AN INTEGRATED STOCHASTIC-FUZZY METHOD FOR SUPPLY CHAIN LEANNESS EVALUATION IN IRANIAN AUTOMOTIVE SMALL AND MEDIUM ENTERPRISES

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UNIVERSITI TEKNOLOGI MALAYSIA
AN INTEGRATED STOCHASTIC-FUZZY METHOD FOR SUPPLY CHAIN LEANNESS EVALUATION IN IRANIAN AUTOMOTIVE SMALL AND MEDIUM ENTERPRISES

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Especially dedicated to Aba Saleh Al-Mahdi (a.s)
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ABSTRACT

In today’s competitive markets, companies have realized that there is an urgent need to improve the performance of the whole supply chain of which they are members. A measure of leanness is needed to provide decision support information such as the current leanness level, the progress of lean supply chain implementation, and the extent of potential improvements in the supply chain. In spite of the vast amount of studies on lean concepts and related tools and techniques, the evaluation of lean situation (leanness) is less investigated especially in a supply chain. In order to fill this gap, this research was carried out to systematically quantify the leanness of Small and Medium Enterprises' (SMEs) supply chain in the automotive industry with regard to stochastic and fuzzy uncertainties in performance measures. Particularly, four performance categories (quality, cost, delivery and reliability, and flexibility) along with 28 related metrics were developed as surrogates for leanness. These were achieved through a questionnaire survey, using experts' knowledge and experience from SMEs in the automotive industry in Iran. Factor analysis along with principal component analysis was used to validate the measures and metrics. Validity and reliability tests were consequently conducted. Following this, a stochastic-fuzzy method was developed to evaluate and predict the leanness of supply chain. The probability function of the total leanness was identified and different leanness situations were consequently evaluated and predicted. A total leanness index was also provided and connected to fuzzy sets (linguistic terms) to evaluate the current leanness level. The developed method was consequently tested and evaluated by using two case studies, and some management actions were suggested based on different values of leanness level. From the evaluation, it was found that the proposed method is applicable and easy to use. In addition, it was found that SMEs in Iran's automotive industry need to be given more attention in order to enhance their leanness level. This study contributes to expand the knowledge on supply chain leanness measurement and provides practical guidelines for manufacturing SMEs in the automotive industry to evaluate, predict, and improve the leanness of their supply chain using an integrated stochastic-fuzzy method.
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CHAPTER 1

INTRODUCTION

1.1 An Overview

This chapter is about the basic philosophies behind this research. It explains the background of this study that includes lean supply chain (LSC) management, related performance measures, and current measurement approaches. The problem statement which provides a basis for this research is then formulated. Following this, the research objectives, scope, questions, and significance of the research are presented. Next, the structure of the thesis is outlined to provide a better illustration of the thesis contents. Finally, this chapter ends with conclusions.

1.2 Background of the Study

Customer satisfaction, nowadays, is one of the most important challenges for which companies have focused on. Flexibility, on-time delivery, quality, competitive price, and service level are some dimensions of customer satisfaction, all related to supply chain management (Johansson et al., 1993). Inventory reduction, improved delivery performance, shorter product development cycle, superior quality, high flexibility, and competitive costs are some potential benefits of a LSC (Fawcett et al., 2008; Daugherty et al., 2005).
On the other hand, waste reduction and continuous improvement techniques, known as lean concepts, help practitioners and managers to pursue perfection. Combining these two management systems, a new concept has been created named lean supply chain management. Many successful cases from various industries have demonstrated the effectiveness of LSC (Plenert, 2007; Manrodt et al., 2008; Husby and Swartwood, 2009).

Lean organizations focus on continuous improvement of quality, cost, delivery, and flexibility by trying to eliminate waste, create smooth flow, and increase the velocity of the system’s ability to comply with customer requirements. Lean production is a western translation of the Toyota Production System (TPS), which was developed by the Japanese carmaker and most famously studied in the book entitled “Machine That Changed the World” by Womack (1996).

Ohno (1988) introduced the lean production principles in TPS that helped Toyota to overcome difficult times since World War II. In an environment lacking of resources, TPS was developed to survive with the minimum amount of resources.

As globalization has forced organizations to become more competitive, lean principles have been expanded to cover all sections across the whole supply chain, and Toyota’s discoveries have resulted in massive revolutions in the business environment. Consequently, the willingness to create value for customers has motivated managers to think about eliminating non-value-added activities all over the supply chain from the start to the end. The primary goal of lean manufacturing is delivering more value to the customer. It will be achieved through eliminating all kinds of wastes from the organization's processes to meet customer’s requirements. The LSC concept is built on the broader goal of providing value to the customer by optimizing the performance of the supply chain as a system (Phelps et al., 2003).

The objective of a LSC is increasing productivity through applying lean tools and techniques into the whole supply chain in order to eliminate wastes and make it effective and efficient enough to satisfy the customer (Srinivasan, 2004). Various
methods and tools have been developed to identify and eliminate wastes. For example, Value stream mapping (VSM) as a graphical tool was developed by Rother and Shook (1998) to visually identify improvement opportunities within processes. It has become one of the most important tools to find non-value-added activities in a business environment, and enables organizations to become more efficient and effective in supporting continuous improvement.

VSM starts by identifying the current processes include both value-added and non-value-added activities. By gathering and analyzing the data on the map, the wasteful activities will be obvious. This is the current state VSM. The current state map will be used as a guide to identify what should be changed in the process to simplify it or to make it more productive. Defining the targets and removing all the wastes, the future state mapping will be obtained. Having these two maps, the practitioners have to develop and utilize tools and techniques to move from current state to the future state.

Wee and Wu (2009) followed a four-step problem solving process to demonstrate how a LSC affects product cost and quality. They presented how VSM helps a LSC to identify potential opportunities for continuous improvement and eliminate wastes. Eight identified wastes in TPS are overproduction, over processing, waiting, excess inventory, transportation, movement, defects, underutilized employee creativity, and the biggest one being overproduction (Monden, 1998; Liker, 2004).

Lean performance metrics are developed to track improvements. After implementing lean tools and techniques, it is important to evaluate the leanesssituation. Although it is important that a group of lean metrics can simultaneously evaluate the effectiveness of the lean initiatives of supply chain, but existing lean assessment metrics usually evaluate the performance of a fraction of the overall leaness (Wan and Chen, 2006). In other words, an integrated measure of supply chain leaness is absent in the literature. By establishing a set of lean metrics for a supply chain, managers can track the improvement in each specific area and build an accurate image of the overall leaness. As a result, measuring supply chain leaness
will help practitioners and managers to know where a supply chain is in the lean journey.

Measurement is a significant key to manage improvement. A comprehensive measure of leanness is needed to provide decision support information such as the current leanness level, the progress of LSC implementation, and the extent of potential improvements in a supply chain. While the efficiency and effectiveness of supply chain activities are continuously improved by lean tools and techniques, a quantitative measure of the leanness level of supply chain to determine the probability of different leanness levels and support the improvements has not been developed. In addition, there is a lack on leanness measurement with an integrated single unit-less index. Without an integrated leanness measure, the leanness level of the current situation is unknown, and the improvement of leanness in supply chain cannot be tracked.

1.3 Problem Statement

Applying lean principles to a supply chain will create a LSC. In this context, the progress and effectiveness of lean implementation in a supply chain are the major concerns for managers and decision makers to know how lean the current supply chain is, and how it can become leaner.

Researchers have proposed several tools and techniques to reduce wastes and enhance the leanness of supply chain. The question, “how supply chain can become leaner” has been answered by these lean tools and techniques. However, the existing literature does not provide an explicit indication on “how lean a supply chain is”, or what is the probability of having a specific lean level. The current methods to measure the leanness of supply chain have some deficiencies such as unable to address stochastic variables, need sufficient data of previous periods, lack of integrating stochastic and fuzzy uncertainties when measuring leanness, and require external benchmarking (Wan and Chen, 2006; Mikko and Ilkka, 2009).
To overcome the limitations of previous studies, a method to evaluate the leanness level of supply chain needs to be developed. The leanness measurement method should be able to measure and unify various metrics into a single index. In addition, it should be able to address deterministic and stochastic metrics. To compare the current leanness level of each metric with a target, an ideal leanness level needs to be identified. As a result, practitioners and managers can evaluate the leanness level by comparing the current leanness level against the leanness target without doing external benchmarking. Consequently, the leanness evaluation method should lead to improvement actions that can enhance the total leanness of supply chain in order to be successful in the competitive market.

1.4 Research Objectives

The main objective of this research is to develop a method to evaluate the leanness of supply chain and presenting it through a single unit-less index which can be interpreted both linguistically and probabilistically. It will raise the awareness of supply chain practitioners about leanness levels and set targets to reach in the future state. In more detail, the objectives are as listed below.

- **To determine a set of key metrics that affect the leanness of supply chain:**

  By doing an intensive literature review and conducting a survey, the key leanness metrics of supply chain performance will be identified, grouped, and validated.

- **To develop a method with a final single unit-less index to evaluate the leanness of supply chain:**

  To develop a method in order to quantify the leanness level of a supply chain, and provide an integrated single index in order to find “how lean the supply chain is” and “what is the probability of having a specific lean level”. The method should provide insights to analyze and identify the potential opportunities in different areas
in order to help the supply chain practitioners to improve the current performance level towards the leanness target.

1.5 Research Scope

The scope of this research is limited to manufacturing SMEs in the automotive industry in Iran. The manufacturing SMEs along with their suppliers and customers are considered as a chain. The distributor is supposed to be the manufacturer since SMEs can directly distribute their products to the large companies as their customers (Teng, 2012). Leanness metrics will be extracted from the literature and then they will be filtered by experts. Consequently, a method will be developed to measure the leanness level of supply chain by using the selected metrics.

1.6 Research Questions

Questions to which this study tries to answer are as listed below:
1. What are the key performance measures and metrics to consider when measuring the leanness of SMEs’ supply chain in automotive industry of Iran?
2. How to develop a method in order to quantify and analyze the leanness level of supply chain, and provide an integrated single index?

1.7 Significance of the Research

This research can be useful for SMEs by presenting a leanness measurement method to inform the decision makers “how lean their supply chain is” and “what are the probabilities of different leanness levels”. Based on the results, the practitioners are able to set some goals and measure them periodically. Removing wastes, cutting
cost, improving delivery, reducing cycle time, and enhancing quality are some beneficial goals that could be established after such an evaluation. In addition, this study will provide a beneficial method to identify the most important metrics in the area of LSC which can be useful for SMEs in the automotive industry.

From theoretical aspect, this study will develop a measurement method which is able to integrate qualitative and quantitative variables as well as deterministic and probabilistic metrics into a single unit-less index which is a challenge in leanness assessment. It is also able to unify the metrics with different scales and units.

1.8 Structure of the Thesis

This thesis is arranged into seven chapters. Chapter 1 is an introduction to the research as aforementioned. The background, problem statement, objectives, scope, questions, and significance of the research are all explained in this chapter. Chapter 2 is an extensive review of literature on related topics, concepts, and issues. Previous works and researches along with individual frameworks, methods, and models are described in this chapter, and critical discussions are consequently provided. Chapter 3 will explain the research methodology, and all steps for conducting the research are described. The mathematical tools (i.e. fuzzy set theory, beta distribution, and central limit theorem) applied to this research are also explained in this chapter.

Chapter 4 will discuss the identification of LSC performance measures and metrics which are used in the measurement method. The survey, the method of extracting measures and metrics, and their validity and reliability will be explained in this chapter. Chapter 5 is assigned to the development of a stochastic-fuzzy method for supply chain leanness evaluation. Chapter 6 deals with the evaluation of the developed method by conducting two case studies from the automotive industry in Iran. Finally, Chapter 7 provides conclusions and recommendations for future studies on LSC performance measurement.
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