ELSEVIER
Available online at www.sciencedirect.com
ScienceDirect
Procedia Technology 11 (2013) 1292 – 1298
Procedia Technology

The 4th International Conference on Electrical Engineering and Informatics (ICEEI 2013)

A Conceptual Model of Lean Manufacturing Dimensions

Amelia Natasya Abdul Wahab[a,]*, Muriati Mukhtar[a] , Riza Sulaiman[b]

[a]*Faculty of Information Science and Technology, Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia*
[b]*Institute of Visual Informatics, Universiti Kebangsaan Malaysia, 43600, Bangi, Selangor, Malaysia*

Abstract

Lean manufacturing or also known as lean production has been one of the most popular paradigms in waste elimination in the manufacturing and service industry. Thus, many firms have grabbed the benefits to practice lean manufacturing in order to enhance quality and productivity. However, previous research shows that there are various sets of tools or techniques that had been adopted at a certain degree across firms according to their own understanding of lean manufacturing. The scenario resulted with varying leanness measures in order to measure lean practices. This paper describes a preliminary study in developing a conceptual model to measure leanness in manufacturing industry. Thorough literature survey, books and report analysis contribute to the main preliminary analysis of this study. The most common tools or techniques and their usefulness have been investigated. In this research, a conceptual model for leanness measurement in the manufacturing industry has been developed and designed in two main levels, namely the dimensions and the factors. There are seven main dimensions in measuring leanness in lean manufacturing practices such as manufacturing process and equipment, manufacturing planning and scheduling, visual information system, Supplier relationship, customer relationship, workforce and product development & technology. In addition, the model also shows how lean dimensions in the manufacturing system relate to eight types of wastes.

Selection and peer-review under responsibility of the Faculty of Information Science & Technology, Universiti Kebangsaan Malaysia.

Keywords: lean manufacturing, lean production, leanness, lean indicators, lean assessment, lean model;

* Corresponding author. Tel.: +6-003-8921-6725; fax: +6-003-8925-6732
E-mail address: srikandi_waja@yahoo.com

Selection and peer-review under responsibility of the Faculty of Information Science & Technology, Universiti Kebangsaan Malaysia.
doi:10.1016/j.protcy.2013.12.327

1. Introduction

The word “lean” refers to lean manufacturing or lean production as it uses less of everything, compared to mass production. It only uses half of the human effort in the factory, half of the manufacturing space, half of the investment in tools and half of the engineering hours to develop a new product in half the time [1, 2]. Based on the research conducted by Bayou and Korvin [3], manufacturing leanness is a strategy to earn less input to better achieve the organization’s goals through producing better output, where ‘‘input’’ refers to the physical quantity of resources used and their costs, and ‘‘output’’ refers to the quality and quantity of the products sold and the corresponding customer services. In another review of lean manufacturing, Narasimhan et al. [4], have concluded that the efficient use of resources through the minimization of waste is the essential aspect of leanness as the aim of lean manufacturing is to reduce waste and non-value added activities. Essentially, the core idea of lean manufacturing is to maximize customer value while minimizing waste. The ultimate goal of implementing lean production in an operation is to increase productivity, enhance quality, shorten lead times, reduce cost and so on [5]. These factors indicate the performance of a lean production system. Some claim that lean manufacturing techniques were first identified as a cause of Japanese success. The supported idea is based on the fact that the lean management model was first developed at Toyota Motor Company by the Japanese after the Second World War in their effort to reduce cost. Therefore, the introduction of lean has significantly changed the market and the strategy during its first emergence in the development of the car industry that was pioneered by Toyota Production System (TPS). The success of TPS shows and proves that lean techniques are powerful and significant. The overwhelming scenario has led other companies from different industries such as electric and electronics [6-8], automotive [3, 9], auto and machinery [10], wood [11], ceramic [12], machine tool industry [13] and so on to implement lean in their manufacturing. However, most of the companies have implemented lean and have assessed lean practice in their own unique way. The reason for this scenario lies in their internal issues such as lack of knowledge and their understanding of lean, culture, skills and so on. Other factors such as age [14] and size [8, 10, 14] of the company also contribute to the degree of adoption of lean tools or techniques in one’s company. Thus, these situations have a big implication on the companies by restricting them in the measurement or comparison of their performance across companies and industries. Some of the companies have also given up continuing practicing lean due to the mentioned factors. Therefore, a research should be conducted to identify and determine the determinants or indicators for leanness measurement in the manufacturing companies.

2. Methodology

Thorough literature survey on lean manufacturing and lean assessment has been carried out in order to achieve the objective of this research. The existing and current model of leanness is identified and studied. However, the emphasis of the research is more on the identification of indicators, practices or tools or techniques for the implementation of lean in manufacturing. Keywords such as “lean manufacturing”, “lean production”, “lean assessment”, “lean measurement” and “lean indicators” have been used throughout the literature survey on various databases such as Scopus, Google scholar, ISI Web of Knowledge and so on. The survey has finally resulted in a total of 25 articles for this assessment purpose, which basically focuses more on the determinants and key areas for leanness measurement in manufacturing. The aim of the study is to determine, through literature survey, the most used or common indicator and the usefulness of the indicators in the manufacturing industry. Thus, the frequency of each indicator which has been mentioned by previous scholars has been used as the basic analysis in order to design the conceptual model (see Table 1).

From Table 1, we may summarize that most of the authors have reported that *workforce development [4, 5, 8, 9, 12, 13, 15-22]* and *total quality management (TQM)* [3, 4, 6, 8, 12-14, 17-19, 21-24] are significant in their study on lean practices. However, the rate of frequency has only been categorized as ‘high’ value instead of ‘very high’. The highest value is only fourteen out of twenty five literature studies which have included the mentioned variables as part of their study. Besides, there are only eighteen main articles which have been reported in this study. Indicators with a frequency of less than four have been omitted from the study. As mentioned previously, the aim of this article is to report on the most common and most useful indicators. The basic practices/tools/techniques which have been identified will be validated using the Delphi Method in the next stage of further research.

Table 1. Lean dimension and its factor.

	Dimension	Factor	*Frequency
1	Workforce	workforce development	14 (H)
		workforce involvement	4 (VL)
2	Manufacturing process & equipment	SPC	12 (L)
		TQM	14 (H)
		process focus	13 (L)
		pull	13 (L)
		just-in-time (JIT)	11 (L)
		elimination of waste (TPM)	12 (L)
		setup time reduction	11 (L)
		process control	8 (VL)
		work standardization	6 (VL)
		continuous improvement	5 (VL)
		production smoothing	6 (VL)
		5S	5 (VL)
		new process/equipment technologies	4 (VL)
		safety improvement, cleanliness & order	4 (VL)
		cycle time reduction	4 (VL)
		value identification	4 (VL)
3	Supplier	supplier development	8 (L)
		JIT deliveries by supplier	7 (VL)
4	Manufacturing planning & scheduling	shop floor organization/management	7 (VL)
5	Customer	customer relationship	6 (VL)
		customer involvement	5 (VL)
6	Visual information system	visual management system	5 (VL)
		visual information system	4 (VL)
7	Product development & technology	DFM/DFMA	4 (VL)

*Frequency scale: 1 to 7 = Very Low (VL); 8 to 13 = Low (L); 14 to 19 = High (H); 20 to 25 = Very High (VH)

3. Development of the conceptual model

Generally, the manufacturing system is an Input-output model. The system receives the input elements and then later undergoes a few processes in the transformation stage. Finally, the desired product is produced in the output stage. Quality and cost of the final output rely heavily on the factors that affect or control the system during the transformation process. The goal is to produce the right product at the right time and with the right cost in order to gain profitability and stay competitive by continuing the sales growth.

Fig. 1 shows that there are seven main elements in the boxes which are the *supplier relationship, workforce management, manufacturing process and equipment, manufacturing planning and scheduling, visual information system, product development and technology* and also *customer relationship.* The text in italics in Fig. 1 represents waste and the text in boxes represents lean dimension in manufacturing. As mentioned previously, there are seven types of dimensions that have been identified from the analysis of literature and Table 2 outlines the description for each dimension. Fig. 1 also shows the relationship between lean dimensions and wastes, for instance *supplier relationship* dimension may have a relationship with two types of wastes which are inventory and waiting. The same rule applies to the other dimensions. The emphasis on the relationship may be important as it would help the practitioners in identifying the right tools or techniques in solving problems according to their goal. On the other hand, the arrow shows the direction of contribution in the system. In the input phase for example, the *supplier relationship* and *workforce* dimensions may contribute to the next phase of the system which is also known as the transformation process. The transformation process consists of four dimensions such as, the *manufacturing process and equipment, manufacturing planning and scheduling, visual information system, product development and technology.* A feedback loop function is also shown in Fig. 1. The feedback function plays an important role in gaining feedback or information from *customer relationship* in the output phase to the manufacturing system in order to produce the right product which the customers value and are satisfied with. By-product output will go to scrap system.

3.1 Lean dimensions in manufacturing system

From the analysis of literature, these seven elements have been identified as the main dimensions in measuring leanness in manufacturing. The analysis was done by asking the following questions:

1. What is the indicator to measure leanness in the manufacturing system?
2. What are the similarities among the indicators that have been discussed by scholars?
3. What is the difference between the findings?

Later, the list of indicators is categorized into seven main dimensions by considering the number of scholars (frequency) who have mentioned them in their study. Each dimension is then broken down into one or more factors as shown in Table 1 and Table 2 shows the description for each dimension. Fig. 1 shows the location of each dimension in the manufacturing system e.g. *supplier relationship* and *workforce* in the input or early of the process stage, *manufacturing process and equipment* in the transformation or manufacturing stage and *customer relationship* in the final or output stage.

Table 2. Lean manufacturing (LM) dimensions and their descriptions.

Dimension in LM	Description
Manufacturing Process & Equipment	Aims to ensure that quality standards are being respected. Great efforts are made in order to reduce setup time to obtain continuous flow- type production, redesign of production process according to cellular manufacturing and preventive maintenance [15].
Manufacturing Planning & Scheduling	To synchronize production and market demand. The goal can be attained through leveled production, the use of small lots, pull control of flows and so on. Adapted from [15].
Visual Information System	A simple information system relying on direct information flows to the relevant decision makers, which allow rapid feedback and corrective action. Consists of performance information displayed on notice boards [5].
Product Development & Technology	Choices regarding product structure, materials and technical solutions. The adoption of innovative practices in product design/advanced methodologies such as QFD, design review, FMEA or VRP and so on [15].
Workforce Management	Involvement of workers in continuous quality improvement programs, expansion of their autonomy and responsibility. Includes recruitment and selection, education and training, evaluation and reward in order to promote employee contribution and to increase employee empowerment and responsibility [15].
Supplier Relationship	To increase the degree of "operational integration" between buyer and supplier. The buyer and the supplier are integrated with aspects regarding the transfer of materials from the supplier to the supplier (logistics relation). It influences several aspects in R&D and logistics. Adapted from [15].
Customer Relationship	Develops a logistic relation. Efforts are made to ensure reliable and prompt deliveries, to develop commercial and marketing techniques in order to make demands both more predictable and more stable and also to improve both professionalism and the competence of personnel directly involved in relationships with customers [15].

3.2 Wastes in lean manufacturing

Womack and Jones [25] define waste as any human activity which absorbs resources but creates no value. 'Muda' is a Japanese word for waste and Ohno [26] has identified seven types of waste which are also known as Ohno's seven muda. They are overproduction, waiting, transportation, unnecessary motion, inappropriate processing and defect. Waste is always linked to lean. But later, the eight wastes have been added to Ohno's original list by other authors, namely as "underutilized people". However, Liker [27] uses a different term for the same type of waste which is known as "unused employee creativity". The description of the eight types of wastes has been discussed and agreed by many scholars.

3.2.1 Waste of overproduction

Overproduction is making too much, too early or "just in case". Ohno believed that this type of waste is the most crucial of wastes as it is the root of so many problems and other wastes [28, 29].

3.2.2 Waste of waiting

Waste of waiting is directly relevant to flow and it is probably the second most important waste. It occurs when time is not being used effectively. In a factory, this type of waste occurs when goods is not moving and it affects both the goods and workers [28, 29]. According to Bicheno and Holweg [28], waiting is directly relevant to lead time which contributes to competitiveness and customer satisfaction.

3.2.3 Waste of unnecessary motion

Unnecessary motion refers to both human and layout. The human dimensions relate to the ergonomics of production where operators have to stretch, bend and pick up, move in order to see better and such waste is tiring for the employees and is likely to lead to poor productivity and quality problems [28, 29]. The layout dimensions refer to poor workplace arrangement, leading to micro waste movement and today, motion waste is also a health and safety issue [28].

3.2.4 Waste of transportation

Movement of materials and double handling is waste. This will affect productivity and quality issue [28, 29].

3.2.5 Waste of processing

This waste refers to machines and processes that are not quality-capable. A capable process requires correct methods, training and required standard that does not result with making defects. Over-processing also occurs in situations where overly complex solutions are found for simple procedures such as using a large inflexible machine instead of several small flexible ones. Over-complexity generally discourages ownership and encourages the employees to overproduce to recover the large investment in the complex machines. Such an approach encourages poor layout, leading to excessive transport and poor communication. The ideal, therefore, is to have the smallest possible machine, capable of producing the required quality, located next to preceding and subsequent operations [28, 29].

3.2.6 Waste of inventory

There are three types of inventory such as raw material, work in process and end items. Inventory tends to increase lead time, prevents rapid identification of problems, and increases space that would affect communication [28, 29].

3.2.7 Waste of defects

Defects in internal failure are scrap, rework and delay while the external failure includes warranty, repairs, and field service. Defects are direct cost for both immediate and long term. Defect in TPS is an opportunity to improve rather than something to be traded off [28].

3.2.8 Waste of underutilized people

Refers to more people involved in a job than necessary, not involving the associates in process improvement, not leveraging the potential individual to the fullest, not using the creative brainpower of employees, not giving the right assignment/work, uneven work distribution/load balancing, and losing time, ideas, skills, improvements, and learning opportunities by not engaging or listening to your employees [27, 30].

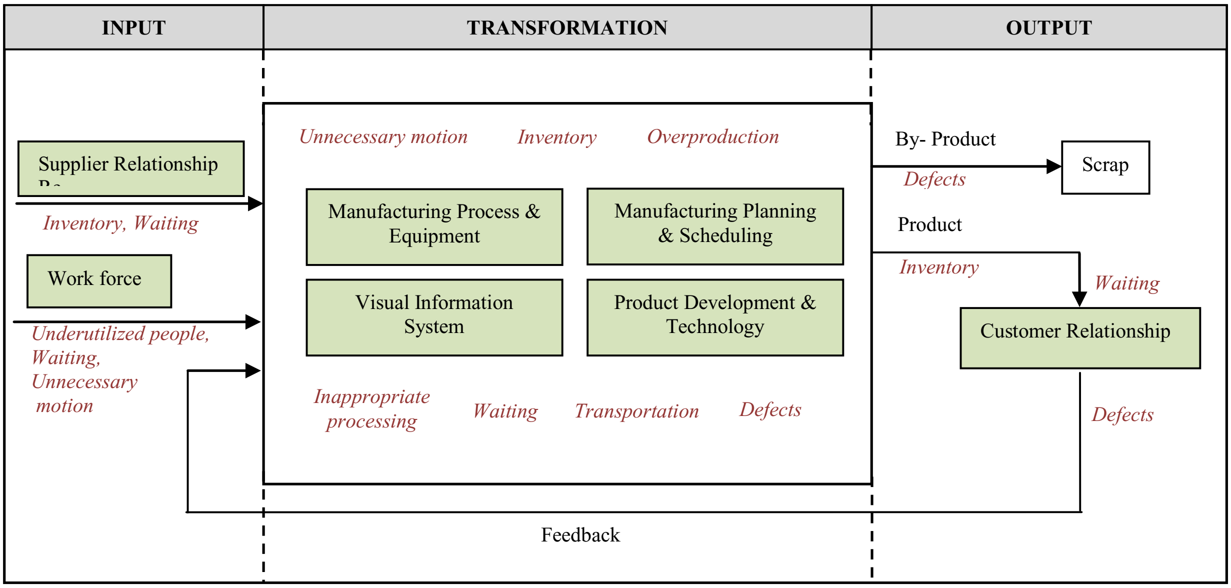

Fig. 1 Lean dimensions in a manufacturing system and its relation to wastes.

4. Discussion and conclusion

This study was undertaken to design the conceptual model for lean manufacturing measurement in the manufacturing industry. Initially, the factors or determinants that contribute to the measurement of lean practices have been identified. Similar practices/tools/techniques with the same characteristics are grouped into the same dimension. Thus, the result of this research has shown that there are seven main dimensions that contribute to leanness measurement in manufacturing. We limit our model development by considering and selecting the practice/tool/technique that is proposed by the empirical approach or a combination of both quantitative and qualitative approaches as the aim of the study is to provide a general guideline for all companies and industries in the manufacturing sector. Elsewhere in this study, it has been mentioned that the quantitative approach has resulted with a measure of lean index which is unique for the particular unit analysis of the author's study. On the other hand, these findings have enhanced our understanding of lean concepts and the determinants of variables which contribute to the progress towards leanness. Further work needs to establish whether the relationship between the dimensions and wastes are true by conducting the Delphi method approach. The conceptual model can also be modelled into a diagnostic model for leanness measurement in future work. Practitioners and scholars may benefit from this study as it will aid in improving the general effectiveness of the strategic manufacturing performance.

References

[1] Womack, JamesP., Jones, DanielT., Roos, D., The Machine That Changed The World: Based on the Massachusetts Institute of Technology 5-Million Dollar 5-Year Study on the Future of the Automobile, Scribner; 1990.
[2] Rao, K., Becoming Lean: Inside Stories of US Manufacturers, Monthly Labor Review, 1999;122.
[3] Bayou, M. E.,de Korvin, A., Measuring the Leanness of Manufacturing Systems: A Case Study of Ford Motor Company and General Motors, Journal of Engineering and Technology Management 2008;25:287.
[4] Narasimhan, R., Swink, M., Kim, S. W., Disentangling Leanness and Agility: An Empirical Investigation, Journal of Operation Management 2006.24:440.
[5] Karlsson, C., Ahlstrom, P., Assessing Changes Towards Lean Production, International Journal of Operations and Production Management 1996;16:24.
[6] Wong, Y. C., Wong, K.Y.,Ali, A., A Study on Lean Manufacturing Implementation In the Malaysia Electrical and Electronics Industry, European Journal of Scientific Research 2009;38:521.

[7] Wong, Y. C., Wong, K. Y., Approaches and Practices of Lean Manufacturing: The Case of Electrical and Electronics Companies, African Journal of Business Management 2011; 5:2164.
[8] Doolen, T. L.,Hacker, M. E., A Review of Lean Assessment In Organizations: An Exploratory Study of Lean Practices By Electronics Manufacturers, Journal of Manufacturing Systems 2005;24:55.
[9] Nordin, N., Deros, B. M.,Wahab, D. A., A Surveyon Lean Manufacturing Implementation In Malaysian Automotive Industry, International Journal of Innovation, Management and Technology 2010;1:374.
[10] Sanchez, A. M., Perez, M. P.,2001. Lean Indicators and Manufacturing Strategies, International Journal of Operation and Production Management 21:1433.
[11] Ray, C. D., Zuo, X., Michael, J. H.,Wiedenbeck, J. K. The Lean Index: Operational" Lean" Metrics for The Wood Products Industry, Wood and Fiber Science 2006; 38:238.
[12] Soriano-Meier, H., Forrester, P. L., A Model for Evaluating The Degree of Leanness of Manufacturing Firms, Integrated Manufacturing Systems 2002;13:104.
[13] Eswaramoorthi, M., Kathiresan, G. R., Prasad, P. S. S.,Mohanram, P. V., A Survey on Lean Practices In Indian Machine Tool Industries, International Journal of Advanced Manufacturing Technology 2011;52:1091.
[14] Shah, R., Ward, P. T., Lean Manufacturing: Context, Practice Bundles and Performance, Journal of Operation Management 2003;21:129.
[15] Gama, K. T.,Cavenaghi, V., "Measuring performance and Lean Production: a review of literature and a proposal for a performance measurement system." Proceedings of the Production and Operation Management Society (POMS) 20th Annual Conference. 2009.
[16] Shah, R.,Ward, P. T., Defining and Developing Measures of Lean Production, Journal of Operation Management 2007;25:785.
[17] Wan, H.-d., Frank Chen, F. A, Leanness Measure of Manufacturing Systems for Quantifying Impacts of Lean Initiatives, International Journal of Production Research 2008; 46:6567.
[18] Srinivasaraghavan, J., Allada, V., Application of Mahalanobis Distance as a Lean Assessment Metric, The International Journal of Advanced Manufacturing Technology 2006; 29:1159.
[19] Boyer, K. K., An Assessment of Managerial Commitment to Lean Production, International Journal of Operation and Product Management 1996;16:48.
[20] Panizzolo, R. , Applying the Lessons Learned from 27 Lean Manufacturers. The Relevance of Relationships Management, International Journal of Production Economics 1998;55:223.
[21] Kojima, S., Kaplinsky, R., The Use of a Lean Production Index In Explaining the Transition to Global Competitiveness: The Auto Components Sector In South Africa, Technovation 2004;24:199.
[22] Manotas D, D. F., Rivera C, L., Lean Manufacturing Measurement: The Relationships Between Lean Activities and Lean Metrics, Estudio Gerenciales 2008;23:69.
[23] Machado, V. C., Pereira, A. Modelling lean performance. IEEE; 2008.
[24] Rose, A. M. N., Deros, B.Md., Rahman, M.N., Nordin, N. Lean manufacturing best practices in SMEs. Proceedings of the 2011 International Conference on Industrial Engineering and Operations Management; 2011.
[25] Wong, Y. C., Wong, K. Y., "A lean manufacturing framework for the malaysian electrical and electronic industry".Proceedings of the 3rd International Conference on Information and Financial Engineering; 2011.
[26] Lewis, M. A., Lean Production and Sustainable Competitive Advantage, International Journal of Operation and Production Management 2000:20.
[27] Goodson, R. E., Read a Plant-Fast. Harvard Business Review 2002; 80:105-113.
[28] Lean Enterprise Self-Assessment Tool (LESAT) Version 1.0, Massachusetts Institute of Technology and University of Warwick; 2001.
[29] Womack, JamesP., Jones, DanielT, Lean Thinking: Banish Waste and Create Wealth In Your Corporation, Simon & Schuster, New York; 1996.
[30] Ohno, T., Sistem Pengeluaran Toyota:Melangkaui Pengeluaran Skala Besar / Karya Taiichi Ohno; Penterjemah Muhammad Syariff Paridudin, MOVE Associates, Petaling Jaya, Malaysia; 2010.
[31] Liker, JeffreyK., The Toyota Way: 14 Management Principles from The World's Greatest Manufacturer, McGraw-Hill, New York. 2004.
[32] Bicheno, John.,Holweg, Matthias., The Lean Toolbox: The Essential Guide to Lean Transformation, Production and Inventory Control, Systems and Industrial Engineering (PICSIE); 2009.
[33] Hines, P., Rich, N., The Seven Value Stream Mapping Tools. International Journal of Operations and Production Management 1997;17:46.
[34] Asif, M., Lowik, S., Weusthof, W.,De Bruijn, E. J"Challenges in lean implementation in knowledge intensive services". 15th Cambridge International Manufacturing Symposium: Innovation in Global Manufacturing-New Model for Sustainable Value Capture; 2010.