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A methodology to assess the supply chain performance based on gap-based measures

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ABSTRACT

The motivation of this article lies in the application of two-stage gap-based measurement (GBM) in supply chain management. It adopts GBM model to construct a mixed integer program to measure the various stages of supply chain management in manufacturing practice. This paper proposes a new assessment system that aims to measure the aggregated efficiency of the entire supply chain. In this system, "plan source" and "plan make" are the major elements, they are a widely accepted industry standard by Supply Chain Operations Reference (SCOR). "Plan source" emphasizes the assessment of demand/supply planning strategy and suppliers' performance; "plan make" emphasizes the shop floor control, profitability and equipment effectiveness. The resulting GBM scores provide complete information on how to project inefficient DMUs on to the frontier. This article continues with a demonstration of GBM in the company cases, for the results of the assessment; this paper finds the worst efficiency of the DMUs and proposes improvement programs.

1. Introduction

Data Envelopment Analysis (DEA) is the measurement of the relative performance of a particular DMU, also known as DMU_o, among all DMUs. DEA used to determine a set weight of the inputs and outputs that maximizes DMU_o's aggregated efficiency score. The aggregated efficiency score is the ratio of the sum of weighted outputs (virtual-output) to the sum of weighted inputs (virtual-input). For input-oriented DEA, the score of DMU_o will be equal to, or less than 1. In the case where DMU_o's score is less than 1, it will achieve its improvement target of each input and output.

Two-stage DEA research concerns the process of Stage-1 followed by Stage-2. Along with the inputs and outputs, additional indices "links" between Stage-1 and Stage-2 are defined. Seiford and Zhu (1999) and Zhu (2000) have developed a DEA approach for evaluating US commercial banks and Fortune Global 500 companies, respectively. In Stage-1, the profitability is the ratio of weighted *links* to the weighted *inputs*. In Stage-2, the marketability is the ratio of weighted *outputs* to the weighted *links*. Sexton and Lewis (2003) uses a two-stage approach to evaluate the scores of American Major League Baseball teams. Färe and Whittaker (1995) and Färe and Grosskopf (1996) introduce models to compute the efficiency scores of sub-processes in network-structured DEA problems. Lewis and Sexton (2004) introduces a network DEA model that focuses on the effect of efficiency-enhancing strategies on individual stages of the production process. Kao and Hwang (2008) assumes that the weights are the same for both stages, that is, the weights on the outputs in Stage-1 are assumed to be equal to the weights on the inputs in Stage-2. However, in the real world, the relative weight of each stage is determined according to its importance. Thus, recent studies have adopted this approach to determine the efficiency of the entire system. Liu and Peng (2008) introduces common weight analysis (CWA) to determine the single most favorable common set of weights for DMUs on the DEA frontier. The assessment that proceeded based on the original DEA models shows that these DMUs ranked under its most favorable weights by its input indices and output indices. Chen, Cook, and Zhu (2010), Chen, Du, Sherman, and Zhu (2010) shows that the overall efficiency scores resulting from using the models of Kao and Hwang (2008) are not direct indicators of potential input reductions or output increases not realized by inefficient DMUs. They have developed an approach to determine the DEA frontier on DEA projections for inefficient DMUs. Chen, Cook, Kao, and Zhu (2013) notes that the envelopment-based network DEA model should be used to determine the frontier projection for inefficient DMUs, whereas the multiplier-based network DEA model should be used to determine the divisional efficiency, as it does not account for intermediate links. Kao (2013) proposes a dynamic DEA model for multi-period systems that simultaneously measures system and period efficiencies. Jahanshahloo, Lotfi, Khanmohammadi, Kazemimanesh, and Rezaie (2010)

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proposes two ranking methods, the first method is an ideal line be defined and determined a common set of weights for efficient DMUs then a new efficiency score will be ranked them. In the second method, a special line be defined and compared all efficient DMUs with it and ranked them. Kao (2014) reviews 195 studies on network DEA by examining the models used and the structures of the network system. There are seven structures categorized in this paper. Balfaqiha, Nopiaha, Saibani, and Al-Nory (2016) provides an overview of the performance measures employed in supply chain systems. There are 83 of 374 related articles from 1998 to 2015 were selected for final review using the Scopus and ISI databases.

A supply chain consists of many parties and production stages. Applying DEA performance assessment to the supply chain assesses the efficiencies of each stage and the improvement targets for the all inputs, links and outputs. This research adopts a widely accepted industry standard, the Supply Chain Operations Reference (SCOR) model (SCOR, 2005). It shows an application of DEA for the supply chain management processes of companies, i.e. the SCOR processes 'source' and 'make'. The SCOR model is a cross-industry process reference model designed for supply chain management. In SCOR model, it defines the "plan source", "plan make" and "plan delivery" as the major elements of supply chain processes. For a two-stage supply chain system, Stage-1 is known as the 'Plan Source', which focuses on managerial ability. The three major concerns in the assessment of this stage are demand/supply planning strategy, the suppliers' competitive price and service customers' inventory level. 'Plan Make' and 'Shop Floor Control' are terms that refer to the stage where the material arrives to a plant. Production efficiency and company profitability are the two main indices that are used to measure the efficiency of production activities in Stage-2. For instance, Tone and Tsutsui (2009) presents a type of two-stage DEA model where the value of each link between Stage-1 and Stage-2 are *fixed*, while inputs and outputs can be modified to improve the efficiencies of Stage-1 and Stage-2. Despite the condition of *fixed* links, *free* links are another model proposed in Tone and Tsutsui (2009). Each link is free to be treated either 'as-input' or 'as-output.' Decreasing the values of inputs and as-inputs and increasing the values of outputs and as-outputs will improve DMU_o's aggregated efficiency. This paper adopts a new performance evaluation methodology, data envelopment analysis-gap-based measurement (DEA-GBM) Liu (2017) proposes a DEA gap-based measure constant return-to-scale in best practice model, GBM-bc. The prime model of GBM-bc is to determine the maximum virtual gap in terms of shadow slacks of the inputs and outputs bundle and a scalar. The scalar is in terms of shadow prices predetermined by GBM-bc. The dual form of the model aims to identify the minimum virtual gap in terms of shadow prices of the inputs and outputs packet. The two models reached a same minimum technical inefficiency score. That is the first DEA model guarantees both of the optimal shadow prices and shadow slacks are correct. Liu and Huang (2015), to assess the two-stage performance at a manufacturing field. VGM is a non-radial based DEA model where the minimum virtual gap between virtual-input and virtual-output is used to assess performance. Because both inputs and outputs measures are modified for inefficient DMUs, non-radial based DEA models are widely employed in theoretical research and practical applications. Liu and Liu (2017) applies the VGM model to construct network VGM model to solve dynamic network DEA problems.

The first stage, "Plan Source", receives the purchase order or forecast from the customer. There are two categories that express the activities in this stage; one is the material planning strategy and another is the suppliers' performance. (Kochhar & McGarrie, 1992) presents seven case studies for identifying key characteristics used in the election of MPC systems. (Newman & Sridharan, 1995) surveys 185 manufacturing factories from the U.S. and characterize the users of four alternative MPS systems: reorder point system, Kanban system, material requirements planning (MRP) and optimized production technology (OPT). In the (Berry & Hill, 1992) framework, there are three levels in the MPC system. At the master scheduling level, there are three choices: make-to-order (MTO), assembly-to-order (ATO) or make-to-stock (MTS). At the material planning level, the choices are rate-based or time-phased. At the shop floor control level, the choices are MRP-type or JIT-type. In this paper, we categorize the master

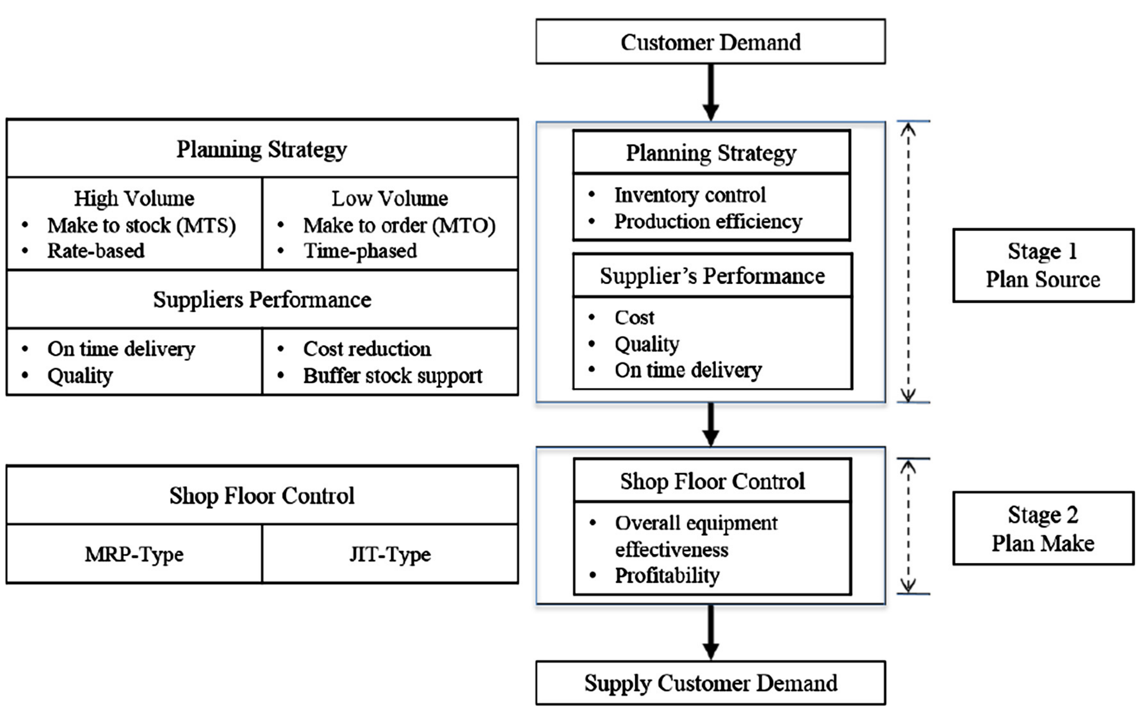

Fig. 1. Two-stage supply chain system.