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A framework for the impact of lean six sigma on supply chain performance in manufacturing companies

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Abstract. The use of lean six sigma in manufacturing industry has been more intense in the past decade. This method comprises two concepts: *lean* and *six sigma*, each with its own objectives. Lean is a concept that aims to optimize the value stream process by eliminating all kind of waste. Meanwhile, the goal of *six sigma* is to increase process capability in the value stream by aiming for zero defects and reduced process variation. The supply chain performance of manufacturing companies is determined by the ongoing internal activities reflected in the value stream, therefore both lean and six sigma applications are hypothesized to have an impact on the performance. Based on the reviewed literature, this study aims to produce a framework that can be used to explain the impact of lean and six sigma on supply chain performance. In the proposed framework, lean indicators are reflected in just-in-time, quality management and employee involvement, whereas six sigma indicators are characterized by the six sigma variables. At the other end of the equation, supply chain performance is defined by four constructs which are supplier selection, production, delivery and logistic performance, and warehouse.

Keywords: lean, six sigma, supply chain performance

1. Introduction

The rapid economic growth has resulted in an increasingly tight competition both in manufacturing and service industries. The increasing market demand, approximately 671% from 1970 [1], has put companies in fierce competition to stay ahead among other competitors in order to meet the market demand. Along with this global development, manufacturing companies should not only think about production but also start focusing on supply chain efficiency and effectiveness because they cover all activities from the procurement stage of raw materials to the delivery of finished goods [2]. Moreover, supply chain can be defined as an integrated chain in a network from upstream to downstream [3]. Supply chain management is a concept that integrates all parties into the overall existing value chain in the system that needs to be managed as company's asset.

Many companies have seen transition from proven practices such as re-engineering, six sigma, total quality management (TQM), data mining, lean six sigma and lean start-ups [4]. Lean six sigma is no longer a foreign method for manufacturing companies as many have applied it to improve product quality [5]. Lean six sigma is an integration of lean and six sigma, defined as a business philosophy, a systemic and systematic approach by identifying and eliminating waste or non-value-added activities through radical continuous improvement [6]. In addition, according to [2], six sigma is a business strategy and systematic methodology, which leads to breakthroughs in profitability through quantum



acquisition in the quality of product or service, customer satisfaction, productivity, effectiveness and efficiency.

A number of research related to lean and six sigma in supply chain management have been carried out, such as design for six sigma (DFSS) to design information technology solutions so that inter-departmental information communication with supply chain operations can be carried out effectively [7]. Furthermore, information sharing between functions is encouraged to improve supply chain performance [8]. Another research argues that an important issue in a supply chain is the incapacity of information and the flow of processes between each interconnected function both from external and internal parties. Another study implemented lean concepts to optimize the use of warehouse layout because of its important role in the supply chain [10]. There are more studies related to the application of lean and six sigma in supply chain, but there are still few studies discussing the impact of lean and six sigma implementation on supply chain performance.

Recent research related to the relationship of lean to supply chain performance is carried out in [11] where the authors tested the effect of lean on sustainable supply chain by considering the green aspect. In this research, sustainable supply chain was measured using three categories, namely sustainable supplier selection, sustainable production and sustainable delivery, and logistics performance. Meanwhile, the research for six sigma was conducted by [12] who discuss the relationship between the implementation of six sigma and the performance of organizations. Both studies, however, were conducted separately, i.e. without integrating lean and six sigma concepts. Given the above gap, this study aims to fill the gap by establishing a framework to explain the relationship between lean six sigma and supply chain performance.

2. Method

Literature review is used as a method in this paper. We collected the key concepts and synthesized the ideas from the literature, and used them as components to develop our proposed framework.

2.1. The benefit of lean and six sigma implementation

The application of lean six sigma is caused by many reasons such as the variations that occur and produce a range of values for certain activities, processes, products or services [13]. Lean sigma means doing things in a simple and efficient way, but still providing superior quality and rapid service. In addition, its application can increase the profitability of the business, increase the effectiveness and efficiency of all operations to meet the customer's and even beyond customers' expectations [14].

2.2 Lean

Lean is adopted from the principles of Kaizen, kanban and just-in-time [15]. This method is identical to minimization of seven wastes, namely (i) over-production, (ii) defect/reject, (iii) unnecessary inventory, (iv) inappropriate processing, (v) excessive transportation, (vi) waiting/idle, and (vii) unnecessary motion [12]. While many researchers have classified waste in manufacturing environment, there is potential waste found in logistics such as inventory, transportation, space and facilities, time, packaging, administration and knowledge [16].

2.3 The relationship between lean and supply chain performance

Lean has been studied independently in relation to various aspects of the supply chain such as sourcing, manufacturing and logistics [17]. Supply chain performance is believed to be prone of disruptions by a number of variations such as demand fluctuations, number of shipments and product quality [18]. In this case, some variations can be seen in factors such as lead times, fill rates, and on-time deliveries [19]. Based on these theories, hypotheses related to lean relationships with supply chain performance were developed [11]. The hypotheses structure is shown in Figure 1.

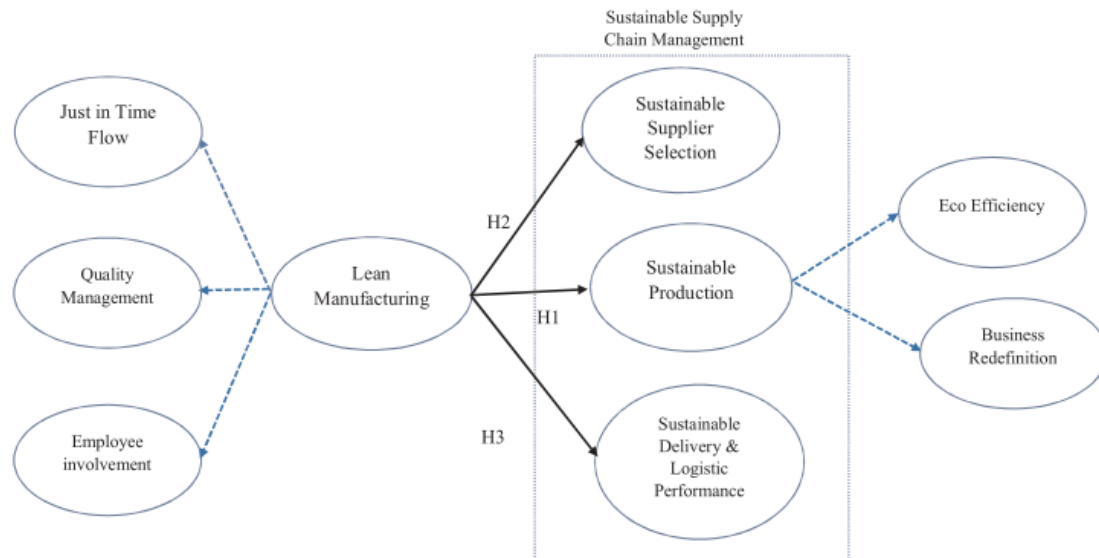


Figure 1. The hypotheses of lean relationship to supply chain performance [11]

2.3.1 The hypothesis on supplier selection. An efficient and flexible supply chain allows companies to be able to choose the right supplier [20]. Supplier selection is an important consideration because purchasing decisions have a major impact on the entire supply chain system [21]. Moreover, “supplier involvement” is an important component of lean production [22]. Based on those theories, it can be concluded that lean has a relationship with the supplier selection.

2.3.2 The hypothesis on sustainable production. Lean has been widely accepted by manufacturing industry to improve performance both in the production process and SCM and to minimize the existing waste [23]. Moreover, lean has a very strong relationship with production. In practice, the considered aspects in determining the right strategy in the supply chain include acquiring materials, converting raw materials into end products and shipping products.

2.3.3 The hypothesis on sustainable delivery and logistic performance. Authors in [11] hypothesized that there is a significant negative relationship between lean and sustainable delivery and logistics performance. Lean distribution causes rapid movement in logistics so that it increases emissions, viewed from the green aspect. It would, however, save logistics costs if balanced with good scheduling.

2.4 Six sigma

Six sigma was developed by Motorola in the 1980s. Six sigma is a process that aims to deliver more value to the customers and stakeholders by focusing on improving product quality and company productivity. DMAIC (*define, measure, analyze, improve and control*) is a standard approach suggested in six sigma implementation. The *define* phase is the first stage that defines the problem to be solved or the process improvement goal. A good problem statement must identify the customer and the CTQ (critical to quality). The *measure* phase focuses on how to measure the internal processes that affect the CTQ. The *analyze* phase focuses on the question of why excessive defects, errors, or variations occur. The *improve phase* gathers ideas and solutions to solve the problems. The proposed ideas are then evaluated and selected to get the most promising and affecting idea to the selected CTQ. The *control* phase focuses on how to maintain continuous improvement, including placing devices in their place and to ensure that the main variables remain within the maximum area that can be received in the modified process.

2.4.1 The relationship between six sigma and supply chain performance. A research was conducted on the implementation of six sigma to improve supply chain management operations on Samsung companies with the aim of improving the process, quality and synchronization of the company's value chain which includes logistics, sales and customer service [24, 27]. The success achieved by Samsung was due to all planned projects that could be executed properly. In addition, a framework on the critical factors that influence the success in six sigma projects was developed in [5]. Another empirical research carried out by [8] discusses the effects of implementing six sigma on operational performance, customer satisfaction and cultural change. One important study that determined the relationship between six sigma and organizational performance was conducted in [12]. In this research, the authors use knowledge indicators with socialization, externalization, combination and internalization variables to measure the success of six sigma projects towards company performance. The relationship model can be seen in Figure 2.

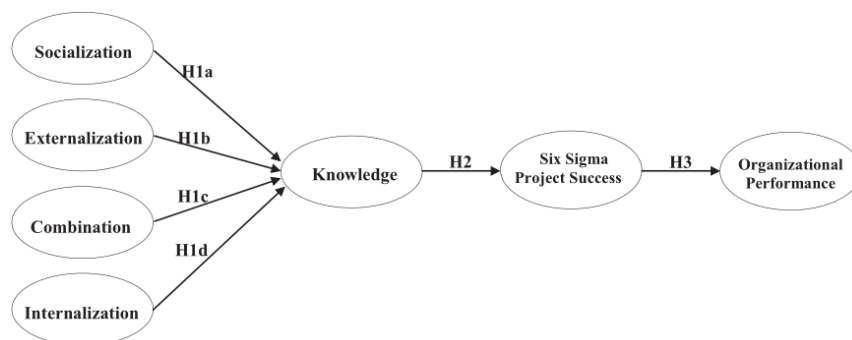


Figure 2. A model of the relationship between six sigma and organizational performance [25]

2.4.2 The hypothesis of six sigma model on company performance. Six hypotheses are proposed in [12]. These are:

- H1a: the socialization has a positive effect on knowledge in six sigma DMAIC project;
- H1b: the externalization has a positive effect on knowledge in six sigma DMAIC project;
- H1c: the combination has a positive effect on knowledge in six sigma DMAIC project;
- H1d: the internalization has a positive effect on knowledge in six sigma DMAIC project;
- H2: the knowledge creations in Six Sigma DMAIC phases have a positive effect on the success of six sigma project;
- H3: the success of six sigma project has a positive effect on organizational performance.

2.5 Warehouse

The warehouse operational coordination is very critical in the supply chain of all manufacturing industries. Realizing the role of a warehouse that could impact supply chain performance, a new strategy to optimize the warehouse with lean principles is suggested in [2] and three variables are proposed, namely providing a most economical storage in relation to retrieval time, use of space, providing maximum flexibility in order to meet changing storage and handling requirements, and providing economical path to collect orders of customers. In 1988, a study was carried out in the United Kingdom concluding that 55% of all warehouse operations costs could be associated with order taking [25].

3. Results and discussion

This study aims to produce a framework to explain the impact of lean and six sigma applications to supply chain performance. Two models from [5] and [11] are integrated into one framework for the said purpose. In addition, warehouse attributes are added to the supply chain performance. This section

explains the process in model development related to lean, six sigma and supply chain performance based on the hypotheses discussed in the literature review.

3.1. Lean model

Lean is the extension of *just-in-time* (JIT) [15]. Moreover, the link of JIT and quality management to green supply chain and organization performance is considered in [26]. All indicators used in this study were equated with the indicators used by [11] as shown in Table 1.

Table 1. Lean indicators

Construct	Code	Definition
Just-In Time	JT1	In order to achieve continuous product flow, processes and layout are redesigned
	JT2	Bottlenecks and buffers are removed, Kanban is implemented
Quality Management	QM1	Worker driven continuous improvement (lean six sigma, quality circle, etc.)
	QM2	Quality is built in design and methods such as mistake proofing (poka yoke)
Employee Involvement	EI1	Suggestions per employee as compared to others in industry
	EI2	Training hours of new production workers
	EI3	Importance to open and honest communication
	EI4	Workers are empowered to stop assembly line if they observe any mistake

3.2. Six sigma model

The impact of six sigma on organizational performance is studied in [25]. However, this study uses six sigma measurement indicators proposed by [13]. The indicators can be seen in Table 2.

Table 2. Six sigma indicators

Construct	Code	Definition
Six sigma method (SSM)	SM1	The project was developed under the six sigma method
	SM2	The method used for conducting the project was DMAIC or DMADV (for DFSS projects)
	SM3	All DMAIC steps were completely fulfilled

3.3. Supply chain performance model

Supply chain performance (SCP) measured using indicators from [11] is divided into sustainable supplier selection, sustainable production, and sustainable delivery and logistics performance. Acknowledging its important role in the supply chain and its linkage to the SCP [10], warehouse factors are included in the SCP model. The indicators can be seen in Table 3.

Table 3. Supply chain performance indicators

Construct	Code	Definition
Supplier Selection	SS1	Jointly develop environmental management solutions
	SS2	Regular audits for environmental compliance and and practices of supplier's operations
	SS3	Combined teams to reduce material use and reuse recycled materials

Table 3. Supply chain performance indicators (cont.)

Construct	Code	Definition
Production (business redefinition)	BR1	Designing product for easy disassemble or reuse
	BR2	Introduction innovative products with sustainability consideration
	BR3	Strive to develop sustainable technology
Delivery & logistic performance	DL1	Environmental consideration while selecting mode of transport
	DL2	Preference to new & more fuel-efficient vehicles
	DL3	Consolidation of freight flow to reduce environmental impact
Warehouse	W1	Economical storage in relation to retrieving time, use of space.
	W2	Flexibility in order to meet changing storage and handling requirements
	W3	Economical path to collect orders of customers

3.4. Framework development

Based on all the constructs and indicators above, a framework is proposed that can be used to explain the relationship between lean and six sigma to supply chain performance. The framework is shown Figure 3. Eight proposed hypotheses are formulated based on the reviewed theories. It is important to note here that the proposed hypotheses above are yet to be tested with empirical data. The hypotheses are:

- H1 lean has a positive relationship to supplier selection;
- H2: lean has a positive relationship with production;
- H3: lean has a negative relationship with delivery and logistics;
- H4: lean has a positive relationship with warehouse;
- H5: six sigma has a positive relationship with supplier selection;
- H6: six sigma has a positive relationship with production;
- H7: six sigma has a positive relationship with delivery & logistics;
- H8: six sigma has a positive relationship with warehouse.

4. Conclusion and remarks for future research

This paper develops a framework to explain the relationship between lean and six sigma applications to supply chain performance. Eight lean indicators are derived from three constructs and three six sigma indicators came from one construct. On the other side of the equation, twelve indicators from four constructs are proposed to represent the supply chain performance. For further research, it is suggested to perform an empirical study by taking samples from manufacturing companies to validate this framework.

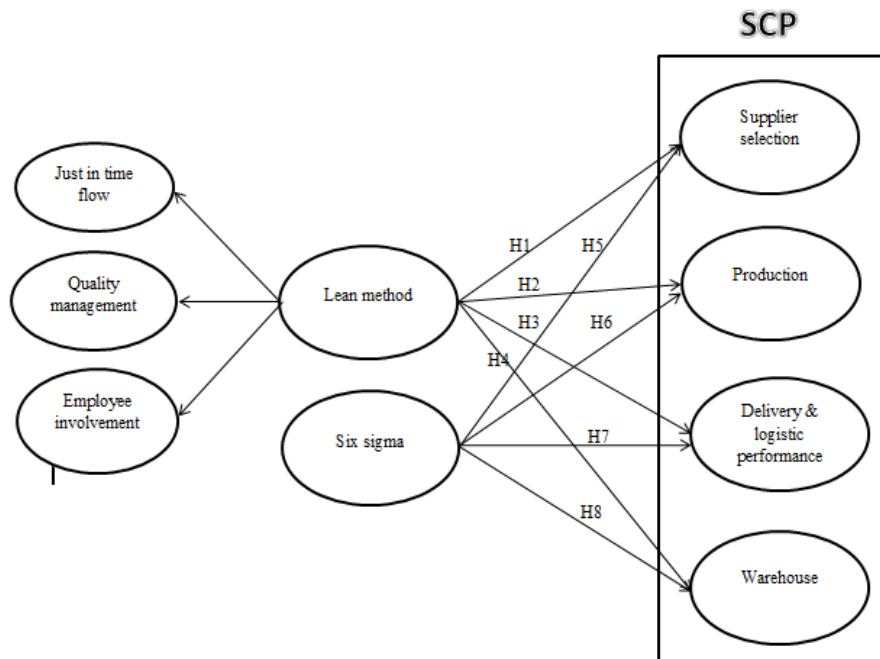


Figure 3. Proposed framework for the relationship between lean six sigma and supply chain performance

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