Lean Thinking

journal homepage: www.thinkinglean.com/ijlt

Develop a Framework of Performance Measurement and Improvement System for Lean Manufacturing Activity

Anita Susilawati*
PhD Student in Mechanical Engineering Department Northumbria University NE1 8ST, UK.
E-mail: anita.susilawati@northumbria.ac.uk

John Tan
Head of Mechanical Engineering Department Northumbria University Newcastle Upon Tyne NE1 8ST, UK.

David Bell
Associate Dean (External Activity) for School of Computing, Engineering and Information Sciences Northumbria University Newcastle Upon Tyne NE1 8ST, UK.

Mohammed Sarwar
Emeritus Professor in School of Computing, Engineering and Information Sciences,Northumbria University Newcastle Upon Tyne, NE1 8ST, UK.

ABSTRACT

Given the complexity, diversity and dynamic developments of business environment, conventional financial performance measures are inadequate for the present manufacturing environment. In this paper the development of a Performance Measurement and Improvement System (PMIS) framework for lean manufacturing practice is proposed. The PMIS framework is constructed by considering the hierarchical levels of the organization and multiple criteria for the lean manufacturing practice performance indicators. Identifying the relevant concepts, various methods associated with lean's PMIS framework for lean manufacturing practice was developed from survey of literature. The PMIS framework consist of measurements throughout the organization that reflect the company's lean strategies and goals, which it designed to motivate and monitor lean behaviour, and improve measurement results (continues improvement). This was produced the system in respect to the derived the key performance indicators that is applicable to organisations of various sizes (large, medium and small companies) within a range of industries.

KEYWORDS

Lean manufacturing,
Performance measurement and improvement system

ARTICLE INFO

Received 01 October 2012
Accepted 01 June 2013
Available online 30 June 2013

1. Introduction

To overcome the limitation of the conventional Performance Measurement System (PMS), a number of alternative approaches have been developed, some of the well-known systems included Strategic Measurement and Reporting Technique (SMART), Balance Score Card (BSC) and Performance Measurement Questionnaire (PMQ). These measures are designed to provide management and operators with up-to-date information needed for process improvements at any given time. One key aspect of these developments is the inclusion of non-financial aspects of the manufacturing systems. For instance, SMART (developed by Wang Laboratories) focuses on measurement of performance and incorporates planning processes as one of its input data. It also has a strong integration between corporate objectives and performance measures. However, one perceived weakness of SMART is that it does not provide any mechanism to identify key performance indicators for quality, cost and delivery (Ghalayini & Noble, 1996).

* Corresponding Author

PMQ enables the management to develop strategies and actions during the planning stage by identifying areas in which improvements would result in enhanced performance (Dixon et al., 1990). However, PQM has a disadvantge, that it does not provide guidance to align action, strategies and performance measures (Ghalayini et al., 1997).

Balance Score Card is commonly used framework for performance measurement (Anand & Kodali, 2008). A weakness of balance score card is the omission of shop floor level consideration as it is mainly designed to provide an overall view of an organizational performance (Ganapathy & Goh, 1997). Balance Score Card does not capture all components of the stakeholder and it does not include the supplier prospective which is important in a lean company (Anand & Kodali, 2008). Maltz et al. (2003) and Basin (2008) argued that Balanced Score Card alone is an inadequate in certain circumstances to measure organization performance and they proposed the Dynamic Multi-dimensional Performance (DMP) framework based on cause and effect relationships strategy for five areas: financial, customer/market performance, process, people and future, to measure performance of organization

Kaplan & Norton (1996) proposed a model for developing performance measurement systems that includes both financial and non financial measures in the areas of customer, financial, internal, innovation and learning. However, as most organizations today tend to be rather complex. As a result, the four perspectives of Kaplan & Norton (1996) model lack the richness to incorporate additional dimensions such as organization culture and business language (Butler, 1997). Hence this model may not be adequate as a quantitative linkage between non-financial and expected financial results (Schneiderman, 1999). Anand & Kodali (2008) enhanced the Balance Score Card framework specifically for lean manufacturing systems. However, their performance measurement framework for lean manufacturing implementation does not demonstrate a clear way of measuring performances at hierarchical levels within an organization i.e. strategic, tactical and production level.

To the author's knowledge, within the current PMS models there is relatively less information which specifically addresses PMS for lean manufacturing (Anand &. Kodali, 2008). They developed the PMS frame work based on the Balance Score Card by incorporating perspectives of the supplier to the four standard perspectives of the Balanced Score Card. In the modification, they do not yet consider other factors such as the size of the company, local and social consideration which is regarded as an important aspect by Suwignjo et al. (2000). It is also clear that all companies are subjected to influence external conditions such as the business environments which differ from one country to another.

Ghalayini et al. (1997) argued that even though companies have employed performance measurement in an integrated form, there are still many problems in today's manufacturing environment that need to be considered. They suggest that some modification of standard financial measures needs to be carried out to make appropriate with internal manufacturing and local external environments. It is therefore, concluded that no generic PMS framework exists. Rather, to be effective a given PMS should continually change in tenant with changes that occur within the business and manufacturing environment. Furthermore, in this paper purposed is to develop a framework of performance measurement and improvement model for lean manufacturing practices.

2. Overview of Performance Measurement Systems

The performance measurement has a crucial role for continuing improvement to make efficient and effective management in the manufacturing companies (Kennerley & Neely 2002, Garengo 2005). Kennerly & Neely (2002) defined performance measurement as the process of quantifying the efficiency

and effectiveness of action. While this definition does not involve strategies development and improvement action, which can be carried out by the existing results of performance measurement. In terms of strategy and performance measurement, the various frameworks have been introduced by many researchers such as the Balance Score Card (BSC) (Kaplan & Norton, 1996), Strategic Measurement and Reporting Technique (SMART) (Cross & Lynch, 1989), Performance Measurement Questionnaire (PMQ) (Dixon, 1990), Performance Prism (Kennerley & Neely 2002, Dixon et al. 1991), Integrated Performance Measurement System (IPMS) (Bititci, 1997), Integrated Dynamic Performance Measurement System (IDPMS) (Ghalayini, 1997) and European Foundation for Quality Management (EFQM) Model (The EFQM Excellence Model 1999, EFQM, 2003).

2.1. Balance Score Card (BSC)

The Balance Score Card was developed by Kaplan & Norton (1996) as a comprehensive performance view of an organization in four perspectives: innovation and learning, financial, customer and internal business, it is shown in Fig. 1. The BSC is a commonly used framework for performance measurement (Anand & Kodali, 2008). It has some advantages, one of which is the integration of organization vision with actions. It provides data of all key indicators at discrete time intervals, and facilitates strategic review that permits formulation of plans to achieve organisational goals. However the BSC cannot view the performance at manufacturing level. Also, the BSC has a weakness to measure long term vision and fails to identify the performance measurement specific level such as employees, suppliers and stakeholder.

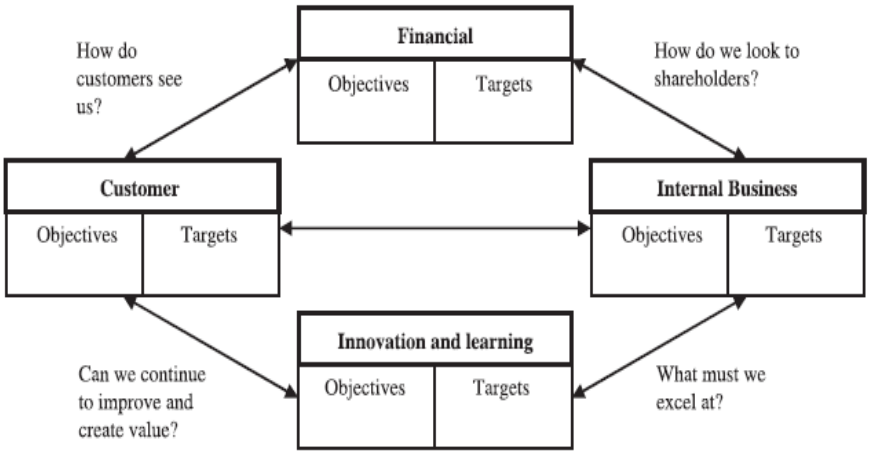

Fig. 1 The BSC Framework (Kaplan & Norton, 1992)

2.2. The Strategic Measurement Analysis and Reporting Technique (SMART) system

The Strategic Measurement Analysis and Reporting Technique (SMART) system was developed by Wang Laboratories to overcome the limitation of traditional performance measurement, with objectives to integrate both financial and non-financial performance indicators (Cross & Lynch, 1989). The SMART system is designed as a four step performance pyramid that can be seen in Fig. 2. The SMART system can integrate organization objectives with operational performance indicators but that excludes continuous improvement (Ghalayini, 1997).

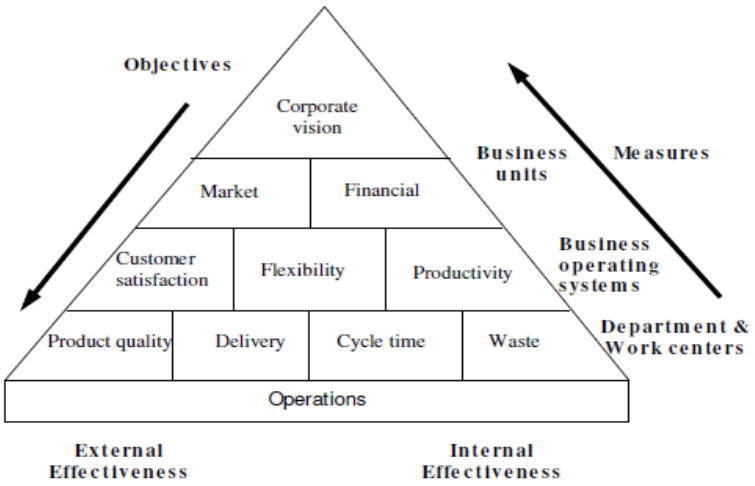

Fig. 2 The SMART Performance Pyramid (Cross & Lynch, 1989)

2.3. Performance Measurement Questionnaire (PMQ)

The Performance Measurement Questionnaire was developed by Dixon et al. (1990, 1991), with the purpose of assessing the existing performance measurement used in an organization/company. The PMQ frame work consist of two main parts (Dixon, 1991): (1) to evaluate the particular improvement areas and the current performance improvement that is already used in the company, (2) to evaluate the particular long term importance of improvement that will be achieved by the company. In terms of the improvement areas, Dixon et al. (1990) identified three categories i.e. quality, labor efficiency and machine efficiency; it can be seen in Fig. 3. The PMQ has the weakness of being relative light on management time during the audit phase and lack of the management involve in the audit processes (Bourne & Neely, 2003). In addition, the PMQ does not pay attention to the continuous improvement concept (Ghalayini & Noble, 1996).

Long-run importance of improvement	Improvement areas	Effect of current performance measures on improvement
None >>>> Great		Inhibit >>>> Support
1 2 3 4 5 6 7	Quality	1 2 3 4 5 6 7
1 2 3 4 5 6 7	Labour efficiency	1 2 3 4 5 6 7
1 2 3 4 5 6 7	Machine efficiency	1 2 3 4 5 6 7

Fig. 3 The Performance Measurement Questionnaire (Dixon et al., 1990)

2.4. Performance Prism

The Performance Prism was introduced by Neely et al., 2001. The PMS framework was developed by five performance perspective i.e. stakeholder satisfaction, strategies, processes, capabilities and stakeholder contribution as shown in Fig. 4. The Performance Prism framework has a comprehensive external organization view i.e. stakeholder satisfaction and contribution but less attention to measure the actual process.

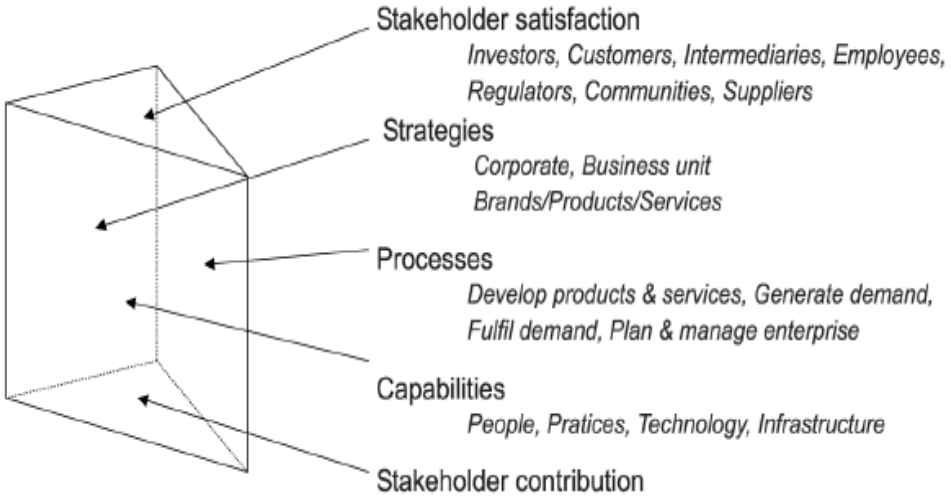

Fig. 4 The Performance Prims (Neely et al., 2001)

2.5. Integrated Dynamic Performance Measurement System (IDPMS)

The IDPMS was developed by Ghalayini et al. (1997) based on integrating three main areas of measurements i.e. management, process improvement teams, and the factory shop floor (Fig. 5). This framework has the ability to measure general and specific areas of success, utilization of improvement and performance measurement reporting (Ghalayini, 1997). However, this framework does not have the capacity to evaluate overall performance score in the company. The performance indicators were only used in the process of improvement of teams and the factory shop floor. Also, the framework does not mention the external organization performance improvement such as stakeholders, customers, supplier etc.

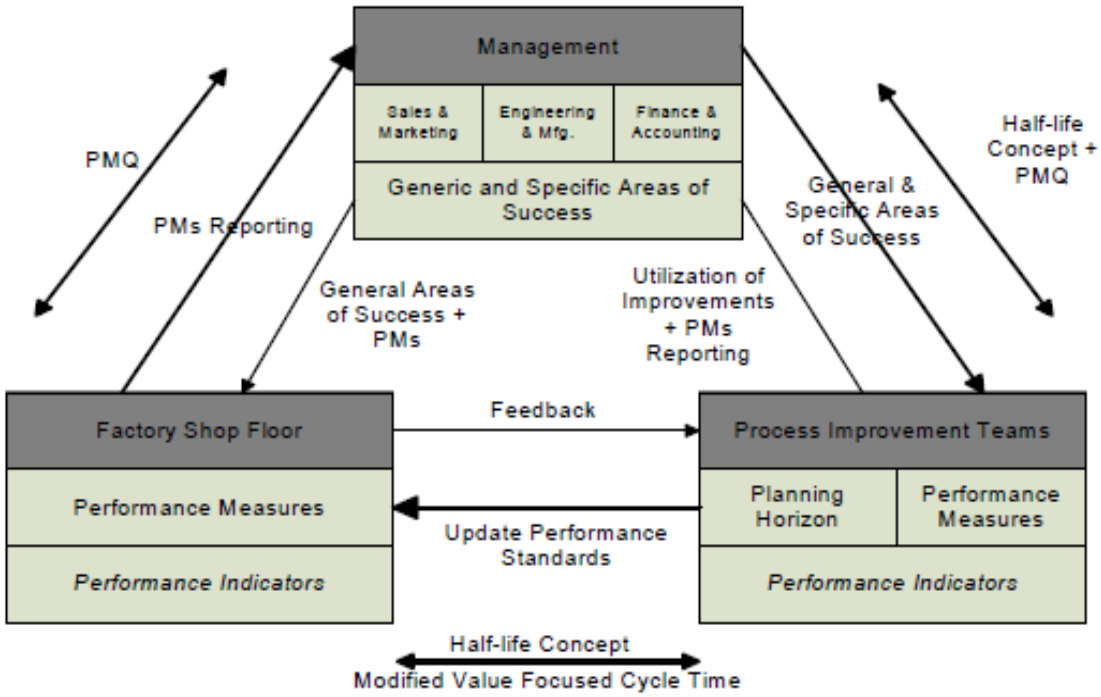

Fig. 5 The Integrated Dynamic Performance Measurement System (Ghalayini et al, 1997)

2.6. Integrated Performance Measurement System (IPMS)

The Integrated Performance Measurement System (IPMS) was developed by Bititci et al. (1997). The IPMS model was designed as a closed loop control system to measure the process of performance management. The IPMS framework can be seen in Fig. 6, which consists of four levels: corporate, business units, business processes and activities (Bititci, 1997). This framework has strength to involve the continuous improvement. However it is unclear to measure in a logical order and manage the relationships between measures (Suwignjo, 2000). Furthermore this framework fails to provide a structured process that specifies objectives and timelines for development and implementation (Pun & White, 2005).

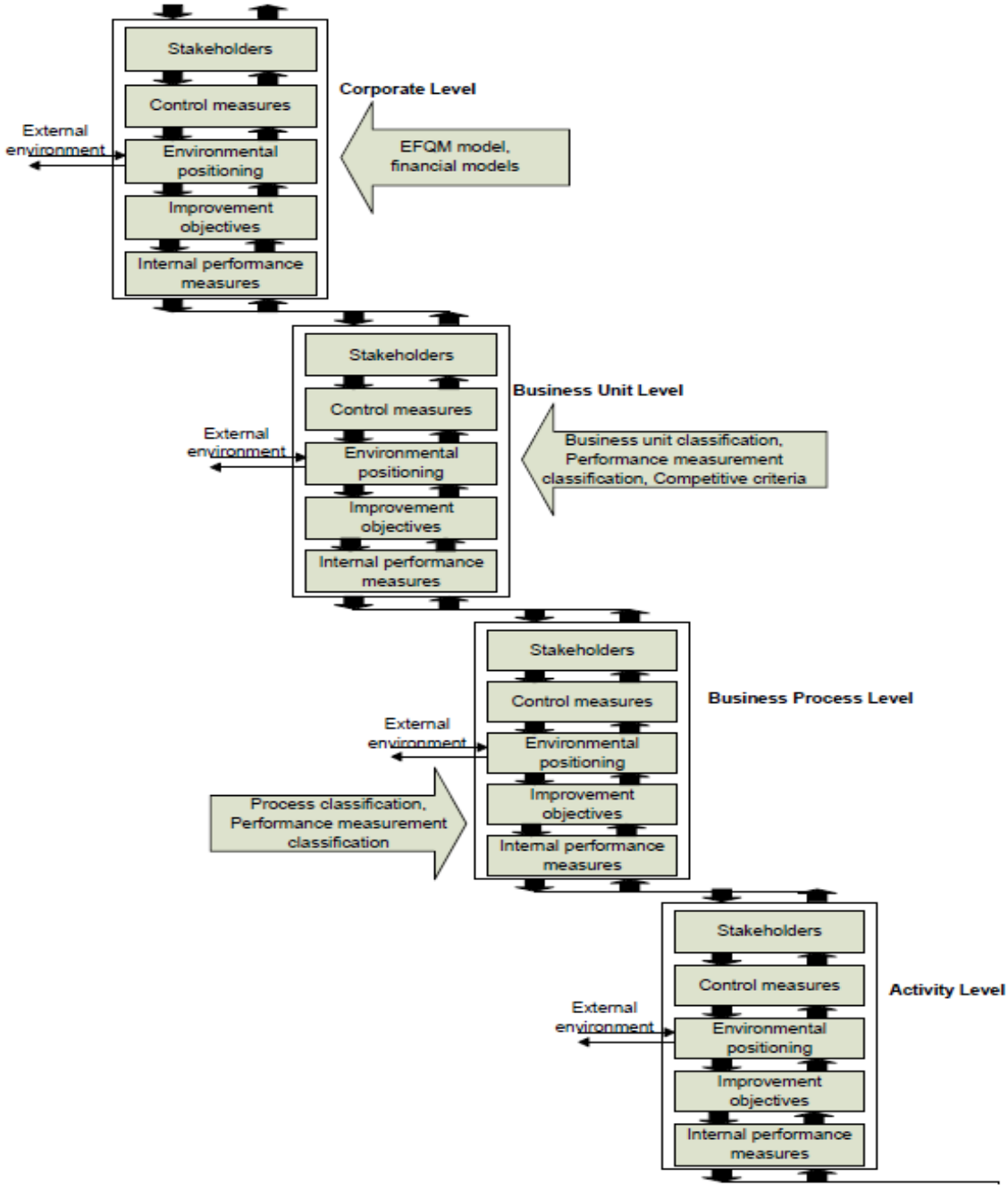

Fig. 6 The Integrated Performance Measurement System (Bititci et al., 1997)

2.7. European Foundation for Quality Management (EFQM) Model

The EFQM model is a non-prescriptive framework based on nine criteria, which five of these are 'enablers' (leadership, people, policy and strategy, partnership and resources, and processes) and four are 'results' (people results, customer results, society results, and key performance results) that can be seen in Fig. 7 (The EFQM Excellence Model 1999, EFQM 2003). The EFQM model is a self-assessment frame work, which intends to give feedback on the practices and performance within the company. However, it does not involve the external assessments or comparing oneself to competitors. Furthermore the model lacks attention to flexible factors such as the implementation that might be different between company's type and the company maturity (Park, 2008).

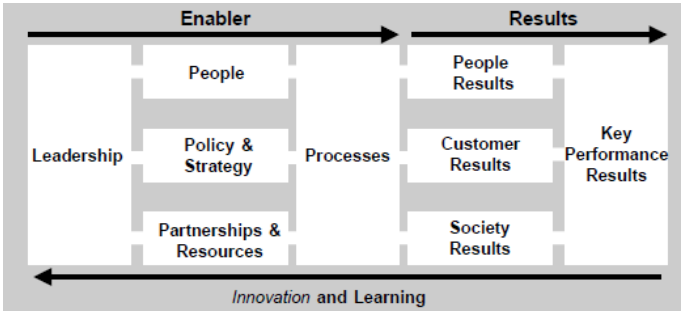

Fig. 7 European Foundation for Quality Management (EFQM) Model
(The EFQM Excellence Model 1999, EFQM 2003)

Therefore, Anand & Kodali (2008) defined the PMS framework for lean manufacturing but never applied one in a real case study. More, their performance measurement framework does not demonstrate a clear way of measuring performances at hierarchical levels within an organization i.e. strategic, tactical and production level. Finally, it can be concluded that the current PMS frameworks were lacking in information in areas of Performance Measurement Systems (PMSs) for lean manufacturing implementation.

3. Methodology

The PMS framework is developed in the following steps:

1. To develop and establish an indicator to determine the potential benefits of lean manufacturing techniques.
2. To develop a framework of appropriate performance measurement model that is applicable to the lean manufacturing practices.
3. To apply the indicator and the framework of performance measurement model developed in (2) and (3) to monitor the performance improvements of specific companies as a result of applications of lean manufacturing practices.

According to Neely et al. (1995) the objective of a performance measure is quantifying efficiency and effectiveness of an action. Pun & White (2005) argued that performance measurement should facilitate decision making to align actions with strategic objectives and provide feedback on operational performance and internal capabilities to the strategic level. From the preliminary literature review performance measurement is mainly used to:

- Monitor and record actual performance.
- Identify and close the gap between expected performance and actual performance.
- Identifying performance improvement opportunities.
- Providing information in making a strategic decision.
- Enabling internal communication across processes and stakeholders.
- Encourage continuous improvement.

The characteristics of lean manufacturing was identified by Carlson & Ahlstrom (1996) as the nine variables of leanness: elimination of waste, continues improvement, zero defect, Just In-Time (JIT) delivery, pull of material, multifunctional term, decentralisation, integration of functions, vertical information systems and time to market. Philips (2000) suggests that in lean manufacturing companies, the manufacturing space becomes highly responsive to customer demand while producing world-class quality products.

Based on the objectives of performance measurement and the characteristics of lean manufacturing, the main measure that included in PMS is identified. The identification is done by using comparative analysis of lean systems related to literature as suggested by White (1996) and by using personal interview of lean manufacturing practitioners. In the comparative analysis, some measures suggested in the literature and from the practitioner are collected and summarised. Some measures based on factors indicating the performance of lean manufacturing such as increased productivity, enhanced quality, shorter lead time and cost reduction are then used.

The framework of PMS was developed by considering:

- Objective of frame work; Kennerley & Neely (2002) identify the objective of frame work of performance measures are to help the organisation to define set measures that reflect their objective and assess their performance in an appropriate way.
- Characteristic of framework; Kennerley & Neely (2002) also suggested that the frame work has to be multidimensional and have the balance between financial and non-financial measures. DTI (1998) also suggest the frame work should predict what is about to happen and what has happened, can encourage people to act according to management desire and should be an integral part of systematic processes for reviewing the measured action.
- Competitive priorities; among competitive priorities of any organisation are (as identified by Dangayach & Deshmuch) (2000) productivity, quality, cost, delivery, morale, flexibility and innovation.
- Company strategy.
- Frame work should involve components of business process such as customers and suppliers.
- Framework should give information for doing improvement

4. Results and Discussions

The development of proposed framework for performance measurement and improvement system for a manufacturing company was involved incorporating a broader range of indicators in defining leanness. Next, establishing a clearer definition of lean principles by identifying various relevant industrial work activities that support the lean principle (known as practices). Then the identifying was revealed key performance indicators (KPIs) of lean, which would have significant influence on company performance. Furthermore, the proposed framework was designed by considering the hierarchical levels of the organization and multiple criteria for the lean manufacturing practice performance indicators.

4.1. Identifying Lean Performance Indicators

The leanness of a company can theoretically be measured by the extent of how the company adopts a list of lean indicators. There are differences in opinions regarding the relevant indicators contributing towards the measure of lean practices. The lean indicators used in this paper were selected based on the definition of leanness from an extensive literature review of papers and work, such as Anand & Kodali (2008), Singh et al. (2010), Saurin & Ferriera (2009), Doolen & Hacker (2005), Karlsson & Ahlstrom (1996), related to components of lean practices. The result of this survey revealed a set of "common denominators": a set of eight indicators which contain sixty six (66) lean practice factors. The eight indicators were Customer Issue, Supplier Issue, Manufacturing Management, Internal Business Management, Manufacturing Efficiency, Research and Development, Learning Prospective and Investment Priority.

The lean tools and techniques were selected and listed by review on a survey based study on the lean manufacturing application in the industries. The lean tools and techniques based on the definition of lean activity from an extensive literature review of papers and works, such as Soriano & Forrester (2002), Wong et al. (2009), Mahapatra & Mohanty (2007), Farhana & Amir (2009), Riveraa & Chen (2007), Singh et al. (2010) , Abdulmalek et al. (2006).

4.2. The proposed frame work for PMIS of lean practices

The proposed framework was established into hierarchical structure of interrelated decision, which consists of the goal, lean indicators and lean sub-indicators/alternatives that can be seen in Fig. 8. In the first level is goal i.e. companies overall performance measurement and improvement. The goal is break into the eight of KPIs of lean activities, and each KPI has alternatives for performance improvement of lean activities.

Then, to measure a percentage improvement as an adopting lean by respective company, a set of assessment framework was adopted and modified from dynamic multi-dimensional performance model (Maltz et al. 2003, Bhasin 2008). The performance indicators were associated with impact of lean activities that used by multi-dimensional performance model as following:

- Financial: focused on profitable and productivity.
- Customers/market measures, which was considered by customers and supplier issues.
- Process: the indicators were selected by manufacturing and internal management, manufacturing efficiency, research and development.
- People: internal management, manufacturing efficiency and learning perspective.
- Future: research and development, and investment priority.

The performance template that consists of the five dimensions to measure improvement of lean activities that can be seen in Table 1.

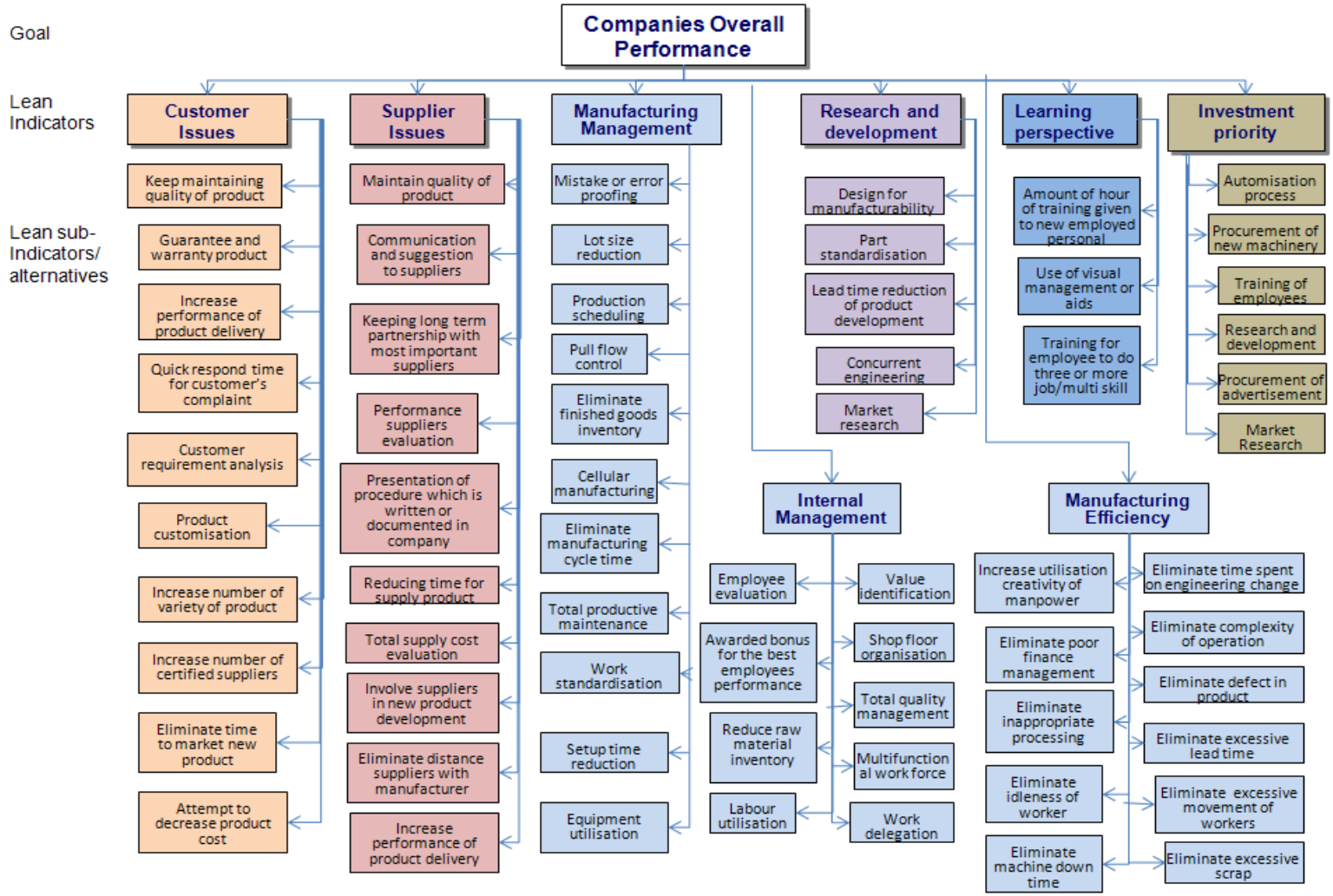

Fig. 8 A hierarchy framework for PMIS of lean manufacturing activities.

Table 1. Lean manufacturing performance template

Impact lean activities	Lean activities of performance indicators
Financial	Profitable Productivity
Customers/market measure	Attempt to reduce number of supplier in supply most important part/material Total supply cost evaluation Attempt to decrease product cost Communication and suggestion to suppliers Increase performance of product delivery Eliminate distance suppliers with manufacturer Maintain quality of product that was sent by suppliers Reducing time to supply product Increase number of variety of product Keep maintaining quality of product Eliminate time to market new product Guarantee and warranty product Customer requirement analysis Increase number of certified suppliers Quick respond time for customer's complaint Product customization Involving suppliers in new product development Keeping long term partnership with most important suppliers Presentation of procedure which is written or documented in the company Performance suppliers' evaluation
Process	Setup time reduction Eliminate manufacturing cycle time Eliminate time spent on engineering change Production scheduling Eliminate complexity of operation Eliminate excessive lead time Lead time reduction of product development Design for manufacture Value identification Part standardisation Mistake or error proofing Eliminate defect in product Eliminate excessive scrap Work standardisation Eliminate inappropriate processing Eliminate machine down time Equipment utilisation Lot size reduction Labour utilisation Eliminate excessive movement of workers Eliminate idleness of workers Increase utilisation creativity of manpower Multifunctional work force Cellular manufacturing Shop floor organisation Total productive maintenance Total quality management Eliminate poor finance management Concurrent engineering Reduce raw material inventory Pull flow control Eliminate finished goods inventory

People	Employees evaluation Awarded bonus for the best employees performance Use of visual management or aids Training for employees to do three or more job (multi skill) Amount of hours of training given to new employee personal Increase utilisation creativity of manpower Work delegation Eliminate poor finance management
Future	Market research for research and development Investment of Research and development Investment of Training of employees Investment of Market research Investment of Procurement of advertisement Investment of Automation processes Investment of Procurement of new machinery

4. Conclusions

The development of a performance measurement and improvement system for lean activities is described in this paper. The performance measurement activities of lean manufacturing (lean performance practices indicators), were reviewed and identified from survey of literature. Then, the proposed framework was constructed based on structure of interrelated decision that was explained in eight indicators and sixty-six sub-indicators or alternatives. Then to derive improvement of the performance measurement of lean activities, the score card was adopted from dynamic multi-dimensional performance model. The proposed framework could be applicable in real implementation by lean manufacturing companies that could support improvement system of their performance measurement practices.

Acknowledgment

This study is supported by the Directorate General of Higher Education (DGHE) of Indonesia.

Reference

Abdulmalek, F.A., Rajgopal, J. And Needy, K. L., A Classification scheme for the process industry to guide the implementation of lean, *Journal of Engineering Management*, 2006; vol. 8, no. 2, pp. 15-25.

Anand, G. and Kodali, R., Performance measurement system for lean manufacturing: a perspective from SMEs, *International Journal of Globalisation and Small Business*, 2008; vol. 2, no.4, pp. 371-410.

Bhasin, S., Lean and performance measurement, *Journal of Manufacturing Technology Management*, 2008; vol. 19, no. 5, pp. 670-684.

Bititci, U.S., Carrie, A.S. and Devitt, L.Mc. Integrated performance measurement systems: a development guide, *International Journal of Operations and Production Management*, 1997; vol. 17, pp. 522-534.

Bourne, M. and Neely, A. "Implementing performance measurement systems: a literature review", International Journal Business Performance Management, vol. 5, no. 1, 2003.

Butler, A., Letza S.R. and Neale, B., Linking the Balanced Scorecard to Strategy, *Long Range Planning*, 1997 *International Journal of Production Economics*; vol. 30, No. 2, pp. 242-253.

Cross, K.F. and Lynch, R.L, The SMART way to define and sustain success, *National Productivity Review*, 1989; vol. 8, no. 1, pp. 23-33,

Dangayach, G.S. and Deshmukh S.G., Manufacturing strategy: experiences from select Indian organisations, *Journal of Manufacturing Systems*, 2000; vol. 19, no. 2, pp. 134-148.

Dixon, J.R. Nanni, A.J. and Vollmann, T.E., An instrument for investigating the match between manufacturing strategy and performance measures, Working Paper: Boston University; 1991.

Dixon, J.R., Nanni, A.J. and Vollman, T.E., *The new performance challenge: measuring operations for world class competition*. IL: Dow Jonws-Irwin, Homewood; 1990.

Doolen, T.L. and Hacker, M.E., A review of lean assessment in organisation: an exploratory study of lean practice by electronics manufacturer, *Journal of Manufacturing Systems*, 2005; vol. 24, pp. 55-67.

DTI (Department of Trade and Industry), Quality cost delivery: seven measures for improved competitiveness in manufacturing industry, London; 1998.

European Foundation for Quality Management (EFQM) Excellence Model, Public and Voluntary Sector, Brussels: EFQM; 2003.

Farhana, F. and Amir, A., Lean production practice: the differences and similarities in performance between the companies of Bangladesh and other countries of the world, Asian Journal Business Management, 2009; vol. 1, no. 1, pp. 32-36.

Ganapathy, B.K. and Goh, C.H., A hierarchical system of performance measures for concurrent engineering, *Concurrent Engineering: Research and Applications*, 1997; vol. 5, no. 2, pp. 137-143.

Garengo, P., Biazzo, S. And Bititci, U.S., Performance measurement systems in SMEs: a review for a research agenda, *International Journal of Management Reviews*, 2005; vol. 7, no. 1, pp. 25-47.

Ghalayini, A.M. and Noble, J.S., The changing basis of performance measurement, *International Journal of Operations and Production Management*, 1996; vol. 16, no. 8, pp. 63-80.

Ghalayini, A.M., Noble, J.S. and Crowe, T.J., An integrated dynamic performance measurement system for improving manufacturing competitiveness, *International Journal of Production Economics*, 1997; vol. 48, pp. 207-225.

Kaplan, R.S. and Norton, D.P., Using the balanced score card as a strategic management system, *Harvard Business Review*, 1996; vol. 74, no. 1, pp. 75-85.

Karlsson, C. and Ahlstrom, P., Assessing changes towards lean production, *International Journal of Operations and Production Management*, 1996; vol. 16, no. 2, pp. 24-41.

Kennerley, M. and Neely, A., A framework of the factors affecting the evolution of performance measurement systems, *International Journal of Operations and Production Management*, 2002; vol. 22, no. 11, pp. 1222-1245.

Mahapatra, S.S. and Mohanty, S.R., Lean manufacturing in continuous industry: an empirical study, *Journal of Scientific and Industrial Research*, vol. 66, pp. 19-27, 2007.

Maltz, A., Shenhar, A. and Reilly, R., Beyod balanced score card: refining the search for organisational success measures, *Long Range Planning*, 2003; vol. 36, pp. 187-204,.

Neely, A., Adams, C. and Crowe, P. The performance prism in practice, *Journal of Business Performance Management*, vol. 5, 2001; no. 2, pp. 6-12.

Neely, A.D., Mills, J.F., Gregory, M.J. and Platts, K.W, Performance measurement system design – a literature review and research agenda, *International Journal of Operations and Production Management*, 1995; vol. 15, no. 4, pp. 80-116.

Park, S.M.D., Reviewing The European Excellence Model from a Management Control View, *The TQM Magazine*; 2008.

Phillips T., Lean manufacturing: building the lean machine; 2000.

Pun, K.F. and White, A.S., A performance measurement paradigm for integrating strategy formulation: a review of systems and frameworks, *International Journal of Management Reviews*, 2005; vol. 7, no. 1, pp. 49-71.

Riveraa, L. and Chen, F.F. Measuring the impact of lean tools on the cost–time investment of a product using cost–time profiles, *Robotics and Computer-Integrated Manufacturing*, 2007; vol. 23, pp. 684-689.

Saurin, T.A. and Ferriera, C.F., The impact of lean production on working condition: a case study of a harvester assembly line in Brazil, *International Journal of Industrial Economics*, 2009; vol. 39, pp. 403-412.

Schneiderman, A.M., Why balanced score cards fail, *Journal of Strategic Performance Measurement*, 1999; pp. 6-11.

Singh, B., Garg, S.K. and Sharma, S.K., Development of index for measuring leanness: study of Indian auto component industry, *Measuring Business Excellence*, 2010; vol. 14, pp. 46-53.

Soriano, M.H. and Forrester, P.L., A model for evaluating the degree of leanness of manufacturing firms, *Integrated Manufacturing Systems*, 2002; pp. 104-109.

Suwignjo, P., Bititci, U.S. and Carrie, A.S., Quantitative models for performance measurement system, *International Journal of Production Economics*, 2000; vol. 64, no. 1-3, pp. 231-241,.

The EFQM Excellence Model, Brussels: European Foundation for Quality Management; 1999.

White, G.P., A Survey and taxonomy of strategy-related performance measures for manufacturing, *International Journal of Operations and Production Management*, 1996; vol. 16, no. 3, pp. 42-61.

Wong, Y.C., Wong, K.Y. and Ali, A., A study on lean manufacturing implementation in the Malaysian electrical and electronics Industry, *The European Journal of Scientific Research*, 2009; vol. 38, no. 4, pp. 521-535.