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Leanness assessment and optimization by fuzzy cognitive map and multivariate analysis

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ABSTRACT

The strategy of organizational lean production emphasizes on increasing efficiency, quality improvement and cycle time reduction by eliminating non-value added activities (MUDA). This paper presents a comprehensive approach based on data envelopment analysis (DEA), fuzzy DEA (FDEA), fuzzy cognitive map (FCM), Decision Making Trial and Evaluation Laboratory (DEMATEL) and Analytic Hierarchy Process (AHP) for evaluating and optimizing the leanness degree of organizations to survive in competitively growing market. In this regard, a comprehensive list of quantitative and qualitative leanness measures is extracted from the literature. The efficiency of organizations is assessed and optimized by DEA. A heuristic algorithm is proposed to obtain a full ranking of leanness levels of organizations. Accordingly, a sensitivity analysis is carried out to determine impact of each leanness factor on lean strategy. The approach has been found fruitful while applying for a number of packing and printing organizations, in Iran, as a case study. Apart from evaluating overall lean performance metric, the proposed approach can evaluate the impact degree of leanness factors on each other as well as the impact of leanness factors on lean strategy. The result show that production procedure among the leanness measures has the most impact on leanness strategy in the organizations under study. To the best of our knowledge, this is the first study that develops and implements an efficient decision-making procedural hierarchy to support leanness extent evaluation.

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Motivation and significance

To survive in today's competitive market, providing products and services with highest quality and lowest cost are the most important challenges. During the last years of World War II many approaches in different fields have been developed to achieve these aims. But one of the most common approaches in the past two decades that have paid much attention to these concerns, is the lean manufacturing approach (Lewis, 2000). Consequently these approaches can be utilized to evaluate a company's success level in implementing lean culture in comparison with other similar organizations. Nowadays, several techniques have been developed for this aim, but these techniques have shortcomings. In this paper, a novel approach is proposed to cope with these shortcomings. The shortcomings can be expressed in two areas: first, the proposed techniques are usually used for specific parts of organization; second, these methods are not quite systematic.

1. Introduction

Lean production is introduced by Womack (1990). In an integrated system, lean production is a multi-dimensional method that includes a widespread range of management practices like just-in-time (JIT) (Huson & Nanda, 1995), total quality management (TQM) (Andersson, Eriksson, & Torstensson, 2006), team working (Delbridge, Lowe, & Oliver, 2000), cellular manufacturing (Singh, Garg, & Sharma, 2010), supplier involvement (MacDuffie & Helper, 1997). In fact, in all industries, there is a hidden factory that produces defective parts. Modifying processes of this factory reduces costs of system (Miller & Vollmann, 1985).

In this context, fourteen principles of Toyota associated with lean manufacturing are commonly used (Morgan & Liker, 2006). According to these principles wastes is classified into three groups: MUDA, MURI and MORA (Rinehart, 1997). MUDA refers to those activities of processes that do not add value (Waste). MURI refers to any variation leading to unbalanced situations (unevenness). MORA refers to all activities asking material, employees or equipment for irrational stress or effort (overburden). The elimination of MUDA (waste) in lean manufacturing has special effects on the performance of different industries (Rother & Shook, 2003). There

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are many procedures by which these concepts can be applied. According to lean production attitude, when non-value added activities are eliminated, organization would benefit lean outcomes (Wan & Chen, 2008).

One of the concerns of any organization is inventory control. From lean production perspective, storing excessive inventory is wrong because: (1) it increases system costs and (2) problems and gaps of system would remain hidden (Hofer, Eroglu, & Rossiter Hofer, 2012). Examining complexity of products design and dynamic markets can result in valid decision variables for transferring from traditional manufacturing to lean manufacturing (Liker, 1997). Characteristics of lean manufacturing are reducing costs, increasing speed of process, and reducing delivery time (Barber & Tietje, 2008).

According to literature, only a small number of organizations' activities are value added and unfortunately, most of processes are non-value added (Hines & Rich, 1997) which leads to lost in time and capital (Holweg, 2007). Consequently, two issues arise here:

(1) How to reach lean production?
(2) How to assess leanness efficiency degree in organizations?

In this paper, we aim to answer second question and use three methods including DEA, FDEA and FCM to examine important measurements. Therefore, with the help of proposed model, organizations' status is determined in terms of leanness. Need for a novel methodology to determine performance of a company can be addressed by leanness approach, since the existing techniques typically focus on a specific aspect of performance and cannot show the full range of leanness strategy (Wan & Chen, 2008).

In this study, a comprehensive list of measures is obtained for leanness assessment from the literature. To assess and evaluate leanness level in 40 organizations, two methods consisting of FDEA and weighted FCM are utilized and the results of the methods are compared with each other. For verification and validation the results of FDEA, DEA is employed and its ranking results is compared with FDEA at α-cut = 1. Note that we employed two fuzzy methods in order to alleviate vagueness and uncertainty of data sets. In addition, DEMATEL methodology is used to assess the degree of influences that each leanness factor has on other factors. Also, leanness factors are ranked according to their impact degree on lean manufacturing policies by AHP and DEA. Final ranking of organizations is performed by a novel heuristic approach. A sensitivity analysis on DEA model is performed for determining the impact of each leanness factor on leanness strategy. Moreover, AHP is used to consider expert's experiments as well as to determine and rank impact level of each leanness factor on leanness strategy. Fig. 1 depicts the roadmap of this study.

The rest of paper is organized as follows: literature review is provided in Section 2. Problem is defined in Section 3. Model and techniques used in this paper are briefly discussed in Section 4. Case study is addressed in Section 5. Section 6 represents results and sensitivity analysis. Finally, we conclude this paper in Section 7. Future research directions are included in this section, too.

2. Literature review

The performance measurement is one of the most important issues in manufacturing and service systems. Most managers are

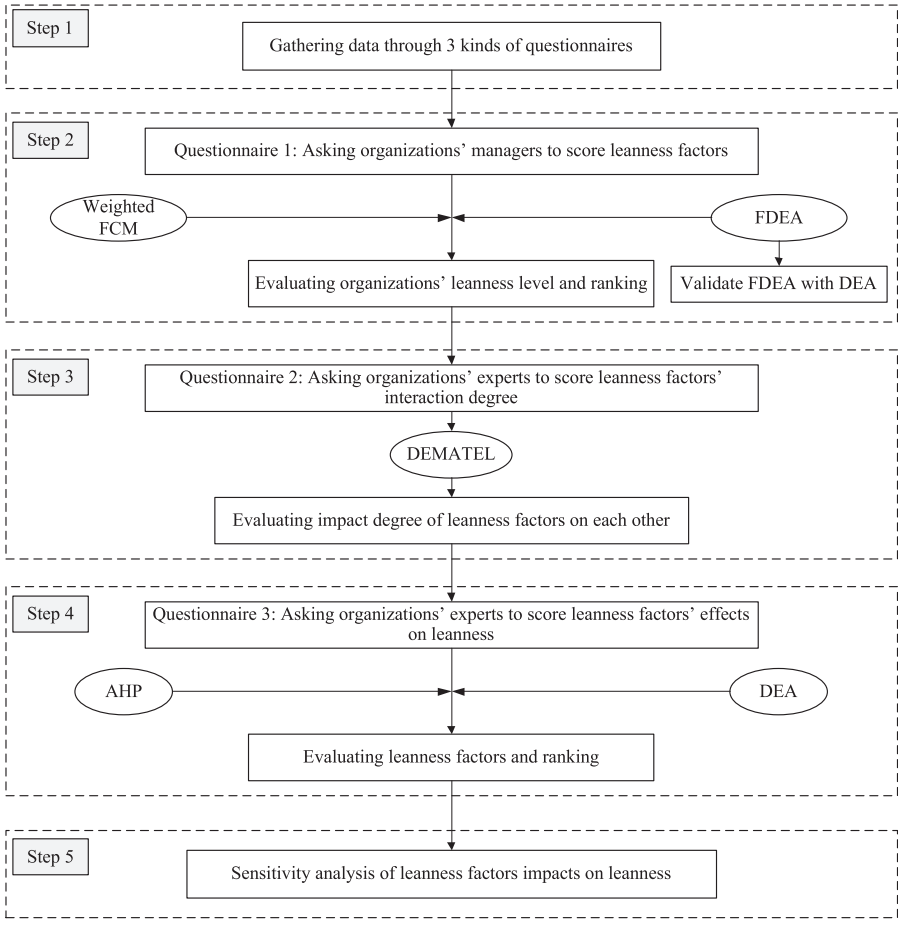

Fig. 1. Flowchart of the proposed approach for leanness assessment.