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Assessing Convergent And Discriminant Validity Of Lean Production Constructs

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Abstract

The primary purpose of this study is to empirically assess the convergent and disriminant validity of lean production constructs. Grounded by the Socio-technical System Theory (STS), this study formulates and examines a conceptual model of lean production practices. The study segregates lean production practices into two main dimensions, namely socially-oriented lean production and technically-oriented lean production. This study utilizes two hundred and five manufacturing companies, selected randomly from the Federation of Malaysian Manufacturers Directory. The study measures senior production or lean managers' view of the lean production practices at their companies. Convergent validity and discriminant validity of the lean practices are assessed.

INTRODUCTION

Lean production has created a lot of attention in the manufacturing companies worldwide and in academic research since 1980s and it is also claimed to be the universal practices for the 21st century (Womack, Jones and Roos 1990; Shah and Ward 2003, 2007; Liker 2004; Li et al. 2006; Matsui 2007; Pham et al. 2008). The nucleus of lean production philosophy lies on the premise that it has brought changes in management practices by enhancing customer satisfaction as well as improving organizational effectiveness and efficiency (Ferdousi and Ahmed 2009). Theoretically, lean production requires only half of the human effort in the factory, half of the manufacturing space, half of the investment tools, half of the engineering hours and half of the time to develop new products compared with the traditional mass production practices (Womack et al. 1990). Although lean production has received a lot of attention by academicians in recent years, the understanding on its content is still indefinite due to conflicting results reported. The inconsistencies of the previous research findings and the lack of empirical studies on lean production have triggered this study. The main aim of this study is to generate a valid and reliable survey instrument to measure lean production practices in the manufacturing companies, specifically in Malaysian manufacturing industry context.

LITERATURE REVIEW

Cua et al. (2001) and Shah and Ward (2003, 2007) define lean production practices as a set of activities undertaken by an organization to eliminate waste and respect for people. Meanwhile, Womack and Jones (1996) outline five fundamental principles of waste elimination in production, namely, (i) specify what does and does not create value from the customer's perspective, (ii) identify all the steps necessary to design, order and produce the product across the whole value stream to highlight non-value-adding waste, (iii) make those actions that create value flow without interruption, detours, backflows, waiting or scrap, (iv) only make what is pulled by the customers just-in-time; and (v) strive for perfection by continually removing successive layers of waste as they are uncovered. Consequently, they propose that lean production practices are composed of five major elements, namely (i) set-up reduction, (ii) pull production, (iii) short lead times from suppliers, (iv) streamlining ordering, receiving and other paperwork, and (v) continuous improvement (Womack and Jones 1996; Liker 2004; Shah and Ward 2003, 2007). However, for the purpose of this study, lean production practices are regarded as any actions which contribute to the reduction of waste and any activities that reflect the respect of people in the company (Liker 2004; Shah and Ward 2007). Table I outlines the matrix table showing various lean production practices as proposed by different researchers from past literature. Having reviewed past empirical studies on lean production such as Katayama and Bennett (1996), Lewis (2000), Sanchez and Perez (2001), Cua et al. (2001), Shah and Ward (2003, 2007), Shahram (2008), Pettersen (2009), and Fullerton and Wempe (2009), this study incorporates eight elements that have been mostly cited in the literature as lean production practices, namely; (i) supplier focus, (ii) employee focus, (iii) continuous improvement, (iv) customer focus, (v) quality at source, (vi) just-in time, (vii) flow system, and (viii) technology and innovation.

Grounded by Socio-technical System Theory (STS), this study proposes the practices should be grouped together into two main dimensions, namely Socially-oriented Lean Production (SLEAN) and Technically-oriented Lean Production (TLEAN). Consequently, this study has classified 'customer focus', 'supplier focus', 'employee focus' and 'continuous improvement' in a group, called Socially-oriented Lean Production (SLEAN). Meanwhile, 'just-in time', 'flow system', 'quality at source' and 'technology' are incorporated under Technically-oriented Lean Production (TLEAN). According to Shah and Ward (2007), the full benefits of lean production can only be realized if both orientations are holistically applied and simultaneously implemented. Womack et al. (1990) and Liker (2004) further claim that the above mentioned practices can be implemented in any organizations or industries all over the world. Even though this production philosophy has been developed in the Japanese automobile industry, the practices and principles can be applied to all other industries and service around the globe (Womack et al. 1990; Liker 2004). The bottom line is that these practices are developed to help manufacturers enhancing their performance (Womack et al. 1990; Liker 2004).

TABLE I
LEAN PRODUCTION PRACTICES AND THEIR APPEARANCE IN KEY REFERENCES

Lean Practices	1	2	3	4	5	6	7	8	9	10	11
Socially-oriented Lean Production (SLEAN)											
1. Supplier focus	*	*	*		*		*	*	*	*	
2. Employee focus	*	*		*	*		*	*	*	*	
3. Continuous improvement	*	*	*	*	*		*	*	*	*	*
4. Customer focus	*	*			*		*			*	*
Technically-oriented Lean Production (TLEAN)											
5. Quality at source	*	*			*		*			*	*
6. JIT	*	*			*		*	*	*	*	
7. Flow system	*	*	*	*	*		*		*	*	*
8. Technology & Innovation		*			*				*		*

(1) Shahram (2008); (2) Shah and Ward (2007); (3) Bhasin and Burcher (2006); (4) Woorley and Doolen (2006); (5) Liker (2004); (6) Wu (2003); (7) Shah and Ward (2003); (8) Sanchez and Perez (2001); (9) Cua et al. (2001); (10) Karlsson and Ahlstrom (1996); (11) Katayama and Bennett (1996); Womack et al. (1990).

Supplier Focus - The main thrust of supplier focus on lean production is the development programs developed by the manufacturers to their suppliers (Womack and Jones 1996; Liker 2004; Carreira 2005). Liker (2004) indicates that supplier development programs include a series of aggressive target and challenge to meet the goals set by the manufacturers. Suppliers should be given full authority and responsibility to supply components in the long-term mutual understanding with the manufacture. Lean suppliers should be selected based on their past relationships and proven record performance with the manufactures not on bids alone. Generally lean manufacturing companies keep fewer number of suppliers compared with the non-lean manufactures. By having a small number but reliable suppliers, companies are expected to shorten their product development cycle time, improve quality and thus will reduce waste and enhanced the performance (Womack and Jones 1996; Liker 2004; Carreira 2005). Supplier focus also means that the manufactures and their suppliers or partners are working hand-in-hand to grow the business together for the mutual benefits in the long-term.

Employee Focus – In lean environment employee focus is defined as recognizing the essence of all workers in the company and their full involvement enables their abilities to be used for the company's benefit (Womack and Jones 1996; Liker 2004; Carreira 2005). Liker (2004) suggests that the motivated and empowered employees are very vital to the success of the company. Furthermore, he asserts that people or employees are the key element in determining the achievement of lean performance. Consequently, in the lean production environment, people or workers are regarded as an asset to the company because they are the ones who are going to solve problems and improve processes in the production line (Liker 2004). Employees should be given the opportunity to utilize their creativity for improvement. The unused people's creativity is considered as one of the sources of waste to the company. Practicing job rotation in the production process is considered as one of the feature of 'employee focus' in the lean production environment (Liker 2004). Generally, job rotation creates cross-trained and multi-tasked employees. As a result, employees are able to respond faster to the changes in product and process requirements.

Continuous Improvement – In lean context, continuous improvement or '*Kaizen'* in Japanese term is defined as small-step ongoing improvement activities conducted within existing processes by people in the company (Womack and Jones 1996; Liker 2004; Carreira 2005). The purpose of continuous improvement activities in lean environment is to increase the probability of enhancing work process. People in the company are the best source of ideas for continuous improvement activities and should work together as team or work group. Teamwork or work in a team is the core of a lean manufacturing company (Liker 2004). Therefore, people in the company who involved in continuous improvement activities (work groups) should be provided with the authority, technical support and necessary resources in ensuring the smooth implementation of lean production practices. Continuous improvement can be realized through the incorporation of employees' ideas and participation to assist the accomplishment of the targeted goal. In lean environment, the important part of continuous improvement is the improvement of workflow whereby the improvement of workflow will facilitate a smooth and productive production process which eventually will promote quality of products.

Customer Focus - It is defined as an understanding of current and future customer needs, meeting customer requirements and striving to exceed customer expectations (MS ISO 9000: 2005). Customer focus also is regarded as "doing the right thing for the customer". By focusing on its customers' needs, companies are expected to remain in business and ensuring their sustainability. Relationships with customers are also vital in ensuring the successes of lean production companies. Customers are deciding what they want to buy, when they want to buy and how they want to buy a product (Liker 2004; Carreira 2005; Shah and Ward 2003, 2007). Therefore, it is essential to develop a good relationship with customers because the value of a product is determined by them. Hence, companies should set up good relationships with customers in order to understand and meet customers' needs and predict their demands accurately. In short, customer focus should be regarded as any actions leading to healthy interaction between manufacturers and its customer. These actions include frequently in contact with customers; constantly provides feedback to them on any issues arises; getting feedback from customers regarding the new product design; and establishing an effective communication system with customers.

Quality at Source – It is also known as '*Autonomation'* or *'Jidoka'* in Japanese term. '*Autonomation'* is regarded as any equipment or machines that are endowed with human intelligence to stop by itself when a problem occurs in the manufacturing process (Womack and Jones 1996; Liker 2004; Carreira 2005). Quality at source is also known as 'in-station quality'. It means preventing problems from being passed down the line. It is much more effective and less costly by preventing problems from occurring rather than inspecting and repairing the problems after it occur. In lean environment, 'quality at source' functions in a manner when equipment or machine shuts down, flag or light, usually with accompanying music or an alarm. It indicates the help is required to solve a quality problem at the particular work station or 'cell' (Liker 2004; Carreira 2005). The signalling system is referred as *'Andon'* in Japanese term. '*Andon'* means the light signal for help (Ohno 1988; Liker 2004). In practices, worker at the station is given authority to stop the whole assembly line immediately if problems appear that he or she cannot fix it (Ohno 1988; Liker 2004). In turn the whole team members will come over to work on the problem at the source. This is actually the spirit of quality at source (Liker 2004).

Just-in-time - It is very well known and common practice in lean environment. Just-in-time (JIT) is defined as a set of principles, tools, and techniques that allows a company to produce and deliver products in small quantities with shortest lead times, to meet specific customer needs (Ohno 1988; Womack and Jones 1996; Liker 2004). Simply, JIT is regarded as delivering the right items at the right time in the right amounts. The significance of JIT is that it allows companies to be responsive to the day-by-day shifts in customer demand. Another perspective of JIT is that it commonly used to describe a '*stockless'* production system. In this system, only the right parts are completed and delivered to customers at the right time. Consequently, it is also expected that the right part is received from suppliers at the right time as well. Explicitly, JIT should compose of four basic principles, namely: (1) produce at the right time, (2) at the right place, (3) in the right quantity, and (4) with the right quantity (Liker 2004). In summary, JIT is simply about producing at the right time, at the right place, in the right quantity, and with the right quantity.

Flow System - The basic concept of the flow system is that the part or sub-assembly does not stop except for it to be processed or for value-added work (Shah and Ward 2003). A flow system can be visualized through value stream mapping (VSM). A value stream mapping (VSM) is applied to identify bottlenecks and help to understand the process flow better. Originally, Ohno (1988) defines a flow system as designing and organizing equipment or machineries to follow the flow of material as it is being transformed into a product. Later, this concept is refined and became popular as '*lean cell'* or cellular manufacturing principle (Liker 2004; Carreira 2005). The cellular manufacturing principle takes into account the arrangement of equipment or machine in the station or "cell". This arrangement shall take into consideration of efficient movement of people or ergonomics, smooth flow of materials and good communication. In order for a flow system to be effective, people need to be multi-skilled and should be able to work across different functions or stations (cells) in the manufacturing process. Additionally, Davis and Heineke (2005) claim that a flow system shall be coupled with the concept of "takt" time logic. The "takt" time logic refers to the frequency of which customer consumes a unit of product. Simply, takt time logic is referred as the amount of time that is needed to produce a unit of product to meet the demand of customer.

Technology and Innovation – No doubt that technology and innovation has contributed a major role in our daily activities. This is no exception in lean environment. Generally, we have reached the point where one can push a button and be immediately abundant with technical and managerial information. The fact that today we are living in the world of technological edge. In the lean production setting, the principle is that the adoption of new technology in manufacturing processes must support people, process and values, not vice-versa (Liker 2004). Therefore, lean production utilizes only a reliable and thoroughly tested technology that serves people and process (Liker 2004). Accordingly, Liker (2004) states that a tested technology involves both the existing technology and the new or cutting-edge technology and innovation that one has thoroughly evaluated and piloted to prove it work. Ideally, the deployment of a tested or proven technology and innovation leads to a company's better performance with lesser risk. Companies that develop their technological base are able to capitalize on technology's ability to make a positive contribution to the performance. Technology can improve company's performance in a manner that it facilitates workers to perform their job. As a result, the job becomes easier and faster to deliver with less stress to the people and higher quality product (Liker 2004). The utilization of technology in lean production setting will also improve the skill of employees or people in the company as they have to continually learn to keep abreast with the never-ending changing technology. Lean production can improve the technological base of a company by enhancing equipment technology and improving the skill of employees (Cua et al. 2001).

METHODOLOGY

This study adopts a quantitative cross-sectional research approach utilizing two hundred and five primary data from lean practitioner representing manufacturing companies in Malaysia selected randomly from the Federation of Malaysian Manufacturers (FMM) Directory. The data were analyzed using the statistical package SPSS.

RESULT AND DISCUSSION

Face and Content Validity

Face and content validity of the instrument were assessed by extensive literature review and evaluated by four experts, who were two lean practitioners from the selected company and two academicians. Based on the expert's opinion, some of the items were reworded to fit with the research context. Once the measurement items were validated, the survey instrument was pre-tested at five manufacturing companies prior to the pilot study, and once again revised accordingly. Based on the outcome of pre-test study and on the extensive review of existing literature, and expert's opinion, this study has assured that the content and face and content validity of the research instrument was achieved.

Convergent Validity of Lean Production Constructs

Convergent validity of a construct can be determined through various indicators such as Cronbach's alpha (α), Average Variance Extracted (AVE) and Composite Reliability (CR) index (Hair et al. 2006). Hair et al. (2006) add that a construct with convergent validity should have a high reliable scale. A highly reliable scale of a construct indicates the construct measures the same latent concept. Meanwhile, a reliability test assesses whether a set of variables is consistent with what it measures (Hair et al. 2006). Additionally, Hair et al. (2006) state a reliable measure will show consistent results in repeated tests. For the purpose of this study, three indicators, namely 'Cronbach's alpha (α)', 'Average Variance Extracted (AVE)' and 'Composite Reliability

(CR)' were examined to justify the convergent validity and reliability of the proposed latent constructs, namely 'Socially-oriented Lean Production (SLEAN)' and 'Technically-oriented Lean Production (TLEAN)'. The Average Variance Extracted (AVE) is calculated as follows: Average Variance Extracted (AVE) = ∑(standardized loading^2) / ∑(standardized loading^2) + $\sum \varepsilon_j$; meanwhile the Composite Reliability (CR) index is figure out as follows: Composite Reliability = (∑standardized loading)^2 / (∑standardized loading) ^{2} + $\sum \varepsilon_j$.

Table II depicts the Cronbach's alpha (α) for lean production constructs. The Cronbach's alpha (α) value for 'supplier focus' (SupF), 'continuous Improvement' (Cont_Imp), 'employee focus' (EmpF), and 'customer focus' (CusF), 'technology' (TechNo), 'quality at source' (QaS), 'just-in-time' (JIT) and 'flow system' (FlowS) were 0.663, 0.859, 0.71 7, 0.728, 0.822, 0.701, 0.763 and 0.692 respectively. The results suggested that all values were greater than the threshold values of 0.6, hence all items for measurement were reliable. Meanwhile, the Cronbach's alpha (α) for the latent constructs, namely Socially-oriented Lean Production (SLEAN), Technically-oriented Lean Production (TLEAN) were 0.728 and 0.704 respectively. This study suggested that all constructs had demonstrated high reliabilities. Table II also indicated that the Average Variance Extracted (AVE) values for the latent constructs of lean practices namely Socially-oriented Lean Production (SLEAN) and Technically-oriented Lean Production (TLEAN) were 0.743, 0.840 respectively. Hair et al. (2006) and Cohen et al. (2003) suggest that the commonly accepted threshold value for the Average Variance Extracted (AVE) is 0.5. Furthermore, they claim that the higher the AVE value the better the reliability of a construct. As exhibited in Table 2, both AVE values of SLEAN and TLEAN were greater than 0.5. Additionally, this study investigated the Composite Reliability (CR) index to evaluate the construct validity and reliability of lean production constructs. As demonstrated in Table 2, the Composite Reliability (CR) values for Socially-oriented Lean Production (SLEAN) and Technically-oriented Lean Production (TLEAN) were 0.916 and 0.961 respectively which is higher than threshold value of 0.7 as suggested by Hair et al. (2006). Therefore, it was noted that both SLEAN and TLEAN constructs had convergent validity.

TABLE II

RELIABILITY VALUES OF LEAN PRODUCTION CONSTRUCTS.

Variables	No. of Items	Cronbach's alpha (α)	Composite Reliability (CR)	Variance extracted (AVE)	(Corr)^2
Socially-oriented Lean Production (SLEAN)	**4**	**0.728**	**0.916**	**0.743**	**0.285**
1. Supplier Focus (SupF)	3	0.663			
2. Continuous Improvement (Cont_Imp)	3	0.859			
3. Employee Focus (EmpF)	3	0.717			
4. Customer Focus (CusF)	3	0.728			
Technically-oriented Lean Production (TLEAN)	**4**	**0.704**	**0.961**	**0.840**	**0.266**
1. Technology and Innovation (TechNo)	3	0.822			
2. Quality at source (QaS)	3	0.701			
3. Just-in-time (JIT)	3	0.763			
4. Flow System (FlowS)	3	0.692			

Discriminant Validity of Lean Production Constructs

Discriminant validity refers to the extent in which a certain construct is different from other construct (Hair et al. 2006). Indicators from one scale should not load closely to other scales. Highly correlated scales, for example from two scales similar in nature, may suggest that they are measuring the same construct instead of two different construct (Hair et al. 2006). Therefore, these constructs need to be tested for discriminant validity so that it can verify that the scales develop to measure different constructs, are indeed measuring different constructs (Hair et al. 2006). This study assessed discriminant validity of the latent constructs by comparing the Average Variance Extracted (AVE) value with the Correlation Squared (Corr)^2 value of the constructs. As demonstrated in Table 2, the Average Variance Extracted (AVE) values for SLEAN and TLEAN were 0.743 and 0.840 respectively. Meanwhile, the Correlation Square (Corr^2) values for SLEAN and TLEAN were 0.285 and 0.266 respectively. The result verified that the Average Variance Extracted (AVE) values of SLEAN and TLEAN constructs were higher than that of their correspondent Correlation Square (Corr^2) values. Therefore, this study suggested that the latent constructs in the measurement model had discriminant validity.

CONCLUSION AND IMPLICATION

Conclusively, this study confirms the validity (i.e. face and content validity, convergent validity, discriminant validity and reliability) of the measurement instrument for lean production constructs. Both the convergent and discriminant validity are empirically verified. The implication of this study is that future researchers would simply adopt the developed instrument for upcoming works in this field. This study provides not only future researchers but also lean practitioners with a reliable research instrument to capture lean production practice in a manufacturing company.

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