

---

## Review the influence of lean tools and its performance against the index of manufacturing sustainability

---

Muhamad Zaki Yusup\*

Sustainable and Responsive Manufacturing Research Group,  
Faculty of Manufacturing Engineering,  
Universiti Teknikal Malaysia Melaka,  
76100 Hang Tuah Jaya, Melaka, Malaysia  
and

Department of Quality and Productivity,  
Kolej Kemahiran Tinggi MARA Kuantan,  
Km 8, Jalan Gambang, 25150 Kuantan, Pahang, Malaysia  
Email: muhamad.zaki@kktmkuantan.edu.my

\*Corresponding author

Wan Hasrulnizam Wan Mahmood and  
Mohd Rizal Salleh

Sustainable and Responsive Manufacturing Research Group,  
Faculty of Manufacturing Engineering,  
Universiti Teknikal Malaysia Melaka,  
76100 Hang Tuah Jaya, Melaka, Malaysia  
Email: hasrulnizam@utem.edu.my  
Email: rizal@utem.edu.my

Azrul Shahimy Mohd Yusof

Department of Language Studies,  
Universiti Teknologi MARA Cawangan Kedah,  
P.O. Box 187, 08400 Merbok, Kedah, Malaysia  
Email: azrulshahimy@kedah.uitm.edu.my

**Abstract:** Lean production is known as a social-technical management philosophy that encompasses multiple disciplines that focus on increasing the manufacturing productivity by emphasising on the elimination of waste, and increasing the value-added activities. Recognising the internal influences brought by lean in manufacturing practices, this article focuses on how the convergences in lean philosophies are able to contribute in establishing a sustainable manufacturing practice. Based on three performance of sustainability, namely the competency accomplishment performance, economic achievement performance and the environmental responsiveness performance, the discussion is focused on exploring how performance of lean implementation contributes in increasing the development performance of sustainable manufacturing. The findings in this study are able to be used for future researches in formulating new strategies in managing the manufacturing

operations. This eventually brings an enormous benefit for further research in improving the operational efficiency, in order to remain competitive in dealing with the intense competition in a global manufacturing environment.

**Keywords:** lean production; lean tools; lean performance; manufacturing sustainability index; general review.

**Reference** to this paper should be made as follows: Yusup, M.Z., Wan Mahmood, W.H., Salleh, M.R. and Mohd Yusof, A.S. (2015) 'Review the influence of lean tools and its performance against the index of manufacturing sustainability', *Int. J. Agile Systems and Management*, Vol. 8, No. 2, pp.116–131.

**Biographical notes:** Muhamad Zaki Yusup is a Lecturer at the Department of Quality and Productivity, Kolej Kemahiran Tinggi MARA, Kuantan, Pahang. He holds a BEng (Mechanical-Industrial), Masters in MSE, and currently is a PhD candidate at Universiti Teknikal Malaysia Melaka (UTeM) in a competitive manufacturing research area. He is experienced in production operation and design transfer process in new product development while working as an engineer with several Malaysian and Japanese companies. His current research is related to the adoption of cleaner production and lean production in improving the competitiveness, responsiveness and sustainability in manufacturing.

Wan Hasrulnizzam Wan Mahmood is a Senior Lecturer at the Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka (UTeM). He also has extensive consultancy experience in empowering lean manufacturing practices. His research interests are maintenance management, supply chain management, lean manufacturing, operational research, quality and reliability.

Mohd Rizal Salleh is an Associate Professor in Industrial Engineering at the Faculty of Manufacturing Engineering, Universiti Teknikal Malaysia Melaka (UTeM). He has been working as a process engineer with several numbers of Japanese companies. His research interests include lean manufacturing, metrology, manufacturing processes, measurement uncertainty, and agile manufacturing.

Azrul Shahimy Mohd Yusof holds a BEd (Hons) in TESL and MA in Linguistics and ELS. He is currently a Lecturer at the Department of Language Studies, Universiti Teknologi MARA (UiTM) Kedah, and specialisation in English language studies. His research interest includes speech science, language endangerment, indigenous language and cultural documentation.

---

## 1 Introduction

Lean production (LP) has a great influence in controlling and reducing the usage of material and resources in product development, reducing the operation cost, controlling the inventory level and requirement, maximise the use of available space, and increase the utilisation of labour. The ability to adopt to this philosophy do not only influence the financial and physical aspect, but also give the opportunity to the manufacturer to adapt to the emergence of new techniques and technologies in improving the manufacturing performance (Prince and Kay, 2003; Houshmand and Jamshidnezhad, 2006). For

example, the adoption of several techniques in LP such as just-in-time (JIT), total quality management (TQM), total productive maintenance (TPM), human resource management (HRM), gembu, and kaizen evidently contributed in achieving these objectives (Doolen and Hacker, 2005; Shah and Ward, 2007). Moreover, it is also able to increase the integrity of data in a continuous improvement activity, primarily in improving the manufacturing productivity (Powell et al., 2013).

In the new global economic framework, the changes of laws and regulations, the introduction of new requirements in a manufacturing operation, as well as the high insistence from stakeholders have increased the pressure and responsibility of manufacturers in making sure the implementation of sustainable manufacturing practices is achievable (Martínez-Jurado and Moyano-Fuentes, 2014; Yusup et al., 2014). Therefore, the integration of existing manufacturing practices with multiple disciplines and techniques in manufacturing is required (Hallstedt et al., 2013). This is to make sure that there is continuity in improving the manufacturing operations, as well as increasing the level of competitiveness in a new global manufacturing environment (Schrettle et al., 2014).

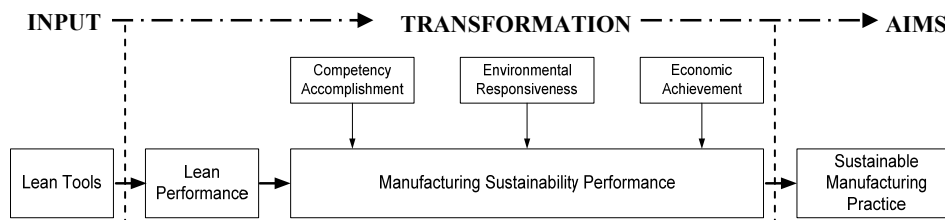
Nowadays, the adaptation of LP practice has been acknowledged having a significant effect on the continuous improvement activity in manufacturing sectors. This philosophy is also proven to have a great influence in producing a high quality work environment, enhances the capability in managing the overall manufacturing operations, as well as increasing the ability to manage the negative influence from manufacturing activities on the environment (Demeter and Matyusz, 2011). This consequently allows manufacturers increase the level of responsiveness against new manufacturing requirements, particularly in addressing the environmental issues, improve the economic performance, and increase the level of competency in fulfilling the social needs in establishing sustainable manufacturing environment (Vithayasrichareon et al., 2012; Yusup et al., 2013a). In addition, it is also able to bring opportunities for the manufacturer to quickly respond to a stiff competition in producing a high quality product at a reasonable cost, in a shorter waiting time (Aguado et al., 2013).

For all these reasons, this article focuses on investigating how the implementation performance of the LP contributes in establishing sustainable manufacturing practices. This was carried out by identifying the interrelationship between the performance of LP practices with the level of sustainable manufacturing, based on three sustainability performance that were identified, namely the competency accomplishment performance (CAP), economic achievement performance (EAP) and environmental responsiveness performance (ERP). The findings in this article are able to provide a new perspective to the manufacturers in adopting and enhancing the performance of LP practices, particularly in increasing the sustainability of manufacturing performances. The organisation of this article is as follows. Section 2 explains about the research method, Section 3 discusses on the influences of LP practices in establishing the manufacturing sustainability (MS), and finally a conclusion and suggestion for future research in Section 4.

## 2 Research method

The method of research in this article is based on qualitative analysis. This groundwork is used for understanding and enhancing advanced knowledge in a specific area that usually requires a detailed research (Martínez-Jurado and Moyano-Fuentes, 2014). To make sure the review process within the scope, the review focuses on investigating how the performance of LP through the adaptation of LP tools in manufacturing operations influences the establishment of sustainable manufacturing practice based on three aspects of MS performance: CAP, EAP and ERP. The form of the review concept in article is illustrated in Figure 1.

**Figure 1** Review concept in investigating lean tools and its performance against the level of manufacturing sustainability performance



As in Figure 1, this review concept is used as a guide to identify the LP tools and practice that hypothetically can support the establishment of the three pillars of sustainable manufacturing (social, economic and environmental). The exploration on the social is based on the level of CAP, the economic aspect is based on the level of EAP, while for the environmental aspect is based on the level of ERP.

Next, based on the six steps of the literature review process, namely selection, comprehension, application, analysis, synthesising and evaluating (Levy and Ellis, 2006), each article is systematically analysed against several research articles published from 2003–2014. This is to make sure the information required in the discussion is obtained under controlled conditions (Kitchenham, 2004). After that, the cross analysis with articles linked to the LP and MS was carried out to identify the influence of LP performance against the performance of MS as mentioned in Figure 1. Through the focus on the interrelationship links between LP and the MS, the data obtained from the analysis is then used as the main essence in this review process. A pre-verification with four operations managers also been carried to verify each of the LP performance highlighted, in which have high tendency to influence the performance of manufacturing sustainability. Each sustainability performance was then used to explain how the performance in LP practices and the utilisation of LP tools influences the level of MS performance.

## 3 Lean production for manufacturing sustainability advantages

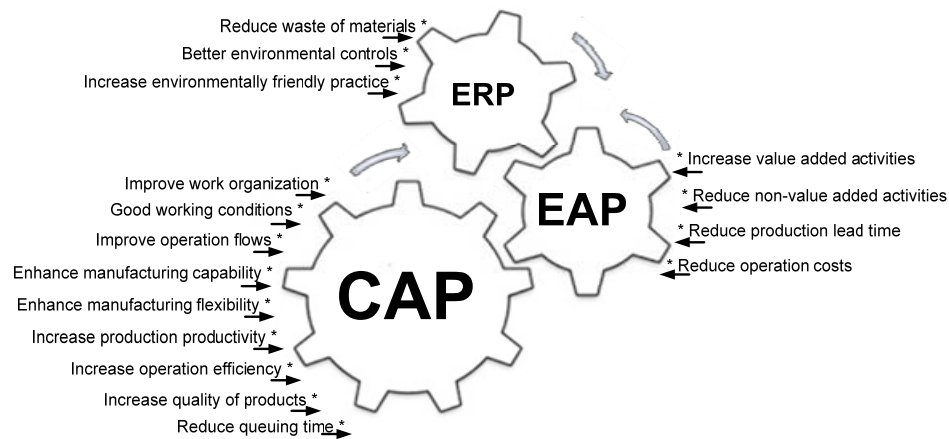
The implementation of LP evidently has improved the performance and image of the manufacturer. Competency in LP practices has allowed manufacturers to quickly react to the fluctuating needs of customers, employees, shareholders and surrounding communities (Bhasin, 2012). LP's also gives the opportunity to the manufacturer to

properly plan the capacity of resources and costs that required (Hosseini Nasab et al., 2012). This is important in managing and improving the operation and performance of manufacturing, particularly through the diversification of LP practices in manufacturing operations such as kanban, JIT and TQM (Melton, 2005; Abdulmalek and Rajgopal, 2007; Saurin and Ferreira, 2009).

The implementation of LP practices do not only expedite the production process, but also has proven able to improve the financial performance. It is vital in dealing with the increase of pressure that is caused by challenging market conditions (Hofer et al. 2012). Therefore, the adaptation of LP as part of the management philosophy in manufacturing operations is important in establishing a sustainable manufacturing practice in a dynamic manufacturing environment (Yusup et al., 2013b). This is realised by strengthening the performance of LP, specifically in developing the continuity of the sustainable manufacturing practice in confronting new global market environment (Tseng et al., 2013; Schrettle et al., 2014).

The literatures had disclosed that the influences of LP performance against the MS begins from the early stage of product development to how the manufacturer need to be responsive to issues in the manufacturing, during and after the products is produced (Yang et al., 2011; Dombrowski et al., 2012). This interrelationship is able to be evaluated through three classifications of MS performance that are identified: CAP (Garrett et al., 2009; Vánca et al., 2011), EAP (Vinodh and Jeya Girubha, 2012; Khalili-Damghani and Sadi-Nezhad, 2013) and ERP (Jayal et al., 2010; Seuring and Gold, 2013). These performance are seen to give a contribution in increasing the MS practices that is driven by the performance in LP practices. The influence of the LP performance against MS performance is summarised in Figure 2.

**Figure 2** Influence of lean production performance on manufacturing sustainability performance



From Figure 2, the performance in LP is seen to have a major influence against the level of CAP. This evidently achievable through high level of competency and full focus in adapting the LP practice in manufacturing operations (Bhasin, 2012). It allows manufacturers to attain a high MS level by establishing best practice to react to new challenges in a competitive manufacturing environment. This subsequently increase the affordability of having a better manufacturing platform in producing better quality products (Sundin et al., 2011; Dombrowski et al., 2012).

The EAP is important in achieving sustainable manufacturing practices (Jayal et al., 2010; Aguado et al., 2013). It can be strengthened by integrating the LP practices through a variety of value added activities during regulate the manufacturing operations. For example, the deployment of LP technique such as value stream mapping (VSM) has allowed manufacturers analyse and plan the best option in managing the manufacturing operation from the beginning to the finished product is successfully delivered to the customer, using a systematic approach (Ostlin and Ekholm, 2007). This technique is not only able to reduce the product lead times, but is also able to be used to develop a better contingency plan to monitor and improving the current manufacturing activities (Hofer et al., 2012; Rahani and al-Ashraf, 2012). This positively helps to eliminate and reduce non-value added activities that are typically hindered by the requirement of increasing the manufacturing capacity (Abdulmalek and Rajgopal, 2007; Hosseini Nasab et al., 2012).

High performance in LP practices is also influencing the ways of how manufacturers take a responsibility in dealing with the environmental issue that arise at the final cycle of product manufacturing stage. The ability to adopt and integrate the LP practice in managing the environmental issue had provided the opportunity for manufacturers to develop a better plan to manage material utilisation, reduce the unused material, as well as reduces the pollution emission and industrial waste (Meade et al., 2006). This is obviously important to manage the environmental issues and why ERP is required in establishing the MS must be increased (Ziout et al., 2013).

### *3.1 Competency accomplishment performance*

High integration level, focus, commitment, and continuous effort in adopting LP practices in manufacturing operations can increase the level of CAP. This brought large implication on the social aspect in sustainable development of manufacturing practice, primarily in increasing the efficiency of work organisation and workflow (Holden, 2011), increasing productivity and manufacturing efficiency (Van Passel et al., 2009; Ziout et al., 2013) and ability to produce better quality products (Tseng et al., 2013). As a part of the main pillar in MS, high level of CAP is desirable. This is to ensure the dynamic in the LP practice are increased in line with the changes that occurs in the manufacturing environment, either internally or externally (Hon, 2005). From the review, nine categories of LP performance had identified, and twelve LP techniques are suggested to be adopted in manufacturing operations potentially effect on the level of CAP. The influence of these matrixes on the CAP level is illustrated in Table 1.

The ability to implement and monitor the LP practices through the performance review, learning, stewardship and routine work area are found to influence the CAP level. Besides, it is also useful in assessing the commitment of manufacturers in adopting this philosophy in manufacturing operations (Glover et al., 2011). This gives the chances to the manufacturers to identify the risks and opportunities to improve the working environment to be in line with the products produced (Hallstedt et al., 2013). Furthermore, LP practices do not only emphasise on the achievement of the technical aspects, but also cover a social aspect that makes this philosophy able to be adapted to any conditions and situations (Womack and Jones, 2003). The adaptation of several techniques of LP do not only increase the level of CAP, but it also gives the opportunity for manufacturers to optimise the usage of the workspace and improve work organisations, primarily to increase the capacity and ability of production in producing various products at different volumes (Saurin and Ferreira, 2009). This internally

envisioned by the level of competency achievement by employees in performing their works. In fact, Despeisse et al. (2013) claimed that the performance in workflow management provides tangible guidelines for manufacturers to approach sustainability at an operational level.

**Table 1** Matrix of lean tools and its performance over the level of CAP

	<i>Lean tools</i>													
	<i>5 S</i>	<i>JIT</i>	<i>Root cause analysis</i>	<i>SMED</i>	<i>Takt time</i>	<i>Bottleneck analysis</i>	<i>Standardised work</i>	<i>Jidoka</i>	<i>Poka-yoke</i>	<i>Heijunka</i>	<i>CFA</i>	<i>Kanban</i>	<i>Andon</i>	<i>Visual factory</i>
Improve work organisations	H	H	L				M	L			L		L	L
Increase operation efficiency	H	M	H	H	H		M	M	L	L	L	M		
Increase production productivity	M			M	M	H	H	L	M	M	L	M	M	M
Increase quality of products	L		H				M	H	H					
Reduce queuing time	L		L	M	M	H				H	H		M	
Enhance manufacturing capability			M		L	L	L	M		H	M	H		L
Enhance manufacturing flexibility		L	L	H		L		L		H	M	H		L
Good working conditions	H	H											L	
Improve operation flows	M	L	M	L		M	M	M	H	L	H		H	H

Notes: CAP level: H – high, M – moderate, L – low.

Saurin and Ferreira (2009) found that most employees agreed that the working conditions were better after the introduction of LP practice. The adoption of LP practice such as 5S that aims to eliminate waste through five basic disciplines (sort, set in order, shine, standardise, and sustain) is a popular technique used in improving the work arrangement and workflow (Martínez-Jurado and Moyano-Fuentes, 2014). This has motivated the employee to perform their work in a well-organised routine, through a quality work space in a comfortable work environment in fulfilling the manufacturing objectives (Chen et al., 2012; Jabbour et al., 2013). In addition, it also has simplified the execution of work assignment, as well as enhancing the role and responsibility of employees in suggesting and implementing changes to the work arrangements. The process flow also becomes smoother and easier in increasing the acceptance of employees with the changes of work arrangements towards the development of sustainable manufacturing practice as organisational work culture (Losonci et al., 2011). Besides, it is also able to encourage the development of versatile and highly qualified labour in execution of the processes and job procedures (Aguado et al., 2013). This can be used to streamline the operational procedures in identifying the best practices, particularly in determining the time required to complete the task given (Jayal et al., 2010). In addition, the adoption of other techniques such as andon or visual control to monitor and report the current status of production floor increases the commitment, as well as the level of CAP using real time info (Doolen and Hacker, 2005). Bhasin (2012) found that 83% of large companies, 75% of medium-sized organisations and 83% of small organisations has adopted 5S and visual

management in their operations. He also found that 68.6% of managers have adopted these tools within their organisations. This had increased the ability to detect the signal of problems faced on the production floor at an early stage, and allowing quick actions taken by the operating team (Dombrowski et al., 2012).

The implementation also allows manufacturers shorten the lead time, and producing a variety of products with a varying quantity. The production lots sizes also can be frequently adjusted to meet the customer's demand at a minimum inventory rate (Meade et al., 2006; Demeter and Matyusz, 2011). In addition, the ability to utilise jidoka technique (automation), JIT and kanban are also able to increase the index of CAI (Ostlin and Ekholm, 2007; Hosseini Nasab et al., 2012). The jidoka techniques do not only increase the capacity of the production floor, but also reduce the energy consumption, cost of labour, customer waiting time and finally increase product sales (Holweg, 2007). The willingness to increase the competency in adopting all these LP technique is seen as having a significant influence in achieving high levels of CAP, in attaining the sustainable manufacturing practice.

Meanwhile, the ability to use bottleneck analysis especially to strengthen the weakest work station and problematic process, expedite the flow of the manufacturing process (Sundin et al., 2011). The competency in implementing this technique in line with SMED practice was a valuable input in production planning processes (Melton, 2005). This is important in streamlining the flow of production, increase the productivity as well as improve the CAP in establishing the sustainability in manufacturing (Ngai et al., 2013). Besides, the adoption of LP techniques such as TQM (Abdulmalek and Rajgopal, 2007; Yang et al., 2011) and poka-yoke or mistake proof (Doolen and Hacker, 2005) at a high competency level potentially increase the quality of product being produced as desired, particularly in fulfilling the customer's requirements, increasing the reliability of products, as well as meet the increasingly critical business objective. All these contribute in increasing the level of CAP, particularly to meet the social aspects of internal communities in implementing the MS practice. This is in line with the development of manufacturing climate nowadays, particularly in sustaining in a competitive environment, in which the market monopoly of products is getting smaller and more challenged.

### *3.2 Economic achievement performance*

The strength of the EAP is crucial for manufacturers in strengthening their position to enhance business domination in the market (Hofer et al., 2012). Nowadays, high competition level in the manufacturing sector had pressured the business in the manufacturing sector. The implementation of the right strategy is required to remain relevant, and to react positively through radical changes in dealing with the intense competition in manufacturing industry (Schrettle et al., 2014). To support these changes, the sustainability of EAP is compulsory. This performance do not only allow manufacturers fulfilling the requirement of economic pillar in establishing the MS practice, but also important in increasing the ability to survive in the global market environment (Jayal et al., 2010; Khalili-Damghani and Sadi-Nezhad, 2013). In addition, the EAP also influences the ability in streamlining the management of manufacturing operations. High level of EAP will allow appropriate financial resource being allocated in improving manufacturing operations (Vithayasrichareon et al., 2012). This is significantly contributing to increasing the profitability to manufacturers, and needed to form a strong foundation in an increasingly competitive manufacturing



environment (Tseng et al., 2013). Therefore, decent EAP level is important, in tandem with advances of technology in a new product development cycle (Sreenivasan et al., 2010).

The adaptation of LP practice in the modern manufacturing paradigms is seen to influence the level of EAP. It is necessary to ensure the continuity in implementing a comprehensive manufacturing sustainability practice are achievable (Chen et al., 2012; Seuring and Gold, 2013). For example, the adaptation of LP technique such as bottleneck analysis and continuous flow analysis (CFA) successfully improve the chain of performance in manufacturing operations (Melton, 2005; Ostlin and Ekholm, 2007). These techniques also allow manufacturers to eliminate or at least minimise non-value added activities that normally occur when trying to increase the production capacity. The awareness and the commitment in this matter also improve the competency of resource utilisation in current manufacturing operations, reduce the production of semi-finished products or the work-in-progress (WIP) and the quantity of buffers (Demeter and Matyusz, 2011). As a result, the inventory level, waiting time, and transportation is able to be reduced and minimised (Abdulmalek and Rajgopal, 2007). This indirectly increases the EAI and consequently strengthens the economic performance, particularly in formulating better strategies and practices in establishing MS.

Besides that, the adoption of LP techniques such as heijunka (level scheduling) and jidoka (automation) in manufacturing operations has directly influenced the increase of efficiency in manufacturing operations (Wilson, 2010; Hosseini Nasab et al., 2012; Galeazzo et al., 2014). It is allowing manufacturers to produce products in a smaller capacity, reduce lead times, as well as expedite the production cycles. This also enables the manufacturers to monitor the manufacturing operations more efficient and reduce the dependence on human labour that potentially increase the manufacturing cost (Kojima and Kaplinsky, 2004; Doolen and Hacker, 2005). This is because the ability to control the manufacturing cost is an important element in maintaining the continuity of competitiveness in the market. In addition, the high performance in other LP techniques such as VSM also increases the level of EAP (Rahani and al-Ashraf, 2012; Aguado et al., 2013). Subsequently, this allows manufacturers to identify new opportunities in improving the operation and activity in managing the manufacturing operation.

The ability to implement single minutes exchange of die (SMED) or one touch machine setup (OTED) also increases the EAP. Through the focus on minimising the setup times (time change) during operation change, these techniques allow the manufacturers to frequently change the production line and produce a variety of products in similar product groups, at different lot sizes. The impression of this technique against EAP is clearly significant when combined with other LP techniques such as JIT or kanban (Holweg, 2007; Rivera and Frank Chen, 2007). This allows the manufacturers to produce the products in a smaller lot size, reduce the inventory, improve the customer responsiveness and avoid the use of excessive financial resources (Bhasin, 2012). This does not only increase the cash flow for a better financial performance, but also prevent manufacturers from producing the excess products that potentially give negative influence on the financial performance.

Moreover, high performance in implementing gembu and kaizen allows the manufacturer to identify the problem in manufacturing operations in a more realistic condition (Stojkic et al., 2014). This is necessary in developing a framework and action plan to handle any problem that may potentially occur on the production floor. Besides that, the collaboration and involvement of employees in the continuous improvement

activity increases with the continuity of sustainability practice in manufacturing (De Haan et al., 2012; Ngai et al., 2013). By focusing on identification of the root cause of the problems on addressing the manufacturing issues, every information collected are able to be used to develop a better framework in tackling the waste produced from the manufacturing activity (Glover et al., 2011). This does not only shorten the time required to identify the problem, but also proactively help manufacturers overcome and prevent potential problems immediately without waiting for the problem to happen. This subsequently leads to the adoption of other LP techniques such as TPM and visual factory tools that have positive implications on the performance of manufacturing operations (Azadegan et al., 2013; Kaya et al., 2014). Besides, integration with other LP techniques also gives benefits to the manufacturer in the form of better monitoring of manufacturing operations. Level of communication on the manufacturing floors also increased (Welo et al., 2013). This makes the production activity is easier to be accessed and clear information is attainable. For example, Abdulmalek and Rajgopal (2007) found that high performance level in TPM at an integrated steel mill industry has successfully reduced the lead time from 48 to 15 days (reduction by 70%). The adaptation of this technique also increases the responsibility of employee's, and reduce the maintenance costs, particularly those carried out by third parties, and increase the utilisation of labour in maintaining the performance of manufacturing operations.

In general, four categories of LP performance are summarised and found to contribute in increasing the level of EAP. This can be achieved through the adaptation of 21 tools and techniques of LP in manufacturing operations. The matrix of lean tools and its performance over the EAP level is illustrated in Table 2.

**Table 2** Matrix of lean tools and its performance over the level of EAP

		Lean tools																				
		5'S	JIT	Root cause analysis	SMED	Takt time	Bottleneck analysis	Standardised work	Jidoka	Poka-yoke	Heijunka	CFA	Kanban	Andon	Visual factory	Gemba	Kaizen	Muda	Hoshin kanri	OEE	VSM	TPM
Lean performance	Increase value-added activities	H		H			M	H	M	L		L		H	H	H	H	L		L	H	H
	Reduce non-value added activities	H	L	H	L		L	H	H		M				H		H	H			H	
	Reduce production lead time	H	H		H	M	H	L	H		H	H	H					M		H	H	H
	Reduce operation costs	L	H	M	H	H	H		H	H	H	H	H			L	L	L	L	H	H	

Notes: EAP level: H – high, M – moderate, L – low.

These have made LP practices as the holistic approach in maintaining and improving the level of EAP or financial performance, primarily in establishing the sustainable manufacturing practice (Meade et al., 2006; Yang et al., 2011; Short et al., 2012). Besides, it is also useful in reducing the production lead times to expedite the production pace to meet the customer's demand (Shah and Ward, 2007; Sundin et al., 2011).

### *3.3 Environmental responsiveness performance*

In achieving sustainability in manufacturing, the utilisation of resources that have an adverse effect on the environment must be avoided or minimised (Sreenivasan et al., 2010). As a complex multi-dimensional approach, the recognition of the ERP in fulfilling the environmental pillar in MS practice is needed to ensure the benefits of these practices are achievable (Jayal et al., 2010; Vinodh and Jeya Girubha, 2012). This is required mainly in integrating the aspect of environmental in managing the resources allocated in manufacturing operations (Van Passel et al., 2009; Ghadimi et al., 2012). The constant practice in managing the activity and resources in achieving environmental sustainability are required in maintaining the sustainable competitive advantages (Tseng et al., 2013). This enables manufacturers to reconsider the business models and restructure the manufacturing operations (Schrettle et al., 2014). The focus on improving the level of ERP also may balance any changes in new paradigms of manufacturing, such as the increasing cost of natural resources, new mandates from government, and strict environmental regulations (Short et al., 2012; Ziout et al., 2013).

Besides that, the awareness of manufacturers in minimising the waste from manufacturing operations would reduce the hidden cost that needed to be borne in addressing the problems that occur in manufacturing plants (Ghadimi et al., 2012). This indirectly increases the level of ERP, particularly in fulfilling part of the pillars and the requirements needed in establishing sustainability practice in manufacturing (Khalili-Damghani and Sadi-Nezhad, 2013). This is in line with the current circumstances where the amount of raw materials used in manufacturing operations needs to be reduced. The responsiveness of manufacturers with this circumstance is needed to maintain the continuity of the manufacturing sector in the future.

From review, three categories of LP performance had been identified and summarised, and twelve LP techniques are suggested to be adopted in manufacturing operations to improve its implementation performance. This implementation potentially influences the ERP level in establishing the sustainability practice in manufacturing. In general, the matrix between the tool and technique of the LP and its performance on ERP level is illustrated as in Table 3.

The focus of LP implementation in tackling internal waste from manufacturing operations can be extended to manage the associated environmental issues (Yang et al., 2011). It directly allows manufacturers to increase the environmental management performance and gain competitive advantage by formulating comprehensive environmental management strategies, such as pollution prevention or minimising emissions, as well as effluents and industrial waste. This significantly contributes in reducing the marginal cost required in environmental management (Aguado et al., 2013). Furthermore, the principle of LP practices is usually close to the overall objective set by environmental management systems such as ISO 14001, pollution prevention and recycling of materials (Hajmohammad et al., 2013). The support against environmental

management tends to be greater when manufacturers adopt LP practices. Through proactive environmental management practices, manufacturers are also able to generate additional business opportunities, promote production efficiency and eventually reduce the cost in manufacturing and pollution management (Despeisse et al., 2013). This evidently shows that high performance in LP practices do not only increase the level of ERP, but also helps manufacturers to plan the proper action in managing the manufacturing operations to achieve sustainable development in manufacturing (Ngai et al., 2013).

**Table 3** Matrix of lean tools and its performance over the level of ERP

		<i>Lean tools</i>										
		<i>Root cause analysis</i>	<i>Standardised work</i>	<i>Jidoka</i>	<i>Poka-yoke</i>	<i>CFA</i>	<i>Visual factory</i>	<i>Gemba</i>	<i>Kaizen</i>	<i>Hoshin kanri</i>	<i>TPM</i>	<i>KPI</i>
Lean performance	Reduce waste of material	M	H	H	H	H		H	H	M	H	H
	Increase environmentally friendly practice	L		L		H	H	H	H	H	L	L
	Better environmental control	H	M	M		H		H	L	H		H

Notes: ERP level: H – high, M – moderate, L – low.

The adaptation of various LP techniques such as CFA in managing environmental issues has allowed manufacturers to carefully plan the use of resources, and avoid wastage that possibly increases industrial waste (Sundin et al., 2011; Rahani and al-Ashraf, 2012). This potentially increases the ability of manufacturers to manage the activity in the manufacturing operation independently. Besides that, the ability to adapt and increase the implementation performance of other LP techniques such as kaizen and gemba also increase the ability of manufacturers to identify any risk and problems that possibly influence the level of ERP (Vais et al., 2009). This eventually allows manufacturers to identify potential environmental issues and problems that could possibly occur, and develop a comprehensive action plan in handling any problem that could possibly occur from the activity that was carried out. Besides that, the adaptation of the LP that in line with the environmental policies to meet business goals and strategies is also able to increase the ERP level. Through the right environmental policy, it may potentially improve the implementation performance of LP, as well as minimise the lack of communication and inconsistent actions in addressing the environmental issues (Jabbour et al., 2013). The willingness of manufacturers to accept ERP as a key performance index (KPI) in improving manufacturing operations may encourage better implementation of LP practices, as well as ensuring the level of ERP are in the best position to achieve the sustainability in manufacturing practices.

#### 4 Conclusions and future research

This article discloses that high performance in LP practices do not only increase the manufacturing productivity in managing the manufacturing operations, but is also capable to increase the chances of achieving high sustainability in manufacturing practices. The discussion has revealed that proactive action in LP implementation has high influence against the MS performance identified namely CAP, EAP and ERP. This can be achieved if manufacturers have the ability to adapt with several LP practices and techniques that potentially influence the economic performance, environmental, and the level of competency in managing the manufacturing operations.

For future research, quantitative analysis through empirical study will be used to measure the degree of influence of the LP performance against each performance of MS. This may lead to in depth analysis in order to understand the influence of LP implementation's performance against MS. The findings can be used to develop a framework in establishing a diagnostic model that can be used by academicians and industrial practitioners in developing a strategic plan, in hopes of creating a comprehensive framework that increase the performance of the manufacturing sectors in the future.

#### Acknowledgements

This research was co-funded by Universiti Teknikal Malaysia Melaka (UTeM) under an ERGS Grant (ERGS/1/2013/TK01/UTEM/02/08/E00029).

#### References

- Abdulmalek, F.A. and Rajgopal, J. (2007) 'Analyzing the benefits of lean manufacturing and value stream mapping via simulation: a process sector case study', *International Journal of Production Economics*, Vol. 107, No. 1, pp.223–236.
- Aguado, S., Alvarez, R. and Domingo, R. (2013) 'Model of efficient and sustainable improvements in a lean production system through processes of environmental innovation', *Journal of Cleaner Production*, May, Vol. 47, pp.141–148.
- Azadegan, A., Patel, P.C., Zangouinezhad, A. and Linderman, K. (2013) 'The effect of environmental complexity and environmental dynamism on lean practices', *Journal of Operations Management*, Vol. 31, No. 4, pp.193–212.
- Bhasin, S. (2012) 'Performance of lean in large organisations', *Journal of Manufacturing Systems*, Vol. 31, No. 3, pp.349–357.
- Chen, D., Heyer, S., Seliger, D. and Kjellberg, T. (2012) 'Integrating sustainability within the factory planning process', *CIRP Annals – Manufacturing Technology*, Vol. 61, No. 1, pp.463–466.
- De Haan, J., Naus, F. and Overboom, M. (2012) 'Creative tension in a lean work environment: implications for logistics firms and workers', *International Journal of Production Economics*, Vol. 137, No. 1, pp.157–164.
- Demeter, K. and Matyusz, Z. (2011) 'The impact of lean practices on inventory turnover' *International Journal of Production Economics*, Vol. 133, No. 1, pp.154–163.
- Despeisse, M., Oates, M.R. and Ball, P.D. (2013) 'Sustainable manufacturing tactics and cross-functional factory modelling', *Journal of Cleaner Production*, March, Vol. 42, pp.31–41.

- Dombrowski, U., Mielke, T. and Engel, C. (2012) 'Knowledge management in lean production systems', *Procedia CIRP*, Vol. 3, pp.436–441.
- Doolen, T.L. and Hacker, M.E. (2005) 'A review of lean assessment in organizations: an exploratory study of lean practices by electronics manufacturers', *Journal of Manufacturing Systems*, Vol. 24, No. 1, pp.55–67.
- Galeazzo, A., Furlan, A. and Vinelli, A. (2014) 'Lean and green in action: interdependencies and performance of pollution prevention projects', *Journal of Cleaner Production*, 15 December 2014, Vol. 85, pp.191–200.
- Garrett, R.P., Covin, J.G. and Slevin, D.P. (2009) 'Market responsiveness, top management risk taking, and the role of strategic learning as determinants of market pioneering', *Journal of Business Research*, Vol. 62, No. 8, pp.782–788.
- Ghadimi, P., Azadnia, A., Mohd Yusof, N. and Mat Saman, M.Z. (2012) 'A weighted fuzzy approach for product sustainability assessment: a case study in automotive industry', *Journal of Cleaner Production*, September, Vol. 33, pp.10–21.
- Glover, W.J., Farris, J.A., Van Aken, E.M. and Doolen, T.L. (2011) 'Critical success factors for the sustainability of Kaizen event human resource outcomes: an empirical study', *International Journal of Production Economics*, Vol. 132, No. 2, pp.197–213.
- Hajmohammad, S., Vachon, S., Klassen, R.D. and Gavronski, I. (2013) 'Lean management and supply management: their role in green practices and performance', *Journal of Cleaner Production*, January, Vol. 39, pp.312–320.
- Hallstedt, S.I., Thompson, A.W. and Lindahl, P. (2013) 'Key elements for implementing a strategic sustainability perspective in the product innovation process', *Journal of Cleaner Production*, 15 July 2013, Vol. 51, pp.277–288.
- Hofer, C., Eroglu, C. and Rossiter Hofer, A. (2012) 'The effect of lean production on financial performance: the mediating role of inventory leanness', *International Journal of Production Economics*, Vol. 138, No. 2, pp.242–253.
- Holden, R.J. (2011) 'Lean thinking in emergency departments: a critical review', *Annals of Emergency Medicine*, Vol. 57, No. 3, pp.265–78.
- Holweg, M. (2007) 'The genealogy of lean production', *Journal of Operations Management*, Vol. 25, No. 2, pp.420–437.
- Hon, K.K.B. (2005) 'Performance and evaluation of manufacturing systems', *CIRP Annals – Manufacturing Technology*, Vol. 54, No. 2, pp.139–154.
- Hosseini Nasab, H., Aliheidari Bioki, T. and Khademi Zare, H. (2012) 'Finding a probabilistic approach to analyze lean manufacturing', *Journal of Cleaner Production*, July, Vol. 29–30, pp.73–81.
- Houshmand, M. and Jamshidnezhad, B. (2006) 'An extended model of design process of lean production systems by means of process variables', *Robotics and Computer-Integrated Manufacturing*, Vol. 22, No. 1, pp.1–16.
- Jabbour, C.J.C., Jabbour, A.B.L.D.S., Govindan, K., Teixeira, A.A. and Freitas, W.R.D.S. (2013) 'Environmental management and operational performance in automotive companies in Brazil: the role of human resource management and lean manufacturing', *Journal of Cleaner Production*, May, Vol. 47, pp.129–140.
- Jayal, A.D., Badurdeen, F., Dillon, O.W. and Jawahir, I.S. (2010) 'Sustainable manufacturing: modeling and optimization challenges at the product, process and system levels', *CIRP Journal of Manufacturing Science and Technology*, Vol. 2, No. 3, pp.144–152.
- Kaya, O., Catic, A. and Bergsjö, D. (2014) 'Exploring the possibilities of using image recognition technology to create a hybrid lean system for pulse methodology', *Procedia Computer Science*, Vol. 28, pp.275–284.
- Khalili-Damghani, K. and Sadi-Nezhad, S. (2013) 'A hybrid fuzzy multiple criteria group decision making approach for sustainable project selection', *Applied Soft Computing*, Vol. 13, No. 1, pp.339–352.

- Kitchenham, B.A. (2004) 'Systematic reviews', *2004 10th International Symposium on Software Metrics*, Vol. 26, No. 4, p.2000.
- Kojima, S. and Kaplinsky, R. (2004) 'The use of a lean production index in explaining the transition to global competitiveness: the auto components sector in South Africa', *Technovation*, Vol. 24, No. 3, pp.199–206.
- Levy, Y. and Ellis, T.J. (2006) 'A systems approach to conduct an effective literature review in support of information systems research', *Informing Science Journal*, Vol. 9, pp.181–212.
- Losonci, D., Demeter, K. and Jenei, I. (2011) 'Factors influencing employee perceptions in lean transformations', *International Journal of Production Economics*, Vol. 131, No. 1, pp.30–43.
- Martínez-Jurado, P.J. and Moyano-Fuentes, J. (2014) 'Lean management, supply chain management and sustainability: a literature review', *Journal of Cleaner Production*, 15 December 2014, Vol. 85, pp.134–150.
- Meade, D.J., Kumar, S. and Houshyar, A. (2006) 'Financial analysis of a theoretical lean manufacturing implementation using hybrid simulation modeling', *Journal of Manufacturing Systems*, Vol. 25, No. 2, pp.137–152.
- Melton, T. (2005) 'The benefits of lean manufacturing', *Chemical Engineering Research and Design*, Vol. 83, No. 6, pp.662–673.
- Ngai, E.W.T., Chau, D.C.K., Poon, J.K.L. and To, C.K.M. (2013) 'Energy and utility management maturity model for sustainable manufacturing process', *International Journal of Production Economics*, December, Vol. 146, No. 2, pp.453–464.
- Ostlin, J. and Ekholm, H. (2007) 'Lean production principles in remanufacturing – a case study at a toner cartridge remanufacturer', *Proceedings of the 2007 IEEE International Symposium on Electronics & the Environment*, Orlando, FL, IEEE pp.216–221.
- Powell, D., Alfnes, E., Strandhagen, J.O. and Dreyer, H. (2013) 'The concurrent application of lean production and ERP: towards an ERP-based lean implementation process', *Computers in Industry*, Vol. 64, No. 3, pp.324–335.
- Prince, J. and Kay, J.M. (2003) 'Combining lean and agile characteristics: creation of virtual groups by enhanced production flow analysis', *International Journal of Production Economics*, Vol. 85, No. 3, pp.305–318.
- Rahani, A.R. and al-Ashraf, M. (2012) 'Production flow analysis through value stream mapping: a lean manufacturing process case study', *Procedia Engineering*, Vol. 41, (IRIS 2012), pp.1727–1734.
- Rivera, L. and Frank Chen, F. (2007) 'Measuring the impact of lean tools on the cost-time investment of a product using cost-time profiles', *Robotics and Computer-Integrated Manufacturing*, Vol. 23, No. 6, pp.684–689.
- Saurin, T.A. and Ferreira, C.F. (2009) 'The impacts of lean production on working conditions: a case study of a harvester assembly line in Brazil', *International Journal of Industrial Ergonomics*, Vol. 39, No. 2, pp.403–412.
- Schrettle, S., Hinx, A., Scherrer, M. and Friedli, T. (2014) 'Turning sustainability into action: explaining firms' sustainability efforts and their impact on firm performance', *International Journal of Production Economics*, January, Vol. 147, Part A, pp.73–84.
- Seuring, S. and Gold, S. (2013) 'Sustainability management beyond corporate boundaries: from stakeholders to performance', *Journal of Cleaner Production*, 1 October 2013, Vol. 56, pp.1–6.
- Shah, R. and Ward, P.T. (2007) 'Defining and developing measures of lean production', *Journal of Operations Management*, Vol. 25, No. 4, pp.785–805.
- Short, T., Lee-Mortimer, A., Luttrupp, C. and Johansson, G. (2012) 'Manufacturing, sustainability, ecodesign and risk: lessons learned from a study of Swedish and English companies', *Journal of Cleaner Production*, December, Vol. 37, pp.342–352.
- Sreenivasan, R., Goel, A. and Bourell, D.L. (2010) 'Sustainability issues in laser-based additive manufacturing', *Physics Procedia*, Vol. 5, pp.81–90.

- Stojkic, Z., Majstorovic, V., Visekruna, V. and Zalenika, D. (2014) 'Application of lean tools and xRM software solutions in order to increase the efficiency of business processes', *Procedia Engineering*, Vol. 69, pp.41–48.
- Sundin, E., Björkman, M., Eklund, M., Eklund, J. and Engkvist, I. (2011) 'Improving the layout of recycling centres by use of lean production principles', *Waste Management*, Vol. 31, No. 6, pp.1121–32.
- Tseng, M.L., Chiu, A.S.F., Tan, R.R. and Siriban-Manalang, A.B. (2013) 'Sustainable consumption and production for Asia: sustainability through green design and practice', *Journal of Cleaner Production*, February, Vol. 40, pp.1–5.
- Vais, A., Miron, V., Pedersen, M. and Folke, J. (2006) "'Lean and green" at a Romanian secondary tissue paper and board mill-putting theory into practice', *Resources, Conservation and Recycling*, Vol. 46, No. 1, pp.44–74.
- Van Passel, S., Van Huylenbroeck, G., Lauwers, L. and Mathijs, E. (2009) 'Sustainable value assessment of farms using frontier efficiency benchmarks', *Journal of Environmental Management*, Vol. 90, No. 10, pp.3057–3069.
- Váncza, J., Monostori, L., Lutters, D., Kumara, S.R., Valckenaers, P. and Van Brussel, H. (2011) 'Cooperative and responsive manufacturing enterprises', *CIRP Annals – Manufacturing Technology*, Vol. 60, No. 2, pp.797–820.
- Vinodh, S. and Jeya Girubha, R., (2012) 'PROMETHEE based sustainable concept selection', *Applied Mathematical Modelling*, Vol. 36, No. 11, pp.5301–5308.
- Vithayasrichareon, P., MacGill, I.F. and Nakawiro, T. (2012) 'Assessing the sustainability challenges for electricity industries in ASEAN newly industrialising countries', *Renewable and Sustainable Energy Reviews*, Vol. 16, No. 4, pp.2217–2233.
- Welo, T., Tonning, O.R.B. and Rølvåg, T. (2013) 'Lean systems engineering (LSE): hands-on experiences in applying LSE to a student eco-car build project', *Procedia Computer Science*, Vol. 16, pp.492–501.
- Wilson, L. (2010) *How to Implement Lean Manufacturing*, The McGraw-Hill Companies, Inc., USA.
- Womack, J.P. and Jones, D.T. (2003) *Lean Thinking-Banish Waste and Create Wealth in Your Corporation*, Simon & Schuster, UK.
- Yang, M.G. (Mark), 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, No. 2, pp.251–261.
- Yusup, M.Z., Wan Mahmood, W.H., Salleh, M.R. and Rahayu, T. (2013a) 'A review on optimistic impact of cleaner production on manufacturing sustainability', *Journal of Advanced Manufacturing Technology*, Vol. 7, No. 2, pp.79–99.
- Yusup, M.Z., Wan Mahmood, W.H., Salleh, M.R. and Mohd Rosdi, M.N.H. (2013b) 'The trigger signal for lean production practices: a review', *Global Engineers & Technologists Review*, Vol. 3, No. 6, pp.23–32.
- Yusup, M.Z., Wan Mahmood, W.H., Salleh, M.R. and Muhamad, M.R. (2014) 'The influence factor for the successful implementation of cleaner production: a review', *Jurnal Teknologi*, Vol. 67, No. 1, pp.89–97.
- Ziout, A., Azab, A., Altarazi, S. and ElMaraghy, W.H. (2013) 'Multi-criteria decision support for sustainability assessment of manufacturing system reuse', *CIRP Journal of Manufacturing Science and Technology*, Vol. 6, No. 1, pp.59–69.