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Manufacturing evaluation system based on AHP/ANP approach for wafer fabricating industry

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ABSTRACT

The critical role played by manufacturing performance measurement systems in achieving competitive success is increasingly recognized. Manufacturing success may depend on the compatibility between a performance measurement system in operation at subordinate organizational levels and an organization's global goals. Therefore, developing an integrated performance measurement model is significant for strategy management. This study proposes an integrated process that allows manufacturing systems to construct performance measurement model. Performance criteria from the literature and an expert questionnaire were utilized prior to building the performance measurement model. The analytical hierarchy process (AHP) and the analytical network process (ANP) are utilized to determine the weight of each criterion when generating the performance model for manufacturing systems.

1. Introduction

Many manufacturers have faced increased competition from both overseas and local manufacturers in recent years. Global competition and rapid technological development have changed customer requirements and business patterns. To improve the ability of manufacturers to compete in the global marketplace, manufacturers have changed operating philosophies to total quality management, just-in-time, and continuous improvement. Many manufacturers utilize performance indicators based on cost accounting systems; these indicators are inconsistent with new operational philosophies. Furthermore, many improvement efforts are difficult to be quantified in financial terms. Several studies have indicated that performance measures should support a company's strategic goals, and should present both financial and non-financial information (Ghalayini, Noble, & Crowe, 1997; Wang, Huang, & Lai, 2008; Yuan & Chiu, 2007).

Performance indicators have been introduced in manufacturing systems to evaluate the system performance and improve manufacturing competitiveness. To achieve these goals, selection of a range of performance indicators appropriate for manufacturers should be made based on a company's strategic intentions that suit competitive environments and the nature of business. When choosing an appropriate range of performance measures, it is necessary to balance these measures, to ensure that one dimension or a set of dimensions of performance is not emphasized to the detriment of other measures. Moreover, the performance indicators selected must be measurable, and allow managers to monitor performance and goal realization. Numerous studies have focused on developing overall performance measurement models that combine more than one aspect.

This study proposes a measurement model for evaluating overall manufacturing performance, and generates indications of performance to assist managers in realizing the advantages/disadvantages of operational conditions. The general model creates relationships between strategic criteria for evaluation in a multi-attribute decision analysis. However, performance evaluation models in manufacturing usually encompass several interdependent criteria, and each criterion has numerous detailed sub-criteria. How to best balance these indicators is an important issue. An incomplete measurement model can result in inappropriate actions that may harm company competitiveness. To accurately evaluate the influence of these criteria in terms of goals and detailed criteria with respect to upper level criteria, the analytic hierarchy process (AHP) approach and analytic network process (ANP) approach are utilized.

The remainder of this paper is organized as follows: In Section 2, the literature pertaining to performance measurement criteria is reviewed. In Section 3, brief reviews of AHP and ANP approaches are provided. In Section 4, the proposed AHP/ANP-based performance evaluation model is presented, and the model components and relationships among components are described in detail. In

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Section 5, the proposed evaluation model is applied to evaluate the efficiency of manufactory for three companies that manufacture wafers. Conclusions are presented in the last section.

2. Criteria for manufacturing performance

Conventional performance evaluation systems are based on accounting standards, and characterize information solely on financial terms. However, accounting-based measurement systems have several limitations: they do not allow managers to monitor, control, and improve manufacturing systems continuously. For example, conventional measurement systems present information on financial reports; such data have a considerable time lag and are usually outdated. Moreover, such reports only show previous data and may mislead managers to pursue temporary solutions and ignore long-term improvement (Ghalayini et al., 1997; Liu, 2008; Önüt, Kara, & Işik, 2008).

An effective manufacturing performance measurement system should be both explicit and objective, and provide a means for continuously improving a system. Cost, delivery, flexibility, and quality are the most common dimensions/criteria utilized in performance measurement models; each dimension is composed of several detailed criteria. In addition to these four dimensions, customer satisfaction, technology, innovativeness, productivity, inventory, safety and environment, employee morale, and education and training have been considered by different studies addressing specific objectives (Adbel-Maksoud, 2004; Ahmad & Dhafr, 2002; Chenhall, 1996; Ertuğrul & Karakaşoğlu, 2007; Lee, Chen, & Chang, 2008; Yurdakul, 2002).

Leong, Snyder, and Ward (1990) surveyed the literature and generated a composite model for manufacturing performance measurement. This model includes five dimensions: quality, delivery, cost, flexibility, and innovativeness and all dimensions decompose into 37 detailed criteria. Ghalayini et al. (1997) presented an integrated dynamic performance measurement system that provides an overall view of company performance that helps managers identify areas in their organizations that need improvement. This measurement system has eight criteria: customer satisfaction, integration with customers, quality, delivery, manufacturing cycle time, cost of non-value-added activities, process technology, and education and training. Compared with the model developed by Leong et al. (1990), the model created by Ghalayini et al. (1997) has broader dimensions concerned with customer relationships and human resource issues.

In the studies done in the past, it was typically assumed that relationships between these dimensions and associated detailed criteria are independent and are based on a strict hierarchical structure. The AHP approach is one of the most popular analytical tools. However, dimensions and detailed criteria are usually interrelated when improving manufacturing performance. Using AHP will sometimes cause deviation. A network structure to present the interrelationship is more suitable in reality. The ANP approach is a good alternative for evaluating dimensions that are interrelated (Agarwal, Shankar, & Tiwari, 2006; Chung, Lee, & Pearn, 2005; Wu, Shih, & Chan, 2008).

3. Review of the AHP and the ANP

Both the AHP and ANP were introduced by Saaty. The ANP is a general form of AHP. The AHP is utilized when dimensions are independent, and the ANP is suited to solving problems among dimensions that are dependent. The ANP does not require a unidirectional hierarchical relationship and incorporates feedback and interdependent relationships among elements. The ANP provides a general framework for dealing with decisions without generating assumptions about the independence between levels as a hierarchy (Saaty, 2005). This is also an effective tool for modeling complex decision environments. Both the AHP and ANP derive ratio scale priorities by generating pairwise comparisons of elements on a common property or criterion.

There are four basic steps when using the AHP and ANP: (1) deconstructing a problem into a complete set of hierarchical or network model; (2) generating pairwise comparisons to estimate the relative importance of various elements at each level; (3) building a supermatrix to represent the influence priority of elements; and, (4) making decisions based on the supermatrix. The final procedure is suitable when using the ANP approach. In the following section, a manufacturing performance evaluation model is developed based on these steps.

4. Performance evaluation model

To establish a manufacturing performance evaluation model, this study proposes the following three-step procedure: building initial criteria; modifying dimensions and detailed criteria; and building an evaluation model (Fig. 1).

Step 1. Building the initial model.

In this step, this study refers to the literature reviewed in Section 2. Their indicators are generalized—for evaluating manufacturing performance—into six dimensions and 60 detailed criteria. The six dimensions are cost, delivery dependence, employee, flexibility, quality, and utilization.

Step 2. Modifying the initial model.

External experts/scholars in production management, heads of management departments, and heads of operation departments were invited to identify which dimensions and criteria are appropriate for evaluating manufacturing performance. When more than 90% reviewers judge that a detailed criterion would be suitable for evaluating the performance of an upper level criterion, it will be listed in the modified model directly. When >70% and <90% of reviewers judge a criterion to be suitable for evaluating the perfor-

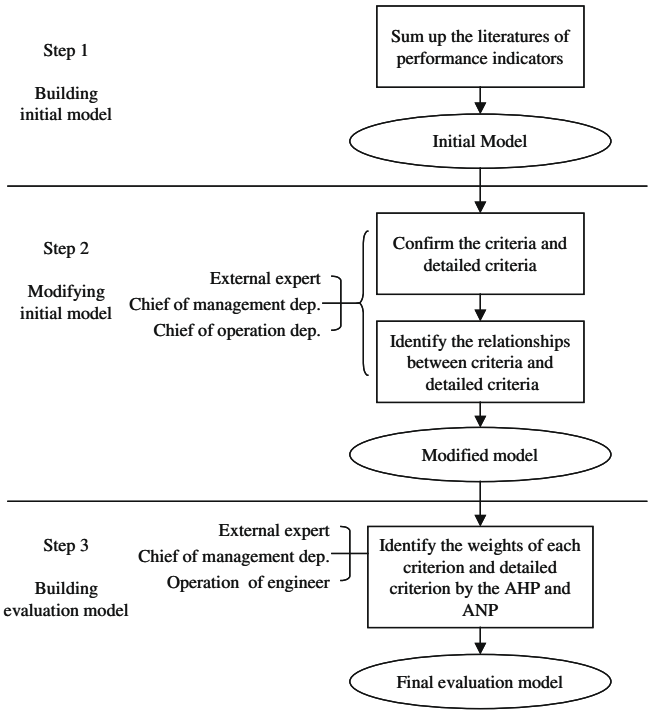

Fig. 1. The procedure of building evaluation model.