007-0254

The relationship between JIT production and Manufacturing strategy and their impact on JIT performance

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POMS 18th annual conference
Dallas, Texas, U.S.A.
May 4 to May 7, 2007

Abstract

This study constructs multi-item scales to measure key components of JIT production and manufacturing strategy and examines the relationship between them, and the impact of manufacturing strategy on JIT performance for machinery, electrical & electronics and automobile industries in Japan, USA, and Italy. JIT production scales include JIT schedule, JIT layout, JIT delivery by suppliers, JIT link with customers, pull system, and setup time reduction. Manufacturing strategy scales are measured in terms of achievement and leadership of functional integration, anticipation of new technologies, communication of manufacturing strategy, formal strategic planning, manufacturing-business strategy linkage, and proprietary equipment. The results from regression analysis show that after controlling for the industry and country effects, manufacturing strategy scales have positive and significant impact on JIT production. The results also show that manufacturing strategy scales have positive and significant impact on JIT performance.

Key words: Just-in-time production; Manufacturing Strategy; International comparison; Empirical research

1. Introduction

In the past two decades, Japanese manufacturing practices in general and Just-In-Time production in particular have received a great attention from western researchers and manufacturing firms in trial to catch-up Japan in terms of quality, productivity, and low cost.

The JIT advocates the elimination of waste by simplifying production processes, reductions in set up times, controlling material flows, and emphasizing preventive maintenance are seen as ways by which excess inventories can be reduced or eliminated, and resources utilized more efficiently (Kannan and Tan, 2005).

Published research papers covered a wide area of JIT. Early papers tried to identify JIT elements and whether or not they were associated with Japanese culture and their applicability in western manufacturing firms. Golhar and Stamm (1991) classified articles associated with JIT published in the 1980s as follows: Global productivity comparison articles, JIT/MRP/OPT comparison articles, articles on JIT practices, Kanban, cellular manufacturing, accounting, Human resource management, purchasing, and quality.

Later, emphasize was given to the impact of JIT on both competitive and financial performances of the firm. In addition to that, the relationship between JIT and other operational practices was given a special attention. These operational practices included total quality management, total preventive maintenance, human resource management, supply chain management, information systems, technology and others.

Sakakibara et al. (1997) asserted that the connection between JIT and manufacturing strategy is rarely discussed in the literature. During our review of JIT literature, we could find only two papers that regarded manufacturing strategy as necessary infrastructure for JIT production (Sakakibara et al. (1997); Ahmad et. al. (2003)).

In this paper we try to examine empirically the relationship between JIT and manufacturing strategy. The data was collected from three countries-Japan, USA, and Italy to investigate this relationship. In addition to that, the impact of manufacturing strategy on JIT performance will be examined. The findings of this study are discussed to shed more light on manufacturing strategy as a necessary infrastructure for successful JIT implementation.

2. Literature review

2.1. Just in time

The notion of JIT production was described by Taiichi Ohno, the godfather of Toyota production system, as " All we are doing at the time line from the moment the customer gives us an order to the point when we collect the cash, and we are reducing that time line by removing the non-value-added wastes" (Liker, 2004). One motivating reason for developing JIT and other better production techniques was that after World War II, Japanese people had a very strong incentive to develop good manufacturing techniques to help them rebuild the economy (Cheng, 1996).

There are seven forms of waste were identified by Toyota engineers: Waste of overproduction, Waste of inventory, Waste of repair/defects, Waste of motion (unnecessary movement), Waste of processing, Waste of waiting, and Waste of transport (Womack and Roos, 1990; Imai, 1997; Taylor and Brunt, 2001; Liker, 2004).

There is no agreement on a clear definition of JIT. The complex subject is usually summarized in a very brief statement, this result in information being omitted and causes confusion (Hallihan et al., 1997). Voss and Robinson (1987) defined JIT as:

> "JIT may be viewed as a production methodology which aims to improve overall productivity through the elimination of waste and which leads to improved quality. In the manufacturing/assembly process JIT provides the cost-effective production and delivery of only the necessary quality parts, in the right quantity, at the right

time and place, while using a minimum of facilities, equipment, materials and human resources. JIT is dependent on the balance between the stability of the user's scheduled requirements and the supplier's manufacturing flexibility. It is accompanied through the application of specific techniques which require total employee involvement and team work".

Many researchers have tried to identify the main elements of JIT. However, there is little consensus among researchers regarding the relative importance of these elements in the JIT implementation process (Ramarapu et al., 1995).However, the potential synergic benefits are not fully realized until all elements of a JIT system are integrated (Goyal and Deshmukh , 1992).

Research has shown several benefits obtained by implementing JIT production. According to Hay (1988), JIT not only provide companies with great increases in quality of their manufactured goods, but also help a company to cut response time to market by as much as 90 percent. The most cited JIT benefit is cost reduction. Other benefits included: inventory reduction, increased quality and productivity levels, improved relationship with suppliers, improved customer service, reduced lead time, reduced work in process and raw materials, increased inventory turnover, downtime reduction, workspace reduction (Mehra and Inman 1992; Sohal et al., 1993; Markham and McCart 1995; Yasin and Wafa 1996; Sriparavastu and Gupta, 1997; Imai 1997)

There are also barriers that may potentially impede successful implementation of JIT production. The absence of senior management commitment and support was the most frequently reported reason for JIT failure. Supplier education is an often neglected part of JIT implementation, and companies seeking to implement JIT fully would benefit greatly by addressing this issue (Sohal et al., 1993). One important barrier is local culture in countries other than Japan. Many researchers insisted on Japanese culture as one of the main reasons for JIT success in Japan (Ramarapu et al., 1994). Other barriers include lack of formal training/education for management and workers, and lack of cooperation with suppliers (Salaheldin, 2005), obstacles to employee participation (Lawrence and Lewis, 1993), schedules may be more complex because changeovers are frequent (Brown and Mitchell, 1991), and lack of accurate forecasting system (Wafa and Yasin, 1998)

Based on our literature review, we focus on the following dimensions of JIT:

1. *Daily Schedule Adherence*: Measures whether there is time allotted for meeting each day's schedule including catching up after stoppages for quality considerations or machine breakdown.
2. *Equipment layout*: Measures use of manufacturing cells, elimination of forklifts and long conveyers, and use of smaller equipment designed for flexible floor layout, all associated with JIT.
3. *JIT Delivery by Suppliers*: Measures whether vendors have been integrated into production in terms of using kanban containers, making frequent (or just-in-time) delivery and quality certification.
4. *JIT Link with Customers*: Measures whether the plant has applied the JIT delivery concept and the pull concept in the operational link with its customers.
5. *Kanban*: Measures whether or not the plant has implemented the physical elements of kanban/pull system.
6. *Setup Time Reduction*: Setup Times/Lot Size Reduction measures whether the plant is taking measures to reduce setup times and lower lot sizes in order to facilitate JIT.

2.2 Manufacturing Strategy

Hofer and Schendel (1978) have defined three levels of strategy: Corporate Strategy: defines the businesses the corporation should be in. Business Strategy: defines the ways to compete in a given business. And Functional Strategy: defines how each function contributes to the competitive advantage of the business. Manufacturing strategy belongs to the third type-functional strategy, and it usually answers the question: How can manufacturing contribute to the competitive advantage of the business. Manufacturing strategy is the process companies use to build the resources and the capabilities to create competitive advantage, and to align their competitive priorities with the marketing function (Schroeder and Flynn, 2001). Bates et al. (1995) defined manufacturing strategy as a design or blueprint for the manufacturing function that frames the acquisition, development and elimination of manufacturing capabilities far into the future.

In order to maintain their competitive position, Manufacturing managers must be able to combine constant improvement of existing manufacturing processes with judicious investment in new processes, utilizing both human and capital resources (Schroeder and Flynn, 2001). In addition to that, manufacturing strategy is used to coordinate manufacturing decision making, including selection of technologies, suppliers, production planning and control systems, work force, and qualitative practices (Bates et al., 1995). Skinner (1969) identified five areas that represent the pillars of manufacturing strategy: plant and equipment, production planning and control, labor and staffing, product design, and organization and management.

Manufacturing strategy implementation means widely communicating how to relate decisions made within plants to business unit goals (Schroeder and Flynn, 2001). They added that plants with high levels of manufacturing strategy implementation consistently outperformed those that did not. Ahmad et al. (2003) suggested that plants with a well defined manufacturing strategy are expected to be more focused than plants without a manufacturing strategy, and thus will provide support for JIT.

Leong et al., (1990) observed that process research has been relatively neglected both conceptually and empirically. Following Bates et al. (1995), Susan et al. (1995), sakakibara et al. (1997), Schroeder and Flynn (2001), and Ahmad et al. (2003), we investigate manufacturing strategy from process-based point of view. Performance measurement as well as the pursuit of particular operational methods is out of the scope of our definition of manufacturing strategy. Thus, we investigate manufacturing strategy based on the following dimensions:

1. *Achievement of Functional Integration*: Functional integration measures whether or not the different functional areas of the company are integrated in terms of goals, decisions made, and knowledge of one another's areas. Each function has a responsibility to develop processes, procedures, systems, people and other capabilities in line with the needs of agreed markets (Hill, 1995). He also indicated that the corporate strategy is the outcome of functional strategies and can only be achieved by integration across the functional boundaries.
2. *Communication of Manufacturing Strategy*: reflects the opinions of several categories of plant employees' knowledge of the plants operations strategy. Voss (1995) stated that manufacturing strategy should be developed through a participative approach, and after that should be freely shared with all employees in the organization. In addition to that, the extent of understanding the manufacturing strategy by the employees is an indicator of world class manufacturer (Susan et al., 1995).
3. *Anticipation of New Technologies*: Measures whether the plant is prepared in advance of technological breakthroughs to engage in the implementation of new technologies when such technologies become available.
4. *Formal Strategic Planning*: Plant management involvement in strategic planning and frequently updated strategic plans indicate a world class orientation. According to

McGrath and Hoole (1992), many firms have no formal manufacturing strategy. Hill (1989) discussed that although firms within an industry may share access to the same technology, manufacturing systems, and infrastructure elements, they are not equally successful in linking those aspects to the criteria critical to winning orders. This will be achieved by agreed upon strategic plan which translates the business strategy into manufacturing terms (Leong et al., 1990).

5. *Manufacturing-Business Strategy Linkage*: Measures the consistency between the manufacturing strategy and the business strategy and whether or not manufacturing strategy supports the business strategy. Skinner (1969) stressed that manufacturing should not merely make products and services, but should provide competitive advantage to the business, and this will be achieved when manufacturing decisions are supportive of the business strategy.
6. *Proprietary Equipment*: Measures whether or not the plant is pursuing development of in-house equipment as a source of competitive advantage.

3.3 JIT performance

JIT performance can be measured by inventory turnover, cycle time, lead time, delivery performance, and other measures (Flynn et al., 1995). Yasin et al. (1997) suggested fourteen variables to measure JIT performance such as: the extent of reduction of inventory due to JIT; the extent of reduction of rejects of finished goods due to JIT; the extent of improvement in on-time receipts from suppliers due to JIT; the extent of lead time reduction due to JIT, and the extent of improvement of relationship with suppliers due to JIT.

For our study, we focus on the following dimensions to measure JIT performance:

1. On time delivery performance

2. Flexibility to change volume
3. Inventory turnover
4. Cycle time

3. Framework and research hypotheses

This research has been based on the proposed framework (Fig. 1). The framework considers the impact of manufacturing strategy on JIT and JIT performance. As was discussed earlier, JIT, manufacturing strategy, and JIT performance elements in the framework have been derived from the literature. We hypothesize that there is a significant positive impact of manufacturing strategy on JIT production. We also hypothesize that there is a significant positive impact of manufacturing strategy on JIT performance. We discuss our hypothesized relationships in this section.

Our data was collected from three different countries and three different industries. JIT production was initiated by Japanese companies and for long time it was regarded as a Japanese unique operational production philosophy. Although JIT production have been widely adopted by may western manufacturers, we expect that the level of JIT implementation and development still higher in Japan. In addition to that, JIT production was initiated by Toyota and many researchers still refer to it as Toyota production system. Later, JIT was adopted by many automobile companies in order to catch up with Toyota’s high quality and low cost cars. We expect that the implementation of JIT production still higher in automobile industry than electronics and machinery.

The nature of JIT production is that it requires everyone’s participation and contribution in order to assure smooth operations. Cooperation and coordination among employees, processes, and functions are of crucial importance for JIT success. In addition to that, Supply chain management is the focal point in JIT environment and failure in properly managing suppliers and customers will necessarily impede JIT production. This implies that additional responsibilities will be borne by managers and workers. Such new responsibilities include everyone's responsibility for quality control and preventive maintenance, multi-functional employees, suggestions for continuous improvements and participation in small groups for problem solving. Technology also plays an important role in JIT environment to assure that schedules are always met and set up times are reduced to the lowest possible. Advanced and innovative technology will also enhance the competitiveness of the firm and new products development. Therefore, we propose that a sound and well-developed and communicated manufacturing strategy company wide will contribute to the level of JIT development and implementation. The effectiveness of JIT production is expected to be higher in an organization with a well-defined manufacturing strategy (Ahmad et al., 2003). Manufacturing strategy is expected to encompass all the issues discussed above and will serve as a clear road-map so that everyone in the plant is expected to know that the business strategy is built upon the manufacturing capabilities and that he or she is playing a central strategic role in the implementation of JIT production. Manufacturing strategy here differs from human resource management practices usually associated with JIT; it rather highlights the strategic role of the manufacturing which is expected to lead the overall business strategy in JIT environment.

H1a. Country and industry explain a significant portion of variation in JIT implementation level.

H1b. Manufacturing Strategy significantly contributes to JIT implementation level.

We also expect country and industry to affect the level of JIT performance. JIT manufacturing depends on the overall strength of an organization (Sakakibara et al., 1997). They also concluded that JIT practices have value when they are used to build infrastructure, and have no direct effect on performance. We propose that Japanese manufacturing companies still have better infrastructure to support JIT production, and therefore are expected to have higher JIT performance. We also expect automobile industry to have better infrastructure for JIT and subsequently higher JIT performance.

The way the firm manages its manufacturing strategy seems to play an important role in manufacturing performance (Sakakibara et al., 1997). A well-developed Manufacturing strategy is expected to affect all the elements of JIT performance. On time delivery performance is expected to be highly affected by the degree of the integration among functions and processes, by the existing technology and how close it meets JIT requirements in terms of reliability and quick set ups. In addition to that formal planning and widely communicating manufacturing strategy internally as well as along the supply chain is expected to enhance responsiveness by suppliers in terms of time and quality as qualifying suppliers at the preparation stage of JIT is one aspect of the strategic formal planning.

Inventory turn over is another JIT performance that is expected to be affected by manufacturing strategy. Firms keep safety stock to cope with unpredictable problems such as late deliveries, machines breakdowns and quality problems to assure meeting customer needs on time. A formal and sound manufacturing strategy is expected to prevent such problems by establishing a strong internal infrastructure for JIT as well as external infrastructure including suppliers and customers. As a subsequent, these strategic issues are expected to decrease cycle time. Flexibility is also an important out put of JIT production and it is expected to be highly affected by the technology, integration, and overall planning.

H2a. Country and industry explain a significant portion of variation in JIT performance.

H2b: Manufacturing Strategy is positively related to JIT performance.

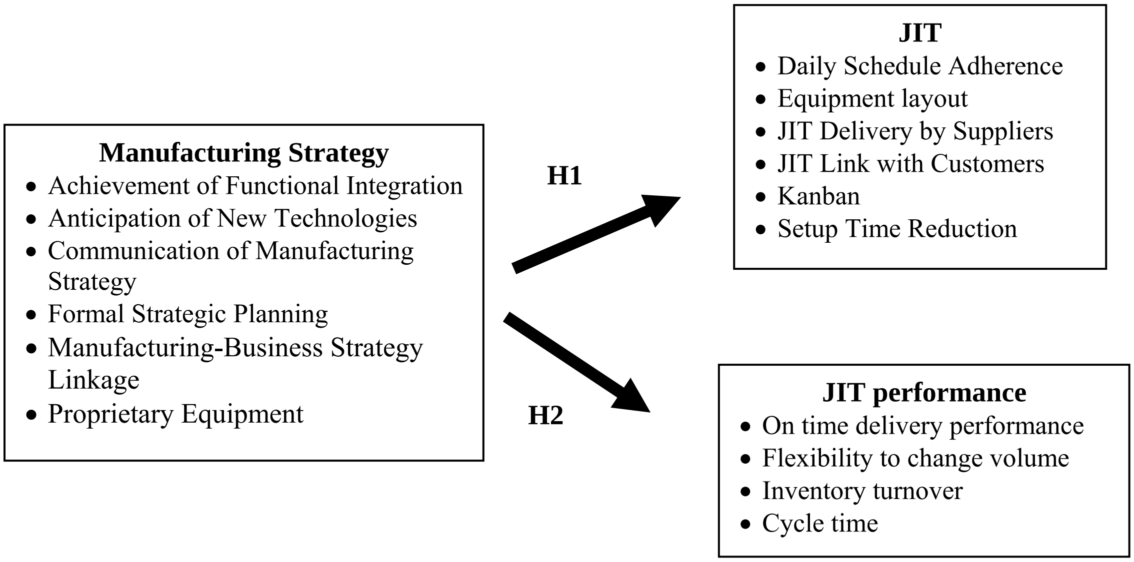

Fig.1. Research framework

4. Methodology

4.1 Description of data

The data used for this empirical research were collected as part of an ongoing High Performance Manufacturing (HPM) project (previously called world class manufacturing project (WCM)), round 3 being conducted by a team of researchers in eight countries: Japan, Korea, USA, Germany, Italy, Austria, Sweden, and Finland. The HPM database was assembled in 2003 and 2004 and consists of randomly selected world-class and traditional manufacturing companies from three different industries: machinery, electronics and transportation. For this study, our sample comprised of 91 manufacturing plants located in Japan, USA, and Italy representing Asia Pacific, North America, and Europe.. Table 1 shows the distribution of the plants used in this research classified by country and industry.

Table 1
Number of sample plants classified by country and industry

Country	Industry			Total
	Machinery	Electronics	Transportation	
Japan	10	12	13	35
USA	9	11	9	29
Italy	10	10	7	27
Total	29	33	29	91

The measurement instrument of this project was developed after conducting an extensive review of relevant literature by project members. The developed scales were reviewed by a panel of 3-5 experts to assure content validity, and the scales were revised as needed. Finally, the questionnaire was pre-tested at several manufacturing plants and with academics for pilot testing, and was revised as needed.

The original questionnaire was translated into each county's language by experts of operations management from those countries and then back translated to English to ensure equivalency.

The selected manufacturing plants were contacted personally by a member of HPM in each country. The project member asked the plant managers for their voluntary participation in the project. About 60% of contacted managers agreed to participate and assigned one manager to be responsible for data collection and to serve as a coordinator with the project member. Participating plants were promised to receive a comprehensive feedback concerning their managerial and operational practices compared to other plants. The right respondents in terms of experience, specialty, and knowledge were agreed upon between the team member and the assigned coordinator in each plant.

Then the questionnaire was completed by 12 direct labors who received the same questionnaire and 14 managers who each received a different questionnaire, allowing respondents to address their particular area of expertise. In addition to that, multiple respondents were asked to complete each question in order to obtain greater reliability of the data and to eliminate potential respondent bias.

The items used to measure the different practices of JIT, manufacturing strategy and JIT performance can be found in appendixes A-C. For JIT and manufacturing strategy questions, the respondents were asked to indicate their agreement or disagreement with the statements provided using seven point Likert scales where 7 indicates strong agreement and 1 indicates strong disagreement. For JIT performance measures, respondents were asked to evaluate JIT performance relative to their competitors in the same industry, on a global basis using five point Likert scales where 5 indicates superior to competitors and 1 indicates poor, low end of industry.

4.2. Measurement of variables

As was discussed earlier, six multi-item scales were selected to measure JIT production and six multi-item scales to measure manufacturing strategy. To measure JIT performance, four non-scale items were selected. Table 2 shows correlation matrix and summary of statistics of these measures.

To ensure that JIT and manufacturing strategy scales are reliable indicators of their constructs, factor analysis was carried out. Only items that had a factor loading of at least 0.40 and eginevalue of at least 1 were retained (tables 3 and 4). Three JIT variables failed to meet this cutoff loading leaving a total of 31 variables constructing the six JIT constructs.

One manufacturing strategy variable failed to meet the cutoff loading leaving a total of 26 variables constructing the six manufacturing strategy constructs. Cronbach's coefficient α was used to evaluate the reliability of the scales.

Five JIT scales and five manufacturing strategy scales have met the recommended standard of $\alpha \geq 0.70$ and considered to be internally consistent (Nunnally, 1967).

Table 2
Means, standard deviations, and correlations among variables[a]

	Mean	S.D.	1	2	3	4	5	6	7	8	9	10	11	12	13
1. Daily Schedule Adherence	4.93	4.9342	1												
2. Equipment layout	4.95	4.9557	0.403**	1											
3. JIT Delivery by Suppliers	4.56	4.5695	0.568**	0.500**	1										
4. JIT Link with Customers	4.80	4.8047	0.546**	0.371**	0.604**	1									
5. Kanban	3.79	3.7998	0.401**	0.366**	0.589**	0.447**	1								
6. Setup Time Reduction	4.85	4.8569	0.595**	0.336**	0.504**	0.403**	0.365**	1							
7. Achievement of Functional Integration	5.06	5.0635	0.331**	0.218*	0.267*	0.463**	0.117	0.376**	1						
8. Anticipation of New Technologies	5.07	5.0784	0.332**	0.159	0.368**	0.419**	0.125	0.445**	0.549**	1					
9. Communication of Manufacturing Strategy	4.88	4.8817	0.438**	0.219*	0.296**	0.307**	0.092	0.330**	0.284**	0.403**	1				
10. Formal Strategic Planning	5.06	5.0668	0.198	0.187	0.186	0.319**	0.051	0.337**	0.480**	0.648**	0.378**	1			
11 Manufacturing-Business Strategy Linkage	5.29	5.2987	0.268*	0.200	0.250*	0.437**	0.186	0.354**	0.606**	0.664**	0.251*	0.633**	1		
12 Proprietary Equipment	4.27	4.2769	0.194	0.225*	0.259*	0.282**	0.250*	0.110	0.074	0.192	0.047	0.107	0.134	1	
13.JIT performance	3.63	.59293	0.374**	0.467**	0.444**	0.428**	0.230*	0.377**	0.311**	0.488**	0.229*	0.322**	0.373**	0.552**	1

[a]N=91
*P ≤ 0.05
**P≤ 0.01

The reliability of the remaining two scales "JIT link with customers" and "Communication of manufacturing strategy" has been 0.660 and 0.607 respectively. Nunnally recommends a minimum standard of 0.60 for newly developed scales; therefore we decided to retain these two scales.

The six JIT scales were averaged into a single overall JIT super scale. Factor analysis was carried out for this super scale and all the factor loadings are higher than 0.40 and the eginevalue is 3.355 with Cronbach's coefficient α of 0.824 as shown in table 3. We also carried out a super scale of JIT performance as shown in table 3. All factor loadings are higher than 0.40, eginevalue of 2.148, and Cronbach's coefficient α of 0.707.

Table 3
Factor analysis: JIT scales

Variables	Descriptions	Initial factor loading	Revised factor loading	Reliability coefficient α	Eigenvalue	Proportion
	Daily Schedule Adherence					
JSFTN03		0.809	0.830			
JSFTN05		0.510	0.489			
JSFTN06		0.813	0.813			
JSFTN07		0.294	deleted			
JSFTN08		0.202	deleted			
JSFTR09		0.770	0.794			
JSFTR10		0.770	0.787			
				α = 0.792	2.838	56.763%
	Equipment layout					
JSPLN02		0.682				
JSMHN01		0.631				
JSMHN05		0.431				
JSMHN06		0.809				
JSMHN07		0.811				
JSMHN08		0.750				
				α = 0.769	2.923	48.720%
	JIT Delivery by Suppliers					
JSVNN01		0.793				
JSVNN02		0.641				
JSVNN09		0.758				
JSVNN10		0.623				
JSVNN11		0.591				
				α = 0. 712	2.351	47.015%

	JIT Link with Customers					
JSVCN01		0.772	0.782			
JSVCN02		0.422	deleted			
JSVCN04		0.535	0.590			
JSVCN05		0.569	0.568			
JSVCN06		0.538	0.505			
JSVCN07		0.784	0.800			
				α = 0. 660	2.177	43.546%
	Kanban					
JSVNN03		0.846				
JSVNN04		0.818				
JSPLN06		0.836				
JSPLN07		0.831				
				α = 0. 853	2.774	69.3592%
	Setup Time Reduction					
JSSUN01		0.699				
JSSUN02		0.656				
JSSUN04		0.745				
JSSUN05		0.691				
JSSUN07		0.744				
JSSUR08		0.624				
				α = 0. 781	2.895	48.246%
	JIT super scale					
JSFT	0.793					
JSMH	0.647					
JSVN	0.852					
JSVC	0.760					
JSPL	0.704					
JSUU	0.714					
				α = 0. 824	3.355	55.920%
	JIT performance					
grcpn03	0.741					
grcpn06	0.693					
grcpn07	0.699					
grcpn08	0.793					
				α = 0.707	2.148	53.696%

Table 4
Factor analysis: manufacturing strategy scales

Variables	Descriptions	Initial factor loading	Revised factor loading	Reliability coefficient α	Eigenvalue	Proportion
	Achievement of Functional Integration					
SSAFN01		0.792				
SSAFN02		0.823				
SSAFN03		0.865				
SSAFN04		0.677				
				α = 0. 780	2.513	62.814%

	Anticipation of New Technologies					
SSR4N04		0.743				
SSR4N05		0.885				
SSATN06		0.799				
SSATN07		0.856				
				α = 0. 836	2.706	67.662%
	Communication of Manufacturing Strategy					
SSCSN01		0.840				
SSCSR02		0.646				
SSCSN04		0.776				
				α = 0. 607	1.723	57.447%
	Formal Strategic Planning					
SSFPN01		0.863				
SSFPN03		0.882				
SSFPN04		0.780				
SSFPR05		0.754				
				α = 0. 837	2.700	67.500%
	Manufacturing-Business Strategy Linkage					
SSR3N02		0.768				
SSR3N03		0.658				
SSR3N04		0.736				
SSR3N05		0.800				
SSMBR06		0.424				
SSMBR07		0.631				
				α = 0. 741	2.782	46.364%
	Proprietary Equipment					
SSR4N01		0.836	0.846			
SSPER03		0.469	Deleted			
SSPEN04		0.598	0.603			
SSPEN05		0.806	0.810			
SSPER06		0.624	0.618			
SSPEN07		0.502	0.552			
				α = 0. 718	2.422	48.441%

4.3 Control variables

As was discussed earlier, our data was collected from three different countries and industries. In order to investigate the country and industry effect in our analysis, we include two country control variables, USA (USA compared to Japan), and Italy (Italy compared to Japan). We also include two industry control variables, Electronic (electronic compared to automobile industry), and Machinery (machinery compared to automobile industry).

5. Results and discussion

Differences among countries and industries are often attractive to researchers in operations management; therefore we start our analysis by investigating the differences in manufacturing strategy elements among countries and industries.

Results of one-way ANOVA to investigate differences among countries are shown in table 5. Least Significant Difference test (LSD) was used to test mean differences between each pair of countries, however we don't include it in the table.

F-statistic is found significant for three elements of the manufacturing strategy: Anticipation of New Technologies, Communication of Manufacturing Strategy, and Formal Strategic Planning. Not surprisingly that Japanese manufacturing plants have the highest levels of anticipation of new technologies as Japanese manufacturers were always characterized by their high technology, and it appears that they still at the leading position in this regard and significantly differ from USA and Italy. Communication of manufacturing strategy is another distinctive competence of Japanese plants where they significantly differ from American and Italian plants. This might be attributed to the human resource management practices in Japan which rely heavily on employee involvement and the unique system of life time employment. Italian plants appear to be the lowest in communicating their manufacturing strategies. Japanese manufacturers are also leading in formal strategic planning and significantly differ from Italian manufacturers.

For the other three elements of manufacturing strategy: Achievement of Functional Integration, Manufacturing-Business Strategy Linkage, and Proprietary Equipment significant differences were not found among countries.

Table 5
MS practices across countries

Practice	Countries			F-value	p-value
	JPN	USA	ITA		
SSAF	5.11	4.93	5.08	0.52	0.59
SSAT	5.41	4.75	4.84	7.63	0.00
SSCS	5.36	4.70	4.23	35.62	0.00
SSFP	5.35	4.97	4.72	4.08	0.02
SSMB	5.35	5.08	5.41	1.55	0.21
SSPE	4.25	4.42	4.23	0.46	0.63

To investigate differences among industries, we again use one-way ANOVA as shown in table 6. F-statistic is found significant for four elements of the manufacturing strategy: Achievement of Functional Integration, Anticipation of New Technologies, Formal Strategic Planning, and Manufacturing-Business Strategy Linkage. Automobile industry appears the highest to emphasize manufacturing strategy elements while machinery the lowest. For the two other elements: Communication of Manufacturing Strategy, and Proprietary Equipment significant differences were not found among industries.

Table 6
MS practices across industries

Practice	Industries			F-value	p-value
	E	M	T		
SSAF	5.0675	4.8641	5.2864	4.030	0.021
SSAT	5.0632	4.8203	5.3875	4.253	0.017
SSCS	4.8926	4.7368	5.0359	1.396	0.253
SSFP	4.9234	4.8375	5.4713	5.065	0.008
SSMB	5.3324	5.0596	5.5370	4.718	0.011
SSPE	4.1998	4.2508	4.3837	0.508	0.603

5.1. Hypothesis 1

To test this hypothesis, we used a multiple regression models using JIT super scale as a dependent variable (table 7). In the first model, we entered country and industry control variables: USA, Italy, Electronics, and Machinery. In the next models we entered the control variables, manufacturing strategy elements independently, and the interaction effects between each element of the manufacturing strategy and the control variables. In the second model, for instance, we entered the control variables, the independent variable Achievement of functional integration (SSAF), and the interaction effects between SSAF and the control variables.

In the first model, we test the impact of country and industry alone on the level of JIT implementation and development. The model reveals that country and industry significantly contribute to the level of JIT implementation ($R^2adj = 0.112$, $P < 0.01$). From this model we found that the country in which the plant is located does not explain to the level of JIT implementation. Although this finding might appear surprisingly as Japan is often expected to have higher levels of JIT implementation, but western manufacturers have paid a lot of attention on Japanese operational practices during the last two decades in a trial to catch up Japan in terms of high quality and low cost products and many of them have implemented JIT production in their plants.

As for the industry effect on JIT production, Electronics and Machinery have significantly lower levels of JIT implementation than Automobile industry ($P < 0.01$ for both). This seems to be logical as JIT production was initiated by Toyota Company and since then automobile companies were regarded as the most intensive users of JIT.

Hypothesis H1a is partially accepted.

In the next models, we found that the main effect of all manufacturing strategy elements on the explanation of the level of JIT implementation is positive and significant. Overall, the Adjusted R squares of the models reported in table 7 are interpreted as indicating a relatively strong relationship- for Achievement of functional integration SSAF ($R^2adj = 0.202$, $P < 0.05$), for Anticipation of New Technologies SSAT ($R^2adj = 0.235$, $P < 0.01$), for Communication of Manufacturing Strategy SSCS ($R^2adj = 0.329$, $P < 0.01$), for Formal Strategic Planning SSFP ($R^2adj = 0.179$, $P < 0.01$), for Manufacturing-Business Strategy

Linkage SSMB ($R^2adj = 0.183$, $P < 0.01$), and for Proprietary Equipment SSPE ($R^2adj = 0.208$, $P < 0.01$).

The results provide full support for hypothesis H1b and give evidence that the association between the use of manufacturing strategy elements and the level of JIT implementation is positive and highly significant. Obviously, there are other infrastructure practices that affect the level of JIT implementation and the importance of their impact on JIT production is out of the scope of this paper. However, the results suggest that the implementation of manufacturing strategy elements alone contributes to higher levels of JIT implementation and development.

To further investigate the effect of country and industry on the association between manufacturing strategy elements and the level of JIT implementation, we included the interaction effects between each element of manufacturing strategy and country and industry control variables. In the second model, we observe that the impact of Achievement of functional integration SSAF on JIT implementation level is significantly less in Italy than Japan ($P < 0.05$). In the third model, Anticipation of New Technologies SSAT is significantly less in USA than Japan ($P < 0.05$). In the fourth model, Communication of Manufacturing Strategy SSCS is significantly less in the Machinery industry than the Automobile ($P < 0.05$). In the fifth model, Formal Strategic Planning SSFP is significantly less in Italy than Japan ($P < 0.05$). In the seventh model, the impact of Proprietary Equipment SSPE on JIT implementation level is significantly less in USA and Italy than Japan ($P < 0.1$).

Table 7
Regression analysis-dependent variable JIT super scale

	Model (1) Coefficient	Model (2) Coefficient	Model (3) Coefficient	Model (4) Coefficient	Model (5) Coefficient	Model (6) Coefficient	Model (7) Coefficient
(Constant)	4.893***	4.807***	4.644***	4.637***	4.721***	4.778***	4.857***
USA	0.132	0.185*	0.296***	0.282**	0.215*	0.182*	0.109
Italy	0.021	0.048	0.215*	0.324**	0.099	-0.004	0.017
Electronics	-0.333***	-0.304***	-0.277**	-0.344***	-0.280**	-0.252**	-0.294***
Machinery	-0.413***	-0.288**	-0.297***	-0.317***	-0.348***	-0.269**	-0.349***
SSAF		0.511**					
SSAF*USA		-0.148					
SSAF*ITA		-0.362**					
SSAF*ELEC		0.152					
SSAF*MACH		0.092					
SSAT			0.777***				
SSAT*USA			-0.346**				
SSAT*ITA			-0.249				
SSAT*ELEC			0.019				
SSAT*MACH			-0.040				
SSCS				0.744***			
SSCS*USA				0.163			
SSCS*ITA				-0.146			
SSCS*ELEC				-0.083			
SSCS*MACH				-0.276**			
SSFP					0.800***		
SSFP*USA					-0.175		
SSFP*ITA					-0.451**		
SSFP*ELEC					-0.024		
SSFP*MACH					-0.259		
SSMB						0.669***	
SSMB*USA						-0.142	
SSMB*ITA						-0.142	
SSMB*ELEC						-0.131	
SSMB*MACH						-0.133	
SSPE							0.668***
SSPE*USA							-0.242*
SSPE*ITA							-0.216*
SSPE*ELEC							-0.197
SSPE*MACH							-0.067
R^2	0.152	0.282	0.312	0.396	0.261	0.264	0.288
Adjusted R^2	0.112	0.202	0.235	0.329	0.179	0.183	0.208
F	3.851***	3.535***	4.080***	5.909***	3.181***	3.234***	3.634***

* $P \leq 0.1$.
** $P \leq 0.05$.
*** $P \leq 0.01$.

5.2. Hypothesis 2

To test this hypothesis, we used again a multiple regression models using JIT performance super scale as a dependent variable (table 8). In the first model, we entered the country and industry control variables: USA, Italy, Electronics, and Machinery. In the next models, we entered the country and industry control variables, one element of manufacturing strategy, and the interaction effects between the manufacturing strategy element and the control variables.

In the first model, we test the impact of country and industry alone on the level of JIT performance. The model reveals that country and industry insignificantly contribute to the level of JIT performance (R^2adj =0.046, $P > 0.1$). In this model, electronics industry appears to have lower levels of JIT performance than Automobile industry at significance level of 0.1. Hypothesis H2a was almost rejected.

In the next models, we found that the main effect of manufacturing strategy elements on the explanation of the level of JIT performance is positive and significant except for Communication of manufacturing strategy SSCS (R^2adj = 0.022, $P > 0.1$). Overall, the Adjusted R squares of the five significant models reported in table 8 are interpreted as indicating a relatively strong relationship- for Achievement of functional integration SSAF (R^2adj = 0.142, $P < 0.05$), for Anticipation of New Technologies SSAT (R^2adj = 0.300, $P < 0.01$), for Formal Strategic Planning SSFP (R^2adj = 0.282, $P < 0.01$), for Manufacturing-Business Strategy Linkage SSMB (R^2adj = 0.203, $P < 0.01$), and for Proprietary Equipment SSPE (R^2adj = 0.338, $P < 0.01$).

Hypothesis H2b was almost accepted, and the results suggest that there is a positive and highly significant association between the manufacturing strategy elements, except for communication of manufacturing strategy, and the level of JIT performance.

It is surprisingly to find that communication of manufacturing strategy has no direct effect on JIT performance. This could be attributed to our particular sample which consists of world class and traditional plants, or to our measurement scales. In addition to that, Ahmad et al. (2003) suggested that highly competitive plants may not devote much effort to manufacturing strategy as it could be embedded in their routine decision making processes.

To investigate the effect of country and industry on the association between manufacturing strategy elements and the level of JIT performance, we included the interaction effects between each element of manufacturing strategy and the country and industry control variables. In the second model, we observe that the impact of Achievement of functional integration SSAF on JIT performance level is less in USA than Japan ($P < 0.1$). In the third model, the impact of Anticipation of New Technologies SSAT on JIT performance is significantly less in USA than Japan ($P < 0.01$), and slightly lower in Italy than Japan ($P < 0.1$). In the fifth model, the impact of Formal Strategic Planning SSFP is less in Italy than Japan ($P < 0.1$), and significantly less in the electronics ($P < 0.05$) and Machinery ($P < 0.01$) industries than Automobile industry. In the seventh model, the impact of Proprietary Equipment SSPE on JIT performance level is less in Italy than Japan ($P < 0.1$).

Table 8
Regression analysis-dependent variable JIT performance

	Model (1) Coefficient	Model (2) Coefficient	Model (3) Coefficient	Model (4) Coefficient	Model (5) Coefficient	Model (6) Coefficient	Model (7) Coefficient
(Constant)	3.833***	3.739***	3.475***	3.654***	3.479***	3.681***	3.763***
USA	0.086	0.132	0.319***	0.199	0.203*	0.139	0.063
Italy	-0.140	-0.093	0.116	0.048	-0.097	-0.158	-0.136
Electronics	-0.234*	-0.193	-0.146	-0.210	-0.038	-0.148	-0.172
Machinery	-0.180	-0.124	-0.016	-0.138	0.031	-0.034	-0.100
SSAF		0.625**					
SSAF*USA		-0.308*					
SSAF*ITA		-0.295					
SSAF*ELEC		0.141					
SSAF*MACH		-0.027					
SSAT			0.993***				
SSAT*USA			-0.385***				
SSAT*ITA			-0.294*				
SSAT*ELEC			0.006				
SSAT*MACH			-0.033				
SSCS				0.460			
SSCS*USA				-0.063			
SSCS*ITA				-0.095			
SSCS*ELEC				-0.084			
SSCS*MACH				-0.124			
SSFP					1.324***		
SSFP*USA					-0.166		
SSFP*ITA					-0.375*		
SSFP*ELEC					-0.443**		
SSFP*MACH					-0.589***		
SSMB						0.766***	
SSMB*USA						-0.265	
SSMB*ITA						-0.129	
SSMB*ELEC						0.034	
SSMB*MACH						-0.162	
SSPE							0.822***
SSPE*USA							-0.138
SSPE*ITA							-0.195*
SSPE*ELEC							-0.074
SSPE*MACH							-0.149
R^2	0.091	0.233	0.374	0.126	0.282	0.288	0.408
Adjusted R^2	0.046	0.142	0.300	0.022	0.197	0.203	0.338
F	2.019	2.559***	5.042***	1.212	3.319***	3.413***	5.822***

* $P \leq 0.1$.
** $P \leq 0.05$.
*** $P \leq 0.01$.

6. Conclusions

Based on our study, the following conclusions are drawn. First, country and industry alone explained a significant portion (15.2%) of variation in JIT implementation level. This variance was mainly explained by the industry, and our analysis did not reveal significant differences among the three countries-Japan, USA, and Italy in the level of JIT implementation. As for industry, the results showed that the automobile industry has higher levels of JIT implementation and significantly differs from electronics and machinery industries.

Second, country and industry alone explained an insignificant portion (9.1%) of variation in JIT performance level. The results reveal that automobile industry has higher levels of JIT performance than electronics industry.

Third, this study indicated that manufacturing strategy elements have a positive and significant impact on JIT implementation and development level. This provides guidance for managers considering or attempting implementation of JIT production. The results suggest that manufacturing strategy is an important infrastructure for JIT and should be included to the traditional infrastructure practices usually associated with JIT production. The results showed that some manufacturing strategy elements are more implemented in Japan than USA and Italy (Anticipation of New Technologies, Communication of Manufacturing Strategy, and Formal Strategic Planning). The results also indicated that the impact of manufacturing strategy elements on JIT production is higher in Japan than USA and Italy. The results showed that although the implementation of four manufacturing strategy elements is significantly higher in the automobile industry than electronics and machinery industries, the impact of manufacturing strategy elements on JIT production is similar in the three industries except for the communication of manufacturing strategy where the impact is significantly less in the machinery industry than automobile.

Fourth, the analysis showed that all the manufacturing strategy elements, except for Communication of Manufacturing Strategy, have a positive and significant impact on JIT performance. This finding provides additional support to previous research indicating that JIT performance does not rely merely on JIT practices, but on the plant's infrastructure. The results showed that manufacturing strategy elements are an important infrastructure for JIT success. The results also indicated that the impact of some manufacturing strategy elements on JIT performance is higher in Japan among countries and automobile industry among industries.

The limitation of our study is that only three developed countries were included and about half of the sample plants are world-class, therefore the results may showed some bias and restriction of range. In addition to that, JIT performance was measured relative to competitors, not to performance prior to JIT introduction.

Similar research should be undertaken for less developed countries. Also, further research is needed with a larger sample and additional industries so that casual modeling techniques of analysis could be applied. Finally, further research is needed to investigate how manufacturing strategy affects other operational practices and employee involvement.

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Appendix A
Measures of JIT practices

Daily Schedule Adherence

JSFTN03	We usually meet the production schedule each day.
JSFTN05	Our daily schedule is reasonable to complete on time.
JSFTN06	We usually complete our daily schedule as planned.
*JSFTN07**	We build time into our daily schedule to allow for machine breakdowns and unexpected production stoppages.
*JSFTN08**	We build extra slack into our daily schedule, to allow for catching up.
JSFTR09	We cannot adhere to our schedule on a daily basis.
JSFTR10	It seems like we are always behind schedule.

Equipment Layout

JSPLN02	We have laid out the shop floor so that processes and machines are in close proximity to each other.
JSMHN01	We have organized our plant floor into manufacturing cells.
JSMHN05	Our machines are grouped according to the product family to which they are dedicated.
JSMHN06	The layout of our shop floor facilitates low inventories and fast throughput.
JSMHN07	Our processes are located close together, so that material handling and part storage are minimized.
JSMHN08	We have located our machines to support JIT production flow.

Just-in-Time Delivery by Suppliers

JSVNN01	Our suppliers deliver to us on a just-in-time basis.
JSVNN02	We receive daily shipments from most suppliers.
JSVNN09	We can depend upon on-time delivery from our suppliers.
JSVNN10	Our suppliers are linked with us by a pull system.
JSVNN11	Suppliers frequently deliver materials to us.

Just-in-Time Link with Customers

JSVCN01	Our customers receive just-in-time deliveries from us.
*JSVCN02**	Most of our customers receive frequent shipments from us.
JSVCN04	We always deliver on time to our customers.
JSVCN05	We can adapt our production schedule to sudden production stoppages by our customers.
JSVCN06	Our customers have a pull type link with us.
JSVCN07	Our customers are linked with us via JIT systems.

Kanban

JSVNN03	Suppliers fill our kanban containers, rather than filling purchase orders.
JSVNN04	Our suppliers deliver to us in kanban containers, without the use of separate packaging.
JSPLN06	We use a kanban pull system for production control.
JSPLN07	We use kanban squares, containers or signals for production control.

Setup Time Reduction

JSSUN01 We are aggressively working to lower setup times in our plant.
JSSUN02 We have converted most of our setup time to external time, while the machine is running.
JSSUN04 We have low setup times of equipment in our plant.
JSSUN05 Our crews practice setups, in order to reduce the time required.
JSSUN07 Our workers are trained to reduce setup time.
JSSUR08 Our setup times seem hopelessly long.

*: Items are deleted

Appendix B
Measures of manufacturing strategy

Achievement of Functional Integration

SSAFN01 The functions in our plant are well integrated.
SSAFN02 Problems between functions are solved easily, in this plant.
SSAFN03 Functional coordination works well in our plant.
SSAFN04 Our business strategy is implemented without conflicts between functions.

Anticipation of New Technologies

SSR4N04 We pursue long-range programs, in order to acquire manufacturing capabilities in advance of our needs.
SSR4N05 We make an effort to anticipate the potential of new manufacturing practices and technologies.
SSATN06 Our plant stays on the leading edge of new technology in our industry.
SSATN07 We are constantly thinking of the next generation of manufacturing technology.

Communication of Manufacturing Strategy

SSCSN01 In our plant, goals, objectives and strategies are communicated to me.
SSCSR02 Strategies and goals are communicated primarily to managers.
SSCSN04 I understand the long-run competitive strategy of this plant.

Formal Strategic Planning

SSFPN01 Our plant has a formal strategic planning process, which results in a written mission, long-range goals and strategies for implementation.
SSFPN03 This plant has a strategic plan, which is put in writing.
SSFPN04 Plant management routinely reviews and updates a long-range strategic plan.
SSFPR05 The plant has an informal strategy, which is not very well defined.

Manufacturing-Business Strategy Linkage

SSR3N02 We have a manufacturing strategy that is actively pursued.
SSR3N03 Our business strategy is translated into manufacturing terms.
SSR3N04 Potential manufacturing investments are screened for consistency with our business strategy.
SSR3N05 At our plant, manufacturing is kept in step with our business strategy.
SSMBR06 Manufacturing management is not aware of our business strategy.
SSMBR07 Corporate decisions are often made without consideration of the manufacturing strategy.

Proprietary Equipment

SSR4N01	We actively develop proprietary equipment.
*SSPER03**	Our equipment is about the same as the rest of the industry.
SSPEN04	We have equipment that is protected by our firm's patents.
SSPEN05	Proprietary equipment helps us gain a competitive advantage.
SSPER06	We rely on vendors for most of our manufacturing equipment.
SSPEN07	We frequently modify equipment to meet our specific needs.

*: Item is deleted

Appendix C
JIT Performance Scales

Please circle the number that indicates your opinion about how your plant compares to its competition in your industry, on a global basis.
1: Poor, low end of industry; 2: Equivalent to competitors; 3: Average; 4: Better than average; 5: Superior

On time delivery performance	1	2	3	4	5
Flexibility to change volume	1	2	3	4	5
Inventory turnover	1	2	3	4	5
Cycle time (from raw materials to delivery)	1	2	3	4	5