
The impact of just-in-time practices on new product development: a managerial perspective

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Abstract: The focus of this article is to show that the principles of just-in-time (JIT) in manufacturing can also be used to improve new product development using simultaneous engineering (NPDSE) process. Five hypotheses regarding the relationships between JIT and NPDSE were developed and tested using survey data from a sample of 500 manufacturing organisations in Midwestern United States. The survey data strongly support the hypotheses that successful JIT organisations will design new products with fewer design changes, less development time, better competency, less development cost and less manufacturing cost. The *p*-value for all tests is less than 0.0005. Statistical results also indicate that successful JIT manufacturing organisations are able to develop new products with 67% fewer design changes, 61% less development time, 74% more frequency, 45% less development cost and 36% less manufacturing cost.

Keywords: just-in-time; new product development.

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1 Introduction

Just-in-time (JIT) manufacturing system received considerable attention since the early 1980s. Some of the main benefits of JIT such as inventory reduction, quality improvement and quick delivery are well documented (Temponi and Pandya, 1995; Deshpande and Golhar, 1995; Handfield, 1993; Lawrence and Hottenstein, 1995; Golhar, Stamm and Smith, 1990; Moras and Dieck, 1992). However, in a global competitive market, price, quality and quick delivery are not sufficient to stay ahead of

competition once the product reaches the maturity stage of its lifecycle. To stay competitive in the market, in addition to price, quality and speed, organisations need to develop agility to innovate, design and introduce new products to the market quickly. Introducing new products to the market early has several strategic and operational advantages. It often means charging premium price, building name recognition, controlling a large market share and enjoying the bottomline profit. Better competitive position in the market also makes it difficult for competition to enter the market (Blackburn, 1991; Cooper and Kleinschmidt, 1994; Eppinger, 2001; Krishnan and Ulrich, 2001; Zahra and Ellor, 1993).

During the last two decades, world class JIT manufacturers have dominated competition not only in the areas of price, quality and speed but also in the areas of innovation, design and quick new product development (Bebb, 1989; Blackburn, 1991; Clark and Fujimoto, 1991; Ulrich and Eppinger, 2000). The question of interest in this paper is to investigate if there is a link between successful implementation of JIT in manufacturing and successful management of NPDSE process. Using existing JIT and new product development data since the early 1980s, Meybodi (2003) showed that success in JIT has a positive impact on new product development. To understand the relationships between JIT and NPDSE, one has to examine carefully the two fundamental principles of waste elimination and respect for people in a JIT system (Cook and Rogowski, 1996; Billesbach, 1991; Hobbs, 1994; Payne, 1993). In a JIT system, elimination of waste is achieved by adopting elements such as total quality management, focused factory, reducing setup times, small lot sizes, flexible resources, group technology layout, pull production system and effective use of technology (Gargeya and Thompson, 1994; Shunk, 1992; Spencer and Guide, 1995; Suzaki, 1987). Respect for people includes elements such as teamwork, fair compensation, worker training, worker participation and new attitude towards suppliers (Shoal, Ramsay and Samson, 1993).

Unfortunately, since its beginning a narrow view of JIT, mainly inventory reduction and frequent deliveries, have been accepted and practised by many manufacturing managers. Applications of JIT to reduce inventory and deliver frequently are only a small fraction of the full potential benefits of a JIT system (Blackburn, 1991; Gilbert, 1994; Towner, 1994). To take advantage of the full benefits of JIT, one needs to have a broader view of JIT principles (Blackburn, 1991). Looking at JIT as a process to eliminate waste and to respect people rather than an inventory reduction and frequent delivery method, its principles can also be applied to other areas of business such as new product development, supply chain management, and even to service organisations in which there is no physical inventory.

The objective of this paper is to show that the principles of JIT in manufacturing can also be used to improve the NPDSE process and to demonstrate statistically that organisations with successful JIT manufacturing systems are also successful in NPDSE process. The paper develops five hypotheses regarding the impact of JIT on NPDSE performances. The hypotheses are tested using survey data from a cross section of organisations in a variety of industries.

2 Sequential and simultaneous new product development methods

The new product development process is a sequence of interconnected activities in which information regarding customer needs is translated into final product design. In a

traditional sequential or 'over the wall' approach, the process typically involves the following phases: idea generation and validation, preliminary design, final design, process design, pilot production and ramp-up (Wheelwright and Clark, 1992; Russell and Taylor, 1998). Rosenthal (1992) and Urban and Hauser (1993) pointed out that some companies use a phase gate approach to manage a sequential NPD process. In this approach, at the end of each phase a group of senior managers review the viability of the design and make appropriate recommendations of either 'pass' by allowing the design to be passed to the next stage or 'modify' in which the design needs to be modified or 'terminate' meaning the design needs to be terminated. A major drawback of a sequential approach, even utilising a phase gate method with limited feedback at the end of each phase, is that the output from one design stage is passed to the next stage with limited cross functional communication. Limited cross-functional communication and feedback cause the process to become very slow, requiring too many design changes, which are very costly and often of poor quality. The final result is that the design is often rejected because it is either outdated due to long development time, or it is unfeasible in terms of manufacturing capability. The two elements of long development time and design change have created a continuous cycle where long development time causes design change and to accommodate design change it needs more development time (Blackburn, 1991; Ulrich and Eppinger, 2000).

Close examination of traditional new product development shows that the process contains problems very similar to traditional manufacturing where the system is organised into separate departments with limited communication. To solve problems associated with traditional sequential new product development process, a complete change in design philosophies, similar to the changes in JIT manufacturing, is needed. In other words, total quality management, focused factory, reduced set-ups, employee empowerment, team work, worker training, effective use of technology and other elements of JIT can also be applied to the NPDSE process. Unlike the traditional approach to new product development, where functional units work sequentially and downstream functions are not involved until late in the process, NPDSE requires early involvement of cross-functional teams. It requires that designers, manufacturers, marketers, suppliers and customers work jointly to design product and process simultaneously. The objective is to integrate product and process design into a common activity (Clark and Fujimoto, 1991; Donnellon, 1993; Millson, Ranj and Wilemon, 1992; Shunk, 1992). Due to early cross-functional communication, NPDSE enables an organisation to be more innovative in terms of improving design quality, shortening development time and reducing development and manufacturing costs (Blackburn, 1991; Ulrich and Eppinger, 2000; Zirger and Hartley, 1996).

3 Comparison of just-in-time and new product development factors

A comparison of JIT and new product development for limited parameters is provided by (Blackburn, 1991). Comparison of traditional manufacturing and sequential new product development as well as JIT manufacturing and NPDSE for a set of factors such as layout, lot size, lead time, quality, material and information flow, employee and supplier involvement and technology is presented by Meybodi (2003). The following is a comparison of a number of critical factors in JIT and NPDSE:

3.1 Layout and flow

The layout in JIT manufacturing is often in the form of product focus and manufacturing cells. This type of layout is necessary because small lot size production requires the layout to be compact and efficient to ensure smooth flow of materials. A pull production system requires close communication between work stations. Unlike traditional manufacturing, the flow in a JIT system is in two directions; material is pulled forward, but information flows backward to provide feedback on material requirements. In NPDSE, overlapping of a large number of activities requires a complete change in layout that facilitates communication and encourages teamwork. Instead of organising by sequential functions, NPDSE emphasises cross-functional integration and the formation of a design team. The design team works together in one location, creating a type of project layout. A project layout creates an environment for frequent, two-way communication between team members, which encourages concurrent development of a product and its associated processes.

3.2 Set-up and lot size

In contrast to traditional manufacturing, JIT manufacturing requires production of small lot sizes. Production of small lot sizes is possible by drastically reducing set-up times. It is well documented in the literature that production of small lot sizes in JIT manufacturing is closely associated with improved quality, reduced inventory, reduced manufacturing cost, faster delivery and better market responsiveness. Similar to JIT, NPDSE also utilises small lot sizes. The only difference is that in JIT manufacturing small lot sizes of goods are processed. However, NPDSE requires continuous flow of small lot sizes of information among team members (Blackburn, 1991; White, 1993). With continuous flow of small lot sizes of information, downstream team members can begin working on different phases of the design while final design is evolving. A continuous flow of information among team members reduces uncertainty and encourages early detection of problems, which enables organisations to avoid costly, time-consuming changes.

3.3 Employee involvement/empowerment

In a JIT system, management encourages employee involvement and teamwork. Employees are also empowered by passing the responsibility for job scheduling and quality to the teams on the shop floor. Due to small lot size production, delegation of authority to the teams on the shop floor is essential for smooth production flow. Similar to JIT, in NPDSE, the responsibility for scheduling of the activities is often pushed down to the product development team at the lowest level. Passing responsibility down to the new product development team is essential to achieve a high level of activity coordination and information sharing among team members. In JIT and NPDSE suppliers also work closely with the organisation to improve quality, shorten delivery time and offer ideas toward new product design.

3.4 Supplier relationships

In JIT, managers view suppliers as partners; they are involved not only in frequent deliveries but also in solving manufacturing problems. As partners, they share

information on schedules, technical problems and responsibility for solving quality problems. In NPDSE, suppliers are also heavily involved in design and engineering of new products. In fact, they are often members of cross-functional teams. Close supplier relationships have contributed significantly to NPD lead time reduction (Clark and Fujimoto, 1991). This suggests the strong supplier relationships that support lead time reduction in JIT also support development time reduction NPDSE.

3.5 Quality

Under JIT manufacturing and NPDSE, organisations are often proactive and quality means getting it right the first time. In JIT, since lot sizes are small, quality at source and continuous improvement are the main foundations. Shop floor workers are empowered to become their own inspectors responsible for the quality of their output. In NPDSE, because of the teamwork and two-way flow of information among team members, quality problems are detected earlier and solved before they have a cumulative impact on the rest of the project.

3.6 Technology

In a JIT manufacturing system, technology comes after simplification and understanding of the entire system, and is not viewed as a substitute or shortcut to process improvement. Rather, technology has been utilised after process analysis and simplification has been performed. The role of technology in NPDSE is enormous. Successful organisations use technology for their new product development similar to the way they use technology in their JIT systems. The key to the success of technology in NPDSE is building an effective design team with open cross-functional communication lines. The process requires that the design team with diverse expertise makes a large number of interrelated decisions regarding the form, fit, function, cost, quality and other aspects of the design (Karagozoglu and Brown, 1993). This requires supply and processing of relevant information from multiple sources in a coordinated manner. In NPDSE, the design team utilises appropriate technologies and tools at various stages of new product development process. Effective use of technologies and tools can dramatically shorten new product development time, reduce the number of prototypes, cut costs and improve quality of the design (Karagozoglu and Brown, 1993).

4 New product development performances

One of the major challenges of new product development process is performance measurement. The difficulty is due to multidimensionality and often competing performance measures (Mallick, Schroeder and Tirumalai, 2002; Syamil, Doll and Apigian, 2002; Tatikonda and Montoya-Weiss, 2001; Suzaki, 1987). Through comprehensive review of new product development literature, the following dimensions of number of design changes, development time, development competency, development cost and manufacturing cost are selected to represent new product development performance measures (Ulrich and Eppinger, 2000; Wheelwright and Clark, 1992):

- *Number of design changes*: Number of design changes during new product development process and early manufacturing phase is used as a measure of development quality. A large number of design changes is often the result of incomplete information and miscommunication among different functions resulting in longer development time and higher development cost
- *Development time*: Development time is the length of time between initial idea generation until the new product is ready for introduction to the market. Shorter development time and successful early market introduction raise the competitive value of the new product in terms of premium price, larger market share and higher profit margin. Product development time determines how responsive the firm can be to competition and to technology, as well as how quickly the organisation receives financial returns from the sales of the product.
- *Development competency*: Development competency is the ability of an organisation to develop future products better, faster and more cheaply. A competent workforce and effective use of technologies are important elements of organisational new product development 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 organisations, development cost is usually a significant portion of the budget and must be considered in the light of budget realities and the timing of budget allocations.
- *Manufacturing cost*: Manufacturing cost includes initial investment in equipment 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% of future manufacturing cost, organisations often spend far too little time and resources during this stage (Huthwaite, 1991). To save future manufacturing cost, it is prudent for the companies to spend more time and resources during the early design phases of new product development process where critical design decisions are made.

5 Research hypotheses

As mentioned earlier, manufacturing literature during the last two decades indicates world class organisations that have been successful in their JIT system, have also been successful in their new product development process (Bebb, 1989; Clark and Fujimoto, 1991; Ulrich and Eppinger, 2000; Meybodi, 2003; Blackburn, 1991). Comparison of a number of critical JIT and new product development factors in the previous section also shows a high degree of similarity between JIT manufacturing and NPDSE. With these similarities between the two and evidence from manufacturing literature, one would expect to see that successful deployment of JIT principles would have a strong impact on the NPDSE process. In other words, since JIT focuses on eliminating waste, improving quality, reducing costs, shortening delivery time and improving teamwork, it is natural to apply the same principles to NPDSE. The impact of JIT success on NPDSE performances is tested using the following hypotheses:

- H1:* Successful JIT organisations will design new products with fewer design changes
- H2:* Successful JIT organisations will design new products with less development time
- H3:* Successful JIT organisations will design new products with better competency
- H4:* Successful JIT organisations will design new products with less development cost
- H5:* Successful JIT organisations will design new products with less manufacturing cost.

6 Methodology

The data used in this article are part of a larger study conducted in Midwestern United States. A comprehensive survey instrument that covered various aspects of manufacturing and contained more than 100 questionnaire items was developed. A panel of three practitioners who had experience in implementation of JIT and also had a background in NPD and two JIT researchers were used to validate the survey. A sample of 500 manufacturing firms with more than 50 employees was chosen from the 2002 manufacturers' directory of the states of Illinois, Indiana, Ohio, Michigan and Wisconsin. The sample covered organisations in a variety of industries ranging from fabricated metal, communications, electronics, automotive, tools, chemicals, rubber and paper products. Although the survey covered organisations in a variety of industries, the objective of this study was not to examine the differences among various industries. Rather, the focus was to obtain overall NPD performances before and after JIT across various industries. With each survey, there was a detailed covering letter personally addressed to potential respondents. At the top of the letter, there was a note in bold letters emphasising that completion of the survey required background in JIT manufacturing and NPDSE. The first half of the letter was devoted to providing some background on JIT and NPDSE. The second half of the letter focused on the purpose of the study and guidelines for answering each section of the survey. A follow-up post card was sent to those who had not responded two months later. A number of phone calls and e-mails were made to answer the questions that respondents had about certain items.

For the purpose of this study, the survey instrument contained 13 general managerial and organisational profile items and five NPD performance items. For these items, the respondents needed to answer NPD performances before and after JIT implementation. The five questionnaire items are shown in Table 1.

Since the purpose of the study was to obtain data on NPD performance improvement after JIT implementation, the respondents were asked to use a broader view of 'new product', whether it was a complex finished product or a simple part or component. They were also reminded that in order to answer the questions on NPD performance measures before and after JIT, they may need to consult with other colleagues in the company. Out of 91 completed surveys received, 84 surveys were usable resulting in a response rate of 17%.

Table 1 New product development performance questions before and after JIT

<i>Before JIT Implementation</i>	<i>Answer the Following Questions Based on Your Experience with New Product Development Before JIT Implementation (Left Column) and After JIT Implementation (Right Column)s</i>	<i>After JIT Implementation</i>
	<ul style="list-style-type: none"> • Number of design changes during new product development process and early manufacturing phase • Number of months between initial idea generations for new product until the product was ready for market introduction • Number of months between introductions of new products to the market (frequency of new products introduction) • New product development cost (or percentage changes) • New product manufacturing cost (or percentage changes) 	

Analysis of survey data indicates that majority of the respondents had various high level managerial positions from organisations with fewer than 500 employees. Presidents and vice presidents accounted for 29% and plant managers 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. In terms of total manufacturing experience, about 28% of the respondents had between 10 and 20 years of experience and 60% had more than 20 years of experience. About 72% of the sample had more than 10 years of JIT experience and close to 65% of the sample had more than 10 years of new product development experience.

7 Results

The five hypotheses state that successful JIT organisations will design new products with fewer design changes, less development time, better competency, less development cost and less manufacturing cost. Statistical results of new product development performances before and after JIT implementation are shown in Table 2.

Table 2 New product development performances before and after JIT

<i>Performance</i>	<i>Sample Size (n)</i>	<i>Mean (Before JIT)</i>	<i>Mean (After JIT)</i>	<i>Improvement (%)</i>	<i>d**</i>	<i>sd**</i>	<i>t-value**</i>	<i>p-value***</i>
Number of design changes	56	5.28	3.16	67	2.12	3.79	4.19	<0.0005
Development time (months)	64	39.25	24.38	61	14.87	18.30	6.50	<0.0005
Development competency (Months)	54	55.20	31.70	74	23.50	29.30	5.89	<0.0005
Development cost	51	144.50*	100*	45*	44.5	48.74	6.52	<0.0005
Manufacturing cost	48	135.70*	100*	36*	35.70	41.60	5.94	<0.0005

Note: * Data reported in terms of percent improvement

** d = mean difference between performance measures before JIT and after JIT; sd = standard deviation; t -value = computed t value

*** small p -value indicates the difference between two measures is statistically significant

As shown in Table 2, after removal of outliers from 84 surveys, the number of valid responses to the five survey questions are, respectively, 56, 64, 54, 51 and 48. From Table 2, the average number of design changes before and after JIT is, respectively, 5.28 and 3.16, an improvement of 67% after JIT implementation. The average development time prior to JIT is 39.25 months while after JIT is 24.38 months, an improvement of 61%. For development competency, the average time between introduction of new products is 55.20 months before JIT and 31.70 months after JIT, an improvement of 74%. Table 2 also indicates that after JIT implementation, organisations enjoy a 45% reduction in new product development cost and 36% reduction in manufacturing cost.

Since data on new product development performances cover organisations before and after JIT implementation, dependent samples were used to test the hypotheses. From Table 2, it is clear that all hypotheses are supported by the survey data. Hypothesis H1 states that organisations with successful JIT manufacturing system will design new products with fewer design changes. This hypothesis is supported by the data as indicated by the t -value of 4.19. The data also strongly support the relationships between JIT and new product development time, hypothesis H2, with the t -value of 6.50. The stated relationships between JIT and frequency of new production introduction, hypothesis H3, is also strongly supported by the data as indicated by the t -value of 5.89. Finally, Table 2 shows that JIT has a significant impact on reducing development and manufacturing costs, hypotheses H4 and H5. The t -values for the two hypotheses are, respectively, 6.52 and 5.94. The p -values for all five tests of hypotheses are less than 0.0005, indicating strong statistical significance of the tests at 0.01 significance level.

8 Conclusion

Innovation and rapid new product development are strategic business activities that are crucial for organisational success in a global market. The objective of this paper was to demonstrate the impact of JIT success on NPDSE process. Five tests of hypotheses were developed to compare new product development performances before and after JIT implementation. The hypotheses were tested using survey data from a sample of 500 manufacturing organisations in the Midwest United States. The t -values for the five tests were, respectively, 4.19, 6.50, 5.89, 6.52 and 5.94. The p -values for all five tests were less than 0.0005. Large t -values and small p -values indicate that the difference between NPD performances before and after JIT is statistically significant at 0.01 significance level.

Statistical results also showed that compared with the period prior to JIT implementation, successful JIT organisations are able to develop new products with 67% fewer design changes, 61% less development time, 74% more frequency, 45% less development cost and 36% less manufacturing cost.

In summary, the statistical significance of NPD performances before and after JIT is a clear evidence of the possible links between successful implementation of JIT in manufacturing and successful management of NPDSE. The success of world class organisations in both JIT and NPD and similarities between a number of critical factors in JIT and NPDSE provide other evidence that supports possible links between JIT and NPDSE.

The managerial implication of this paper is that successful implementation of JIT principles goes beyond inventory reduction and frequent deliveries. Since JIT focuses on

elimination of waste and respect for people, application of the same principles to other areas of business such as new product development is natural.

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