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Fuzzy performance measurement of a supply chain in manufacturing companies

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ABSTRACT

This paper is aimed to present a fuzzy decision making approach to deal with the performance measurement in supply chain systems. In the manufacturing environment, performance measurement is based on different quantitative and qualitative factors. Some of these factors may have a larger effect on the performance measure than others. Units of measure of the quantitative factors are different such as time, money, percentage, ratio, and counts. Thus, this paper presents a performance measurement approach based on fuzzy set theory and the pair-wise comparison of Analytical Hierarchy Process (AHP), which ensures the consistency of the designer's assignments of importance of one factor over another to find the weight of each of the manufacturing activity in the departmental organization. In the proposed model, various input factors have been selected, and treated as a linear membership function of fuzzy type. It is tested on a numerical example. The approach provides an effective decision tool for the performance measurement of a supply chain in manufacturing environment.

1. Introduction

Supply chain management has received considerable attention in the business management literature. The supply chain is a continuous process, from raw materials to finished goods. It contains different functions such as products design, forecasting, purchasing, process design, manufacturing, distribution, sales and marketing. Improvement of this business integration enables management to focus upon managing the business and delegating the management of the support infrastructure to achieve the benefits of the economies of scale. Success in the flow of supply chain management produces products of high quality at low cost and a good customer service.

Many companies have responded to these requirements by implementing innovative managerial practices such as JIT, invested in advanced manufacturing technologies such as CAD/CAM and emphasizing quality, delivery, innovation and flexibility in meeting customer needs (Banker, Potter, & Schroeder, 1993). These changes are often supported by employee empowerment with increased worker involvement in the control of all phases of manufacturing, and by management information and decision making being diffused throughout the organization (Banker et al., 1993; Kaplan, 1983).

In a parallel but related, it has been suggested that 'day to day' control of manufacturing and distribution operations is best handled with performance measure (Abdel-Maksoud, Dugdaleb, & Luther, 2005). Performance Measurements (PM) is an activity that managers perform in order to reach predefined goals that are derived from the company's strategic objectives (Clemens, Fortuin, & Wouters, 2004), and based on the firm's strategy. It aims to support the implementation and monitoring of strategic initiative. The actual results achieved for the various measures reflect how well the firm succeeds in achieving these strategic choices.

Several authors provide reviews of the literature on PM in operations (Beamon, 1999; Chow, Heaver, & Henriksson, 1994; Neely, Gregory, & Platts, 1995). As operation changes and becomes more central to the success of companies, performance measures need to be improved to support new operations practices. Many other researchers have shown that the traditional financially based performance measurement systems have failed to measure and integrate all the factors critical to success of a business (Andersson, Aronsson, & Storhagen, 1989; Bititci, Suwignjo, & Carrie, 2001; Fisher, 1992; Flapper, Fortuin, & Stoop, 1996; Fortuin, 1988; Fransoo, & Wouters, 2000; Jammernegg & Reiner, 2007). Thus, several performance measurement systems have been proposed, such as activity based costing (Cooper, 1988), the balanced scorecard (Kaplan & Norton, 1996), the SMART system (Cross & Lynch, 1988), and the performance measurement questionnaire (Dixon, Nanni, Alfred, & Vollmann, 1990). Some researchers, providing general frameworks of designing performance measurement system, preferred proposing criteria for the design of the performance measurement systems (Globerson, 1985).

A characteristic of many of these methods is the focus on developing performance indicator PI and PMS based on the firm's strategy and process (Bourne, Mills, Wilcox, Neely, & Platts, 2000). The literature also addresses the comparison on desired performance measures with existing measures to identify which

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current measures are kept, which existing measures are no longer relevant, and which gaps exists so new measures are needed (Medori & Steeple, 2000) and the periodic revision of PMS are implemented.

The development of a PMS may conceptually be separated into phases of design, implementation and use (Bourne et al., 2000). The design phase is about identifying key objectives and designing measures. In the implementation phase, systems and procedures are put in place to collect and process the data that enable the measurements to be made regularly. In the use phase, managers review the measurement results to assess whether operations are efficient and effective, and the strategy is successfully implemented. This may also lead to challenging the strategic assumptions. The design, implementation, and use of a set of performance measures are not a one-time effort: A firm should install processes that ensure continuous review of the system. Review processes imply that a measure may be deleted or replaced, the target may change, and the definition of measures may change. A typical development process is described in Table 1 (Neely et al., 1995).

Maskell (1992) proposes common characteristics for the design of performance measurement system, these are: Performance measures should relate directly to manufacturing strategy, performance measures should vary between companies, and performance measures should change overtime. According to (Beamon, 1999), a supply chain measurement system must place emphasis on three separate types of performance measures: Resource measures, output measures, and flexibility measures. Each of these three types of performance measures has different goals: Resource measures are oriented to reach high levels of efficiency, output measures to achieve customer satisfaction, flexibility measures to respond to a changing environment in limited cost and time.

Suwignjo, Bititci, and Carrie (2000) propose a model for identifying factors affecting performance and their relationships and quantifying the effect of the factors on performance. Brewer and Speh (2000), propose a model based on four perspectives: Internal, customer, financial, innovation and learning. A set of goals and consistent measures are suggested for each perspective. Holmberg (2000), analyses supply chain performance measurement problems from a systems perspective. Several types of problems are identified, namely: Lack of connection between strategy and measurements, biased focus on financial metrics, use of inappropriate measures, and lack of system thinking.

Lambert and Pohlen (2001) develop a framework focused on managing customer relationships and supplier relationships at each link in the supply chain. Metrics should be defined by analyzing the impact of customer and supplier relationship management on the economic value added. Kleijnen and Smits (2003) used a balanced scorecard approach. They postulated that since each company is an economic and legal entity, each should have its own scorecard. Chan (2003) analyses seven performance measurement areas (or attributes): Cost, resource utilization, quality, flexibility, visibility, trust, and innovativeness. For each of them, the work proposes a set of measures that can be included in supply chain performance measurement systems. The SCOR (supply chain operations reference model) (Supply Chain Council, 2005), defines four main processes (source, make, deliver, return) and can be used to describe virtually any supply chain. The performance metrics incorporated in the model are inter-organizational, process-oriented, and combine customer-facing areas (reliability, responsiveness and flexibility) and internal facing areas (cost and assets).

Folan and Browne (2005) propose an extended enterprise performance measurement system. At each node of the extended enterprise, firms should measure indicators (in the areas of cost, time, quality, precision, innovation) consistent with the company mission and strategy according to the perspective influenced (i.e., internal, supplier, customer, extended enterprise). The model proposed by Bititci and Mendibil (2005) is based on the assumption that extended enterprises emerge through collaboration among firms at the business unit level. Therefore, their model includes five scorecards, differing in the organizational level (business unit, enterprise, extended enterprise) and in the orientation (process or organization). Storey, Emberson, Godsell, and Harrison (2006) investigate among other issues, the consistency of performance metric system deployment. The approach helps to link metrics at different levels, but on the other hand, does not take into account that "the sum of the parts does not equate to the whole. Gungor and Arikan (2007) propose a fuzzy decision making system to improve the quality-based investment in small firm. They consider five endogenous factors as input variables: Quality of design, defectiveness of raw materials, incoming defective components, percentage of defective products achieved in the production department, and defective final products. Applying this algorithm, quality-based investments are scored.

Evaluating real life manufacturing environments requires understanding of all the factors affecting the performance. In general, an accurate performance measurement of the supply chain activities in a manufacturing environment is based on quantitative measure such as cost and resource utilization and qualitative measure such as manufacturing flexibility and quality. The data relevant to the quantitative indicators can be retrieved from companies annual and financial reports. Data corresponding to the qualitative indicators can be obtained from the company management opinion. Because the variety of personnel response, it is recommended to conduct the evaluation in a fuzzy environment. This lets managers define a range of linguistic variables within a fuzzy scale based on their own subjective judgments. Fuzzy linguistic models permit the translation of verbal expressions into numerical ones. In general, performance measurements in manufacturing companies adhere to uncertain and imprecise data. In this respect, this paper suggests a new algorithm which a fuzzy decision making system (FDMS). The FDMS method can deal with the ratings of both quantitative as well as qualitative criteria and perform a performance measurement effectively. The proposed method provided an evaluation of performance of the different departments of the company. The published research measures general dimensions such as flexibility, trust, visibility, cost, quality,

Table 1
Nine steps to develop a PMS.

Step	Action
1	Clearly define the firms mission statement
2	Identify the firm's strategic objectives using the mission statement as a guide (profitability, market share, quality, cost, flexibility, dependability, and innovation)
3	Develop an understanding of each functional area's role in achieving the various strategic objectives
4	For each functional area, develop global performance measures capable of defining the firm's overall competitive position to top management
5	Communicate strategic objectives and performance goals to lower levels in the organization. Establish more specific performance criteria at each level
6	Assure consistency with strategic objectives among the performance criteria used at each level
7	Assure the compatibility of performance measures used in all functional areas
8	Use the PMS
9	Periodically re-evaluate the appropriateness of the established PMS in view of the current competitive environment