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doi:10.4028/www.scientific.net/AMM.761.560
Accepted: 21.11.2014

The Relation between Manufacturing Sustainability and Lean Production in Malaysian Industries - An Initial Study

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Keywords: Manufacturing sustainability, Lean production, Initial study, Malaysia

Abstract. A diversity of techniques and practices in Lean Production (LP) as a tool for cultivating a culture of continuous improvement has successfully produced a holistic approach in achieving a high level of sustainability in manufacturing. Therefore, this study was undertaken to investigate the current performance of manufacturing sustainability in manufacturing industry in Malaysia, and the contribution of Lean in manufacturing sustainability. The findings show that manufacturing industry in Malaysia has a high sustainability in social competency, followed by economic and environmental competency. Even though the environmental sustainability is ranked lowest, the result reveals that aiming to have better control in environment and labour safety is crucial in producing high quality products. In addition, the correlation analysis reveals that this situation has a high relation to the adoption of Lean in production operations. A high competency in adapting Lean does not just increase the manufacturing efficiency, but also has a substantial influence in producing a sustainable product. This indicates that Lean is not just suitable in fulfilling the manufacturing function, but has the potential to be adapted comprehensively, primarily in achieving high manufacturing sustainability.

Introduction

Currently, the ability to achieve manufacturing sustainability that covers elements such as environmental, economic and social competency is very crucial in ensuring the continuity of a business in a new era of manufacturing environment. The consideration of using new technology that is consistent with a comprehensive manufacturing practice potentially improves the level of manufacturing sustainability. This further encourages the formation of new manufacturing management style that potentially raises the ecological safety and good economic returns [1]. In addition, it also allows a new paradigm in the manufacturing sector be developed through a comprehensive transformation in managing a complex manufacturing operations that cover changes in the behavior and technologies used [2,3].

The adaptation of Lean Production (LP) practices in achieving high efficiency in production operation has a significant influence on each of the elements needed to establish a sustainable manufacturing practice. The integration of this practice can provide high added value in managing the production operations in a more effective manner [4]. This eventually promotes a more proactive approach in improving the quality and the sustainability of the product in meeting the needs and opportunities in the future market.

Therefore, this initial study was conducted to investigate the relation between the performance of manufacturing sustainability with the performance of current practice of LP in Malaysia's manufacturing industry based on three components namely Sustainability in Environment (SEP), Sustainability in Economic (SCP) and Sustainability in Social Competency (SSC). The findings can

be used in shaping a more comprehensive actions to achieve high manufacturing sustainability. Besides that, the outcomes from this study can be used by the manufacturer, particularly to identify the initiatives that are required in enhancing LP in order to achieve high sustainability in production operations. Moreover, the evidences from this study can be used to develop a new manufacturing framework to strengthen the current practice in manufacturing operations.

Research Methods

The analysis of this study was based on data obtained from questionnaires. The questionnaires were distributed by mail to several manufacturing industries in Malaysia. The respondents were all staff at management level who have more than 2 years of experience in the same organisation. The questionnaire comprises 25 items on LP, 19 items on sustainability of environmental performance (e), 21 items on sustainability of economic performance (c) and 23 items on sustainable of social competency performance (s). For each item, the respondents were asked to rate each performance based on a seven-point Likert's scale (e.g.: 1=strongly disagree to 7=strongly agree). From a total of 340 questionnaires, only 42 were returned, at a response rate of 12.4 percent. As for the analysis, only 40 questionnaires on LP, 41 on SEP, 39 on SCP and only 39 for SSC were considered valid for the analysis in this initial study.

Results and Discussion

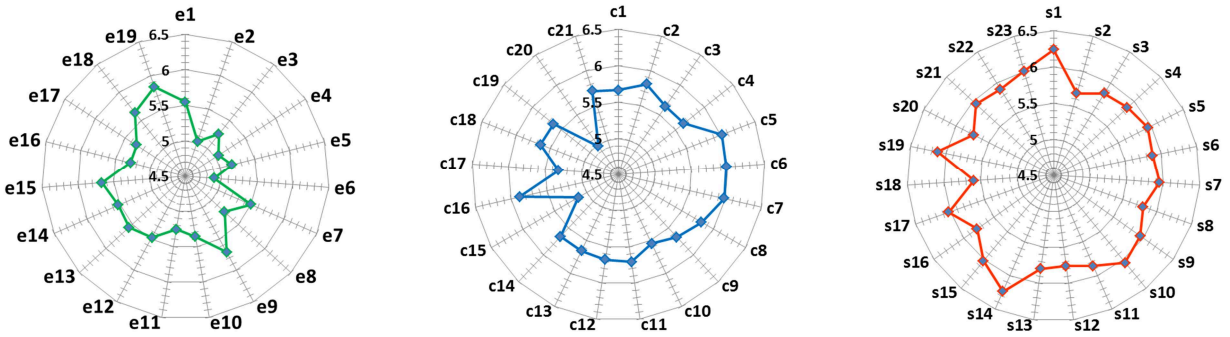
The highest number of company ownership was by Malaysia (64.3%), followed by other Asian countries (26.2%) while 9.5% are the US and Europe companies. Nearly half of the respondents were from the mechanical products group (42.9%). Others are from electric and electronic products group (19%), automotive (16.7%), chemical (14.3%) and 7.1% are from other product group. The majority of the respondents work for Malaysian companies with less than 150 employees (35.9%), while the lowest number of respondents were from the foreign companies that have more than 750 employees (17.9%). Meanwhile, 45.2% of the respondents have experience with ISO14001 while 78.9% have more than 10 years of experience with this management system. Furthermore, 73.6% of the respondents had obtained other management certification such as ISO9001 (73.8%), OHSAS 18001 (11.9%), TS 16949 (21.4%) while 4.8% possess other management certifications such as ISO 13485 and QS9000.

Manufacturing Sustainability Performance. The Cronbach's alpha analysis shows that all items in the questionnaires are consistently reliable at a value of 0.980 for SEP, 0.984 for SCP and 0.979 for SSC. For SEP, the respondents agreed that all 19 items have fulfilled the current practice where the ability to have better control of environmental management (e19) has the highest mean score of 5.83. This is followed by the ability to increase the practice, management and environmental performance (e9), the action to reduce the waste of material (e15), and the consideration of direct effects on the environment from operation (e18) at a mean score of 5.71, 5.67 and 5.64 respectively. However, the ability to adopt reusing and recycling the design of a product (e6) is still less popular as this item gets the lowest score with a mean score of 4.90.

As for SCP, the ability to increase the quality of products (c5) has the highest mean score value at 6.02, followed by the ability to reduce non-value added activities (c6) and to increase added value activities (c7) at a mean score value of 5.98 respectively. Respondents also agreed that they often purchase materials, parts, and manage the resource required based on demand (c16) and this reported a mean score value of 5.88. In contrast, the reduction of the number of parts in the product (c20) has less influence as the respondents appraised this with the lowest mean score value of 4.98.

SSC on the other hand shows that, high competency in complying with environmental regulations and safety issues (s14), and the ability to improve the housekeeping and safety of labour (s1) have the highest mean score value at 6.24. This is followed by the claim that they have a holistic environmental policy statement (s19) at a mean score value of 6.12. The respondents also agreed that the consideration of workforce engagement in the process (s17) and the consideration of current

technology feasibility and labour safety in the operation (s15) are also significant in SSC with a mean score of 6.02 respectively. Meanwhile, collaboration with the communities, government and non-government agencies regarding environmental issues is at the lowest rank at a mean score value of 5.59. The dispersal of the mean scores for all three sustainability components measured is shown graphically in Figure 1.



(a) Sustainability of Environmental Performance (SEP)

(b) Sustainability of Economic Performance (SCP)

(c) Sustainability of Social Competency Performance (SSC)

Fig. 1 The Performance of Components in Manufacturing Sustainability.

This result shows that generally the manufacturing industry in Malaysia's has a high focus on improving the environmental performance. This is not surprising because the focus on dealing with environmental issues is crucial to remain competitive in a modern manufacturing era. This is evidently shown in Fig. 1 where SSC has the biggest dispersal for mean score compared to the other components measured. As for SCP, the performance is influenced by the ability to increase the quality of product, and reduction of non-value added activities. This subsequently leads to reduction of non-value added cost of the production operation, and increase the business and the environment [5]. This is in line with Awudu and Zhang [6] where the ability to react in this situation can reduce the total production cost, where the uncertainties of price in the market are closely monitored. Although the mean score for SEP has the smallest dispersion, the results show that the manufacturers are aware of the need to have better control in environmental management. The current practice that focuses on reducing the waste of material in production operation, potentially reduces the pollutants produced, as stated by Hongbing and Haiyan [7]. This situation can generate opportunities in business strategies, in producing a more sustainable product [8]. This fact indicates that Malaysia's manufacturing industry nowadays has a good platform in achieving high sustainability in manufacturing, particularly to remain competitive in a new manufacturing environment.

The Relation Between Manufacturing Sustainability and Lean Production. In this study, from a total of 1575 matrices of relationship created from Spearman's correlation analysis between all three components of sustainability namely SEP, SCP and SSC with the LP, 32.8% of the matrices has produced a strong positive correlation relationship ranging from 0.600 to 0.864, at a significant level of 0.01, as tabulated in Table 1. The analysis also shows that, 19 items in the LP section have a strong relationship with SEP, where a significant correlation relationship exists between the ability to increase of opportunities in preventing pollution (e13) with the ability to reduce the lead time in production operations (LP23) at a value of 0.757.

As for the relationship between SCP and LP, 96% of the items in LP have produced a strong relationship with SCP, where 5 items in SCP and 4 items in the LP have a very strong relationship with each other at a value ranging from 0.801 to 0.864. Furthermore, there seems to be a very strong correlation at a value of 0.864 between the ability to relocate the resources based on requirement (c13) with the ability to reduce the setup time (LP13).

Table 1 Spearman correlation between LP against Sustainability of Environmental, Economic and Social Competency Performance.

Item	Sustainability of Environmental Performance (e)	Sustainability of Economic Performance (c)	Sustainability of Social Competency Performance (s)
LP1	e4, e5, e9	c3, c4, c7, c9, c10, c11, c12, c13*, c14, c15, c21,	s5, s6
LP2	e9	c13, c15, c18,	s1, s2, s4, s5, s6, t12, s15, s16
LP3	-	c3, c15, c18,	s1, s2, s3, s4, s5, s12, s15, s16, s17
LP4	e10, e11, e14, e16, e17, e19	c1, c3, c4, c7, c9, c10, c11, c13, c14, c15, c17, c18, c19, c21	s1, s2, s3, s4, s5, s6, s7, s8, s9, s10, s11, s12, s13, s17, s20, s21, s23
LP5	e18, e19	c7, c11, c13,	s1, s3, s4, s5, s6, s15
LP6	e9, e18, e19	c3, c7, c11, c13, c14,	s1, s2, s3, s4, s5, s6, s12, s15, s16, s17
LP7	-	c6, c7, c9, c11, c13, c14, c19, c21	s2, s3, s4, s5, s6, s7, s8, s12, s21
LP8	-	c3, c7, c9, c13, c14, c17, c18, c19, c21	s2, s3, s4, s5, s6, s8, s9, s10, s11, s12, s17, s20, s21, s22
LP9	e9, e18	c3, c9, c21	s3, s4, s5, s8, s16, s17
LP10	e9, e19	c1, c2, c3, c9, c11, c13, c21	s2, s3, s4, s5, s6, s8, s15, s16, s17, s21
LP11	e1, e5, e8, e9, e11, e14, e15, e17, e18, e19	c1, c2, c3, c4, c7, c9, c10, c11, c12, c13, c14, c15, c16, c17, c18. c19, c20, c21	s2, s3*, s4, s5, s6, s7, s8*, s10, s11, s12, s13, s15, s17, s20, s21, s23
LP12	e9, e18, e19	c3, c4, c6, c7, c9, c10, c11, c13, c14, c19, c21	s1, s2, s3, s4, s5, s6, s8, s9, s12, s14, s15, s16, s17
LP13	e8, e9, e11, e14, e16, e17, e18, e19	c1, c2, c3*, c4, c6, c7*, c8, c9*, c10, c11, c12, c13*, c14, c16, c17, c18. c19, c20, c21*	s2, s3*, s4*, s5*,s6*, s7, s8* , s9, s10, s11, s12, s15, s17, s20, s21, s23
LP14	e1, e3, e8, e9, e10, e14, e16, e17, e18, e19	c3, c4, c7, c9, c10, c11, c13, c14, c15, c17, c18, c19, c21	s1, s2,s3*, s4, s5, s6, s7, s8, s11, s12, s13, s15, s16, s17, s20, s21, s23
LP15	e1, e3,e8, e17, e19,	c1, c3, c4, c5, c6, c9, c10, c11, c12, c13, c14, c15, c19	s2, s3, s4, s5, s6, s7, s11, s13, s17, s21, s23
LP16	e9	c1, c2, c5, c16	s3, s4, s5, s6, s7, s21
LP17	e19	c1, c4, c6, c7, c10, c11, c12, c13, c14, c19	s2, s3, s4, s5, s6, s7, s15, s16, s21
LP18	-	c6, c7, c12, c13,	-
LP19	e14, e17, e18, e19	c1, c3, c4, c6, c*, c9, c10, c11*, c12, c13*, c14, c21	s2, s3, s4, s5, s6, s7, s8,
LP20	-	-	-
LP21	-	c6, c7, c11, c13	s7
LP22	e19	c1, c2, c6,	s1, s3, s4, s5, s6, s7, s15, s16, s17
LP23	e1, e2, e3, e8, e9, e14, e15, e16, e17, e18, e19	c1, c2, c3, c4, c6, c7, c8, c9, c10, c11, c12, c13*, c14, c16, c17, c18, c19, c21	s2, s3*, s4, s5, s6*, s7, s8, s9, s10, s11, s12, s13, s15, s17, s20, s21, s23
LP24	e9, e18, e19	c3, c9, c10, c11, c13, cp19	s2, s3, s4, s5, s15
LP25	e9, e18, e19	c3, c4, c11, c14, c15,	s1, s2, s3, s4, s5*, s6, s7, s8, s12, s15, s16, s17, s21

* Item with a very strong relationship

Meanwhile, there are 5 items in SSC and 5 items in the LP section that shows a very strong relationship with each other at a score range of 0.801 to 0.848. From this relationship, the ability to improve the manufacturing capability and flexibility (s6) has a high significant positive correlation with the ability to reduce the setup time (LP13), and the ability to reduce the lead time in production operations (LP23) with a value of 0.848.

The results indicate that LP not only successfully improves operational efficiency, but also positively influences matters concerning the environment. This is because LP have always had a close relation with the objectives set in the environmental management [9]. This has been proven by the results that show that the ability to reduce the production lead times through the adaptation of LP has a strong relationship with the ability to increase the opportunity to reduce pollution, which is potentially able to be streamlined with the ability to increase the capacity and flexibility in manufacturing. This is not surprising because through high flexibility, manufacturers can manage the production operations in a more efficient manner, including the way to manage pollution that possibly results from the activities implemented. Furthermore, the ability to reduce the setup times also correlates with the ability to allocate resources based on the requirements. This does not only increase the level of operational efficiency, but can also reduce the operating cost, as well as the marginal cost in handling the environmental concerns. This indicates that LP always has a strong relationship with the manufacturing efficiency, primarily in achieving high sustainability in manufacturing operations.

Conclusion

As a conclusion, this initial study has shown that LP has a strong relationship in the development of manufacturing sustainability. Coupled with correlation analysis, it is shown that each of the practices in LP has a significant positive correlation with each item in the manufacturing sustainability components. The findings in this study can be used as a basis in the next stage of a study in developing a more comprehensive strategy in establishing manufacturing sustainability, primarily in Malaysia's manufacturing industry.

Acknowledgement

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

APPENDIX

1. Performance of Lean Production Practice (LP)
How you rate your current performance in lean production practices for the past two (2) years? (On a seven point scale from strongly disagree to strongly agree).

Item	Lean Production Performance
LP1	Decrease customer lead time
LP2	Improve layout to reduce unnecessary movement
LP3	Increase knowledge in production management
LP4	Improve the production takt time
LP5	Defect detection ability of the product
LP6	Reduction in the throughput time
LP7	Maximise the operational flexibility
LP8	Minimising handling
LP9	Optimise usage of equipment
LP10	Reorganise of working space
LP11	Reduce changeover & handling time
LP12	Reduce inventories & storage
LP13	Setup time reduction
LP14	Better environmental management & control
LP15	Environmental practice & performance
LP16	Increase quality of products
LP17	Improve working conditions
LP18	Reduce the non-added value activities
LP19	Increase manufacturing capability & flexibility
LP20	Increase the operation efficiency
LP21	Increase the production productivity
LP22	Improve the organization of work environment
LP23	Reduce the production lead time
LP24	Improve the material flow
LP25	Improve the operation procedure

2. Sustainability of Environmental Performance (SEP)
What are your current environmental performances from the past two (2) years? (On a seven point scale from strongly disagree to strongly agree).

Item	Sustainability in Environmental Performance
e1	Increase recyclability activities
e2	Use recycle material in product & process
e3	Increased reusable, non-toxic & bio-degradable materials
e4	Increase amount of recycled components
e5	Increase amount of recycling of packaging materials
e6	Adapt reuse & recycling in design
e7	Use eco-friendly material
e8	Increase usage of renewable material
e9	Increase practice, management & performance in environmental
e10	Establish material & energy consumption reduction programmes
e11	Decrease energy consumption in the process
e12	Establish pollution prevention & reduction control
e13	Increase the opportunities of preventing pollution
e14	Reduce emission of substances & control
e15	Reduce the waste of materials
e16	Established waste reduction & energy efficiency programmes
e17	Use easily degradable chemicals
e18	Consider the direct environmental effect on operation
e19	Better environmental management and control

3. Sustainability of Economic Performance (SCP)
What are your current economic/financial performances from the past two (2) years? (On a seven point scale from strongly disagree to strongly agree).

Item	Sustainability in Economic Performance
c1	Minimise overall production cost
c2	Increase business and financial performance
c3	Efficient utilization of equipment and technology
c4	Efficient utilization of resources
c5	Increase the quality of product
c6	Reduce the non-added value activities
c7	Increase added value activities
c8	Reduce the total operation cost
c9	Reduce the total production lead time
c10	Minimize environmental costs in transportation
c11	Consider economic effect on the selection of the system
c12	Consider the risk taken in the investment
c13	Reallocating the resources based on requirement
c14	Increase the innovative in technological improvements
c15	Use renewable energy in production & transportation
c16	Purchase materials, parts & resources based on demand
c17	Product easily disassembly
c18	Establish quantitative, objective of quality in operation
c19	Redefine the competitive environment
c20	Reduce the number of parts in a product
c21	Properly plan the requirements of the material

4. Sustainability of Social Competency Performance (SSC)
What are your current social competency performances from the past two (2) years? (On a seven point scale from strongly disagree to strongly agree).

Item	Sustainability in Social Competency Performance
s1	Improve housekeeping & labour safety
s2	Improve process & flexibility
s3	Increase efficiency and competitiveness
s4	Increase product durability
s5	Driving force for improvement & process innovation
s6	Improve the manufacturing capability & flexibility
s7	Improve working conditions
s8	Improve the movement of operation flow
s9	Increase the operation efficiency
s10	Increase the production productivity
s11	Improve the organization of work environment
s12	Reduce the queuing time
s13	Develop standard & establish the consistency in the process
s14	Comply with environmental, regulation & safety issue
s15	Consider technology feasibility & labour safety
s16	Consider the social effect in product development
s17	Consider engaging of the workforce in the process
s18	Collaborate with other parties on environmental issues
s19	Possess environmental policy statements
s20	Possess strategic alliance with organizational strategies
s21	Use long length of life of components
s22	Utilize the electronic communication & documentation
s23	Consider previous & the common experience in operation

References

[1] S. Vinodh, Improvement of agility and sustainability: A case study in an Indian rotary switches manufacturing organisation, J. Cleaner Prod. 18 (2010) 1015-1020.

[2] M. Despeisse, M.R. Oates, P.D. Ball, Sustainable manufacturing tactics and cross-functional factory modelling, J. Cleaner Prod. 42 (2013) 31-41.

[3] S. Schrettle, A. Hinz, M. Scherrer, T. Friedli, Turning sustainability into action: Explaining firms' sustainability efforts and their impact on firm performance, Int. J. Prod. Econ. 147 (2014) 73-84.

[4] M.Z. Yusup, W.H. Wan Mahmood, M.R. Salleh, M.N.H. Mohd Rosdi, The trigger signal for lean production practices : A review, Global Eng. Technol. Rev. 3 (2013) 23-32.

[5] S. Vinodh, R.J. Girubha, PROMETHEE based sustainable concept selection, Appl. Math. Modell. 36 (2012) 5301-5308.

[6] I. Awudu, J. Zhang, Uncertainties and sustainability concepts in biofuel supply chain management: A review, Renewable Sustainable Energy Rev. 16 (2012) 1359-1368.

[7] Y. Hongbing, Z. Haiyan, Sustainable development strategies of manufacturing in Jiangsu based on the constraints of resources and environment, Energy Procedia. 5 (2011) 872-878.

[8] E.W.T. Ngai, D.C.K. Chau, J.K.L. Poon, C.K.M. To, Energy and utility management maturity model for sustainable manufacturing process, Int. J. Prod. Econ. 146 (2013) 453-464.

[9] S. Hajmohammad, S. Vachon, R.D. Klassen, I. Gavronski, Lean management and supply management: Their role in green practices and performance, J. Cleaner Prod. 39 (2013) 312-320.