The current issue and full text archive of this journal is available at
www.emeraldinsight.com/1741-038X.htm

Impact of lean practices on operations performance and business performance

Some evidence from Indonesian manufacturing companies

Received 4 March 2012
Revised 13 August 2012
26 September 2012
Accepted 8 October 2012

Gusman Nawanir, Lim Kong Teong and Siti Norezam Othman
School of Technology Management and Logistics, Universiti Utara Malaysia, Sintok, Malaysia

Abstract

Purpose – This study aims to investigate the relationship between lean practices, operations performance (OP), and business performance (BP).

Design/methodology/approach – This survey-based study was a cross-sectional study. The samples were drawn by using stratified random sampling procedure from large Indonesian manufacturing companies based on the directory provided by the Data and Information Center of Indonesian Ministry of Industry with the final number of respondents of 139. Four main hypotheses were developed and tested statistically by applying multivariate data analyses.

Findings – The results provided evidence that lean practices should be implemented holistically. Lean practices have a positive and significant impact on both OP and BP. Moreover, OP partially mediates the relationship between lean practices and BP.

Research limitations/implications – The data used in this survey represent self-reporting by mainly the middle or top management in production.

Practical implications – This study contributes to the lean manufacturing (LM) body of knowledge by identifying the relationships between the LM practices, OP, and BP. Understanding these relationships will help practitioners in making better decisions in manufacturing organizations as well as enable application of the concepts in this study to other contexts such as service organizations.

Originality/value – Although there are a growing number of anecdotal and empirical evidences in favor of LM in manufacturing environment, there has been almost no theory-building and methodologically rigorous research examining the link between LM, OP, and BP. This study is addressed to fill this gap.

Keywords Business performance, Indonesia, Lean manufacturing, Lean practices, Operations performance

Paper type Research paper

Introduction

The origin of lean manufacturing (LM) was established on the shop-floors of the Toyota Motor Corporation during 1970s (Shingo, 1981), under the names of Toyota Production System (TPS) or just-in-time (JIT) manufacturing (Taj, 2008). Papadopoulou and Özbayrak (2005) explained that the term "lean" was first coined by Krafcik (1988)

The authors acknowledge financial support from the Universiti Utara Malaysia. Thanks are also addressed to Indonesian manufacturing companies, which have participated as respondent of this study.

Journal of Manufacturing Technology Management
Vol. 24 No. 7, 2013
pp. 1019-1050

1741-038X
DOI 10.1108/JMTM-03-2012-0027

to describe a production system that uses fewer resources compared to mass production. Due to the practices of LM, JIT, and TPS being about the same (Heizer and Render, 2008), these terms are often used interchangeably (Heizer and Render, 2008; Taj, 2008). According to Papadopoulou and Özbayrak (2005), LM is merely an Americanized version of the TPS or the JIT. The concept of LM is constantly evolving as well as experiencing expanding scope and focus (Papadopoulou and Özbayrak, 2005). Recently, the term "lean manufacturing" has become more prevalent, thus it is subsequently used in this study to encompass all the related practices.

Facts and figures have indicated that LM contributed significantly to the success of the Japanese and US companies during the last three decades. Even Krafcik (1989) suggested that high performance depends on creating a LM system. Nowadays, the concept of LM is transferred actively across countries and industries due to its global superiority in cost, quality, productivity, flexibility, and quick response (Schonberger, 2007).

Various studies concluded that LM has helped numerous companies to improve performance through waste elimination. At the operations level, several studies postulated that LM has become a powerful approach in escalating operations performance (OP) in terms of quality (Fullerton and Wempe, 2009; Shah and Ward, 2003), inventory minimization (Chong *et al.*, 2001; Fullerton and McWatters, 2001), delivery (Ahmad *et al.*, 2003, 2004), productivity (Fullerton and Wempe, 2009; Singh *et al.*, 2010), and cost reduction (Cua *et al.*, 2001; Hallgren and Olhager, 2009). Surprisingly, LM has also been recognized as a fantastic strategy to improve business performance (BP) in terms of profitability (Ahmad *et al.*, 2003; Fullerton and Wempe, 2009), sales (Green and Inman, 2007; Kannan and Tan, 2005), and customer satisfaction (Green and Inman, 2007; Sakakibara *et al.*, 1997). This condition remains a fundamental question; "how LM leads to the better BP?" While there is a growing number of anecdotal and empirical evidence in favor of LM in manufacturing environment, there has been almost no theory-building and methodologically rigorous research examining the link between LM, OP, and BP.

More importantly, much of the research had examined the impact of LM on performance in the developed countries, such as Japan, the USA, the UK, Germany, Italy, etc. Amoako-Gyampah and Gargeya (2001) suggested that not much attention had been paid to investigate the LM-performance relationships in the developing countries. The researchers believed that in order to obtain a clearer picture regarding the impact of LM practices on performance, investigations in the context of developing countries are substantially required.

The purpose of this paper is to investigate the interrelationships between LM, OP, and BP in Indonesian manufacturing companies. Specifically, the extent of LM implementation is examined comprehensively by using the nine practices, whereas performance is assessed simultaneously in two levels; OP and BP. Finally, the role of OP in mediating the LM practices-BP relationship will be investigated.

Indonesian manufacturing sector

Indonesia, the largest archipelago in the world with strategic location along major sea lanes between the Indian Ocean and Pacific Ocean, is recognized as the country with abundance of natural resources. Reported by CIA (2012), Indonesia is currently in the top four of the most populated country in the world with about 249 million peoples. Nowadays, with its abundant resources, Indonesia plays a major role domestically and in export markets with total exports US$203.50 billion and imports US$177.44 billion in 2011 (BPS-Statistics Indonesia, 2012b).

The main contributor to the Indonesian exports (i.e. manufacturing sector), as reported by the BPS-Statistics Indonesia (2010), was dominated by food and beverage (23.99 percent); textile, wearing apparel and leather products (22.26 percent); wood products, furniture and fixtures (14.86 percent); non-metallic mineral products (6.98 percent); plastic and rubber (6.73 percent); metal and metal product (4.70 percent); chemical (4.31 percent); and tobacco products (4.27 percent); besides industrial machinery, electronic, electrical equipment, instrumentation and motor vehicle (6.44 percent). Recently, the BPS-Statistics Indonesia (2012c) stated that production growth of Indonesian large and medium manufacturers tended to increase significantly from 2001 to 2011. Although a negative growth was occurred in 2006, a significant growth of 5.57 percent was observed in the year 2007. In the following years, production grew rapidly from 1.34 percent in 2009, 4.45 percent in 2010, 5.56 percent in 2011 and tended to increase in 2012.

More importantly, it is indisputable that manufacturing sector contributed significantly to the total economic structure of Indonesia. This sector gave the highest contribution (23.80 percent) to the total gross domestic product (GDP) in the year 2011 compared to other sectors (BPS-Statistics Indonesia, 2012a). Although this sector contributed significantly to the economics of Indonesia, lack of technical efficiency (Anatan, 2006; Margono and Sharma, 2006; Zailani *et al.*, 2008) has been highlighted as one of the major obstacles faced by the Indonesian manufacturing companies. Margono and Sharma (2006) noted that improvement in technical efficiency drove the growth of manufacturing companies positively. Relevant to the LM, there is a consensus that LM improves the technical efficiency and subsequently improves organizational performance. It is expected that LM implementation would help Indonesian manufacturing companies to enhance better technical efficiency and companies' performance. Nowadays, to the researchers' knowledge, there are very limited studies that have been carried out for particular cases like Indonesia.

Literature review

Although many studies have provided empirical evidence that LM significantly improves performance, only fewer studies have investigated the simultaneous synergistic effects of multiple aspects of LM and performance. Many studies did not consider the significant effects of LM on both OP and BP simultaneously (Bartezzaghi and Turco, 1989; Bhasin, 2008; Chang and Lee, 1995). Sometimes, LM and performance were examined individually or in very limited subsets, thus the results occasionally produced misleading information and misconceptions (Ahmad *et al.*, 2003; Fullerton and Wempe, 2009; Furlan *et al.*, 2011b). In addition, literatures had provided evidence that LM was not implemented as a total system (Cua *et al.*, 2001; Fullerton and Wempe, 2009), while Goyal and Deshmukh (1992), Harber *et al.* (1990) and White and Prybutok (2001) argued that potential benefits of LM will not be realized before it is implemented as a total system.

LM practices

For LM to work well in achieving a better performance, some fundamental practices must be in place. According to Ahmad *et al.* (2003), Ramarapu *et al.* (1995) and Shah and

Ward (2007), although many researchers and practitioners have attempted to identify the main LM practices, there was no single agreement among them regarding the relative importance of the practices. The practices varied widely based on the authors' background. These differences caused practitioners and researchers to offer diverse sets of practices under the same concept. Due to the overall consensus that is still lacking, the most commonly used practices proposed by several past studies are compiled by regrouping various activities into nine practices. Even though this study did not include some of the LM practices discussed in literature as separate components, many were assimilated into related practices as exhibited in Table I.

Performance measurement

Performance measurement underwent a revolution, from pure financial focus to include more comprehensive business characteristics (Neely *et al.*, 2005). Neely *et al.* (2000) noted that although practitioners argued some areas in which performance measurement might be useful, little guidance is given on how appropriate measures can be applied to manage the business. LM is frequently implemented at the shop-floor and associated with production processes. Hence, the use of non-financial measures, which is not part of traditional accounting systems, seems to be useful in LM areas (Abdel-Maksoud *et al.*, 2005). This suggested that LM companies were more likely to use non-financial measures to a greater extent rather than financial. Non-financial

LM practices	Literature support
Flexible resources (i.e. employee involvement and empowerment, multi-function employees, and multi-function machines and equipment)	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 14, 17, 19, 20, 22
Cellular layouts (i.e. group technology and cellular manufacturing)	1, 2, 3, 4, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 19, 20, 21, 22
Pull system/kanban	1, 3, 4, 5, 6, 7, 8, 9, 10, 11, 13, 14, 15, 18, 19, 20, 21, 22
Small lot production	1, 2, 7, 11, 12, 13, 14, 18, 21, 22
Quick setup (i.e. quick changeover, single minute of exchange dies, setup time reduction)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 17, 18, 19, 20, 21, 22
Uniform production level (i.e. uniform work load, mixed model production, repetitive master schedule, and daily schedule adherence)	1, 4, 5, 6, 7, 8, 10, 12, 13, 14, 15, 21, 22
Quality at the source (i.e. process and product quality control, and quality circles)	1, 2, 4, 5, 6, 7, 8, 9, 10, 11, 14, 17, 18, 19, 20, 22
Total productive maintenance (i.e. preventive maintenance, team-based maintenance, and good housekeeping)	2, 3, 4, 6, 7, 8, 9, 10, 11, 13, 18, 19, 20
Supplier networks (i.e. JIT delivery by supplier, supplier development program, and long term agreement with supplier)	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16, 18, 19, 21, 22

Source: 1 – Lee and Paek (1995); 2 – Ramarapu *et al.* (1995); 3 – Sakakibara *et al.* (1997); 4 – Callen *et al.* (2000); 5 – White and Prybutok (2001); 6 – Chong *et al.* (2001); 7 – Fullerton and McWatters (2001, 2002); 8 – Fullerton *et al.* (2003); 9 – Ahmad *et al.* (2004); 10 – Olsen (2004); 11 – Shah and Ward (2007); 12 – Matsui (2007); 13 – Abdallah and Matsui (2007); 14 – Dal Pont *et al.* (2008); 15 – Hallgren and Olhager (2009); 16 – Jayaram *et al.* (2008); 17 – Fullerton and Wempe (2009); 18 – Rahman *et al.* (2010); 19 – Taj and Morosan (2011); 20 – Yang *et al.* (2011); 21 – Furlan *et al.* (2011a); 22 – Furlan *et al.* (2011b)

Table I.
Common practices of LM

measures are actually measuring OP, which subsequently influences the BP. Bartezzaghi and Turco (1989), Chang and Lee (1995) and Jeyaraman and Leam (2010) postulated that OP is influenced by operating conditions and represents performance at each production resource level. BP is regarded as a higher-level looking at a business as a whole, with OP taking the role as a mediator variable. This study uses the two performance levels as detailed in Table II.

Hypotheses

The study tested a set of hypotheses to analyze the question of whether LM practices affect performance. These were structured by articulating the problem as a need to understand the relationships among the variables. Four main hypotheses were posited:

H_1. LM practices have a positive relationship with OP.

LM practices are believed to have a positive relationship with OP (Abdel-Maksoud *et al.*, 2005; Fullerton and Wempe, 2009; Hallgren and Olhager, 2009; Rahman *et al.*, 2010) because it is widely considered to be a potentially powerful approach to enhance better OP through waste elimination. This leads to the following specific hypotheses:

H_{1a}. LM practices have a positive relationship with quality.

H_{1b}. LM practices have a positive relationship with inventory minimization.

H_{1c}. LM practices have a positive relationship with delivery.

H_{1d}. LM practices have a positive relationship with productivity.

Performance measures	Literature support
Operations performance	
Quality (i.e. quality of product conformance, quality of service, and first passed quality yields)	2, 3, 5, 6, 7, 8, 10, 11, 12, 14, 16, 17, 18, 19
Inventory minimization (i.e. inventory turnover and inventory level reduction)	2, 3, 4, 5, 6, 8, 12, 16, 17, 18, 19
Delivery (i.e. on-time delivery and fast delivery)	3, 5, 7, 10, 12, 16, 17, 18, 19
Productivity (i.e. labor productivity and facility/ machine productivity)	8, 11, 12, 13, 18, 19
Cost reduction (i.e. unit manufacturing cost and quality cost)	3, 7, 8, 10, 11, 12, 16, 17, 18
Business performance	
Profitability (i.e. profit margin and return on investment)	2, 4, 5, 6, 9, 12, 13, 14, 15, 18, 19
Sales (i.e. sales growth and market share)	2, 12, 13, 14, 15, 18
Customer satisfaction (i.e. delivery lead time, overall quality of products, responsiveness, and product competitive prices)	1, 3, 5, 8, 12, 13, 15, 16, 17, 18

Source: 1 – Flynn *et al.* (1995); 2 – Chang and Lee (1995); 3 – Sakakibara *et al.* (1997); 4 – Claycomb *et al.* (1999); 5 – Callen *et al.* (2000); 6 – Fullerton and McWatters (2001); 7 – Cua *et al.* (2001); 8 – Chong *et al.* (2001); 9 – Fullerton *et al.* (2003); 10 – Ahmad *et al.* (2003); 11 – Shah and Ward (2003); 12 – Ahmad *et al.* (2004); 13 – Olsen (2004); 14 – Kannan and Tan (2005); 15 – Green and Inman (2007); 16 – Matsui (2007); 17 – Abdallah and Matsui (2007); 18 – Bhasin (2008); 19 – Fullerton and Wempe (2009)

Table II. Common measures of performance

H_{1e}. LM practices have a positive relationship with cost reduction.

The second hypothesis is as follows:

H_2. LM practices have a positive relationship with BP.

It is hypothesized that LM practice would lead to higher BP because the central theme of LM is to have the right items of the right quality and quantity in the right place and at the right time. This means that waste must be extremely eliminated. Hence, it is believed that LM practice encourages higher profits (Green and Inman, 2007; Yang *et al.*, 2011), outstanding sales (Green and Inman, 2007; Yang *et al.*, 2011), and higher customer satisfaction (Abdallah and Matsui, 2007; Chong *et al.*, 2001). Therefore, the following specific hypotheses were posited:

H_{2a}. LM practices have a positive relationship with profitability.

H_{2b}. LM practices have a positive relationship with sales.

H_{2c}. LM practices have a positive relationship with customer satisfaction.

The third hypothesis is:

H_3. OP has a positive relationship with BP.

OP is believed to have a positive relationship with BP (Durden *et al.*, 1999; Van der Stede *et al.*, 2006) because the improvement on each production resource level would increase the companies' ability to obtain higher profits, to enhance the sales, and to satisfy customers. Furthermore, it is also believed that the success of the companies with respect to overall performance is sufficiently determined by the success at the operations level (Fullerton and Wempe, 2009; Said *et al.*, 2003). This led to the following three specific hypotheses:

H_{3a}. OP has a positive relationship with profitability.

H_{3b}. OP has a positive relationship with sales.

H_{3c}. OP has a positive relationship with customer satisfaction.

The last hypothesis is:

H_4. OP mediates the relationship between LM practices and BP.

It is hypothesized that OP acts as a mediator in the relationship between LM practices and BP (Ahmad *et al.*, 2004; Fullerton and Wempe, 2009).

Methodology

This study was a cross-sectional study performed once, and it represents a snapshot of one point in time (Cooper and Schindler, 2003). Organization was the unit of analysis. Respondents were required to answer a set of close-ended with ordered choice questions adapted from several sources. This study emphasizes in measuring LM in nine practices, OP and BP in five and three measures, respectively, (Appendices 1-3). OP and BP were measured based on the achievement during the past three years to reduce the influence of temporary fluctuations in the variables. The measurement was perceptual with a five-point Likert scale: strongly disagree (1); disagree (2); neither agree nor disagree (3); agree (4); and strongly agree (5).

The Data and Information Center of the Indonesian Ministry of Industry (2008) provided a directory of 22,259 manufacturing companies in Indonesia. Large companies were selected as population of the study having more than 100 employees, because they commonly implemented LM more often than do small companies (Shah and Ward, 2003, 2007). The original list was reduced to 2,421 by eliminating small and medium companies, and sectors those were uncommonly selected in previous studies. Using stratified random sampling procedure, 1,000 of 2,421 companies were selected.

The questionnaires were distributed by mail to the respondents, i.e. top and middle management in production. They were required to return the completed survey booklets within 15 days of receipt in the enclosed self-address envelope with stamp provided. Around 20 days later, the non-response companies were telephoned to maximize the response rate. The data was collected from the early 2010 until mid-2010.

Results

Respondent profile

A total of 161 questionnaires was completed and returned. This led to an effective response rate of 16.10 percent. However, this number was reduced to 139 because of a few missing values and outliers. The companies represent a wide variety of industries; they are paper products (11.51 percent); chemical (10.07 percent); rubber and plastic products (15.11 percent); non-metallic mineral products (6.47 percent); metal products (11.51 percent); industrial machinery (5.76 percent); electronic, electrical equipment and components (16.55 percent); instrumentation (8.63 percent); and motor vehicle and accessories (14.39 percent). Based on the usable responses; the majority of respondents were the manager (62.59 percent), the head of department (20.86 percent), the director (5.04 percent), and other middle and top management positions in production (11.51 percent) who are familiar with LM activities and performance, such as senior manufacturing engineer and LM implementer.

Construct validity and reliability

The first step in examining the data involves testing for the assumptions underlying the statistical based for multivariate data analysis. Even though some multivariate techniques are less affected by violating certain assumptions, in all cases, meeting some of the assumptions will be critical to a successful analysis. For this reason, the normality and linearity tests have been applied. The results suggested that the data fulfill these assumptions.

Cooper and Schindler (2003) described that the researchers have to ensure whether or not the test measures do actually measure what is to be measured (validity) and maintain consistency of measurement results (reliability). Factor analysis was carried out to examine construct validity on each construct separately because of the limitation of sample size (Hair *et al.*, 2010). Only items with a factor loading of at least 0.45 were retained (Hair *et al.*, 2010).

Table III exhibits that a number of items that were recommended to be omitted. The table shows that factor loadings for all retained constructs ranged from 0.47 to 0.88. Moreover, all constructs explain more than 50 percent of total variance, except the three constructs that were still marginally accepted, namely flexible resources (46.57 percent),

Table III.
Validity and reliability of instrument

Construct	No. of items[a]	Deleted items[b]	Factor loading for retained items	KMO	Eigenvalue	% variance	α[c]
LM practices							
Flexible resources	6	3	0.83, 0.73, 0.72, 0.61, 0.47	0.72	2.33	46.57	0.69
Cellular layouts	6	1, 3	0.81, 0.70, 0.69, 0.63	0.70	2.02	50.40	0.66
Pull system	6	2	0.88, 0.87, 0.85, 0.84, 0.75	0.85	3.51	70.22	0.89
Small lot production	6	None	0.86, 0.86, 0.85, 0.85, 0.78, 0.75	0.85	4.08	67.93	0.91
Quick setup	6	2, 3	0.82, 0.72, 0.70	0.61	1.68	56.06	0.60
Uniform production level	6	2, 4	0.79, 0.71, 0.70, 0.64	0.72	2.01	50.31	0.67
Quality at the source	6	3	0.82, 0.73, 0.72, 0.69, 0.64	0.79	2.61	52.11	0.76
TPM	5	2	0.81, 0.77, 0.71, 0.63	0.63	2.14	53.44	0.70
Supplier networks	8	None	0.82, 0.79, 0.78, 0.76, 0.72, 0.72, 0.68, 0.62	0.87	4.35	54.38	0.87
Operations performance							
Quality	6	1, 4	0.83, 0.74, 0.57, 0.56	0.60	1.87	46.64	0.61
Inventory minimization	4	1	0.79, 0.73, 0.69	0.62	1.64	54.52	0.58
Delivery	3	None	0.85, 0.76, 0.75	0.63	1.88	62.51	0.69
Productivity	4	None	0.80, 0.77, 0.65, 0.51	0.66	1.91	47.81	0.63
Cost reduction	4	2	0.75, 0.73, 0.68	0.61	1.55	51.78	0.53
Business performance							
Profitability	4	None	0.82, 0.81, 0.63, 0.62	0.60	2.10	52.46	0.70
Sales	3	None	0.82, 0.75, 0.60	0.57	1.60	53.30	0.56
Customer satisfaction	4	None	0.79, 0.75, 0.71, 0.63	0.70	2.09	52.29	0.68

Notes: [a]Number of items before deletion; [b]sequence number of questionnaire (Appendices 1-3); [c]Cronbach's α after deleting the items in factor analysis stage quality (46.64 percent), and productivity (47.81 percent). Therefore, percent variance values ranged between 46.57 percent and 70.22 percent. Although there are three values that are marginally acceptable, these values are much better than the ones reported in prior studies, such as by Abdallah and Matsui (2007), which ranged from 43.49 to 67.44 percent. All the KMO values are greater than 0.50 as recommended by Kaiser (1974), indicating patterns of correlations are relatively compact, and thus, factor analysis is reliable. In addition, The Bartlett's test is significant at $\alpha = 0.05$ for all the constructs, implying the variables are highly correlated to provide a reasonable basis for factor analysis (Coakes and Steed, 2007). Therefore, the constructs used are valid and eligible.

Construct reliability is assessed by using Cronbach's α. A rule of thumb provided by George and Mallery (2003) stated that α values of greater than 0.50 are adequate. Even, Jones and James (1979) argued that α values ranging from 0.44 to 0.81 were acceptable because α is a function of the number of items in the composite, and it tends to be conservative. Due to this and that the current study used items adapted from past studies, it was decided that α values over 0.50 were adequate. Table III shows that the values range from 0.53 to 0.91. The values are better than Shah and Ward (2003), who reported from 0.51 to 0.81. Thus, construct validity and internal consistency are satisfactory.

Descriptive statistics and linear correlation between variables

The descriptive statistics depicted that means of LM practices ranged from 3.27 (small lot production) to 4.22 (quality at the source), with the standard deviation ranging between 0.46 and 0.99 (Table IV). This indicates that at a certain level, Indonesian manufacturers have been implementing LM. In terms of OP, the mean values ranged from 3.94 (productivity) to 4.18 (cost reduction), with standard deviation ranging between 0.46 and 0.54. This implies high OP. Similarly, the mean values of BP measures also indicated a high BP. The mean values ranged between 3.96 (profitability) and 4.15 (customer satisfaction), with the standard deviation ranging between 0.49 and 0.59.

Cohen (1988) reported the commonly used set of descriptors for the interpretation of correlation coefficients for social science as follows:

- absolute value of 0.00-0.09 equals no correlation;
- absolute value of 0.10-0.29 equals the low correlation;
- absolute value of 0.30-0.49 equals the medium correlation; and
- absolute value of 0.50-1.00 equals the high correlation.

In terms of LM, all the practices were positively associated with one another and significant at $\alpha = 0.01$, with the correlation coefficient (r) values ranging from 0.23 to 0.74. Although there were several r values at the level of low and medium, high correlation more frequently occurs among the LM practices. These positive relationships tend to support the previous consensus that LM practices must be implemented holistically (Feld, 2001; Goyal and Deshmukh, 1992; Mehra and Inman, 1992; White and Prybutok, 2001). Furthermore, the ultimate goal of LM is high performance. LM practices are positively correlated with all measures of OP at the 0.05 significance level, except for uniform production level, which is not significantly correlated with productivity. The r values ranged from 0.11 to 0.62. In short, the better the implementation of LM practices, the better the OP. This result strongly agrees with

Table IV.
Descriptive statistics and correlation matrix of the variables

	$\bar{x}$	SD	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17
1. R	3.87	0.66	1																
2. CL	4.21	0.46	0.42**	1															
3. PS	3.59	0.99	0.58**	0.35**	1														
4. SLP	3.27	0.99	0.52**	0.26**	0.74**	1													
5. QS	3.84	0.65	0.39**	0.50**	0.30**	0.29**	1												
6. UPL	4.06	0.64	0.29**	0.40**	0.23**	0.26**	0.46**	1											
7. QAS	4.22	0.52	0.42**	0.43**	0.46**	0.41**	0.33**	0.42**	1										
8. TPM	4.12	0.53	0.45**	0.41**	0.56**	0.43**	0.40**	0.27**	0.48**	1									
9. SN	3.54	0.71	0.51**	0.34**	0.66**	0.53**	0.32**	0.23**	0.47**	0.52**	1								
10. QUAL	3.96	0.52	0.47**	0.36**	0.52**	0.36**	0.30**	0.17*	0.49**	0.56**	0.62**	1							
11. INV	4.10	0.51	0.31**	0.31**	0.22**	0.24**	0.36**	0.25**	0.41**	0.31**	0.30**	0.37**	1						
12. DEL	3.98	0.54	0.30**	0.36**	0.39**	0.24**	0.32**	0.25**	0.38**	0.39**	0.26**	0.31**	0.16*	1					
13. PROD	3.94	0.51	0.37**	0.26**	0.35**	0.32**	0.26**	0.11	0.34**	0.43**	0.41**	0.49**	0.33**	0.30**	1				
14. COST	4.18	0.46	0.39**	0.35**	0.32**	0.26**	0.26**	0.30**	0.45**	0.33**	0.33**	0.47**	0.36**	0.25**	0.31**	1			
15. PROF	3.96	0.49	0.46**	0.31**	0.46**	0.45**	0.31**	0.26**	0.48**	0.48**	0.53**	0.59**	0.39**	0.23**	0.50**	0.45**	1		
16. SALE	3.99	0.59	0.30**	0.23**	0.25**	0.20**	0.25**	0.16*	0.29**	0.24**	0.40**	0.42**	0.29**	0.18*	0.24**	0.25**	0.46**	1	
17. CUST	4.15	0.51	0.38**	0.34**	0.40**	0.38**	0.24**	0.33**	0.46**	0.38**	0.44**	0.55**	0.32**	0.20*	0.29**	0.31**	0.54**	0.41**	1

Notes: Significant at: $^{*}p < 0.05$ and $^{**}p < 0.01$; FR – flexible resources, CL – cellular layouts, PS – pull system, SLP – small lot production, QS – quick setups, UPL – uniform production level, QAS – quality at the source, TPM – total productive maintenance, SN – supplier networks, QUAL – quality, INV – inventory minimization, DEL – delivery, PROD – productivity, COST – cost reduction, PROF – profitability, SALE – sales, CUST – customer satisfaction previous studies, such as by Abdel-Maksoud *et al.* (2005), Ahmad *et al.* (2003, 2004), Fullerton and Wempe (2009) and Shah and Ward (2003).

The r values indicating the relationships between LM practices and BP measures ranged from 0.16 to 0.48. All the r values are significant at $\alpha = 0.01$; except for one, the relationships between uniform production and sales ($r = 0.16$) was significant at $\alpha = 0.05$. Based on Table IV, the r values of the correlation between LM practices and BP measures are relatively lower than the correlation between LM practices and OP measures. It implies that the relationships between LM practices and OP measures are stronger. These results tend to support Bartezzaghi and Turco (1989) and Chang and Lee (1995), who stated that BP may be regarded as a higher level in the hierarchy objectives with OP taking the role of mediator variable and representing the lower level.

As a mediator variable, OP can take the role as an independent variable, thus the relationships among OP measures should be examined. Correlation coefficients informed that almost all the OP measures were significantly correlated with one another at $\alpha = 0.01$. The correlations are positive in the range from 0.163 to 0.488, which suggests that OP measures are interdependent. More important, all the measures of OP and BP were positively related with each other at $\alpha = 0.01$, except for two ($r = 0.18$ and $r = 0.20$), which were significant at $\alpha = 0.05$. The presumption that OP can drive broader BP was not violated. This finding strongly agrees with Fullerton and Wempe (2009), Said *et al.* (2003) and Van der Stede *et al.* (2006).

Relationships between LM practices and OP, and between LM practices and BP

Multiple regression analyses indicated the significant relationships between LM practices and OP measures (Table V). The adjusted R^2 values ranged between 0.19 and 0.47, while the adjusted R^2 value of quality is the highest of all with 47 percent variance explained by LM practices. The F-statistic, which tests H_0:$R^2 = 0$, was significant at $\alpha = 0.05$ for all models. Similarly, a significant relationship was also found between LM practices and each of BP measures (Table VI). Profitability has the highest adjusted R^2 value as 36 percent of variances was explained by variances in LM practices. Moreover, the F-statistic testing H_0:$R^2 = 0$ was significant for all BP measures at $\alpha = 0.05$. Although the analysis produced a significant F, some of the t-statistic testing H_0:$\beta_i = 0$ indicated an insignificant relationship at $\alpha = 0.05$. For example, the regression model of quality indicated that there were only three LM practices with a significant t, i.e. quality at the source ($p = 0.02$), TPM ($p = 0.01$), and supplier networks ($p = 0.00$). The regression model of inventory minimization showed a similar result, with one significant LM practice at $\alpha = 0.05$ level, i.e. quality at the source ($p = 0.01$). Somewhat similar, just a few LM practices contributed to BP. Sales was only supported by supplier networks ($p = 0.00$), and customer satisfaction was supported only by quality at the source ($p = 0.04$). Moreover, several regression coefficients have the theory contradictory sign, and one of them; the relationship between supplier networks and cost reduction which was significant at $\alpha = 0.10$. The coefficients take on the negative sign, while theory, common sense, and correlation coefficient would suggest a positive relationship. These findings suggest the possibility for multicollinearity (Grapentine, 1997; Hair *et al.*, 2010; Mueller, 1996; Wang, 1996).

Relationships between OP measures and BP measures

In these relationships, the highest adjusted R^2 value is 0.43 (Table VII). The F-statistic is significant at $\alpha = 0.05$ for all BP measures. However, the t-statistics show that only

Table V.
Multiple regression analyses between LM practices and OP measures

IV: LM practices	Unstd. β	SE	Std β	t	Sig.	Unstd. β	SE	Std β	t	Sig.	Unstd. β	SE	Std β	t	Sig.	Unstd. β	SE	Std β	t	Sig.	Unstd. β	SE	Std β	t	Sig.
			DV: QUAL					DV: INV					DV: DEL					DV: PROD					DV: COST		
Constant	1.07	0.36		2.96	0.00	1.63	0.44		3.69	0.00	1.52	0.45		3.38	0.00	1.84	0.43		4.29	0.00	1.82	0.38		4.75	0.00
FR	0.10	0.07	0.13	1.55	0.12	0.08	0.08	0.10	0.97	0.33	0.01	0.08	0.01	0.12	0.90	0.11	0.08	0.14	1.40	0.16	0.13	0.07	0.19	1.85	0.07
CL	0.04	0.09	0.04	0.46	0.65	0.07	0.11	0.06	0.60	0.55	0.15	0.11	0.13	1.33	0.19	0.01	0.11	0.01	0.13	0.90	0.10	0.09	0.11	1.11	0.27
PS	0.05	0.06	0.10	0.93	0.36	−0.09	0.07	−0.18	−1.34	0.18	0.19	0.07	0.35	2.67	0.01	−0.03	0.07	−0.07	−0.51	0.61	0.01	0.06	0.02	0.18	0.86
SLP	−0.07	0.05	−0.14	−1.44	0.15	0.04	0.06	0.07	0.64	0.53	−0.09	0.06	−0.17	−1.46	0.15	0.03	0.06	0.07	0.57	0.57	−0.03	0.05	−0.06	−0.55	0.58
QS	0.02	0.06	0.02	0.25	0.80	0.15	0.08	0.19	1.92	0.06	0.09	0.08	0.11	1.17	0.24	0.05	0.07	0.06	0.66	0.51	−0.02	0.07	−0.02	−0.22	0.83
UPL	−0.09	0.06	−0.11	−1.43	0.16	−0.01	0.07	−0.01	−0.09	0.93	0.03	0.08	0.03	0.34	0.74	−0.09	0.07	−0.12	−1.29	0.20	0.06	0.06	0.09	0.96	0.34
QAS	0.20	0.08	0.19	2.42	0.02	0.26	0.10	0.26	2.63	0.01	0.17	0.10	0.17	1.71	0.09	0.12	0.10	0.12	10.23	0.22	0.24	0.09	0.27	2.77	0.01
TPM	0.22	0.08	0.23	2.76	0.01	0.05	0.10	0.06	0.54	0.59	0.14	0.10	0.14	1.43	0.16	0.21	0.10	0.23	2.23	0.03	0.04	0.09	0.05	0.47	0.64
SN	0.26	0.06	0.35	4.04	0.00	0.07	0.08	0.10	0.91	0.36	−0.10	0.08	−0.13	−1.22	0.22	0.12	0.08	0.17	1.63	0.11	−0.14	0.08	−0.19	−10.73	0.09
R^2			0.51					0.24					0.28					0.26					0.28		
Adj R^2			0.47					0.19					0.23					0.21					0.23		
Sig. F			0.00					0.00					0.00					0.00					0.00		

Table VI. Multiple regression analyses between LM practices and BP measures

IV: LM practices	Unstd. β	SE	Std β DV: PROF	t	Sig.	Unstd. β	SE	Std β DV: SALE	t	Sig.	Unstd. β	SE	Std β DV: CUST	t	Sig.
Constant	1.42	0.37		3.82	0.00	1.97	0.53		3.76	0.00	1.56	0.42		3.72	0.00
FR	0.10	0.07	0.14	1.53	0.13	0.10	0.10	0.11	1.05	0.29	0.06	0.08	0.07	0.76	0.45
CL	−0.03	0.09	−0.03	−0.31	0.76	0.02	0.13	0.01	0.13	0.90	0.09	0.10	0.08	0.90	0.37
PS	−0.03	0.06	−0.07	−0.54	0.59	−0.05	0.08	−0.09	−0.61	0.54	−0.01	0.07	−0.02	−0.13	0.89
SLP	0.06	0.05	0.13	1.26	0.21	−0.03	0.07	−0.05	−0.42	0.68	0.05	0.06	0.10	0.87	0.39
QS	0.03	0.06	0.04	0.50	0.62	0.10	0.09	0.11	1.11	0.27	−0.05	0.07	−0.07	−0.75	0.46
UPL	0.00	0.06	0.00	0.02	0.99	−0.01	0.09	−0.02	−0.16	0.87	0.11	0.07	0.14	1.62	0.11
QAS	0.19	0.08	0.20	2.30	0.02	0.14	0.12	0.12	1.16	0.25	0.19	0.09	0.20	2.08	0.04
TPM	0.15	0.08	0.16	1.79	0.08	−0.02	0.12	−0.02	−0.20	0.84	0.07	0.09	0.07	0.73	0.47
SN	0.18	0.07	0.25	2.65	0.01	0.29	0.09	0.35	3.11	0.00	0.14	0.07	0.20	1.92	0.06
R^2			0.41					0.20					0.32		
Adj R^2			0.37					0.14					0.27		
Sig. F			0.00					0.00					0.00		

Notes: IV – independent variable; DV – dependent variable

Table VII.
Multiple regression analyses between OP measures and BP measures

IV: OP	Unstd. β	SE	Std β DV: PROF	t	Sig.	Unstd. β	SE	Std β DV: SALE	t	Sig.	Unstd. β	SE	Std β DV: CUST	t	Sig.
Constant	0.54	0.38		1.42	0.16	1.40	0.55		2.54	0.01	1.54	0.44		3.50	0.00
QUAL	0.33	0.08	0.36	4.36	0.00	0.39	0.11	0.34	3.44	0.00	0.47	0.09	0.48	5.28	0.00
INV	0.12	0.07	0.12	1.72	0.09	0.17	0.10	0.15	1.69	0.09	0.13	0.08	0.13	1.63	0.11
DEL	−0.01	0.06	−0.01	−0.16	0.87	0.04	0.09	0.04	0.46	0.65	0.02	0.07	0.02	0.24	0.81
PROD	0.23	0.07	0.24	3.17	0.00	0.01	0.11	0.01	0.08	0.94	−0.01	0.08	−0.01	−0.10	0.92
COST	0.18	0.08	0.17	2.21	0.03	0.04	0.12	0.03	0.32	0.75	0.04	0.09	0.03	0.40	0.69
R^2			0.45					0.20					0.32		
Adj. R^2			0.43					0.17					0.29		
Sig. F			0.00					0.00					0.00		

a few OP measures contributed to each of BP measures. Profitability was supported by quality ($p = 0.00$), productivity ($p = 0.00$), and cost reduction ($p = 0.03$) at $\alpha = 0.05$, while sales and customer satisfaction were just supported by quality ($p = 0.00$). In addition, the β values of the relationship between delivery and profitability take on the negative sign, while theory, common sense, and correlation coefficient suggested a positive relationship. Once again, these suggested that multicollinearity might be present in the regression models.

Reducing the effects of multicollinearity

One of the basic assumptions of multiple regression analyses is that the independent variables are not linearly related. Multicollinearity refers to high linear correlation between the independent variables (Hair *et al.*, 2010). Hair *et al.* (2010) stated that as multicollinearity increases, it complicated the interpretation of relationship because it is more difficult to ascertain the effect of any single variable owing to other inter-relationships. More detail, it can affect the following conditions (Wang, 1996):

- the estimated standard errors in the coefficient will be large and produce small values of the *t*-statistic;
- the estimated coefficients may become insignificant or have wrong signs (positive or negative); and
- difficult to assess the relative importance of independent variables, because of the large estimated standard errors.

Referring the tolerance and variance inflation factor (VIF), some literatures such as by Lim *et al.* (2006), Miles and Shevlin (2001) and Quresh *et al.* (2010) suggested that the tolerance value of each independent variable of less than 0.40 and the VIF value of greater than 2.50 are enough to indicate serious multicollinearity. In this study, multicollinearity was present in the regression model with LM practices as independent variables, especially for pull system (tolerance $= 0.32$, VIF $= 3.13$) and small lots production (tolerance $= 0.43$, VIF $= 2.32$) were relatively close to the suggested threshold values. However, Liao (2010) postulated that examining VIF and tolerance alone to ensure the multicollinearity is inadequate. It should be examined with the help of condition indices, eigenvalue, and variance proportion. If the eigenvalue becomes close to 0, then there is a serious multicollinearity. Lani (2009) explained that if the condition index is greater than 15 and less than 30, then basically multicollinearity is a concern, and if the condition index is greater than 30, then it is a very serious concern for the researcher performing the study. In addition, variance proportion values larger than 0.30 are considered problematic. Multicollinearity diagnostics indicated that there were eight dimensions of LM practices with the condition index greater than 15. Surprisingly, three indices were greater than 30. For example, condition index of one dimension (25.86) is highly associated with pull system (variance proportions $= 0.50$) and supplier networks (variance proportions $= 0.49$), then the β weights for pull system and supplier networks are probably not well estimated (Lani, 2009; Liao, 2010; Pedhazur, 1997). In addition, the eigenvalue for several dimensions were very close to 0, meaning that, there was a serious multicollinearity. Furthermore, five dimensions of OP had the condition index greater than 15 and one index was greater than 30. Additionally, the eigenvalue for some dimensions were very close to 0. Condition index of one dimension of OP (25.47) was highly associated with quality (variance proportions $= 0.30$)

and productivity (variance proportions = 0.39), then the β weight for quality and productivity are probably not well estimated. Hence, a serious multicollinearity problem does exist in all the regression analyses conducted.

In reducing the multicollinearity effect, simple regression analysis on the first principal component score of independent variable, as suggested by Adnan *et al.* (2006), De Toni and Tonchia (2001), Hair *et al.* (2010) and Timm (2002), was applied. Principal component analysis (PCA) is aimed to summarize most of the variance in a minimum number of factors for prediction purposes (De Toni and Tonchia, 2001; Hair *et al.*, 2010). Dunteman (1989) explained, PCA linearly transforms an original set of variables into a substantially smaller set of uncorrelated variables representing most of the variance in the set of variables. As suggested by Agus (2000) and Lim (2003), simple regression was applied between the dependent variables with the first principal component score of independent variables by using the model: $Y = \alpha + \beta_1 X_1$. *F*-test was used to point out whether the regression models significantly explained variances of dependent variables.

Relationships between LM practices (collectively) and OP measures, and between LM practices (collectively) and BP measures

PCA produced the first principal component or linear combination of LM practices, which were: 0.35 (flexible resources) + 0.31 (cellular layouts) +0.38 (pull system) +0.35 (small lot production) +0.29 (quick setups) +0.25 (uniform production level) +0.34 (quality at the source) +0.35 (TPM) +0.36 (supplier networks), which explain 48.70 percent of the total variance in LM practices. This value was better than the value obtained by Shah and Ward (2003), which was 46.15 percent. The simple regression indicates that the set of LM practices positively affects all the OP measures (Table VIII).

Model		Unstd. β	SE	Std β	t	Sig.	R^2
The impact of LM practices on OP measures							
DV: QUAL	Constant	1.49	0.27		5.46	0.00	0.38*
	Regression	0.22	0.02	0.62	9.13	0.00	
DV: INV	Constant	2.51	0.31		8.00	0.00	0.16*
	Regression	0.14	0.03	0.40	5.15	0.00	
DV: DEL	Constant	2.14	0.32		6.71	0.00	0.20*
	Regression	0.16	0.03	0.45	5.81	0.00	
DV: PROD	Constant	2.16	0.30		7.20	0.00	0.21*
	Regression	0.16	0.03	0.46	5.99	0.00	
DV: COST	Constant	2.58	0.27		9.56	0.00	0.21*
	Regression	0.14	0.02	0.46	5.97	0.00	
The impact of LM practices on BP measures							
DV: PROF	Constant	1.69	0.26		6.50	0.00	0.36*
	Regression	0.20	0.02	0.60	8.82	0.00	
DV: SALE	Constant	2.33	0.37		6.34	0.00	0.13*
	Regression	0.15	0.03	0.36	4.53	0.00	
DV: CUST	Constant	2.07	0.29		7.15	0.00	0.28*
	Regression	0.18	0.03	0.53	7.22	0.00	

Notes: *F*-statistics are significant at: *0.05 level; IV is the first principal component score of LM practices obtained from PCA

Table VIII. Relationships between LM practices (collectively) and OP measures and between LM practices (collectively) and BP measures

Hence, H_{1a}-H_{1e} are not rejected. The R^2 values range from 16.00 to 38.00 percent. Furthermore, all the LM practices collectively contribute to the measures of BP with R^2 values ranging between 13.00 and 36.00 percent ($\alpha = 0.05$). Therefore, hypotheses H_{2a}-H_{2c} are not rejected.

Relationships between OP (collectively) and BP measures

The first principal component equation of OP resulted from PCA is as follows: 0.52 (quality) +0.42 (inventory minimization) +0.35 (delivery) +0.47 (productivity) +0.46 (cost reduction). This explains 47.40 percent of the total variance in OP. This value is much greater than 39.26 percent as was obtained by Shah and Ward (2003). Table IX suggests that OP measures collectively contribute significantly to each of the BP measures at $\alpha = 0.05$ with R^2 values ranging from 17.00 to 42.00 percent. Therefore, H_{3a}-H_{3c} are not rejected.

Role of OP in mediating the relationship between LM practices and BP

The indirect relationship was evaluated by placing OP as a mediator variable. The first principal component scores of LM practices and OP indicate that the weights were about equal implying that each practice and OP measure is about equally represented in the linear combination. Hence, one scale is then constructed for LM and OP based on the first principal score resulted from PCA. In addition, linear combination of BP obtained from PCA is as follows: 0.60 (profitability) +0.55 (sales) +0.58 (customer satisfaction), explaining 64.70 percent of the total variance in BP.

Following the four steps for mediation test provided by Baron and Kenny (1986), the full results of mediation test are presented in Table X and Figure 1. The results indicated that LM practices directly affect BP with 37.40 percent variance explained. LM practices affect OP with 48.40 percent variance of OP explained. Furthermore, both LM practices and OP positively affect BP by explaining 45.70 percent variance of BP. When regressing LM practices with BP, the results significantly fulfill step 1; LM practices affect BP significantly ($\beta_c = 0.61, p < 0.05$). In addition, when regressing LM practices with OP, the results fulfill step 2; LM practices significantly affect OP ($\beta_a = 0.70, p < 0.05$). In the step 3, LM practices and OP are regressed together on BP. The results indicate that the β value had a decreasing effect in the presence of OP ($\beta_h = 0.32$, $p < 0.05$). It can be seen that the impact of LM practices on BP was significant in both steps 1 and 3. Although the β value of the relationship between LM

Model		Unstd. β	SE	Std β	t	Sig.	R^2
DV: PROF	Constant	0.31	0.37		0.85	0.40	0.42*
	Regression	0.41	0.04	0.65	9.95	0.00	
DV: SALE	Constant	1.17	0.53		2.18	0.03	0.17*
	Regression	0.32	0.06	0.41	5.30	0.00	
DV: CUST	Constant	1.21	0.44		2.76	0.01	0.25*
	Regression	0.33	0.05	0.50	6.73	0.00	

Notes: *F*-statistics are significant at: *0.05 level; IV is the first principal component score of OP obtained from PCA

Table IX. Relationships between OP (collectively) and BP measures

Table X. Results of mediation test

Independent variable	OP	Dependent variable Standardized β BP (without OP)	BP (with OP)
LM practices	0.70*	0.61*	0.32*
R^2	0.48	0.37	0.47
Adjusted R^2	0.48	0.37	0.46
R^2 change	0.48	0.37	0.47
F change	128.29*	82.01*	59.17*

Note: Significant at: $^*p < 0.05$

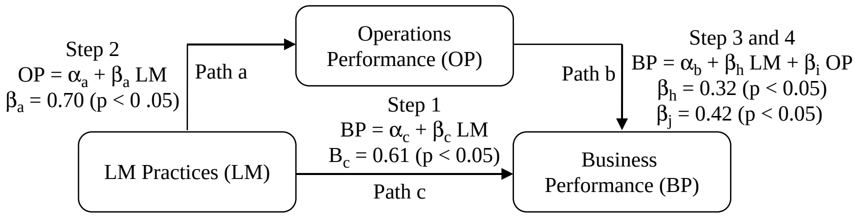

Figure 1. Results of mediation test

practices and BP in step 3 is decreased ($\beta_c = 0.61$ decreased to $\beta_h = 0.32$), the value is still significant. Therefore, OP partially mediates the relationship between LM practices and BP.

The indirect impact of LM practices on BP is formed by multiplying two coefficients together, the partial regression coefficient for OP predicting BP (β_j) and the coefficient for LM practices predicting OP (β_a). Based on Table XI, the direct effect of LM practices on OP was high (0.70). Similarly, direct effects of OP on BP and LM practices on BP were also high (0.42 and 0.61, respectively). Moreover, indirect effect of LM practices on BP was 0.29, which was also statistically significant ($p < 0.05$). Hence, total effect of LM practices on BP was 0.90 (0.61 + 0.29). This value was considered to be very high. In short, when LM practices go up by one standard deviation, BP goes up by 0.90 standard deviations.

This empirical evidence suggested that higher levels of LM implementation would lead to higher levels of OP, and ultimately higher levels of BP. These findings also suggested that OP partially mediates the relationship between LM practices and BP. Thus, the last hypothesis (H_4) is partially supported.

Discussion

As shown in the data analyses, LM practices have been implemented by a number of Indonesian manufacturing companies. This result is comparable with several previous

Table XI. Effects between the variables

Path	Direct effect	Indirect effect	Total effect
LM practices → OP	0.70	–	0.70
OP → BP	0.42	–	0.42
LM practices → BP	0.61	0.29	0.90

studies conducted in the developing countries, such as in Indonesia (Nugroho, 2007), Malaysia (Wong *et al.*, 2009), Thailand (Rahman *et al.*, 2010), Ghana (Amoako-Gyampah and Gargeya, 2001) and Brazil (Forrester *et al.*, 2010). Based on these studies, manufacturers in the developing countries were highly committed to implement the LM concept. Even though previous studies stated that LM has been implemented in those developing countries, manufacturing companies in these countries need to give attention to implement LM practices from a holistic perspective. In other words, more effort is required to improve the level of LM implementation. Hence, the expected benefits after implementing LM practices could be achieved successfully.

The objective of this study has been achieved by applying several statistical analyses. Pearson correlation coefficients among LM practices suggest that LM should be implemented collectively and comprehensively because each practice is interdependent. This is theoretically appropriate; LM practices should not be implemented as individual practice or in a limited subset. Several authors, such as Feld (2001), Furlan *et al.* (2011a), Harber *et al.* (1990), Mehra and Inman (1992), Shah and Ward (2003, 2007) and White and Prybutok (2001), substantially supported this conclusion. The result of the PCA for the LM practices also supports this evidence. The first principal component score or linear combination of LM practices has positive loading and close resemblance values indicating that each component is about equally represented in the linear composite (Agus, 2000; Dunteman, 1989; Lim, 2003; Lim *et al.*, 2006). The first principal component can explain about 49 percent of the variance in LM practices. Supporting this result, Shah and Ward (2003, 2007) have postulated "bundles" of LM practices, because of high inter-correlation and inseparable characteristics among the practices. Moreover, Goyal and Deshmukh (1992), Harber *et al.* (1990), Mehra and Inman (1992), Shah and Ward (2007) and White and Prybutok (2001) provided empirical evidence that if LM practices are not implemented holistically and as a total system, the potential benefits will not be realized. Feld (2001) stated that the holistic approach of LM implementation is meant to imply the dependence and inter-connectivity among the practices. Each practice is necessary and critical for the success in LM deployment. He posited that no one practice can be standalone and be expected to achieve better performance than of all practices combined. When all practices work together, all would contribute significantly to a company's performance.

Relationships between LM practices and OP

The Pearson correlation analysis has provided empirical evidence that LM practices positively associate with all the OP measures. Simple regression analyses asserted that the first principal component of LM practices contributes significantly to all the measures of OP. Hence, a higher extent of LM implementation would lead to better OP. Fullerton and Wempe (2009), Lee and Paek (1995), Singh *et al.* (2010) and Taj and Morosan (2011) supported this result. Furthermore, Kannan and Tan (2005) confirmed that adoption of LM practices is a powerful approach in achieving the strategic goal at the operations level. Numerous authors have developed reasonable considerations. According to Abdel-Maksoud *et al.* (2005), Fullerton and McWatters (2002) and Rahman *et al.* (2010), LM practices are more frequently implemented at the shop-floor level and related to the production process. Bartezzaghi and Turco (1989) and Chang and Lee (1995) also claimed that OP was actually reflected by some internal properties of a production system, which is influenced by the manufacturing practices applied.

This current study has also supported Shah and Ward (2003). Their study led to the conclusion that the LM bundles significantly affect the collective measures of OP (i.e. scrap and rework costs, cycle time, first-passed quality yields, labor productivity, unit manufacturing cost, and customer lead time). More importantly, Rahman *et al.* (2010) conducted a study pertaining to the impact of LM practices on OP in Thailand. Surprisingly, although there are some differences in terms of measurement constructs, to some extent, this current study supports the result of Rahman *et al.* (2010). They reported that LM practices contributed significantly to better OP. Moreover, they found that LM practices are applicable to large, small and medium enterprises; OP of those companies can be driven substantially by LM implementation.

In addition, in the context of Malaysia, Wong *et al.* (2009) underlined that it is very clear that the companies involved in their study gained various benefits after practicing LM concepts. The benefits gained included lower cost, lower non-value added activities, lower inventory level, higher profit, higher quality, higher flexibility, better productivity, and better response time. To some extent, the study conducted by Wong *et al.* (2009) supported this current study that LM practices improved OP in terms of cost reduction, productivity, inventory minimization, and quality.

Relationships between LM practices and BP

The Pearson correlation analyses have provided evidence that LM practices positively associate with BP. Simple regression analysis leads to the conclusion that LM practices contribute significantly to all the measures of BP. Thus, the findings provide strong support that the higher the extent of LM implementation, the better the BP. This relationship has also been investigated by Chong *et al.* (2001), Claycomb *et al.* (1999), Forrester *et al.* (2010), Kannan and Tan (2005) and Yang *et al.* (2011). These researchers concluded somewhat similar results, i.e. LM positively affected BP.

Forrester *et al.* (2010), who conducted a study in the agricultural machinery sector in Brazil, supported the idea that LM practices significantly improve BP and competitiveness over competitors. In addition, this current study strongly agreed with the study of Wong *et al.* (2009), in terms of the impact of LM on profitability and customer satisfaction. According to Wong *et al.* (2009), LM practices improved profitability and response time of electrical and electronics industries in Malaysia. Hence, this current study has confirmed the previous studies by postulating that the LM concept is applicable not only in the developed countries but also in the developing countries. It provides a useful perspective for manufacturing companies throughout the world to corroborate and understand the potential benefits that LM practices can bring if adopted appropriately.

Relationships between OP and BP

The consensus regarding the effect of OP on BP is indisputable. The positive relationship among OP measures provided the evidence that all measures are interdependent. In other words, one measure influences some other measures. To aggregate the five OP measures, PCA has generated the first principal component equation of OP. The weights are closely resembled, so that all the OP measures are equally represented in the linear composite of OP. Equally important, the first principal component explained almost 50 percent of the total variance in OP measures. The results of simple regression analysis between the first principal component of OP and each of the BP measures supported the previous opinions suggested by Bartezzaghi and Turco (1989), Chang and Lee (1995), Durden *et al.* (1999), Fullerton and Wempe (2009), Said *et al.* (2003) and Van der Stede *et al.* (2006) that OP can drive broader BP measures; the better the OP, the better the BP.

Mediation role of OP

The last analysis provided evidence supporting the role of OP in mediating the relationship between LM practices and BP. The collective LM practices can directly improve OP and BP. Furthermore, LM practices can also improve BP indirectly with OP as a mediator variable. The mediation test suggested a significant percentage of variance (48 percent) of OP, which can be explained by LM practices. Furthermore, both LM practices and OP explain a significant percentage of variance (47 percent) of BP. According to Dale *et al.* (2000), in social science, percentage of variance explained by statistical models rarely exceeds 50 percent. Thus, this result is considered acceptable and can be used as consideration in decision making (Miles and Shevlin, 2001).

Fullerton and Wempe (2009) previously investigated the impact of LM practices on non-financial and financial performance. The study led to the conclusion that LM practices affect profitability directly and indirectly. To some extent, Fullerton and Wempe (2009) provided evidence supporting the finding of this current study; operations (non-financial) performance mediates the relationship between LM practices and BP, including profitability. Furthermore, LM practices enhance sales performance by increasing quality, reducing delivery time, and improving productivity (Yang *et al.*, 2011). Moreover, LM practices will improve customer satisfaction by increasing product and service quality, reducing delivery time, and increasing responsiveness (Chong *et al.*, 2001; Shah and Ward, 2003).

Implication of the study

The relationships posited in this study were empirically and theoretically supported. Specifically, this study has confirmed the linkage between LM practices, OP, and BP. The study adds to the knowledge and theories on how LM can affect organizational performance, not only at the operations level but also at the business level. This study provides the notion of integral and holistic practices of LM and a comprehensive approach for performance measurement. Furthermore, this study gives evidence to the importance of OP as a mediator variable in the LM-BP relationship. Moreover, by demonstrating the existence of direct and indirect effects of LM practices on BP; this study provides clear evidence that LM implementation is important to enhance companies' performance.

From the practical perspective, this study allows practitioners to gain deeper knowledge and understanding regarding the LM-performance relationships. In implementing LM, the practices should be holistically implemented because all the practices are interdependent and equally important. It is confirmed through this study; when LM practices are implemented integrally, higher performance can be achieved. In terms of performance measurement, the success of LM implementation to improve performance should be assessed not only at the business level but also at the operations level. The most important thing here is operations level rather than the business level because LM is commonly implemented in the shop-floor and directly influence operating conditions. BP may be regarded as the higher level with OP as a mediator.

The findings of the study imply that in order to survive world-wide competition, a company should be encouraged to implement LM because empirical evidence provides a strong support of their ability to enhance performance. The message for practitioners is that LM contributions toward OP and BP are tremendous. Hence, those companies implementing LM practices will benefit in the long term. In line with this argument, Rahman *et al.* (2010) postulated that LM practices are applicable not only for large companies but also SMEs. Shah and Ward (2003) highlighted; although LM practices are more commonly implemented in the discrete part industries, they are fairly frequently implemented in the process industries as well. In such a way, LM is prevalent in all types of industries.

It is hoped that this study will be a stepping stone for researchers in coping with the very limited empirical studies conducted in the developing countries like Indonesia. Lastly, the study can equip manufacturers throughout the world, not only in the developing countries but also in developed countries, with significant and necessary advantage to compete with both locally and globally.

Limitations and further research

This study is not without limitations. As in all survey-based research, an assumption in data collection was that the respondents had sufficient knowledge to answer the questionnaire, and that, respondents answered the items conscientiously and truthfully. The data used in this study represent self-reporting by mainly the middle or top management in production. To address the issue of common method variance (CMV), several items in the questionnaire were reverse worded questions (Podsakoff *et al.*, 2003), which were reverse scored, a value of 1 indicates "strongly agree" and a value of 5 indicates "strongly disagree". Thus, item-to-item priming effects leading to bias can be reduced. Statistically, following Podsakoff *et al.* (2003), Harman's single-factor test was applied by loading all the measures into an exploratory factor analysis to ensure that CMV may not have been introduced due to a single informant in collecting data. The results indicated that a single factor did not emerge from the factor analysis. Other than that, the correlation matrix showed that correlation coefficients among the measures were less than 0.74, while CMV is commonly presented due to the extremely high correlation (Bagozzi *et al.*, 1991). Hence, a substantial amount of CMV did not present in this study. Although the CMV is not a serious problem in this study, future studies can consider collecting multiple sources of data to ensure the more accurate results. It is hoped that this study would encourage or at least stimulate interest for forthcoming research in similar areas as more research in this subject is necessary.

References

Abdallah, A.B. and Matsui, Y. (2007), "JIT and TPM: their relationship and impact on JIT and competitive performances", paper presented at Conference of the International Decision Sciences Institute (DSI), Bangkok, Thailand, July 13, available at: http://as.nida.ac.th

Abdel-Maksoud, A., Dugdale, D. and Luther, R. (2005), "Non-financial performance measurement in manufacturing companies", *The British Accounting Review*, Vol. 37, pp. 261-297.

Adnan, N., Ahmad, M.H. and Adnan, R. (2006), "A comparative study on some methods for handling multicollinearity problems", *Department of Mathematics, UTM*, Vol. 22 No. 1, pp. 109-119.

Agus, A. (2000), "Reducing the effects of multicollinearity through principle component analysis: a study on TQM practices", *Malaysian Management Review*, Vol. 35 No. 1, pp. 43-50.

Ahmad, A., Mehra, S. and Pletcher, M. (2004), "The perceived impact of JIT implementation on firms' financial/growth performance", *Journal of Manufacturing Technology Management*, Vol. 15 No. 2, pp. 118-130.

Ahmad, S., Schroeder, R.G. and Sinha, K.K. (2003), "The role of infrastructure practices in the effectiveness of JIT practices: implications for plant competitiveness", *Journal of Engineering Technology Management*, Vol. 20, pp. 161-191.

Amoako-Gyampah, K. and Gargeya, V.B. (2001), "Just-in-time manufacturing in Ghana", *Industrial Management & Data Systems*, Vol. 101 No. 3, pp. 106-113.

Anatan, L. (2006), "Examining the moderating effect of technology on the manufacturing strategy and operational performance relationship", *Empirika*, Vol. 19 No. 1, pp. 1-6.

Bagozzi, R.P., Yi, Y. and Phillips, L.W. (1991), "Assessing construct validity in organizational research", *Administrative Science Quarterly*, Vol. 36 No. 3, pp. 421-458.

Baron, R.M. and Kenny, D.A. (1986), "The moderator-mediator variable distinction in social psychological research: conceptual, strategic, and statistical considerations", *Journal of Personality and Social Psychology*, Vol. 51 No. 6, pp. 1173-1182.

Bartezzaghi, E. and Turco, F. (1989), "The impact of the just-in-time approach on production system performance: an analytical framework", *International Journal of Operation & Production Management*, Vol. 9 No. 9, pp. 40-61.

Bhasin, S. (2008), "Lean and performance measurement", *Journal of Manufacturing Technology Management*, Vol. 19 No. 5, pp. 670-684.

BPS-Statistics Indonesia (2010), *Direktori Industri Pengolahan Indonesia 2010* (*Directory of Indonesian Manufacturing Industry 2010*), Badan Pusat Statistik, Jakarta.

BPS-Statistics Indonesia (2012a), *Data Strategis BPS* (*Strategic Data of BPS-Statistics Indonesia*), Badan Pusat Statistik, Jakarta.

BPS-Statistics Indonesia (2012b), *Perkembangan Beberapa Indikator Utama Sosial-Ekonomi Indonesia* (*Trends of Selected Socio-Economic Indicators of Indonesia*), Badan Pusat Statistik, Jakarta.

BPS-Statistics Indonesia (2012c), *Pertumbuhan Produksi Industri Manufaktur Triwulan IV Tahun 2011* (*The Growth of Manufacturing Industrial Production in the Quarter IV Year 2011*), Berita Resmi Statistik, Badan Pusat Statistik, Jakarta.

Callen, J.L., Fader, C. and Krinsky, I. (2000), "Just-in-time: a cross-sectional plant analysis", *International Journal of Production Economics*, No. 63, pp. 277-301.

Chang, D. and Lee, S.M. (1995), "Impact of JIT on organizational performance of US firms", *International Journal of Production Research*, Vol. 33 No. 11, pp. 3053-3068.

Chong, H., White, R.E. and Prybutok, V. (2001), "Relationship among organizational support, JIT implementation, and performance", *Industrial Management & Data Systems*, Vol. 101 No. 6, pp. 273-280.

CIA (2012), *The World Factbook*, available at: www.cia.gov/library/publications/the-world-factbook/geos/id.html (accessed September 24, 2012).

Claycomb, C., Dröge, C. and Germain, R. (1999), "Total system JIT outcomes: inventory, organization and financial effects", *International Journal of Physical Distribution & Logistics Management*, Vol. 29 No. 10, pp. 612-630.

Coakes, S.J. and Steed, L. (2007), *SPSS 14.0 for Windows: Analysis Without Anguish*, Wiley, Richmond.

Cohen, J. (1988), *Statistical Power Analysis for the Behavioral Sciences*, Lawrence Erlbaum, Mahwah, NJ.

Cooper, D.R. and Schindler, P.S. (2003), *Business Research Methods*, McGraw-Hill/Irwin, New York, NY.

Cua, K.O., McKone, K.E. and Schroeder, R.G. (2001), "Relationships between implementation of TQM, JIT, and TPM and manufacturing performance", *Journal of Operations Management*, Vol. 19, pp. 675-694.

Dale, A., Fieldhouse, E. and Holdsworth, C. (2000), *Analyzing Census Microdata*, Oxford University Press, New York, NY.

Data and Information Center of the Indonesian Ministry of Industry (2008), *Direktori perusahaan* (*koleksi Pusat Data & Informasi, DEPPERINDAG*) (*Companies Directory* (*Collection of Data and Information Center, DEPPERINDAG*)), Jakarta, available at: www.depperin.go.id/ Ind/Bus.asp?m2&sm2&ssm1 (accessed November 26, 2008).

De Toni, A. and Tonchia, S. (2001), "Performance measurement systems models, characteristics and measures", *International Journal of Operations & Production Management*, Vol. 21 Nos 1/2, pp. 46-70.

Dunteman, G.H. (1989), *Principal Component Analysis*, Sage, Beverly Hills, CA.

Durden, C.H., Hassel, L.G. and Upton, D.R. (1999), "Cost accounting and performance measurement in a just-in-time production environment", *Asia Pacific Journal of Management*, Vol. 16 No. 1, pp. 111-125.

Feld, W.M. (2001), *Lean Manufacturing: Tools, Techniques, and How to Use Them*, St Lucie Press, Boca Raton, FL.

Flynn, B.B., Sakakibara, S. and Schroeder, R.G. (1995), "Relationship between JIT and TQM: practices and performance", *Academy of Management Journal*, Vol. 38 No. 5, pp. 1325-1360.

Forrester, P.L., Shimizu, U.K., Soriano-Meier, H., Garza-Reyes, J.A. and Basso, L.F.C. (2010), "Lean production, market share and value creation in the agricultural machinery sector in Brazil", *Journal of Manufacturing Technology Management Accounting*, Vol. 21 No. 7, pp. 853-871.

Fullerton, R.R. and McWatters, C.S. (2001), "The production performance benefits from JIT implementation", *Journal of Operations Management*, Vol. 19, pp. 81-96.

Fullerton, R.R. and McWatters, C.S. (2002), "The role of performance measures and incentive systems in relation to the degree of JIT implementation", *Accounting, Organizations and Society*, Vol. 27, pp. 711-735.

Fullerton, R.R. and Wempe, W.F. (2009), "Lean manufacturing, non-financial performance measures, and financial performance", *International Journal of Operations & Production Management*, Vol. 29 No. 3, pp. 214-240.

Fullerton, R.R., McWatters, C.S. and Fawson, C. (2003), "An examination of the relationships between JIT and financial performance", *Journal of Operations Management*, Vol. 21, pp. 383-404.

Furlan, A., Dal Pont, G. and Vinelli, A. (2011a), "On the complementarity between internal and external just-in-tirne bundles to build and sustain high performance manufacturing", *International Journal of Production Economics*, Vol. 133 No. 2, pp. 489-495.

Furlan, A., Vinelli, A. and Dal Pont, G. (2011b), "Complementarity and lean manufacturing bundles: an empirical analysis", *International Journal of Operations & Production Management*, Vol. 31 No. 8, pp. 835-850.

George, G. and Mallery, P. (2003), *SPSS for Windows Step by Step: A Simple Guide and Reference, 11.0 Update*, Allyn & Bacon, Boston, MA.

Goyal, S.K. and Deshmukh, S.G. (1992), "A critique of the literature on just-in-time manufacturing", *International Journal of Operations & Production Management*, Vol. 12 No. 1, pp. 18-28.

Grapentine, T. (1997), "Managing multicollinearity", *Marketing Research*, Vol. 9 No. 3, pp. 10-21.

Green, K.W. and Inman, R.A. (2007), "The impact of JIT-II-selling on organizational performance", *Industrial Management & Data Systems*, Vol. 107 No. 7, pp. 1018-1035.

Hair, J.F., Black, W.C., Babin, B.J. and Anderson, R.E. (2010), *Multivariate Data Analysis: A Global Perspective*, Pearson Education, Upper Saddle River, NJ.

Hallgren, M. and Olhager, J. (2009), "Lean and agile manufacturing: external and internal drivers and performance outcomes", *International Journal of Operations & Production Management*, Vol. 29 No. 10, pp. 976-999.

Harber, D., Samson, D.A., Sohal, A.S. and Wirth, A. (1990), "Just-in-time: the issue of implementation", *Journal of Operations & Production Management*, Vol. 10 No. 1, pp. 21-30.

Heizer, J. and Render, B. (2008), *Operations Management*, Pearson Prentice-Hall, Upper Saddle River, NJ.

Jayaram, J., Vickery, S. and Dröge, C. (2008), "Relationship building, lean strategy and firm performance: an exploratory study in the automotive supplier industry", *International Journal of Production Research*, Vol. 46 No. 20, pp. 5633-5649.

Jeyaraman, K. and Leam, K.T. (2010), "A conceptual framework for critical success factors of lean six sigma: implementation on the performance of electronic manufacturing service industry", *International Journal of Lean Six Sigma*, Vol. 1 No. 3, pp. 191-215.

Jones, A.P. and James, L.R. (1979), "Psychological climate: dimensions and relationships of individual and aggregated work environment perceptions", *Organizational Behavior and Human Performance*, Vol. 23, pp. 201-250.

Kaiser, H.F. (1974), "An index of factorial simplicity", *Psychometrika*, Vol. 39 No. 1, pp. 31-36.

Kannan, V.R. and Tan, K.C. (2005), "Just in time, total quality management, and supply chain management: understanding their linkages and impact on business performance", *The International Journal of Management Science*, Vol. 33, pp. 153-162.

Krafcik, J.F. (1988), "Triumph of the lean production system", *Sloan Management Review*, Vol. 30 No. 1, pp. 41-52.

Krafcik, J.F. (1989), "A new diet for US manufacturing", *Technology Review*, Vol. 92 No. 1, pp. 28-36.

Lani, J.A. (2009), "Multicollinearity", Ohio, available at: www.statisticssolutions.com/methods-chapter/data-entry-cleaning-and-coding/multicollinearity/ (accessed January 12, 2011).

Lee, S.M. and Paek, J.H. (1995), "An enlarge JIT programme: its impact on JIT implementation and performance of the production system", *Production Planning & Control*, Vol. 6 No. 2, pp. 185-191.

Liao, D. (2010), *Collinearity Diagnostics for Complex Survey Data*, University of Maryland, College Park, MD.

Lim, K.T. (2003), "Impak prinsip-prinsip TQM ke atas kepuasan hati pelajar dan pencapaian akademik pelajar: satu kajian empirikal dalam sektor pendidikan tinggi awam di Malaysia" ("The impact of TQM principles on student's satidfaction and student's academic achievement: a study on public universities in Malaysia"), doctoral degree thesis, Universiti Utara Malaysia, Kuala Lumpur.

Lim, K.T., Yusoff, R.Z., Ahmad, Z.A. and Tang, S.M. (2006), "Perhubungan antara prinsip-prinsip TQM dengan prestasi organisasi pendidikan: satu kajian empirikal dalam sektor pendidikan tinggi awam di Malaysia" ("The relationship between TQM principles and educational achievement: an empirical study on higher education sector in Malaysia"), *International Journal of Management Studies*, Vol. 13, special issue, pp. 143-161.

Margono, H. and Sharma, S.C. (2006), "Efficiency and productivity analyses of Indonesian manufacturing industries", *Journal of Asian Economics*, Vol. 17, pp. 979-995.

Matsui, Y. (2007), "An empirical analysis of just-in-time production in Japanese manufacturing companies", *International Journal of Production Economics*, Vol. 108, pp. 153-164.

Mehra, S. and Inman, R.A. (1992), "Determining the critical elements of just-in-time implementation", *Decision Science*, Vol. 23 No. 1, pp. 160-174.

Miles, J. and Shevlin, M. (2001), *Applying Regression and Correlation: A Guide for Students and Researchers*, Sage, London.

Mueller, R.O. (1996), *Basic Principles Structural Equation Modelling: An Introduction to LISREL and EQS*, Springer, New York, NY.

Neely, A., Gregory, M. and Platts, K. (2005), "Performance measurement system design, a literature review and research agenda", *International Journal of Operations & Production Management*, Vol. 25 No. 12.

Neely, A., Mills, J., Platts, K., Richards, H., Gregory, M., Bourne, M. and Kennerley, M. (2000), "Performance measurement system design: developing and testing a process-based approach", *International Journal of Operations & Production Management*, Vol. 20 No. 10, pp. 1119-1145.

Nugroho, P.I. (2007), "The effects of performance measures and incentive systems on the degree of JIT implementation" ("An empirical study at manufacturing firms in Central Java"), Master degree, Diponegoro University, Semarang.

Olsen, E.O. (2004), "Lean manufacturing management: the relationship between practice and firm level financial performance", dissertation, The Ohio State University, Columbus, OH.

Papadopoulou, T.C. and Özbayrak, M. (2005), "Leanness: experiences from the journey to date", *General Review*, Vol. 16 No. 7, pp. 784-807.

Pedhazur, E.J. (1997), *Multiple Regression in Behavioral Research: Explanation and Prediction*, Harcourt College, Orlando, FL.

Podsakoff, P.M., MacKenzie, S.B., Lee, J.-Y. and Podsakoff, N.P. (2003), "Common method biases in behavioral research: a critical review of the literature and recommended remedies", *Journal of Applied Psychology*, Vol. 88 No. 5, pp. 879-903.

Quresh, T.M., Akbar, A., Khan, M.A., Sheikh, R.A. and Hijazi, S.T. (2010), "Do human resource management practices have an impact on financial performance of banks?", *African Journal of Business Management*, Vol. 4 No. 7, pp. 1281-1288.

Rahman, S., Laosirihongthong, T. and Sohal, A.S. (2010), "Impact of lean strategy on operational performance: a study of Thai manufacturing companies", *Journal of Manufacturing Technology Management*, Vol. 21 No. 7, pp. 839-852.

Ramarapu, N.K., Mehra, S. and Frolick, M.N. (1995), "A comparative analysis and review of JIT 'implementation' research", *International Journal of Operations & Production Management*, Vol. 15 No. 1, pp. 38-49.

Said, A.A., HassabElnaby, H.R. and Wie, B. (2003), "An empirical investigation of the performance consequences of nonfinancial measures", *Journal of Management Accounting Research*, Vol. 15, pp. 193-223.

Sakakibara, S., Flynn, B.B., Schroeder, R.G. and Morris, W.T. (1997), "The impact of just-in-time manufacturing and its infrastructure on manufacturing performance", *Management Science*, Vol. 43 No. 9, pp. 1246-1257.

Schonberger, R.J. (2007), "Japanese production management: an evolution-with mixed success", *Journal of Operations Management*, Vol. 25, pp. 403-419.

Shah, R. and Ward, P.T. (2003), "Lean manufacturing: context, practice bundles, and performance", *Journal of Operations Management*, Vol. 21, pp. 129-149.

Shah, R. and Ward, P.T. (2007), “Defining and developing measures of lean production”, *Journal of Operations Management*, Vol. 25, pp. 785-805.

Shingo, S. (1981), *Study of the Toyota Production Systems*, Japan Management Association, Tokyo.

Singh, B., Garg, S.K., Sharma, S.K. and Grewal, C. (2010), “Lean implementation and its benefits to production industry”, *International Journal of Lean Six Sigma*, Vol. 1 No. 2, pp. 157-168.

Taj, S. (2008), “Lean manufacturing performance in China: assessment of 65 manufacturing plants”, *Journal of Manufacturing Technology Management Accounting*, Vol. 19 No. 2, pp. 217-234.

Taj, S. and Morosan, C. (2011), “The impact of lean operations on the Chinese manufacturing performance”, *Journal of Manufacturing Technology Management*, Vol. 22 No. 2, pp. 223-240.

Timm, N.H. (2002), *Applied Multivariate Analysis*, Springer, New York, NY.

Van der Stede, W.A., Chow, C.W. and Lin, T.W. (2006), “Strategy, choice of performance measures, and performance”, *Behavioral Research in Accounting*, Vol. 18, pp. 185-205.

Wang, G.C.S. (1996), “How to handle multicollinearity in regression modeling”, *The Journal of Business Forecasting Methods & Systems*, Vol. 15 No. 1, pp. 23-27.

White, R.E. and Prybutok, V. (2001), “The relationship between JIT practices and type of production system”, *The International Journal of Management Science*, Vol. 29, pp. 113-124.

Wong, Y.C., Wong, K.Y. and Ali, A. (2009), “A study on lean manufacturing implementation in the malaysian electrical and electronics industry”, *European Journal of Scientific Research*, Vol. 38 No. 4, pp. 521-535.

Yang, M.G., Hong, P. and Modi, S.B. (2011), “Impact of lean manufacturing and environmental management on business performance: an empirical study of manufacturing firms”, *International Journal of Production Economics*, Vol. 129, pp. 251-261.

Zailani, S., Asrofah, T. and Fernando, Y. (2008), “Factors influencing the effectiveness of benchmarking practice among manufacturing companies in Indonesia”, paper presented at 8th Global Conference on Business & Economics, Florence, Italy, October 18-19.

Appendix 1. Measurement items of LM practices

Flexible resources

FR1 Many problems have been solved through small-group sessions.

FR2 One operator handles several different tasks in a workstation.

FR3 Our employees undergo training to perform multiple tasks in the production process[b].

FR4 Our plant operates the machines that can perform a number of operations.

FR5 When a machine is stopped, our workers are idle[a].

FR6 When one machine is stopped, we can use a different type of machine to perform the same tasks.

Cellular layouts

CL1 We group dissimilar machines into work centers (called cells) based on product families (product families can be determined based on shapes/design similarity, processing requirement similarity, or routing requirement similarity)[b].

CL2 Our processes are located close together, so that material handling and part storage are minimized.

CL3 The design of the cells/workstations is easily changed depending on the product being manufactured[b].

CL4 We have laid out the shop-floor so that processes and machines are in close proximity to each other.

CL5 The cells/work centers/machines are arranged in relation to each other so that material movement, material handling, and transit times are minimized.

CL6 Our processes physically move closer together and transportation between stations runs simply.

Pull system

PS1 We use a production system in which items are produced only when called for by the users of those items.

PS2 Production is performed based on the shipment of goods from previous workstation[a, b].

PS3 We use a production system in which items are produced only in necessary quantities, no more and no less.

PS4 We use kanban to authorize the production or withdrawal the goods.

PS5 To authorize the order, we use a supplier kanban that rotates between factory and suppliers.

PS6 Production at a workstation is performed based on the current demand of the subsequent workstation.

Small lot production

SLP1 We emphasize producing large quantity of items together[a].

SLP2 We are aggressively working to lower lot sizes in our plant.

SLP3 We emphasize small lot sizes to increase manufacturing flexibility.

SLP4 We reduce the average level of inventory by producing in more frequent but smaller lot size.

SLP5 We operate large lot sizes in our plant as an effort to maximize machine utilization.

SLP6 We tend to have large lot-sizes in our master schedule[a].

Quick setups

QS1 Our shop-floor employees perform their own setups to reduce the time required.

QS2 Our plant emphasizes the importance of good housekeeping, with tools in their normal storage location[b].

QS3 We are aggressively working to lower machine setup times in our plant[b].

QS4 We have converted most of our machine setups to external setups that can be performed while the machine is running.

QS5 We have low machine setup times in our plant.

Uniform production level

UPL1 We make every model of product every day to anticipate customer demand variability.

UPL2 Daily production is arranged in the same ratio as monthly demand[b].

UPL3 We usually meet the production schedule each day.

UPL4 We emphasize to equate workloads in each production process[b].

UPL5 In our master schedule, we produce more than one product model from the hour-to-the hour and day-to-day basis.

UPL6 Our company always maintains some quantity of a product to respond to the variation in customer demand.

Quality at the source

QAS1 Statistical process control is used to identify and prevent quality problems by correcting the process before it starts producing defects.

QAS2 We implement the visual control system as a procedure or mechanism that makes the problems visible.

QAS3 Our shop-floor employees are authorized to stop production for quality problems[b].

QAS4 Statistical techniques are used to identify and reduce process variances.

QAS5 Charts showing quality problems are used on the shop-floor.

QAS6 When quality problems are detected, they can be traced to their source and remedied without reworking too many units.

Total productive maintenance

TPM1 Our equipment is in a high state of readiness for production at all times.

TPM2 Records of routine maintenance are kept[b].

TPM3 We scrupulously clean equipment, tools, workspaces, and machines to make unusual occurrences more noticeable.

TPM4 We dedicate a periodic inspection and maintenance system to keep machines in operation.

TPM5 We dedicate a system of daily maintenance, periodic inspection, and preventive repairs designed to reduce the probability of machine breakdown.

Supplier networks

SN1 We regularly solve problems jointly with our suppliers.

SN2 We emphasize to work together with suppliers in a close relationship for mutual benefits.

SN3 Our suppliers deliver materials/products to us just as it is needed (on a just-in-time basis).

SN4 Our suppliers maintain a warehouse near to our plant.

SN5 Engineering and quality management assistance are commonly provided to the suppliers.

SN6 We can depend upon on-time delivery from our suppliers.

SN7 We have long-term agreements with our suppliers.

SN8 We strive to establish long-term relationships with suppliers.

Note: [a]reverse worded items; [b]items were deleted because of low factor loadings obtained from factor analysis.

Appendix 2. Measurement items of OP (during the past three years)

Quality

QUAL1 Products that do not meet the quality specifications have reduced[a].

QUAL2 We have superior quality of products compared to our competitors'.

QUAL3 Activities in fixing defective products to conform to the quality specifications (reworks) have reduced.

QUAL4 Poor quality products that must be discarded (scraps) have reduced[a].

QUAL5 The percentage of product that passes final inspection the first time (first-pass quality yield) has increased.

QUAL6 We have superior quality of service compared to our competitors'.

Inventory minimization

INV1 Inventory turnover has increased[a].

INV2 The finished goods inventory level has reduced.

INV3 The raw material inventory level has reduced.

INV4 The work in process inventory level has reduced.

Delivery

DEL1 Our ability to deliver products to the market quickly has increased.

DEL2 Our ability to deliver products to the customer as promised has increased.

DEL3 We are capable of delivering products to the market faster than our competitors.

Productivity

PROD1 Labor productivity has increased.

PROD2 Machine productivity has increased.

PROD3 Our labor productivity is higher than our competitors.

PROD4 Our machine productivity is higher than our competitors.

Cost reduction

COST1 Unit manufacturing cost has reduced.

COST2 Our unit manufacturing cost is lower than our competitors[a].

COST3 Internal failure costs (i.e., defect, scrap, rework, process failure, price reduction, and downtime) have reduced.

COST4 External failure costs (i.e., complaints, returns, warranty claims, liability, and lost sales) have reduced.

Note: [a]Items were deleted because of low factor loadings obtained from factor analysis.

Appendix 3. Measurement items of BP (during the past three years)

Profitability

PROF1 Profit margin has increased.

PROF2 Our return on investment reflects sound investments.

PROF3 Our profitability has exceeded our competitors.

PROF4 Our revenue growth rate has exceeded our competitors.

Sales

SALE1 Market share has increased.

SALE2 Our sales (in dollars) growth has been outstanding.

SALE3 Our market share growth has exceeded our competitors.

Customer satisfaction

CUST1 Customers are satisfied with the overall quality of our products.

CUST2 Customers are satisfied with our company's delivery lead time.

CUST3 Customers are satisfied with our company's response to sales enquiries.

CUST4 Customers are satisfied with our products' competitive prices.

About the authors

Gusman Nawanir is a PhD candidate in School of Technology Management and Logistics at the Universiti Utara Malaysia. His bachelor degree was in industrial engineering department at the Andalas University. His Master of science was completed in operations management program (by full research) at the College of Business of Universiti Utara Malaysia. His main research interests include lean manufacturing, inventory management, and performance measurement. He has published his papers in several conferences, and one was awarded as best paper at the International Conference of Technology and Operations Management, July 5-7, 2010, Langkawi Island, Kedah Darul Aman, Malaysia. Gusman Nawanir is the corresponding author and can be contacted at: gsm1410@gmail.com

Dr Lim Kong Teong is an Associate Professor of operations management and former Head of Department of Operations Management at Universiti Utara Malaysia. He received his BSc in applied statistics in 1991 and MSc in mathematics (applied statistics) in 1993 from Universiti

Sains Malaysia, and PhD in quality management in 2003 from Universiti Utara Malaysia. He has been at UUM since 1994. His primary research and publication areas are quality improvement and management, production and operations management, lean operations, and knowledge management. His teaching interests are in the areas of quality management, statistical process control and improvement, production management, and statistical data analysis. He is a member of the Editorial Board for the *Journal of Technology and Operations Management*.

Dr Siti Norezam Othman is a Senior Lecturer at the College of Business, Universiti Utara Malaysia. She attained her Doctor of Engineering in Engineering Management from Universiti Teknologi Malaysia in 2007. Her research interests cover topics in supplier buyer relationships, technology transfer, technology assessment, and operations management. In relation to her research interest, she has supervised PhDs and Master students. She is also a Managing Editor for *Journal of Technology and Operations Management* as well as referee for journal and proceeding articles and was nominated as internal examiner for postgraduate thesis. She has authored a number of academic papers for journals, international conferences, and module. To strengthen her research interest, she affiliates with International Association of Management of Technology.