論　説

The Relationship between Just-In-Time Production and Human Resource Management, and Their Impact on Competitive Performance

Ayman Bahjat Abdallah and Anh Chi Phan

Abstract

This study constructs multi-item scales to measure key components of JIT production and Human Resource Management (HRM) and examines the relationship between them, and the impact of both on competitive performance for manufacturing industries in seven countries: Japan, Korea, USA, Germany, Austria, Sweden, and Finland. The relationship is examined for all the surveyed companies as one pooled sample. Additionally, cross-country and cross-industry differences are investigated for the impact of HRM practices on JIT production.

We find that HRM practices have a positive impact on JIT production. The results show that transportation industry, among industries, and Japan, among countries, have the strongest impact of HRM on JIT production. The results also show that high JIT users have higher levels of HRM implementation while old JIT users do not differ from new users concerning the level of HRM implementation. Finally, we find that both JIT and HRM have positive impact on competitive performance.

Keywords: Just-in-time production; Human Resource Management; International comparison; Empirical research

1. Introduction

Two decades ago, JIT production was seen as inapplicable outside Japan, and its success was often attributed to Japanese culture and management system such as life-time employment, team work, and seniority payment. In addition to that, the unique subcontracting system in Japan was regarded as one of the factors beyond the success of JIT production. Womack *et al.* (1990) concluded after a 5-year study that there is still a big gap between Japanese and Western companies, and that the greater part of Western industry doesn't know how to close it. However, since that time JIT production was given a great attention by many researchers, and hundreds of researches were conducted and published. This led to narrowing the gap between Japanese and Western manufacturers. Increasing number of western companies has learnt how to make JIT production work successfully, and many of them have reported significant benefits from its implementation. Nonetheless, many other manufacturers in the West and less developing countries have failed in their attempts to implement JIT and to benefit from it. One of many factors that might potentially explain their failure, many consider neglecting human resource management practices associated with JIT production the most important.

Flynn *et al*. (1995) asserted that manufacturing competitiveness is based on a foundation of integrating and overlapping practices. Furthermore, Johnson and Manoochehri (1990) suggested that the full potential benefits of JIT can only be achieved by recognizing the changes in worker roles which have important implications for human resource management policies and practices. During our review of JIT literature, we noted that authors have often neglected the linkage between JIT practices and other functions and activities in the plant among which human resource management and we could find few papers that attempted to examine the relationship between JIT and HRM.

In this paper we try to fill this gap by empirically examining the impact of HRM on JIT production. We also examine the impact of JIT and HRM on competitive performance of the plant in an attempt to shed light on the superior performance in JIT environment.

Unlike other studies reported in the literature, the data used for this research were collected from seven countries and three industries that are regarded the most intensive users of JIT. The findings of this study are discussed to shed more light on HRM as a necessary infrastructure for successful JIT implementation.

2. Literature review

2.1 Just in time

JIT is an integrated set of activities designed to achieve high volume production using minimal inventories of raw materials, work-in-process, and finished goods. Parts arrive at the next station 'just in time' and are completed and move through the operation quickly. JIT is also based on the logic that nothing will be produced until it is needed (Chase *et al*., 2003). Schronberger (1982) defined JIT production as " The JIT idea is simple: produce and deliver finished goods just in time to be sold, sub-assemblies just in time to be assembled into finished goods, fabricated parts just in time to go into sub-assemblies, and purchased materials just in time to be transformed into fabricated parts". JIT aims to achieving excellence in manufacturing companies based on continuing elimination of waste and consistent improvement in productivity (Wallace, 1990). Waste occurs when activities are performed that do not add value to products. These non-value–adding activities can account for as much as 90 per cent of the total operations in a non-JIT process (Zhu *et al*., 1995). There are seven forms of waste that JIT production strives to eliminate: 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). Schonberger (1987) asserted that JIT is the most important productivity enhancing management innovation in the last century.

Most authors proposing JIT agreed that some of its objectives are to: (1) identify and solve fundamental problems; (2) reduce waste by eliminating all processes that do not add value to the product; (3) device appropriate systems that identify problems as they occur; (4) continuously improve operations (Moras and Dieck, 1992).

There is a general agreement among researchers that JIT production was initiated by Toyota motor company to meet their specific requirements. Toyota did not have space and money to hold a lot of inventory, could not afford to integrate vertically into all their parts business and Toyota needed to build vehicles for a relatively small market demanding a large variety of vehicles (Liker, 1998). Toyota's objective was to develop in-house design skills, and a production system for small volumes capable of accepting frequent design changes (Hallihan *et al*., 1997). By the end of 1970s, JIT production was being diffused throughout the Japanese motor industry and into other industrial sectors (Lindberg *et al*, 1998). Since then, many consider JIT production as the main factor beyond Japanese competitive success in improving efficiency, productivity and effectiveness (e.g. Schonberger, 1982; Hall, 1983; Mehra and Inman, 1992; Young 1992; McLachlin, 1997; Imai, 1997).

The first requirement for JIT production is to enable all processes to know accurate timing and required quantity (Monden, 1983). This is achieved through pull action of Kanban where parts or components are not produced until needed by the downstream work centre (Byron *et al*., 1986); Kanban card must be attached to every container of parts, therefore the amount of inventory on the shop floor is controlled by the number of cards permitted (Flynn *et al*., 1995).The second major requirement of JIT is the use of cellular layouts of the machines. In cellular layout, each group of dissimilar but sequentially complementary machines is known as a cell, and each cell is set up to meet the processing needs of a particular class , or family, of parts (Brown and Michell, 1991).

Another important aspect of JIT production is set up time reduction. Early when Toyota started JIT Taiichi Ohno, the father of JIT production, realized that by shortening setup time the lot size is minimized and therefore the finished and WIP inventories are reduced (Monden, 1983).

Wafa and Yasin (1998) indicated that JIT failure was mainly attributed to the following reasons: lack of cooperation from vendors in the form of inconsistent lead times and capacity constraints imposed by suppliers, the lack of resources to invest in direct linkages with vendors, the unwillingness of workers to move from work center to other work centers as needed, management perception of JIT to equate workers in the floor with management, the attitude of "management knows what is best for the company", and lack of accurate forecasting system.

During our review of JIT literature, we observed that there is no agreement among researchers concerning JIT practices. The number of JIT practices in the literature ranged from 3 unique JIT practices (Flynn *et al*., 1995) to as much as 21 practices (Shah and Ward, 2003). The latter authors included practices from Total Quality Management (TQM), Total

Productive Maintenance (TPM), and some elements of HRM to their definition of lean production which they used instead of JIT production. Our approach in this research is to focus on technical JIT practices that characterize JIT plants. We do not include elements from other operational practices to our definition of JIT production; therefore, we have selected nine JIT practices that were described in many research papers as unique JIT practices:

2.1.1 Daily Schedule Adherence (DSA): assesses whether there is time allotted for meeting each day's schedule including catching up after stoppage for quality considerations or machine breakdown.

2.1.2 Equipment Layout (EL): use of manufacturing cells, elimination of forklifts and long conveyers, and use of smaller equipment designed for flexible floor layout, all associated with JIT.

2.1.3 JIT Delivery by Suppliers (JITDS): assesses whether vendors have been integrated into production in terms of using Kanban containers, making frequent (or just-in-time) delivery and quality certification.

2.1.4 JIT Link with Customers (JITLC): assesses whether the plant has applied the JIT delivery concept and the pull concept in the operational link with its customers.

2.1.5 Kanban/Pull System (K/PS): assesses whether or not the plant has implemented the physical elements of a Kanban system.

2.1.6 Repetitive Nature of Master Schedule (RNMS): assesses use of small lot sizes, mixed model assembly, and a level daily production schedule in the plant.

2.1.7 Setup Time Reduction (STR): assesses whether the plant is taking measures to reduce setup times and lower lot sizes in order to facilitate JIT.

2.1.8 Synchronization of Operations (SO): Assesses whether or not the manufacturing capacity is balanced throughout the manufacturing process and supply network.

2.1.9 Theory of Constraint (TC): Assesses whether or not efforts are undertaken to identify and control bottleneck (constraint) and to eliminate idle time of the bottleneck process.

2.2 Human Resource Management

Lado and Wilson (1994) defined a human resource system as "a set of distinct but interrelated activities, functions, and processes that are directed at attracting, developing, and maintaining (or disposing of) a firm's human resources."

HRM is a system of practices and policies designed to influence employee's attitudes, behaviors, and performance. Individual performance depends on having the necessary skills and abilities for the job, as well as the motivation to apply those skills and abilities (Schroeder and Flynn, 2001).

Lau (2000) indicated that some JIT companies focus more on the technical aspects of JIT production rather than human aspects of implementation. However, HRM practices are essential for improvement efforts such as JIT production (Spenser and Guide, 1995; White *et al*., 1999).

Generally, the literature has indicated a central place for employee involvement which has been regarded to be either an element of JIT or as a necessary condition for it. Respect for people and their involvement have been seen to be critical to the successful implementation of JIT (Schonberger, 1982; Monden, 1983; Hall, 1986; McLachlin, 1997). Team work and group problem solving allow decision making to be decentralized and therefore variance and uncertainty are easier to manage (Flynn *et al*., 1994).

Forza (1996) asserted that employee involvement will be enhanced by encouraging employee suggestions. He found that in JIT companies suggestions by employees were implemented higher than non-JIT companies, workers performed a higher variety of tasks, and more teams were used in problem solving than non-JIT companies. In addition to that, employee involvement will be enhanced by encouraging cooperation and coordination both vertically and horizontally (Aggrawal and Aggrawal, 1985). Hopkins (1989) further asserted that developing a problem solving teams, a cross-trained workers, and cooperation in decision making are critical to successful JIT implementation.

It is necessary to put a lot of emphasis on human resource management, the process factors, to succeed with the implementation of JIT. One key factor for successful implementation of JIT is to establish confidence among the people in the organization (Storhagen, 1995).

Power and Sohal (2000) have pointed Particular human resource management strategies and practices that can be expected to characterize companies using JIT production-open communication, participative management style, empowering employees, multi skilled and flexible workforce, team based structures, and effective employee development programs. They further suggested that the combination and emphasis of the overall human resource strategy employed in the JIT environment is potentially more important than the individual elements.

Johnson and Manoochehri (1990) have identified the importance of an increased level of technical skills and flexibility for workers for full scale implementation of JIT. Use of group technology and manufacturing cells requires multi skills workers. Workers must be assignable to different machines within a cell or to a different cell depending on production requirements for the cell.

Taylor and Brunt (2001) differentiated between mass and lean production concerning workforce as: workers are interchangeable and industrial engineer and foreman are responsible for improvements in mass production versus flexible teams work process, little management layers, and improvement responsibility throughout the organization in lean production. Moreover, Promotion of employee responsibility, provision of training, promotion of teamwork, and demonstration of visible commitment are necessary conditions for JIT (McLachlin, 1997).

Technology alone does not provide companies with better performance. Rather, it is the joint use of technology and organizational practices that achieve improved performance (Challis and Samson, 2005). Therefore, top management involvement and proper employee training are essential for successful implementation of JIT production (Vora and Scraph, 1990), and firms considering implementing JIT are advised to invest extensively in modifying their workforce, and top manager's involvement in the initiation of the JIT effort is critical (Yasin and Small, 1997).

A larger proportion of firms with high level of JIT success obtained top management commitment as their first step, and in order to have a higher success with JIT, there has to be a program to educate and train employees prior to implementation (Makhram and McCart, 1995).

Ramarapu *et al*. (1994) have pointed to Japanese approach to worker-orientation to be critical for JIT implementation and success. They described Japanese workers to be totally committed to their work and the company. To be loyal, cooperative, and flexible and willing to work long hours when needed. They further pointed that Japanese management is characterized by life time employment, approaching decision making from the bottom up, respect for their workers, and a paternalistic approach towards workers.

Salaheldin (2005) has found that Several human resource barriers may hinder manufacturing companies implementing JIT production successfully such as, lack of formal training for management and workers; lack of communications between workers and management; management and employees resistance; a lack of support from top management; lack of support from production and material management; plus a lack of support from supervisors. He further concluded that, as companies increase their investment in human resource modifications efforts undertaken in preparation for JIT, the operational efficiency and performance effectiveness are increased.

Based on our review of the literature, we found that seven HRM practices were associated with JIT production. Obviously, these are not the only HRM practices employed by JIT plants. Like in traditional plants, JIT plants implement several HRM practices which are out of the scope of this study. Our objective is to shed light on those HRM practices by which JIT plants are characterized.

2.2.1 *Cooperation:* assesses the internal cooperative relationships among employees rather than competition to achieve common goals as well as the external cooperation with suppliers and customers.

2.2.2 Employee Suggestion- Implementation and feedback (ES): assesses employee perceptions regarding management's implementation and feedback on employee suggestions.

2.2.3 Flatness of Organizational Structure (FOS): Assesses whether or not there is many levels in the organizational structure between top and lowest level.

2.2.4 Multi-Functional Employees (MFE): This scale is used to determine if employees are trained in multiple tasks/areas; that is, receive cross training so that they can perform multiple tasks or jobs.

2.2.5 Small Group Problem Solving (SGPS): This scale is designed to assess the effective use of teams on the shop floor for continuous improvement.

2.2.6 Training for Employees (TE): This scale is used to determine if employees' skill and knowledge are being upgraded in order to maintain a work-force with cutting edge skills and abilities.

2.2.7 Top Management Leadership for Quality (TMLQ): assesses top management commitment and personal involvement in pursuing continuous improvement.

2.3 Competitive performance

There are different ways to measure competitive performance. While reviewing the literature, we noted that the most widely used measures are cost, quality, flexibility, and delivery (e.g. Hayes and Wheelwright, 1984; Hill, 1989; Ward *et al*., 1995; Sakakibara *et al*., 1997;Cua *et al*., 2001; McKone *et al*., 2001). In addition to theses measures, we include innovation and new product launch as competitive performance measures. Since the plant does not control sales or costs outside the plants, overall financial measures of plant performance are not appropriate (McKone *et al*., 2001). Moreover, Ahmad *et al*. (2004) found that direct and indirect effects realized from the JIT practices on financial performance are almost non-existent. We use these six measures of competitive performance for our study as follows:

Cost: Unit cost of manufacturing (UCM).
Quality: Conformance to product specifications (CPS).
Flexibility: Flexibility to change product mix (FCPM).
Delivery: On time delivery performance (OTDP).
New product launch: On time new product launch (OTNPL)
Innovation: Product innovativeness (PI).

3. Framework and research hypotheses

This research has been based on the proposed framework (Fig. 1). The framework considers the impact of HRM on JIT production and the impact of both on competitive performance. Our data were collected from seven different countries and three different industries.

As was discussed earlier, JIT production heavily depends upon employees involvement, team spirit, and commitment which are achieved through the proposed HRM practices, therefore we hypothesize that there is a significant positive impact of HRM practices on JIT implementation and development level.

Several studies have shown that JIT is associated with higher performance (e.g. Huson and Nanda, 1995; Lawrence and Hottenstein, 1995; Flynn *et al*., 1995; Cua *et al*., 2001; Fullerton and McWatters, 2001). However, Sakakibara *et al*. (1997) have concluded that JIT practices have value only when they are used to build infrastructure, and have no direct effect on performance. In addition to that, several studies have indicated that HRM is related to higher performance (e.g. MacDuffie, 1995; Youndt *et al*., 1996; Kock and McGrath, 1996; Delaney and Huselid, 1996; Huselid and Becker, 2000).We hypothesize that both JIT production and HRM have a positive impact on competitive performance, and the addition of HRM, given the impact of JIT production is expected to yield an additional incremental effect on competitive performance.

Our literature review of HRM showed that JIT success/failure was often attributed to adopting/neglecting HRM practices associated with JIT, therefore we propose that plants having higher levels of JIT implementation, or in other words more successful in implementing JIT are expected to have higher levels of HRM practices.

The literature suggests that plant age is expected to impede the adoption of new innovative changes due to factors such as resistance to change (e.g. Nelson and Winter, 1982; Pill and MacDuffie, 1996). However, it is rarely discussed in the literature how old users of JIT production differ from new users concerning the adoption of JIT infrastructure such as HRM practices. We expect that plants with longer experience with JIT implementation have had accumulated knowledge with JIT production and its infrastructure, therefore we propose that old users of JIT are expected to have higher levels of HRM practices.

In general, there is agreement among researchers concerning the positive impact of HRM practices on JIT. However, this relationship has mainly been described theoretically, and few studies have tried to investigate it empirically. Therefore, we offer the following hypotheses to guide our study:

H1a. HRM practices significantly contribute to JIT implementation level.
H1b. Manufacturing firms that are identified as high users of JIT have higher levels of implementation of HRM practices.
H1c. Manufacturing firms that are identified as old users of JIT have higher levels of implementation of HRM practices.
H2. JIT production positively influences competitive performance of the plant.
H3a. HRM practices associated with JIT positively influence competitive performance of the plant.
H3b. The addition of HRM, given the impact of JIT production, will further improve competitive performance of the plant.

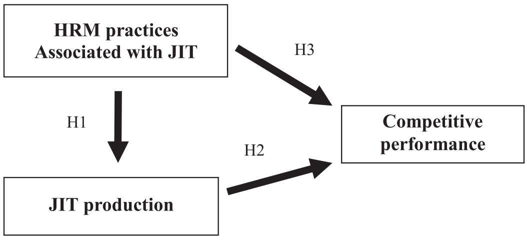

Fig.1. Research framework

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 ten countries: Japan, Korea, USA, Germany, Italy, Austria, Sweden, Finland, Spain, and UK. 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, electrical & electronics and transportation. For this study, our sample comprised of 210 manufacturing plants located in Japan, Korea USA, Germany, Sweden, Finland, and Austria. 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	
Finland	6	14	10	30
USA	11	9	9	29
Japan	11	10	13	34
Germany	13	9	19	41
Sweden	10	7	7	24
Korea	10	10	11	31
Austria	7	10	4	21
Total	68	69	73	210

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. The questionnaire was designed for various managers, supervisors, and direct workers, and 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 from those countries and then back translated to English to ensure equivalency.

The selected manufacturing companies were contacted personally by members of HPM in each country. The project members asked the executive in charge of manufacturing operations for the voluntary participation in the project. About 60% of contacted companies agreed to participate and assigned one plant manager to be responsible for data collection. 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 members and the assigned plant manager.

Next, the questionnaires were completed by five direct workers, four supervisors, and ten 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, HRM, and competitive performance can be found in appendixes A-C. For JIT and HRM 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 competitive performance measures, respondents were asked to evaluate performances 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 analysis and research variables

As has been discussed earlier, nine multi-item scales were selected to measure JIT production and seven multi-item scales to measure HRM. To measure competitive performance, six non-scale items were selected.

To ensure that JIT and HRM scales are reliable indicators of their constructs, factor analysis was carried out with principal components analysis (PCA) as the extraction method. We selected PCA as it is preferred for purposes of data reduction while the other type of factor analysis, principal factor analysis (PFA), is preferred when the research purpose is detecting data structure or casual modeling. The goal of PCA is to extract maximum variance from the data set with each component (Tabachnick and Fidell, 2001). Our purpose was to perform within scale factor analysis to verify that all items loaded onto one factor; therefore we did not use a rotation method. Only items that had a factor loading of at least 0.40 and eginevalue of at least 1 were retained. Table 2 shows that seven JIT variables failed to meet this cutoff loading and were deleted and one variable with factor loading of 0.417 loaded onto another factor and was also deleted leaving a total of 44 variables constructing the nine JIT constructs. Eginevalue of the scales ranged between 1.99 and 2.97.

Cronbach's coefficient α, a widely used indicator for assessing internal consistency of scale variables, was used to evaluate the reliability of the scales. Seven scales of JIT have met the recommended standard of $\alpha \geq 0.70$ and considered to be internally consistent (Nunnally, 1978). The reliability of the remaining two JIT scales, JIT Delivery by Suppliers and

Synchronization of Operations, has been 0.665 and 0.650 respectively. Nunnally recommended a minimum standard of 0.60 for newly developed scales; therefore we decided to retain these scales.

Additionally, we calculated the super scales for JIT production and competitive performance. As shown in Table 2, the Eginevalues of the super scales were 4.780 and 2.622 respectively. Cronbach's coefficient α were 0.849 and 0.740 respectively.

Table 2 Factor analysis: JIT scales

Variables	Descriptions	Initial factor loading	Revised factor loading	Reliability coefficient α	Eigenvalue	Proportion
	DSA					
Question1		0.801	0.818			
Question2		0.684	0.668			
Question3		0.803	0.810			
Question4		0.317	deleted			
Question5		0.180	deleted			
QuestionR*6		0.614	0.646			
QuestionR7		0.743	0.757			
				α = 0.782	2.763	55.257%
	EL					
Question1		0.741				
Question2		0.516				
Question3		0.494				
Question4		0.771				
Question5		0.771				
Question6		0.614				
				α = 0.722	2.626	43.764%
	JITDS					
Question1		0.748				
Question2		0.675				
Question3		0.687				
Question4		0.600				
Question5		0.554				
				α = 0. 665	2.153	43.064%
	JITLC					
Question1		0.788	0.830			
Question2		0.386	deleted			
Question3		0.498	0.475			
Question4		0.417	deleted			
Question5		0.701	0.717			
Question6		0.830	0.867			
				α = 0. 715	2.180	54.504%

Table 2 (continued)

Variables	Descriptions	Initial factor loading	Revised factor loading	Reliability coefficient α	Eigenvalue	Proportion
	K/PS					
Question1		0.765				
Question2		0.764				
Question3		0.818				
Question4		0.824				
				α = 0. 803	2.516	62.912%
	RNMS					
Question1		0.819	0.847			
Question2		0.755	0.751			
Question3		0.753	0.770			
Question4		0.392	deleted			
Question5		0.812	0.823			
QuestionR6		0.209	deleted			
				α = 0. 811	2.553	63.824%
	STR					
Question1		0.702				
Question2		0.617				
Question3		0.602				
Question4		0.728				
Question5		0.768				
QuestionR6		0.610				
				α = 0. 757	2.970	37.126%
	TC					
Question1		0.705	0.707			
Question2		0.732	0.731			
Question3		0.676	0.677			
Question4		0.686	0.687			
Question5		0.594	0.595			
Question6		0.629	0.630			
Question7		0.508	0.511			
Question8		0.061	deleted			
				α = 0. 766	2.977	42.533%
	SO					
Question1		0.788	0.794			
Question2		0.771	0.803			
Question3		0.672	0.684			
QuestionR4		0.521	0.501			
Question5		0.327	deleted			
				α = 0. 650	1.995	49.881%
	JIT super scale					
DSA		0.773				
EL		0.717				
JITDS		0.813				
JITLC		0.737				
K/PS		0.592				
RNMS		0.484				
STR		0.781				
SO		0.840				
TC		0.750				
				α = 0. 849	4.780	53.114%
	Competitive performance super scale					
UCM		0.670				
CPS		0.633				
FCPM		0.607				
OTDP		0.580				
OTNPL		0.751				
PI		0.709				
				α = 0. 740	2.622	43.701%

*R: reversed question

Table 3 shows factor analysis for HRM scales. One HRM variable failed to meet the cutoff loading of 0.40 and was deleted. Another variable loaded onto two factors and was also deleted leaving a total of 37 variables constructing the seven HRM constructs. Cronbach's coefficient α for all HRM scales exceeded 0.70 and ranged between 0.745 and 0.877. Eginevalue of the scales ranged between 2.662 and 3.355. We also calculated the super scale of HRM scales. The Eginevalues of the super scale was 3.691and Cronbach's coefficient α was 0.814.

Table 3 Factor analysis: HRM scales

Variables	Descriptions	Initial factor loading	Revised factor loading	Reliability coefficient α	Eigenvalue	Proportion
	Co					
Question1		0.729	0.726			
Question2		0.682	0.694			
Question3		0.601	0.597			
Question4		0.704	0.707			
Question5		0.580	0.588			
Question6		0.677	0.672			
QuestionR*7		-0.157	deleted			
				α = 0. 745	2.662	44.366%
	ES					
Question1		0.803				
Question2		0.780				
Question3		0.763				
Question4		0.817				
QuestionR5		0.708				
				α = 0. 831	3.006	60.115%
	FOS					
Question1		0.769				
Question2		0.823				
QuestionR3		0.733				
QuestionR4		0.886				
QuestionR5		0.875				
				α = 0. 877	3.355	67.104%
	SGPS					
Question1		0.637				
Question2		0.802				
Question3		0.783				
Question4		0.775				
Question5		0.653				
QuestionR6		0.719				
				α = 0. 824	3.204	53.405%
	MFE					
Question1		0.780				
Question2		0.831				
Question3		0.638				
Question4		0.792				
QuestionR5		0.671				
				α = 0. 796	2.782	55.640%
	TE					
Question1		0.813	0.861			
Question2		0.721	0.773			
Question3		0.669	deleted			
Question4		0.848	0.883			
Question5		0.692	0.613			
				α = 0. 796	2.493	62.321%
	TMLQ					
Question1		0.719				
Question2		0.824				
Question3		0.516				
Question4		0.626				
Question5		0.793				
Question6		0.768				
				α = 0. 796	3.073	51.221%

Table 3 (continued)

Variables	Descriptions	Initial factor loading	Revised factor loading	Reliability coefficient α	Eigenvalue	Proportion
	HRM super scale					
Co		0.729				
ES		0.743				
FOS		0.486				
MFE		0.813				
SGPS		0.785				
TE		0.836				
TMLQ		0.629				
				α = 0. 814	3.691	52.728%

*R: reversed question

4.3 High and low JIT users

To test hypothesis H1b, we have separated the pooled sample plants into two groups: high and low users of JIT. We have averaged JIT scales into one super-scale on a plant level. Next, we calculated the mean value of JIT super scale for the sample plants which was found 4.56. We used this mean value to separate the two groups where super-scales that are ≥ 4.56 have been classified as high users of JIT, and super-scales that are < 4.56 have been classified as low users of JIT.

4.4 Old and new users of JIT

To test hypothesis H1c, we have divided the sample plants into old and new users of JIT. We have decided to use a cutoff point of 5 years since JIT implementation where plants that have been implementing JIT production for more than 5 years, have been classified as old users, and plants that have been implementing JIT for 5 years or less, have been classified as new users of JIT.

5. Results and discussion

5.1 Correlation analysis

Once the measures were determined as reliable and valid, bivariate correlation was carried out for JIT and HRM practices separately. We have included the super scale of competitive performance in the correlations. Table 4 shows that all correlations within JIT scales were significant at p=0.01 level. All the correlations between JIT scales and competitive performance were positive, but the correlation between competitive performance and Repetitive Nature of Master Schedule was not significant. We can see that several independent variables are moderately or highly correlated. This level was expected and consistent with other literature as plants that are advanced on some scales of JIT tend generally to be more advanced on others.

As we later use regression models, analysis and interpretation should be given an additional care. Multicollinearity is a potential problem in regression analysis. In order to deal with this problem in our regression models presented later, we used the Variance Inflation Factor (VIF) Which measures the impact of collinearity among the variables in a regression model. All model variables were well within the VIF limit of 4, indicating that their multicollinearity did not have an unexpected influence on the least-squares estimates.

Table 4 Means, standard deviations, and correlations among JIT variables and competitive performance

	Mean	S.D.	DSA	EL	JITDS	JITLC	K/PS	RNMS	STR	SO	TC
DSA	4.95	0.767	1								
EL	5.06	0.670	0.490**	1							
JITDS	4.46	0.760	0.498**	0.518**	1						
JITLC	4.51	0.861	0.547**	0.381**	0.668**	1					
K/PS	3.73	1.038	0.338**	0.480**	0.560**	0.397**	1				
RNMS	3.89	1.155	0.225**	0.185**	0.428**	0.423**	0.228**	1			
STR	4.65	0.764	0.611**	0.476**	0.530**	0.469**	0.340**	0.330**	1		
SO	4.68	0.705	0.688**	0.638**	0.584**	0.513**	0.359**	0.291**	0.617**	1	
TC	5.11	0.627	0.529**	0.467**	0.508**	0.414**	0.278**	0.302**	0.645**	0.665**	1
Perfor.	3.65	0.550	0.282**	0.360**	0.272**	0.224**	0.155*	0.096	0.320**	0.368**	0.376**

*P ≤ 0.05
**P ≤ 0.01

Table 5 shows the correlation matrix among HRM scales together with competitive performance super scale. All the correlations within HRM scales were positive and significant at p=0.01 level except for the correlation between Top Management Leadership for Quality and Flatness of Organizational Structure which was not significant. All the correlations between HRM scales and competitive performance were positive and significant. Several independent variables are moderately or highly correlated, therefore it was essential to check for potential multicollinearity problems. We again used the Variance Inflation Factor (VIF) to measure the impact of collinearity among the variables in a regression model. All model variables were well within the VIF limit of 4, indicating that their multicollinearity did not have an unexpected influence on the least-squares estimates.

Table 5 Means, standard deviations, and correlations among JIT variables and competitive performance

	Mean	S.D.	Co	ES	FOS	MFE	SGPS	TE	TMLQ
Co	5.75	0.413	1						
ES	5.21	0.599	0.388**	1					
FOS	4.47	0.995	0.395**	0.223**	1				
MFE	5.34	0.603	0.541**	0.479**	0.441**	1			
SGPS	5.06	0.643	0.523**	0.627**	0.307**	0.518**	1		
TE	5.24	0.669	0.505**	0.588**	0.279**	0.716**	0.559**	1	
TMLQ	5.51	0.624	0.396**	0.373**	0.134	0.407**	0.436**	0.493**	1
Perform	3.65	0.550	0.387**	0.222**	0.177*	0.329**	0.271**	0.359**	0.397**

*P ≤ 0.05
**P ≤ 0.01

5.2 Test of hypothesis H1a

Multiple regression analysis has been produced to test this hypothesis where the independent variables of HRM scales have been regressed on the dependent variables of JIT scales (Table 6). We aware that our adj. R^2 is not so high. However, we checked similar research papers and found their R^2 and adj. R^2 similar to us (e.g. Lawrence and Hottenstein, 1995; McKone *et al.*, 1999; Sohel *et al.*, 2003; Sohel *et al.*, 2003[2]; Shah and ward, 2003). We concluded that it is common for such empirical studies of JIT and its infrastructure to have low adj. R^2.

The results suggest that Cooperation and Training of Employees have the most significant and positive impact on JIT scales as they have significant relations to six and five JIT scales respectively. They are followed by Employee Suggestions and Top Management Leadership for Quality where both have significant impact on four JIT scales. Small Group Problem Solving has significant impact on two JIT scales. It is interesting to note that while Multi-Functional Employees has significant and positive impact on only one scale of JIT, it has significant and negative impact on two JIT scales. Finally, Flatness of Organizational Structure has negative impact on all JIT scales including six significant.

We have evidence from the multiple regression to suggest that Flatness of Organizational Structure is not necessarily a prerequisite for JIT implementation and success. Of course we can neither claim that organizations should change their flat structures nor the existence of flat structures will impede JIT implementation. However, we do claim that while flatness of organizational structure might bring different benefits to some organizations, it does not has a direct positive impact on JIT production. Our sample consists of manufacturing plants from different countries with different cultures, and while in some countries flat organizations are a common practice, in others it might be seen as inapplicable practice due to cultural differences. Moreover, we have found for our sample that organizations with high JIT implementation have more levels of management than organizations with low JIT implementation. One important implication of this finding can be addressed to organizations considering JIT implementation either from developed or developing countries where local culture may impede the shift to flat structure.

All other HRM scales obviously have positive impact on JIT production and contribute to its implementation and development level. Again, we can not claim that Multi-functional employees should be ignored because it has two significant negative relations and only one positive with JIT scales. We do indeed insist on the importance of having Multi-functional employees to ensure smooth and successful implementation of JIT, and these negative relations could be attributed either to our multi-cultural international sample or to the high correlations among HRM scales so that the multiple regression sorted out the scales that had no additional positive explanatory power over the powerful scales.

If we look at the relationship from the perspective of JIT practices, we can see that Daily Schedule Adherence and Theory of Constraints are the most positively affected by HRM practices. This finding appears logical as involvement of people, their commitment, and the existing of team spirit and technical skills are crucial in JIT environment to meet daily schedules on time, and to identify and eliminate any potential bottlenecks. Then, we can note that Setup Time Reduction, Synchronization of Operations, and JIT link with Customers are positively affected by three practices each of HRM. Next, Equipment Layout is positively affected by Cooperation and Management Leadership for Quality. And finally, we see three the least affected JIT practices by HRM are JIT Delivery by Suppliers, Kanban, and Repetitive Nature of Master schedule. It is interning to note that while JIT link with customers is affected by three HRM practices, JIT link with suppliers is affected by only one. This can be explained by the nature of each link. JIT link with customers requires workers efforts and capabilities to ensure that customers receive their deliveries frequently and on time, while JIT link with suppliers depends mostly on the top management efforts to qualify and support suppliers; therefore not surprisingly it is affected by training activities.

It is important to note that although HRM practices have a positive impact on JIT in isolation, their combination will yield the optimal impact on JIT production.

Hypothesis H1a has been mostly accepted.

Table 6 Results of multiple regression analysis for HRM and JIT scales

	DSA	EL	JITDS	JITLC	K/PS	RNMS	STR	SO	TC
R	0.621	0.554	0.519	0.514	0.334	0.432	0.637	0.595	0.644
R-square	0.386	0.307	0.269	0.265	0.112	0.187	0.406	0.354	0.415
Adj R-sq	0.365	0.283	0.244	0.239	0.081	0.159	0.385	0.331	0.394
F value	18.049	12.739	10.576	10.328	3.609	6.600	19.603	15.709	20.337
Sig F	0.000	0.000	0.000	0.000	0.001	0.000	0.000	0.000	0.000
Co	0.216***	0.267***	0.149*	0.145*	0.230***	-0.068	0.294***	0.196***	0.269***
ES	0.223***	0.079	0.083	0.212**	-0.001	0.180**	0.117	0.201***	0.131*
FOS	-0.110*	-0.145**	-0.327***	-0.291***	-0.079	-0.316***	-0.266***	-0.088	-0.195***
MFE	0.197**	0.104	-0.104	-0.177*	-0.087	-0.221**	-0.153*	0.033	-0.178**
SGPS	0.053	0.097	0.093	0.187**	0.079	0.126	0.111	-0.057	0.163**
TE	0.038	0.088	0.282***	0.196**	0.181*	0.042	0.320***	0.308***	0.287***
TMLQ	0.138**	0.142**	0.130*	0.030	-0.001	0.081	0.141**	0.091	0.170**

*P ≤ 0.1
**P ≤ 0.05
***P ≤ 0.01

To shed light on the impact of HRM practices on JIT among industries and countries, we use a super-scale of HRM scales which has been defined as an independent variable, and has been regressed to each scale of JIT.

Table 7 shows the regression analysis for the impact of HRM on JIT practices among industries. The results show that transportation industry is the most positively affected by HRM, followed by machinery and electronics respectively. JIT production was initiated by Toyota which made intensive combination between technical and human practices, and then JIT was imitated by competitors and thereafter diffused among other industries. The results indicate that plants in the transportation (Auto) industry still in the leading position of heavily relying on the combination between HRM practices and JIT technical practices to achieve the desired results of JIT system in their competitive market.

Table 7 Results of regression analysis for HRM super-scale on JIT scales by industry

	DSA	EL	JITDS	JITLC	K/PS	RNMS	STR	SO	TC
M	0.395***	0.300**	0.133	0.240**	0.138	-0.047	0.332***	0.468***	0.445***
E	0.600***	0.545***	0.209*	0.103	0.127	-0.153	0.395***	0.417***	0.365***
T	0.656***	0.553***	0.366***	0.419***	0.361***	-0.146	0.525***	0.642***	0.598***

M: Machinery; E: Electronics; T: Transportation
*P ≤ 0.1
**P ≤ 0.05
***P ≤ 0.01

Table 8 shows the regression analysis for the impact of HRM on JIT practices among countries. Japan appears to have the strongest impact of HRM on JIT implementation and development level. This finding is natural as Japan is the origin of JIT production, and the reliance of Japanese companies on HRM practices and their unique management system are widely known. This finding provides support to the advocates of the synergy between HRM and JIT as one of the main factors beyond the Japanese excellence in operations management. Next, we see a strong impact of HRM on JIT practices for three main competitors of Japan: USA, Germany, and Korea. Many companies in these countries have realized the potential benefits of JIT production and its crucial role of competing with Japanese companies. Finally, we see less impact in Austria, Finland, and Sweden. It seems these three countries rely more on technology rather than human factors.

Table 8 Results of regression analysis for HRM super-scale on JIT scales by country

	DSA	EL	JITDS	JITLC	K/PS	RNMS	STR	SO	TC
FIN	0.318*	0.561***	0.350*	0.263	0.229	0.010	0.447**	0.372**	0.171
USA	0.736***	0.636***	0.444**	0.637***	0.392**	-0.091	0.673***	0.728***	0.432**
JPN	0.784***	0.762***	0.579***	0.459***	0.392**	0.683***	0.714***	0.718***	0.665***
GER	0.646***	0.740***	0.600***	0.456***	0.372**	-0.025	0.688***	0.742***	0.787***
SWE	0.453**	0.214	0.232	0.292	0.519***	0.113	0.365*	0.192	0.410**
KOR	0.773***	0.680***	0.705***	0.605***	0.518***	0.294	0.792***	0.765***	0.771***
AUT	0.702***	0.133	0.283	0.053	-0.192	-0.115	0.629***	0.510**	0.826***

*P ≤ 0.1
**P ≤ 0.05
***P ≤ 0.01

5.3 Test of hypothesis H1b

To test this hypothesis, one way ANOVA test was produced (Table 9). All sample plants were separated into low and high levels of JIT implementation based on a cutoff super-scale mean of 4.56. The purpose of this hypothesis is to shed more light on the relationship between intensive implementation of JIT practices and HRM practices. For each HRM practice, JIT groups were compared to investigate whether or not there is a significant difference between low and high users of JIT. The results showed that for six HRM practices: Cooperation, Employee Suggestions, Multi-Functional Employees, Small Group Problem Solving, Task-Related Training for Employees and Top Management Leadership for Quality, high users of JIT have higher levels of these practices and significantly differ from low users of JIT. For the seventh practice, Flatness of Organizational Structure, low users of JIT have higher implementation level, but with no significant difference. We can deduce from the results that there is a general awareness among the organizations that as the implementation of JIT increases, the level of HRM practices associated with JIT should be increased to ensure successful implementation and to achieve full potential of JIT production.

Hypothesis H1b has been mostly accepted.

5.4 Test of hypothesis H1c

To test this hypothesis, one way ANOVA test has been produced (Table 10). All sample plants were separated into old and new users of JIT based on a cutoff point of 5 years since JIT adoption. Our purpose is to investigate the relationship between longer implementation of JIT production and HRM practices. For each HRM practice, JIT groups have been compared to examine whether or not there is a significant difference between them. The results showed that no significant differences between old and new users of JIT for all HRM practice. This implies that longer implementation of JIT is expected neither to automatically change the organizational culture nor to affect HRM. Rather, organizational and human resource modifications should be undertaken prior to JIT introduction. Both managers and workers should fully understand the philosophy of JIT and what is expected from them in the preparation stage through intensive training to ensure smooth implementation. Hypothesis H1c has been rejected.

Table 9 ANOVA analysis of means for changes in HRM practices for high and low users of JIT

HRM scales	Level of JIT implementation	N	Mean	F value	P value
	High	114	5.8693		
Co	Low	96	5.6093	22.790	0.000
	Total	210	5.7504		
	High	114	5.4587		
ES	Low	96	4.9345	48.854	0.000
	Total	210	5.2179		
	High	114	4.4148		
FOS	Low	96	4.5562	1.054	0.306
	Total	210	4.4794		
	High	114	5.4595		
MFE	Low	96	5.2033	9.782	0.002
	Total	210	5.3424		
	High	114	5.3055		
SGPS	Low	96	4.7866	40.286	0.000
	Total	210	5.0683		
	High	114	5.4851		
TE	Low	96	4.9696	36.106	0.000
	Total	210	5.2494		
	High	114	5.7090		
TMLQ	Low	96	5.2740	28.670	0.000
	Total	210	5.5101		

5.5 Test of hypothesis H2 and H3

To test hypotheses H2, H3a and H3b concerning the impact of JIT and HRM on the competitive performance of the plant, we use hierarchical regression analysis with competitive performance as dependent variable (Table 11). We first entered JIT super scale to the model. The results showed that JIT explained a significant portion (13.2%) of the variance in competitive performance among responding plants. In the second equation, we added HRM super scale to the model so that we can measure the incremental impact of HRM on competitive performance given the impact of JIT production. The results showed that the addition of HRM resulted in an additional significant explanation (7.4%) of the variance in competitive performance. In equation (2'), HRM super scale has been regressed on competitive performance to test the direct impact of HRM on competitive performance not given the effect of JIT. Equation (2') shows that HRM explained a significant portion of 16.8% of the variance in competitive performance among the responding plants. All in all, hypotheses H2, H3a, and H3b have been supported.

Table 10 ANOVA analysis for changes in HRM practices for old and new users of JIT

HRM scales	Type of JIT users	N	Mean	F value	P value
Co	Old users	109	5.7792	0.727	0.395
	New users	82	5.7270		
	Total	191	5.7568		
ES	Old users	109	5.2321	0.058	0.811
	New users	82	5.2112		
	Total	191	5.2232		
FOS	Old users	109	1.00858	0.764	0.383
	New users	82	1.00664		
	Total	191	1.00712		
MFE	Old users	109	5.3982	3.194	0.076
	New users	82	5.2399		
	Total	191	5.3302		
SGPS	Old users	109	5.1182	0.581	0.447
	New users	82	5.0469		
	Total	191	5.0876		
TE	Old users	109	5.2976	0.556	0.457
	New users	82	5.2255		
	Total	191	5.2667		
TMLQ	Old users	109	5.5629	2.426	0.121
	New users	82	5.4186		
	Total	191	5.5010		

Table 11 Hierarchical regression analysis of competitive performance

Variables	Eq. (1)	Eq. (2)	Eq. (2')
(Constant)	2.070***	0.761*	1.077**
JIT	0.364***	0.221***	
HRM		0.307***	0.410***
R^2	0.132	0.206	0.168
Adj. R^2	0.128	0.198	0.163
F	28.634***	24.283***	37.918***
Change in R^2		0.074	
F change	28.634***	17.430***	

*P ≤ 0.1
**P ≤ 0.05
***P ≤ 0.01

To further investigate the relationship between JIT, HRM and competitive performance, we performed additional analysis to test the impact of JIT and HRM on individual competitive performance measures (Table 12). We conducted hierarchical regression analysis separately for each competitive performance measure as a dependent variable. In a similar way to previous regression, we entered JIT super scale to the first equation. In the second equation, we added HRM super scale to measure the incremental impact of HRM on each individual measure of competitive performance given the impact of JIT production.

The results showed that JIT explained a significant portion of the variance for five individual measures of competitive performance. For the sixth measure, Product Innovativeness, the impact of JIT was insignificant. The addition of HRM to the models in the second equation resulted of an additional significant increase of R^2 for five measures of competitive performance. As for the sixth measure, Unit Cost of Manufacturing, the addition of HRM did not significantly increase R^2. Equation (2') shows that the direct impact of HRM, not given the effect of JIT, significantly explained a significant portion of the variance for all the individual measures of competitive performance.

Table 12 Hierarchical regression analysis of competitive performance measures

	Eq. (1)	Eq. (2)	Eq. (2')
Dependent variable: Unit cost of manufacturing			
Constant	0.481	-0.344	0.416
JIT	0.373***	0.320***	
HRM		0.116	0.264***
R^2	0.139	0.150	0.070
Adj. R^2	0.135	0.141	0.065
F	30.151***	16.337***	13.936***
Change in R^2		0.011	
F change	30.151***	2.311	
Dependent variable: Conformance to product specifications			
Constant	2.963***	1.551***	1.634***
JIT	0.164**	0.045	
HRM		0.257***	0.278***
R^2	0.027	0.069	0.077
Adj. R^2	0.022	0.069	0.072
F	5.210**	7.979***	15.690***
Change in R^2		0.052	
F change	5.210**	10.485***	
Dependent variable: On time delivery performance			
Constant	1.619***	0.207	0.739
JIT	0.334***	0.237***	
HRM		0.210***	0.320***
R^2	0.112	0.146	0.102
Adj. R^2	0.107	0.137	0.097
F	23.480***	15.921***	21.274***
Change in R^2		0.035	
F change	23.480***	7.541***	
Dependent variable: Flexibility to change product mix			
Constant	3.106***	2.120***	2.230***
JIT	0.140**	0.057	
HRM		0.178**	0.205***
R^2	0.020	0.044	0.042
Adj. R^2	0.014	0.034	0.037
F	3.696**	4.283**	8.096***
Change in R^2		0.025	
F change	3.696**	4.794**	
Dependent variable: On time new product launch			
Constant	1.359***	0.061	0.522
JIT	0.300***	0.209***	
HRM		0.193**	0.291***
R^2	0.090	0.119	0.085
Adj. R^2	0.085	0.109	0.079
F	17.936***	12.208***	16.804***
Change in R^2		0.029	
F change	17.936***	5.989**	
Dependent variable: Product innovativeness			
Constant	2.962***	0.880	0.768
JIT	0.091	-0.048	
HRM		0.301***	0.279***
R^2	0.008	0.079	0.078
Adj. R^2	0.003	0.069	0.073
F	1.528	7.813***	15.319***
Change in R^2		0.071	
F change	1.528	13.988***	

**$P \le 0.05$
***$P \le 0.01$

6. Conclusions

Based on our study, the following conclusions are drawn. First, HRM practices have a direct positive impact on JIT implementation and development. This study suggests that cooperation (team spirit) and Training of Employees are the most critical HRM practices that affect JIT production.

Employee Suggestions, Top Management Leadership for Quality, Multi-Functional Employees, and Small Group Problem Solving have positive impact on different practices of JIT. Flatness of Organizational Structure was found to have negative and significant impact on six JIT elements implying that it is not necessarily a prerequisite for JIT implementation and success.

Second, the results showed that as the implementation of JIT increases, the level of HRM practices is increased, emphasizing that HRM is an inherent part of JIT implementation and success. On the other hand, results showed that old and new users of JIT have similar levels of HRM, implying that human resource modifications should be undertaken prior to JIT implementation.

Third, this study indicated that JIT production has a positive impact on competitive performance of the plant. All the measures of cost, quality, flexibility, delivery, and new product launch were significantly and positively affected by JIT production. However, the impact of JIT on product innovativeness was insignificant.

Fourth, the results showed that HRM has significant and positive impact on all the measures of competitive performance. In addition to that, the addition of HRM, given the effect of JIT production, resulted in an additional significant impact on the competitive performance super scale as well as on the measures of quality, flexibility, delivery, new product launch, and innovation implying that to achieve full potential of JIT production and superior competitive performance, it is of crucial importance to adopt both JIT technical practices and HRM practices associated with JIT implementation. The findings emphasize that HRM practices are a prerequisite and main infrastructure for JIT production.

The limitation of our study is that, as in other empirical research in operations management, the measurement scales of JIT and HRM used for our research may not capture all the practices implemented by the surveyed plants. In addition to that, competitive 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. Further research is also needed to investigate how other operational practices affect JIT and competitive performance. Finally, case studies are needed to investigate how culture affects JIT and HRM.

Appendix A
Measures of JIT practices

Daily Schedule Adherence

Question 1	We usually meet the production schedule each day.
Question 2	Our daily schedule is reasonable to complete on time.
Question 3	We usually complete our daily schedule as planned.
Question 4	We build time into our daily schedule to allow for machine breakdowns and unexpected production stoppages.
Question 5	We build extra slack into our daily schedule, to allow for catching up.
QuestionR 6	We cannot adhere to our schedule on a daily basis.
QuestionR 7	It seems like we are always behind schedule.

Equipment Layout

Question 1	We have laid out the shop floor so that processes and machines are in close proximity to each other.
Question 2	We have organized our plant floor into manufacturing cells.
Question 3	Our machines are grouped according to the product family to which they are dedicated.
Question 4	The layout of our shop floor facilitates low inventories and fast throughput.
Question 5	Our processes are located close together, so that material handling and part storage are minimized.
Question 6	We have located our machines to support JIT production flow.

Just-in-Time Delivery by Suppliers

Question 1	Our suppliers deliver to us on a just-in-time basis.
Question 2	We receive daily shipments from most suppliers.
Question 3	We can depend upon on-time delivery from our suppliers.
Question 4	Our suppliers are linked with us by a pull system.
Question 5	Suppliers frequently deliver materials to us.

Just-in-Time Link with Customers

Question 1	Our customers receive just-in-time deliveries from us.
Question 2	Most of our customers receive frequent shipments from us.
Question 3	We always deliver on time to our customers.
Question 4	We can adapt our production schedule to sudden production stoppages by our customers.
Question 5	Our customers have a pull type link with us.
Question 6	Our customers are linked with us via JIT systems.

Kanban

Question 1	Suppliers fill our kanban containers, rather than filling purchase orders.
Question 2	Our suppliers deliver to us in kanban containers, without the use of separate packaging.
Question 3	We use a kanban pull system for production control.
Question 4	We use kanban squares, containers or signals for production control.

*: Items are deleted

Repetitive Nature of Master Schedule

Question 1	Our master schedule repeats the same mix of products, from hour to hour and day to day.
Question 2	The master schedule is level-loaded in our plant, from day to day.
Question 3	A fixed sequence of items is repeated throughout our master schedule.
Question 4	Within our schedule, the mix of items is designed to be similar to the forecasted demand mix.
Question 5	We use a repetitive master schedule from day to day.
QuestionR 6	Our master schedule does not facilitate JIT production.

Setup Time Reduction

Question 1	We are aggressively working to lower setup times in our plant.
Question 2	We have converted most of our setup time to external time, while the machine is running.
Question 3	We have low setup times of equipment in our plant.
Question 4	Our crews practice setups, in order to reduce the time required.
Question 5	Our workers are trained to reduce setup time.
QuestionR 6	Our setup times seem hopelessly long.

Synchronization of Operations

Question 1	Capacities are balanced in our supply network.
Question 2	Our manufacturing capacity is balanced throughout the entire manufacturing process.
Question 3	We can easily determine bottleneck operations in our supply chain.
QuestionR 4	We have large in-process inventories between different operations.
Question 5	Our suppliers do not use large inventories to supply us.

Theory of Constraints

Question 1	We consistently monitor work-in-process in front of each process to identify the bottleneck (constraint) in the production system.
Question 2	We make every effort to minimize or eliminate idle time of the bottleneck process.

Question 3	We control non-bottleneck processes' levels of utilization and timing of the order release by taking into account the capacity of the bottleneck process.
Question 4	We consistently make efforts to increase the capacity of the bottleneck process.
Question 5	We assign parts to be processed in the bottleneck process by identifying those with the earliest due dates.
Question 6	We make sure that only good parts are processed through the bottleneck process.
Question 7	We consider an hour lost in the bottleneck process as an hour lost for the whole plant.
Question 8	We balance the flow of products through the production facility, rather than balancing the capacities of the processes.

*: Items are deleted

Appendix B
Measures of HRM practices

Cooperation

Question 1	We work as a partner with our suppliers, rather than having an adversarial relationship.
Question 2	We encourage employees to work together to achieve common goals, rather than encourage competition among individuals.
Question 3	We work as a partner with our customers.
Question 4	We believe that cooperative relationships will lead to better performance than adversarial relationships.
Question 5	We believe that the need for cooperative relationships extends to both employees and external partners.
Question 6	We believe than an organization should work as a partner with its surrounding community.
QuestionR 7	Sometimes we encourage competition among employees, in order to improve their performance.

*: Item is deleted

Employee Suggestions – Implementation and Feedback

Question 1	Management takes all product and process improvement suggestions seriously.
Question 2	We are encouraged to make suggestions for improving performance at this plant.
Question 3	Management tells us why our suggestions are implemented or not used.
Question 4	Many useful suggestions are implemented at this plant.
Question 5	My suggestions are never taken seriously around here.

Flatness of Organization Structure

Question 1	Our organization structure is relatively flat.
Question 2	There are few levels in our organizational hierarchy.
QuestionR 3	Our organization is very hierarchical.
QuestionR 4	There are many levels between the lowest level in the organization and top management.
QuestionR 5	Our organizational chart has many levels.

Multi-Functional Employees

Question 1	Our employees receive training to perform multiple tasks.
Question 2	Employees at this plant learn how to perform a variety of tasks.
Question 3	The longer an employee has been at this plant, the more tasks they learn to perform.
Question 4	Employees are cross-trained at this plant, so that they can fill in for others, if necessary.
QuestionR 5	At this plant, each employee only learns how to do one job.

Small Group Problem Solving

Question 1	During problem solving sessions, we make an effort to get all team members' opinions and ideas before making a decision.
Question 2	Our plant forms teams to solve problems.
Question 3	In the past three years, many problems have been solved through small group sessions.
Question 4	Problem solving teams have helped improve manufacturing processes at this plant.
Question 5	Employee teams are encouraged to try to solve their own problems, as much as possible.
QuestionR 6	We don't use problem solving teams much, in this plant.

Task-Related Training for Employees

Question 1	Our plant employees receive training and development in workplace skills, on a regular basis.
Question 2	Management at this plant believes that continual training and upgrading of employee skills is important.
Question 3	Employees at this plant have skills that are above average, in this industry.
Question 4	Our employees regularly receive training to improve their skills.
Question 5	Our employees are highly skilled, in this plant.

*: Item is deleted

Top Management Leadership for Quality

Question 1	All major department heads within the plant accept their responsibility for quality.
Question 2	Plant management provides personal leadership for quality products and quality improvement.
Question 3	The top priority in evaluating plant management is quality performance.
Question 4	Our top management strongly encourages employee involvement in the production process.
Question 5	Our plant management creates and communicates a vision focused on quality improvement.
Question 6	Our plant management is personally involved in quality improvement projects.

Appendix C
Manufacturing 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

Unit cost of manufacturing	1	2	3	4	5
Conformance to product specifications	1	2	3	4	5
Flexibility to change product mix	1	2	3	4	5
On time delivery performance	1	2	3	4	5
On time new product launch	1	2	3	4	5
Product innovativeness	1	2	3	4	5

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〔Ayman Bahjat Abdallah, Departement of Business Management Systems, International Graduate School of Social Sciences, Yokohama National University. E-mail: aymanabdallah@yahoo.com〕

〔Anh Chi Phan, Departement of Business Management Systems, International Graduate School of Social Sciences, Yokohama National University. E-mail: anhpc@yahoo.com〕

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