

Measuring Lean Economic Sustainability: A Scale Development Study

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Abstract

Lean Economic Sustainability is one of the most prominent concepts in the lean and sustainability areas of study. Indeed, previous research has indicated the positive impacts of lean practice on firm performance. Additionally, studies have shown the critical role of economic sustainability on firm's sustainability performance. Despite the growing body of literature on these concepts, the measurement of lean economic sustainability is still lacking. Thus, the purpose of this study is to provide an original, valid, and reliable measure of lean economic sustainability focusing on the production process in the manufacturing firms. Based on established literature on lean and economic sustainability, a scale measurement was developed through a systematic scale development process. Data was collected from 406 automotive industry employees in Multinational Companies (MNCs), Thailand. Exploratory factor analysis was conducted to determine the underlying factorial structure of the scale. The results of the analysis provided a two-dimensional structure of lean economic sustainability, including physical productivity and product quality. The developed scale was tested and validated through confirmatory factor analysis. The implications of the findings and suggestions for future research are discussed.

Keywords: lean economic sustainability; economic sustainability performance; sustainability; automotive manufacturing firms, MNCs, Thailand

Introduction

Many organizations, particularly automotive organizations, struggle in the new customer driven and globally competitive markets. These factors present a big challenge to organizations to look for new tools and methods to continue moving up the ladder in the changed market scenario. To overcome this situation and to become more profitable, many manufacturers have applied lean manufacturing (LM). However, instead of paying attention to LM alone, there is increasing concern in the corporate world about the present global scenario, with the main challenges that our societies now face being climate change, poverty and inequity, population growth, pollution, and the increasing cost of energy and resources. Thus, improving sustainability performance and reducing the negative environmental and social impact of industrial processes is no longer just nice to have, but a business imperative:

sustainability has emerged as a new competitive criterion (Turley-McIntyre, Marchl et al. 2016) (Rusinko 2007),(Young and Dhanda 2012). It is in this context that LM has emerged as a major part of the sustainability answer.

Many researchers and practitioners have covered the possible integration of lean and sustainability and this has received increasing attention. The results of many studies conducted indicate that lean is beneficial for sustainable manufacturing with a dominant perspective on economic aspect manufacturing. The alignment between lean management and economic sustainability is that economic sustainability is usually well understood. At the plant level, it is being operationalized as production or manufacturing costs. The triple-bottom-line concept suggests that firms not only need to engage in socially and environmentally responsible behaviors, but also that positive financial gains can be made in the process(Gimenez, Sierra et al. 2012, Sancha, Longoni et al., 2015). The key benefit of this research is to provide original, valid, and reliable measures of lean economic sustainability to improve actions that need to be adopted to improve lean, and economic sustainability reflecting the manufacturing firm practices in production.

Research Objectives

This research objectives aim to develop lean economic sustainability scale through a systematic scale development process. In the study, exploratory factor analysis is conducted to determine the underlying factorial structure of the scale. Cronbach's alpha results are presented, and the confirmatory factor analysis (CFA) demonstrates acceptable model fit indices of lean economic sustainability.

Literature review: existing methods of measuring lean economic sustainability

Lean Economic Sustainability principles

1. Physical productivity Principle- Units per labor hour

One of the improvement results in the process that creates positive financial gains is plant performance which was measured by physical productivity. Customers today demand high quality products with varying production requirements, and often require deliveries in small lot sizes with short lead times. Manufacturers have adopted initiatives related to setup time reduction, cellular manufacturing, and quality improvement. Production in smaller lot sizes requires more frequent setups. Further, firms limited to mass

production capabilities are often ill-equipped to compete in today's marketplace. Consequently, many firms have sought the flexibility and efficiency associated with cellular manufacturing. Finally, a greater concern with quality on the part of customers has led manufacturers to invest in quality initiatives to retain and expand their customer bases and to reduce the costs associated with quality failures (Huson and Nanda 1995, Ittner and Larcker 1995, Mohrman, Tenkasi et al. 1995, Chanegrih and Creusier 2016). However, other research findings support a positive association between modern manufacturing practices and financial performance. In addition, over-production and excess inventory can result in a negative impact on a firm's profitability (Bergenwall, Chen et al. 2012). Cellular manufacturing (Delgoshaei, Ariffin et al. 2016, Aalaei and Davoudpour 2017) can assist a firm to improve job shop production but the parts to be made must be grouped by similarity into families (Frandsen, Seppänen et al. 2015). In addition, develop lean economic sustainability with existing suppliers' impact to Physical productivity. As well as, appropriate monitoring supplier performance impact to physical productivity.

2. Product quality from process Principle– Defect unit

Quality was measured by the number of defective units in parts per million as reported to the plants by their customers over the same twelve-month period. This defect can be reduced which will have a positive effect on productivity (Lieberman and Demeester 1999, Siregar 2020). How, if, and when this will happen depends on the problem-solving capabilities (Sakakibara, Flynn et al. 1997, Siregar 2020).

Some types of production wastages can be identified from the problems caused WIP and inventory production defects. After this waste is removed or reduced the quality of the final product may improve. Supplier development can involve a long-term cooperative to upgrade a supplier's technical, quality, delivery, and cost capabilities (Krause, Scannell et al. 2000). The main activities used by buying firms to improve supplier performance, include: assessment of a supplier's operations and performance; providing incentives for the supplier to improve; creating competition amongst suppliers; and working directly with suppliers through training, education. In addition, Supplier incentives and supplier assessment affect performance improvement in term of direct involvement activities, involves investments such as training and education of a supplier's personnel.

According to (Poksinska, Pettersen et al. 2010) quality improvement techniques apply in manufacturing industry are process management, failure mode, effect analysis (FMEA), SPC, design of experiments (DOE), and QFD. In addition some authors (Dahlgaard and Mi Dahlgaard-Park 2006, Klefsjo, Bergquist et al. 2006) quality improvement techniques share the same origin and were all developed from Japanese TQM practices. The application of approaches requires a strategic decision of senior management and resources in terms of training or hiring personnel. A system comprises written information in the form of instructions and procedures in order to direct and control some form of operation. A quality management system is an essential element of all the approaches, including TQM and Six Sigma. provide a useful distinction between a quality management tool, such as a Pareto chart, cause and effect, or affinity diagram, and a technique such as statistical process control (SPC) or quality function deployment (QFD).

Lean Economic Sustainability practices

With regard to lean economic sustainability practices, a research model that conceptualized lean manufacturing with a number of its best lean practices characterizing different areas of the company was developed by Secondly apply the study from Fullerton (R. and F., 2009) of Lean manufacturing, non-financial performance measures, and financial performance. Thirdly, compare with (Piercy and Rich, 2015) study with to adopt of lean operational practices and independently the uptake of business practices related to economic sustainability impact. Finally, the selection of lean practices base on the most common practices in reviewing literature on the Lean Economic sustainability principles. There are five lean economic sustainability practices in the physical productivity principle and nine lean economic sustainability practices in the product quality principle (see Table 1).

Table 1: A list of lean Economic sustainability dimensions and practices

Dimension	Practices	
Physical Productivity (“PPE”)	1. Set up time reduction – Single-minute exchange of die (“SMED”) to lower manufacturing cost 2. Cellular manufacturing to improve productivity measured by units per labor hour 3. Approach of lean economic sustainability to develop with existing suppliers 4. Appropriate collaboration documented with supplier performance to improve physical productivity 5. Appropriate tracking supplier performance to improve physical productivity 6. Appropriate monitoring of suppliers performance to improve product quality"	(R. and F. 2009) (Rubrich and Watson 2004) (Piercy and Rich 2015) (Metternich, Bechtloff et al. 2013) (Handfield and Nichols Jr 1999) (Krause, Scannell et al. 2000) (Heide and Stump 1995)
Product Quality (“PQE”)	7. Provide training to suppliers to achieve their economic practices targets 8. Provide incentives to suppliers 9. Quality Improvement processes to reduce defects per unit 10. Improve quality by failure mode and effect analysis (“FMEA”) to reduce defects per unit 11. Improve quality by statistical process control (“SPC”) to reduce defects per unit 12. Improve quality by design of experiments (“DOE”) to reduce defects per unit 13. Improve quality by cause and effect, or affinity diagram to reduce defects per unit 14. Establish culture of quality to reduce defects per unit	(Poksinska, Pettersen et al. 2010, Piercy and Rich 2015) (Dahlggaard and Mi Dahlggaard-Park 2006) (Klefsjo, Bergquist et al. 2006) (R. and F. 2009)

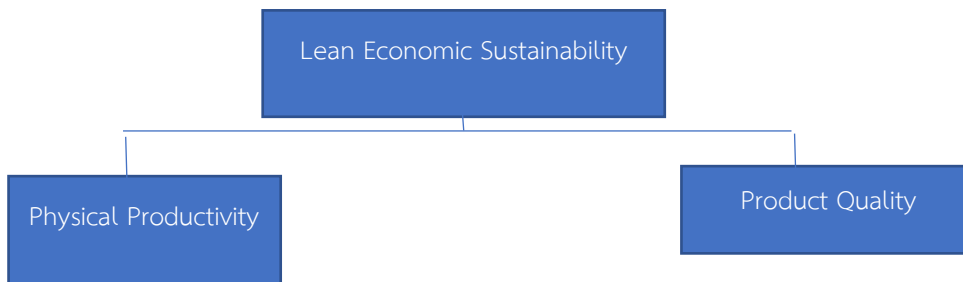


Figure 1: Research Conceptual Model

From literature development, the alignment between lean management and economic sustainability is the improvement of manufacturing costs related to physical productivity and product quality as show in table 1.

Research Methodology

The study involves conducting a survey to obtain the categorical data for statistical testing of the formulated hypothesis. The survey was conducted two ways with the first one using an electronically administered questionnaire, as it was the most convenient way of collecting the required information and the second one using a paper questionnaire. The questionnaire link was sent via e-mail for the electrical format and the paper was sent via post enclosing a return envelope and pre-paid stamp. The surveyed questionnaire was e-mailed and mailed to managers of 50 manufacturing companies or 600 total population with a response return rate totaling 406 copies (Cochran 2007). Two weeks after sending out questionnaire asking them to complete it and send it back, a follow up call was made to respondents as a reminder soliciting their participation. The data collection process was stopped one month after its commencement.

1. Sample and data

The total responses as mentioned earlier was 406 to the questionnaire both by email and return paper questionnaires. So, a response rate of 68% was achieved from the online survey and hard copy questionnaire. The population of this study consists of all manufacturing firms who implement lean practices in the Thailand automotive industry. The population frame for this study was obtained from the Thai Auto Parts Manufacturers Association (“TAPMA”) directory 2020. The most appropriate respondents are key informants who hold managerial positions in manufacturing firms. In this study, sustainable manufacturing with main focus on environmental outcomes have been considered with each

firm surveyed qualified from the perspective of quality system certifications obtain at least to the levels of ISO 9001, ISO 14001. Outcomes are defined as the lean economic sustainability model of factors affecting the economic sustainability performance new measurement scale. Measurement items for the outcomes are developed from the literature.

Data analysis

The EFA which was satisfactorily assured by the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (“KMO”) and Bartlett’s test of sphericity values. The first analysis to present the descriptive statistical analysis, and present Exploratory factor analysis EFA and Reliability Cronbach’s alpha, finally present the second order CFA demonstrated acceptable model fit indices (Hair Jr, Hult et al. 2016, Hair, Risher et al. 2019) as follows:

Research Results

1. Descriptive statistical analysis: LECS was perceived at a high level

Table 2: Descriptive table: Mean, SD., Skewness, Kurtosis, level of mean

Variable	Items	Mean	SD	Ske.	Kur.	Level of mean
Lean Economic Sustainability- LECS	14	4.072	0.510	-0.640	-0.353	High
1. Physical productivity	5	3.998	0.569	-0.292	-0.500	High
2. Product quality	9	4.113	0.563	-0.783	-0.065	High

2. Exploratory factor analysis EFA and Reliability Cronbach’s alpha

The EFA results indicated that the Lean Economic sustainability was gauged from a total of 14 questions. The results generated using principal components and Varimax rotations determined that 2 questions had cross-loadings of greater than 0.40 and no questions had factor loadings below 0.40. As such, the decision was made to exclude 2 questions (PPE02, PPE04). Finally, the remaining 12 questions were arranged into two groupings as per the below table. As a result of the EFA of the new grouping questions there are three questions (PQE06, PQE07, PQE08) pertaining to product quality dimension which rotated in physical productivity. On the other hand, one question regarding physical productivity (PPE05) is rotated in product quality dimension.

Table 3: Exploratory factor analysis Rotated Component Matrix of LECS

	Lean Economic Sustainability - LECS	
	Physical Productivity	Product Quality
PQE06	.820	
PQE07	.800	
PQE08	.667	
PPE01	.626	
PPE03	.600	
PQE01		.682
PQE04		.679
PQE03		.640
PQE02		.624
PPE05		.588
PQE09		.511
PQE05		.430
% of Variance	22.604	21.829
Kaiser-Meyer-Olkin Measure of Sampling Adequacy = 0.674, Bartlett's Test of Sphericity = 337.556, p-value = .000		

The reliability of components concluded from the 12 questions indicated that an internal consistency was found in the physical productivity Cronbach's Alpha 0.790 which was acceptable and the product quality Cronbach's Alpha 0.832 was good. Acceptable range of Cronbach's alpha is a value of 0.70 or above.

3.Second order CFA demonstrated acceptable model fit Lean Economic Sustainability

After modification the results of the CFA demonstrated an acceptable model fit as per the below table 9 and figure 2:

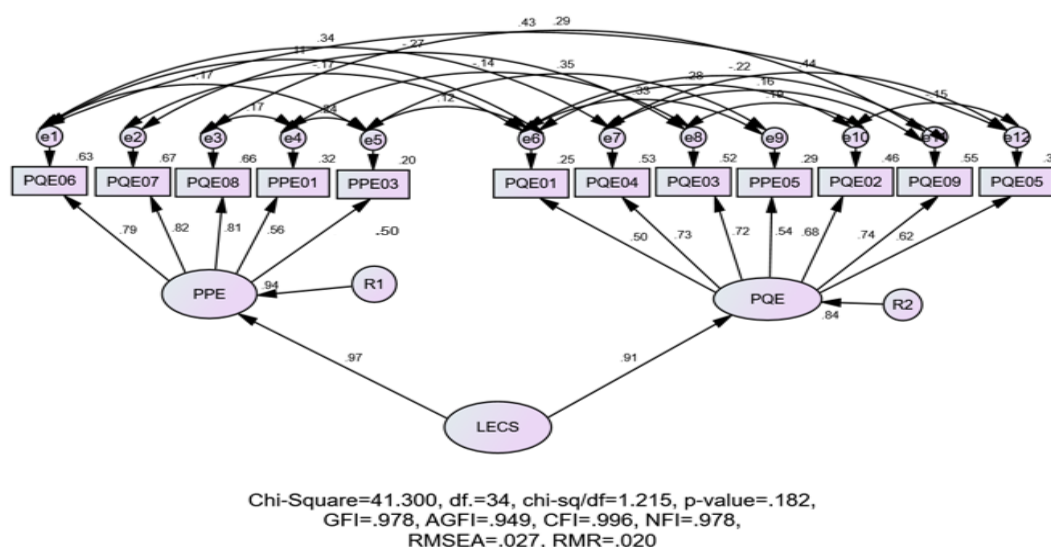


Figure 2 Final model of Lean Economic Sustainability

Table 4: CFA of Lean Economic Sustainability

	χ^2	Df	p-value	χ^2/Df	GFI	CFI	NFI	RMSEA	RMR
Criteria	-	-	-	≤ 3.00	≥ 0.90	≥ 0.90	≥ 0.90	≤ 0.07	≤ 0.09
Final model	41.300	34	.182	1.215	.978	.996	.978	.027	.020

Note: χ^2 = Chi-squares, Df = Degree of freedom, GFI = Goodness of fit index, CFI = comparative fit index, NFI = Normed Fit Index, RMSEA = root mean square error of approximation, RMR = root mean square residual. Fit Index χ^2/df : Acceptable Threshold Levels <3 good, <5 permissible, **GFI**: Acceptable Threshold Levels >0.95 good, >0.90 acceptable, **AGFI**: Acceptable Threshold Levels >0.95 good, >0.90 acceptable, **RMSEA**: Acceptable Threshold Levels <0.07 good, $0.07-0.10$ moderate, **RMR**: Acceptable Threshold Levels <0.09 good, **CFI**: Acceptable Threshold Levels >0.95 good, >0.90 acceptable, **NFI**: Acceptable Threshold Levels >0.95 good, >0.90 acceptable

Conclusion

In this research, a theoretical model was developed to study the effects of Physical Productivity and Product Quality practices in manufacturing firms on lean economic sustainability. The results of the study indicate that Physical Productivity and Product Quality practices were found to have a significant effect on lean economic social sustainability. The new measurement scale indicates that lean economic sustainability practices are established.

Insofar as physical productivity dimension is concerned, the most influential practices are statistical process control (SPC), design of experiments (DOE), cause and effect, or affinity diagram, as a quality improvement technique, SMED (single minute exchange of dies), and all of these suggest that the concept of “lean” to existing local suppliers exist respectively. In product quality dimension, the most influential practices are regular monitors of suppliers’ performance, use of process management as a quality improvement technique, provision of incentives to suppliers, provision of training and teaching to suppliers to improve economic practice targets, tracking of suppliers’ cost-effective solutions focusing on cost reduction goals, quality improvement (“QI”) goals with dedicated QI teams, and uses of a failure mode and effect analysis tool (“FMEA”) as quality improvement techniques respectively.

Discussion

From the studies conducted on the dimension of physical productivity, the results indicate that the physical productivity practices have a positive effect on lean economic sustainability. There were five activities with three of them (PQE06, PQE07, PQE08) indicating that product quality is rotated in physical productivity components. According to the literature studied and reviewed, it would appear that SPC, DOE and Cause and Effect can contribute not only to the improvement of product quality but also to the productivity of the end process result. (Jamil, Khalid et al., 2018). Therefore, these three practices can combine to describe physical productivity as a new measurement scale. In addition, the practice of SMED also prescribes that the physical productivity is confirmed by the literature studied and reviewed that production in smaller lot sizes requires more frequent setups. Therefore, reducing setup time (and cost) is increasingly necessary to serve customers in a timely manner, and profitably (Piercy and Rich 2015). Regarding suggestions that the concept of “lean” applied to existing local suppliers rather than finding new, lean-applied suppliers also mention by (Liker 1997),(Wu and Management 2003),(Krause, Scannell et al. 2000) is that much of the work surrounding the Japanese cooperative supply relationship is based on the assumption that these relationships are established in order to enhance some aspect of supplier manufacturing performance. Thus, the new measurement scale for the dimension of physical productivity is included (PPE 01) SMED technique, (PPE03) suggests the concept of lean” to existing local suppliers, (PPE06) SPC technique, (PQE07) DOE technique, and (PQE08) Cause and effect, or affinity diagram

The dimension of product quality practices reviewed to together with the results of this study shows that product Quality practices have a positive effect on lean economic sustainability. There are seven activities and one of them (PPE05) indicates that the physical productivity is rotated into a product quality component. According to the literature prepared by experts and which was reviewed, the assemblers and the suppliers work together over every detail of the supplier’s production process, looking for ways to cut costs and improve quality. In this study it would appear that the factory aims to improve supplier’s deliverables in terms of cost reduction with positive effects on physical productivity. However, the aim is no only to cut the costs but also the overall expectation is to produce better and improved quality products. Thus, tracking supplier’s cost-effective solutions is

also reasonable and has positive effects to product quality. There are three practices/incentives that can be implemented regarding suppliers that may result in positive effects on product quality dimensions and these include: 1) regularly monitoring suppliers' overall waste reduction, quality improvement and innovation performance; 2) provide training and education to suppliers to improve economic practice targets; and, 3) provide incentives to suppliers to implement economic practices targets.

Reference can be made to the literature which importantly identifies that suppliers have a direct impact (both positive and negative) on several competitive dimensions of a buying firm's business strategy, including cost, quality, technology, delivery, flexibility, and profits (Handfield and Nichols Jr 1999),(Krause, Scannell et al. 2000).

In addition, there are also practices in lean economic sustainability of quality improvement technique, failure mode and effect analysis tool ("FMEA"), and quality improvement ("QI") that have positive effects on product quality which is also in the literature studies that have been conducted. Thus, the new measurement scale for the dimension of product quality is included (PQE1) regularly monitors suppliers' (PQE2) provides training and teaching to suppliers (PQE3) provides incentives to suppliers (PQE4) process management as a quality improvement technique (PQE5) FMEA technique (PQE9) Quality improvement ("QI") goals, and (PPE5) tracks suppliers' cost-effective solutions focusing on cost reduction goals.

Research Suggestions

Data was collected at a single point of time. As the study is a cross sectional study, the findings of the research could only reflect the situation at a particular point in time regarding the practices of lean economic sustainability outcomes. Therefore, a longitudinal study that examines lean economic sustainability practices in a manufacturing firm for an extended period of time would provide a more precise picture of the casual relationship of physical productivity and product quality practices on lean economic sustainability.

The study focuses on automotive manufacturing firms in Thailand which means the study excluded manufacturing firms in other industries. Therefore, the question of whether the study results can be applied to other industries need to be considered.

The overall findings of this paper indicate that the two dimensions including physical productivity and product quality were found to have a significant effect on lean economic

sustainability. Future studies would be encouraged to make use of this study for further investigation of the effects of lean sustainability practices to other areas of firm's performances and also in integrating with other practices hopefully identifying which would be the most suitable types of manufacturing industry that could prove the hypothesis reached.

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