 2019). To take advantage of the full benefits of LM, one needs to have a much broader view of LM principles. Looking at LM as a process of eliminating waste and respectful treatment of employee, its principles can be applied to other areas including service areas such as healthcare, education, government, and joint product development, (Deshpande et.al., 2023; Womack and Jones (2003). Application of LM principles to joint product development has great opportunity to shorten product development time, improve design quality, and reduce product development and manufacturing costs (Anand and Kodali, 2008; Narassima et.al. 2025, and Doratiotto et.al. 2023). 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, Kanban, 5S system, and continuous improvement to eliminate waste from product development activities and bring quality products to market faster than their leading competition (Morges, 2009; Hassan et.al. 2023; and Ward, 2007). However, TPDS is a comprehensive strategy that involves various approaches to eliminate waste from new product development activities. The focus of this article is on special case of TPDS called JPD. Our aim here is to 1) to investigate potential relationships between LM and JPD practices, and 2) to investigate if by using JPD, LM companies have competitive advantage over conventional companies utilizing traditional sequential methods. The remaining parts of the article are organized in the following manner: First, a comparison of the differences between conventional JPD methods of new product development is presented. Second, the article compares and analyzes similarities between LM and JPD for a number of key factors followed by a set of twenty four hypotheses regarding similarities between LM and JPD factors. Third, the article tests new product development performances for conventional and JPD methods. Research methodology, research results, and conclusion are the final sections of the article.

3. Conventional and Joint Product Development

Product development (PD) is a sequence of inter-connected activities in which information regarding customer needs is translated into final product design. In a conventional method, PD process typically involves phases such as idea generation and validation, preliminary design, final design and prototyping, and pilot production and ramp-up (Wheelwright and Clark, 1992; Jacobs and Chase, 2023). Traditionally, this design process is managed sequentially by personnel from various functions of the organization. A major drawback of this approach is that the output from one design stage is passed to the next stage 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 longer development time which indeed causes the process to be too slow, too costly, and often of poor quality. The two elements of long development delay and design changes during the delay creates a never-ending vicious cycle where long development delay causes design change and to accommodate design change it needs more time. The final result is that the designs are often rejected because the design is either outdated due to long development time or it is infeasible in term of manufacturing capability (Yamamoto and Abu Qudeiri, 2010; Blackburn, 1991; Meybodi, 2020; and Ulrich and Eppinger, 2000).

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Unlike conventional approach where functional units work sequentially and downstream functions are not involved until late in the process, JPD requires early involvement of cross functional teams. It requires that designers, manufacturers, marketers, suppliers, and customers work jointly to design the product and manufacturing process in parallel. The design team must truly understand the concept of joint engineering in which activities of product and process design are performed simultaneously and in a coordinated manner. The objective is to integrate product design and process planning into a joint activity (Albers and Braun, 2011; Liang, 2009; and Anderson, 2008). Application of JPD under various manufacturing environments in order to shorten development time, improve quality, reduce risks, and reduce development cost is reported by these researchers (Anderson, 2008; Skalak, 2002; Kowang and Rasli, 2011; Lofstrand, 2010; Moges, 2009). Due to early cross-functional communication, JPD approach enables an organization to be more innovative in terms of improving design quality, shortening development time, reducing design risks, and reducing development and manufacturing costs (Shukla, S.K. and Sushil, 2022; Lynch et.al, 2016; Blackburn, 1991; Ulrich, and Eppinger, 2000; Arora and Mital, 2012; and Katzy et.al, 2012).

4. Analysis of the Similarities of Key Facotos in LM and JPD

Ever since its wide appearance in mid-1980's, there has been an extensive volume of research in the area of JIT/LM. As a result, there is a set of generally accepted guidelines that organizations can follow to achieve manufacturing success. However, there has been limited research on the broader application of JIT/LM practices other areas such as product development (PD) and there is no comparable set of guidelines for successful management of these processes. Recently, a number of world class PD companies have attempted to apply the principles of LM to product development activities (Kowang and Rasli, 2011; De Waal and Knott, 2019; Hichem et.al. 2022; Liang, 2009). The company that started the most famous LM system, Toyota Production System (TPS) is also started Toyota Product Development System (TPDS). TPDS employs LM principles and enable the company to bring the highest quality products to market faster than their leading competition. Also, a number of research on the application of LM principles to PD process has shown that achieving certain manufacturing process improvement such as reducing variation, reducing rework and yield loss, solving process bottlenecks, and managing capacity, can significantly reduce PD times. Meybodi (2020) has shown similarities between lean manufacturing and product development for several critical factors.

5. Factor Hypotheses

Comparison and analysis of several critical factors show a high degree of similarities between LM and JPD. To study further, a set of twenty four hypotheses (H1-H24) that statistically test similarities between LM and JPD is presented. The hypotheses are shown in Table 1. Each hypothesis in Table 1 consists of two parts *a* and *b*. In part *a*, the test is conducted for LM factors and the corresponding test for JPD factors is conducted in part *b*.

Hypotheses (H1-H24):

There is a high degree of similarities between LM manufacturing and JPD factors.

6. Product Development Performances

The following dimensions of quality, time, competency, development cost, and manufacturing cost are used to measure the performance of PD (Ulrich and Eppinger, 2000; Wheelwright and Clark, 1992):

- **Quality**: Quality is ultimately reflected in the price customers are willing to pay, the market share, and the bottom line profit. In PD, quality problems are often the results of incomplete information and miscommunication among various functions. Quality often means a minimal number of redesign or rework. In this article, number of design changes during the development process and early manufacturing phase is used as a measure of design quality.
- **Development time**: Development time is the length of time between initial idea generation until new product is ready for introduction to the market. Shorter development time raises the competitive value of new product in terms of premium price, larger market share, and higher profit margin.
- **Development competency**: Development competency is the ability of the organization to develop future products better, faster, and cheaper. Competent workforce and effective use of technologies are important elements of organizational PD competency. Frequency of new product introduction to the market is used as a measure of development competency.
- **Development cost**: This is the total cost from the early idea generation until the product is ready for manufacturing. For most organizations, development cost is usually a significant portion of the budget and must be considered in light of budget realities and the timing of budget allocations.
- **Manufacturing cost**: Manufacturing cost includes initial investment in equipments and tools as well as the incremental cost of manufacturing the product.

There is a close relationship between manufacturing cost and the type of decisions made during the early design stage. Although early design decisions determine about 70 percent of future manufacturing cost, organizations often spend far too little time and resources during this stage (Huthwaite, B. 1991). To save future manufacturing cost, it is prudent for the companies to spend more time and resources during the early design phases of PD process where critical design decisions are made.

Performance Hypotheses

In the second set of hypotheses (H25-H29), the differences between product development performances for LM manufacturing companies and conventional companies are tested.

Table 1. Survey Items for Comparison of LM and JPD Factors
(1=strongly disagree, 5=strongly agree)

1a. In LM, layout is often in form of group technology (GT) or cellular manufacturing (CM).	1b. In JPD, the layout emphasizes is on cross-functional integration and formation of project or design team.
2a. In LM, GT or cellular manufacturing layout allows smooth flow of materials downward and information flow backward.	2b. In JPD, project layout formed by the design team allows frequent and two-way flow of information among team members.
3a. In LM, the focus is on identification and elimination of bottleneck to shorten manufacturing lead time.	3b. In JPD, the focus is on identification and elimination of bottleneck to shorten NPD time.
4a. LM system requires short set-up time.	4b. JPD requires fast transition (i.e. short set-up time) from one part of the design to another.
5a. LM system requires production of small lot-sizes.	5b. In JPD, continuous and two-way flow of information among team members is equivalent to releasing small batches of information.
6a. In LM, due to production of small lot-size, quality at the source and continuous quality improvement are essential to the success of the system.	6b. In JPD, due to simultaneous development of product and process, early detection of design quality problems and continuous improvement of the design are essential to the success of NPD process.
7a. In LM, production of small lot-size is associated with improving quality.	7b. In JPD, continuous and two-way communication among team members encourages early detection of the design problems, which is associated with improving design quality.
8a. In LM, production of small lot-size is associated with reducing inventory.	8b. In JPD, continuous and two-way communication among team members associated with reducing unnecessary amount of information among team members.

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9a. In LM, production of small lot-size is associated with reducing manufacturing cost.	9b. In JPD, continuous and two-way communication among team members encourages early detection of the design problems, avoids costly design changes, which is associated with reducing development cost.
10a. In LM, production of small lot-size and smooth flow of materials downward and information flow backward is associated with reducing delivery time.	10b. In JPD, continuous and two-way communication among team members encourages early detection of the design problems, avoids time consuming design changes, which is associated with reducing NPD time.
11a. In LM, organizations are more responsive to the changes in customer demand.	11b. In JPD, the design teams are more responsive to the changes in product design.
12a. In LM, management encourages workforce empowerment and teamwork.	12b. In JPD, management encourages employee empowerment and teamwork.
13a. LM requires high level of workforce flexibility.	13b. JPD requires high level of design team flexibility.

Table 1. Survey Items for Comparison of LM and JPD Factors

(1=strongly disagree, 5=strongly agree) (Continue)

14a. In LM, detailed shop floor responsibilities such as job and employee scheduling are passed to the local teams.	14b. In JPD, detailed design responsibilities such as development activities and employee scheduling are passed to the design teams.
15a. In LM, suppliers work closely with manufacturing teams.	15b. In JPD, suppliers work closely with the design and development teams.
16a. In LM, close relationship between suppliers and manufacturing teams is essential in improving quality, reducing manufacturing cost, and shortening delivery time.	16b. In JPD, close relationship between suppliers and design and development teams is essential in improving design quality, reducing design and development cost, and shortening design and development time.
17a. In LM, new technologies such as robots are integrated into manufacturing system after process analysis and simplification has been performed.	17b. In JPD, new technologies such as IT and CAD are integrated into the design and development process after process analysis and simplification has been performed.
18a. LM utilizes 5S practices to organize, clean, and sustain the workplaces.	18b. JPD utilizes 5S practices to organize data and design team members for easy access to timely information to conduct NPD activities.

19a. LM utilizes tools such as flow charts and VSM to eliminate wastes throughout manufacturing and supply chain process.	19b. JPD utilizes tools such as QFD and VSM to eliminate wastes during design and development process.
20a. LM utilizes manufacturing fail-safing to minimize defects throughout manufacturing process.	20b. JPD utilizes NPD fail-safing approach to minimize defects design and development process
21a. In LM, standardization of parts and components is a critical component of the system.	21b. In JPD, standard method of doing activities such as data collection and organization is a critical component of the process.
22a. In LM, due to the principles of elimination of wastes, process activities contain high value-added content	22b. In JPD, simultaneous communication among team members, NPD process contain high value-added content.
23a. As compared with traditional organizations, LM companies are generally better in the alignment of their manufacturing strategy and tactics.	23b. As compared with traditional NPD, JPD teams are generally better in the alignment of their NPD strategy and tactics.
24a. In LM, elimination of wastes and respectful treatment of people are the two main principles.	24b. Similar to LM, the main principles of elimination of wastes and respectful treatment of people are applicable to JPD.

Hypotheses (H25-H29):

H25: By utilizing JPD approach, LM companies are able to design new products with fewer design changes than conventional companies(better quality).

H26: By utilizing JPD approach, LM companies are able to design new products faster than conventional companies.

H27: By utilizing JPD approach, LM companies are able to design new products more often than conventional companies.

H28: By utilizing JPD approach, LM companies are able to design new products with less development cost than conventional companies.

H29: By utilizing JPD approach, LM companies are able to design new products with less manufacturing cost than conventional companies.

7. Research Methodology

The target population for this study consisted of manufacturing firms in the states of Illinois, Indiana, Ohio, Michigan, and Wisconsin. A sample of manufacturing firms with more than 50 employees was chosen from manufacturers' directories of those states. 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 comparison of critical factors (Meybodi, 2020) was developed. A panel of practitioners and researchers with experience in LM and PD was used to validate the survey. In addition to general organization and managerial profile items, the survey contained 48 items (24 paired) regarding similarities between LM and JPD factors. The twenty-four paired questionnaire items are shown in Table 1. The survey instrument also contained a number of questionnaire items on product development performances for LM companies using JPD and conventional companies. Out of 91 completed surveys received, 84 surveys were usable resulting in a response rate of 17%. Based on a number of questionnaire items on the principles of LM practices, 33 organizations were grouped as LM and 51 organizations were categorized as conventional companies. The survey data indicates that majority of respondents had various high level managerial positions from large organizations. Presidents and vice presidents accounted for 29% and plant managers accounted for 30% of the sample. About 35% of the sample had other managerial positions such as operations/production managers, quality managers, and the remaining 6% were production line supervisors.

8. Research Results

As stated earlier, in the first set of hypotheses the objective was to examine similarities between LM and JPD for a set of 24-paired factors. For each item, the null hypothesis was that the mean response for LM is equal to the mean response for JPD. The differences between the mean responses for LM and JPD were compared using statistical t-test. The respondents were asked to rate each factor based on the degree of their agreement to the questions, where (1=strongly disagree; 2= disagree; 3 = indifferent; 4=agree; and 5=strongly agree). Table 2 shows the result of similarities between LM and JPD. As shown in Table 2, overall, the respondents strongly agreed with the statements regarding similarities between LM and JPD factors. Out of twenty-four hypotheses, the respondents agreed that there is a high degree of similarities between LM and JPD for all except four hypotheses H4, H7, H9, and H23 an agreement percentage of about 83%. For H4, the mean ratings for LM and JPD 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 JPD, 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 JPD.

They clearly understood that successful LM requires small lot-size and small lot-size requires short set-up time. However, due to their shorter experience with JPD and because JPD is primarily an information processing process, the links between small batches of information and fast transition time is not clear. H7 hypothesizes the relationships between small lot-sizes and quality improvement for both LM and JPD. For this test, the mean ratings for LM and JPD are respectively 3.43 and 3.89. This indicates for an average manager it is easier to recognize the relationship between JPD and quality improvement than the relationship between LM and quality improvement. The higher rating for JPD is perhaps due to continuous and two-way communication 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 JPD are examined in H9. The mean ratings for LM and JPD are respectively 3.58 and 3.94. For the same reasons as H7, this means for an average manager it is easier to understand this relationship in JPD 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 alignment of strategy and tactics is addressed in H23. The mean ratings for LM and JPD are respectively 4.38 and 3.47. This is also a reasonable result because an average manufacturing manager has longer experience with LM than JPD. The overall impact of LM principles on LM and JPD is examined in H24. It is obvious that the data supports the hypothesis as the mean ratings for LM and JPD are respectively 4.56 and 4.29 indicating strong agreement with the statements that the main principles of waste elimination and respectful treatment of people in LM can also be applied in JPD. The last column of Table 2 shows correlation coefficients between LM and corresponding JPD elements. The correlation coefficients in Table 2 strongly support the above analysis. With the exception of four hypotheses H4, H7, H9, and H23 other coefficients are greater than 0.60 indicating a high degree of linear association between LM and JPD elements.

The performance hypotheses (H25-H29) state that by utilizing JPD 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 3 provides useful statistical information regarding PD performances for LM and conventional companies. The average number of design changes for conventional and LM companies are respectively 5.36 and 3.28, a quality improvement of 63%. The average development time for conventional and LM companies are respectively 37.22 and 24.73 months, an improvement of 51%. 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 3 also indicates that LM organizations enjoy a 45% reduction in PD cost and 36% reduction in manufacturing cost. From the last column of Table 3, it is clear that the hypotheses are strongly supported by the data as the p-value for all five hypotheses is less than 0.005.

Table 2. Comparison of LM and JPD Factors (1=strongly disagree, 5=strongly agree)

	LM		**JPD**			
Factor	**Mean**	**SD***	**Mean**	**SD***	**P-Value**	**Correlation**
1. Layout	3.92	0.85	3.62	1.08	0.140	0.74
2. Flow	4.08	1.03	4.06	0.96	0.640	0.83
3. Bottleneck	4.27	1.33	4.15	1.12	0.540	0.71
4. Set-up	4.34	0.70	3.81	0.96	0.003	0.47
5. Lot-size	3.85	0.88	3.55	1.03	0.100	0.65
6. Quality at source	4.23	0.77	4.28	0.74	0.300	0.69
7. Quality Improvement	3.43	0.90	3.89	0.85	0.000	0.32
8. Inventory	4.22	0.80	3.96	0.85	0.150	0.62
9. Manufacturing cost	3.58	0.80	3.94	0.67	0.001	0.45
10. Delivery	4.26	0.75	4.31	0.72	0.280	0.75
11. Customer responses	4.22	0.73	4.24	0.70	0.480	0.79
12. Teamwork	3.98	0.81	3.83	0.90	0.360	0.76
13. Flexibility	3.86	0.93	3.72	0.96	0.330	0.65
14. Team scheduling	3.72	0.78	3.76	0.78	0.240	0.82
15. Suppliers	3.77	0.79	3.82	0.83	0.350	0.77
16. Suppliers & teams	4.23	0.72	4.02	0.70	0.390	0.73
17. Technology	3.53	0.96	3.68	0.94	0.072	0.69
18. 5S Practices	4.30	0.92	4.12	0.84	0.310	0.71
19. Flowcharts/VSM	4.11	1.12	3.88	1.18	0.281	0.75
20. Fail-safing	4.23	1.31	4.06	1.42	0.352	0.81
21. Standardization	4.22	0.87	3.84	0.88	0.320	0.67
22. Value added	4.28	1.12	4.13	0.98	0.160	0.72
23. Alignment	4.38	0.94	3.47	0.86	0.002	0.38
24. Overall	4.56	0.93	4.29	0.96	0.140	0.73

* SD = Standard deviation

Table 3. Product Development Performances for Conventional and LM Companies using JPD

Factor	Mean Conventional	Mean LM	p-value
H25. Number of design changes	5.36	3.28	0.004
H26. Development time (Months)	37.22	24.73	0.003
H27. Development compet. (Months)	49.46	32.72	0.005
H28. Development cost	144.60*	100*	0.005
H29. Manufacturing cost	135.75*	100*	0.005

* Data reported in terms of percent improvement

9. Conclusion

The focus of this article was to demonstrate possible links between LM practices and JPD. First, comparison and analysis of a number of elements showed remarkable similarities between LM practices and JPD. Second, a set of paired hypotheses was used to test similarities between LM practices and JPD elements. Statistical results clearly support the hypotheses regarding similarities between LM and JPD for majority of elements. Specifically, out of twenty four hypotheses, the respondents agreed that there is a high degree of similarities between LM and JPD for all but three hypotheses. The last pair of hypotheses that examines the overall impact of LM principles is especially important. Statistical results strongly agreed that the main principles of waste elimination and respectful treatment of people in LM is also applicable to JPD. The correlation coefficients between LM and JPD elements also supported the same result. Third, 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.

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