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An integrated analytic approach for Six Sigma project selection

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ABSTRACT

Six Sigma is regarded as a well-structured methodology for improving the quality of processes and products. It helps achieve the company's strategic goal through the effective use of project-driven approach. As Six Sigma is a project-driven methodology, it is essential to prioritize projects which provide maximum financial benefits to the organization. Generating and prioritizing the critical Six Sigma projects, however, are real challenges in practice. This study aims to develop a novel approach based on a combined ANP and DEMATEL technique to help companies determine critical Six Sigma projects and identify the priority of these projects especially in logistics companies. First of all the Six Sigma project evaluation dimension and components are determined. Decision Making Trial and Evaluation Laboratory (DEMATEL) approach is then applied to construct interrelations among criteria. The weights of criteria are obtained through analytic network process (ANP). An empirical case study from logistics industry is used to explore the effectiveness of the proposed approach.

1. Introduction

Six Sigma is one of the powerful business strategies that improves quality initiatives in many industries around the world. It is a company-wide systematic approach to achieving continuous process improvements. Not only a technique but also as a philosophy, performing at Six Sigma means producing only 3.4 defects out of every million opportunities for a business process (Pandey, 2007). There has been a significant increase and development of Six Sigma technology and methodology in organizations (Pande, Neumann, & Cavanugh, 2000, Pyzdek, 2003). Especially in the last decade, as a change and improvement strategy, Six Sigma has received considerable attention in global companies to generate maximum business benefit and competitive advantage (Su & Chou, 2008; Yang & Hsieh, 2009). This strategic approach consists of five basic phases: define measure, analyze, improve and control which can also be symbolized by initials, as D-M-A-I-C.

In selecting the most suitable project, define phase is the critical step to ensure proper selection identifying the problem (Antony, 2006; Fundin & Cronemyr, 2003; Gijo & Rao, 2005; Nonthaleerak & Hendry, 2008). Likely benefits and possible contributors are defined (Knowles, Whicker, Femat, & Canales, 2005). Focussing on the customer needs Six Sigma projects are formed, the requirements and current performance are measured, the criteria and key variables that affect the customer satisfaction are analyzed, the process is improved, by monitoring and checking the systems the process is controlled (Knowles et al., 2005; Pandey, 2007).

Selecting of the right Six Sigma project is one of the most sensitive elements in the deployment of Six Sigma (Antony, Antony, & Kumar, 2007; Gijo & Rao, 2005; Pandey, 2007; Snee & Rodebaugh, 2002). For this reason, in this study we adopted an integrated decision framework based on Decision Making Trial and Evaluation Laboratory (DEMATEL) (Gabus & Fontela, 1973) and analytic network process (ANP) (Saaty, 1996) for selecting the most appropriate Six Sigma project alternative. As a matter of fact, there are numerous applications of DEMATEL and ANP recently used together to supplement and/or support the outcomes of each other in cases such as airline safety measurement (Liou, Tzeng, & Chang, 2007), solid waste management (Tseng, 2008a), choosing knowledge management strategies (Wu, 2008), corporate social responsibility programs (Tsai & Hsu, 2008), identification of key development areas (Dytczak & Ginda, 2008a), selecting management systems (Tsai & Chou, 2009) and location selection (Chen & Yu, 2008).

DEMATEL method is a potent method that helps in gathering group knowledge for forming a structural model, as well as visualizing the causal relationship of sub-systems through a causal diagram (Wu & Lee, 2007). ANP was used by Saaty (1996) to overcome the problem of dependence and feedback among criteria or alternatives (Liou et al., 2007). Here, DEMATEL is used to detect complex relationships and build relation structure among criteria for selecting Six Sigma projects. Additionally, ANP is adopted to deal with the problem of the subsystems interdependence and

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feedback; set priorities among goal, strategy and criteria and to determine the most appropriate project alternative.

The rest of the paper is organized as follows. In Section 2, the proposed Six Sigma project evaluation framework is presented. In Section 3, the developed model is detailed. In Section 4, an empirical case study from logistics industry is given to explore the effectiveness of the proposed approach. In the last section, the findings of this research are discussed.

2. Six Sigma project evaluation framework

There are numerous techniques applied in evaluating Six Sigma methodology. According to De Koning and De Mast (2006), the Six Sigma program offers a wide range of tools and techniques, which might be statistical or non-statistical, that are intended to assist the project leader. Those methods even can be utilized in different phases of the Six Sigma projects. The successful implementation of Six Sigma requires stringent application of tools and techniques at different stages of the methodology (Antony, 2006).

The tools and techniques applied in the evaluation of six sigma phases can be classified as statistical tools like sampling (Anderson-Cook, Patterson, & Hoerl, 2005; De Koning & De Mast, 2006), ANOVA (Yang, Choi, Park, Suh, & Chae, 2007), statistical process control (Anderson-Cook et al., 2005; Antony et al., 2007; De Koning & De Mast, 2006; Knowles et al., 2005; Nonthaleerak & Hendry, 2008; Yang et al., 2007), regression analysis (Antony, 2006; Antony & Banuelas, 2002; Knowles et al., 2005), correlation studies (Antony, 2006; Antony & Banuelas, 2002; Yang et al., 2007) etc., quality tools like quality function deployment (Antony, 2006; Antony & Banuelas, 2002; Antony et al., 2007; Anderson-Cook et al., 2005; Banuelas, Tennant, Tuersley, & Tang, 2006; De Koning & De Mast, 2006; Dedhia, 2005; Pyzdek, 2000, 2003; Pande et al., 2000; Yang et al., 2007), quality costing (Antony, 2006; Antony & Banuelas, 2002), or multi-criteria decision making methods especially analytic hierarchy process (AHP) (Dinesh Kumar, Crocker, Chitra, & Saranga, 2006; Pyzdek, 2000; Pyzdek, 2003; Yang et al., 2007).

Multi-criteria decision making (MCDM) methods assist in reaching critical decisions that cannot be made straightforwardly (Lin, Lee, & Wu, 2009). Saaty (1980) firstly developed AHP method to solve the problems of MCDM. Since AHP method cannot handle interdependence in evaluation criteria, ANP was developed (Yazgan, Boran, & Goztepe, 2009). It is a nonlinear structure, while AHP is hierarchical and linear with a goal at the top level and the alternatives in the bottom level (Wu and Lee, 2007). Since project selection involves considering various states and options, it is reasonable to utilize ANP which extends the AHP method (Carlucci & Schiuma, 2009). Additionally, DEMATEL method is also used in MCDM field to construct interrelations between criteria (Li & Tzeng, 2009).

The effectiveness of decision-making depends on the ability of decision-makers to analyze the complex cause–effect relationships (Lin & Wu, 2008). In recent years, DEMATEL and ANP tools have been successfully used in some areas especially including project selection. Both methods are based on a pairwise comparison foundation and allow including the influence of intangibles. According to Wu (2008), DEMATEL is a wise option to calculate inner dependencies since it can produce more valuable information for making decisions. Following this statement, in this study we preferred to use the same approach applying DEMATEL to obtain relations of influence between sub-factors in a pairwise manner when inner dependency occur within an evaluation cluster, and ANP to calculate the weights of elements of evaluation clusters and to select the optimum alternative in selection of the Six Sigma projects framework. The methods DEMATEL and ANP used in Six Sigma project selection framework are summarized in the following subsections.

2.1. The DEMATEL methodology

The DEMATEL method originated for a Science and Human Affairs Program by the Geneva Research Centre of the Battelle Memorial Institute (Fontela & Gabus, 1976; Gabus & Fontela, 1973). It is a comprehensive method for building and analyzing a structural model involving causal relationships between complex factors (Zhou, Zhang, & Li, 2006). It is especially practical and useful for visualising the structure of complicated causal relationships with matrices or diagraphs (Wu, 2008). The matrices or diagraphs portray a contextual relation between the elements of the system (Tseng & Lin, 2008).

According to the above information, the major application of DEMATEL is to investigate the influential status and strength between the factors and transform them into an explicit structural mode of a system (Chiu, Chen, Tzeng, & Shyu, 2006; Lin & Wu, 2008; Tzeng, Chiang, & Li, 2007). The DEMATEL method has been successfully applied in many fields such as R&D project selection (Lin & Wu, 2008); real estate agent service quality expectation (Tseng, 2008a); evaluation of service solutions in service engineering (Shimomura, Hara, & Arai, 2008); introduction of a new product (Fekri, Aliahmadi, & Fathian, 2008; Zhou et al., 2006); airline safety measurement (Liou, Yen, & Tzeng, 2008; Liou et al., 2007); job performance structuring (Fang, Chen, & Hung, 2008); solid waste management (Tseng, 2008b; Tseng & Lin, 2008); evaluation and selection of knowledge management strategies (Wu, 2008); human factors engineering (Hori & Shimizu, 1999); developing global managers' competencies (Wu & Lee, 2007); evaluation of e-learning programs (Tzeng et al., 2007); hotel service quality (Tseng, 2009), safety and security systems analysis (Su & Zhang, 2007; Tamura, Nagata, & Akazawa, 2002); regional development (Dytczak & Ginda, 2008); strategic planning (Dytczak & Ginda, 2008b; Hung, Chou, & Tzeng, 2007); location selection (Chen & Yu, 2008) etc.

This research explains the definition and steps of DEMATEL with reference to studies of relative scholars (Fang et al., 2008; Lin & Tzeng, 2008; Liou et al., 2007; Tseng, 2008b; Tsai & Chou, 2008; Wu, 2008) are as follows:

Step 1: Generating the direct-relation matrix
Measuring the relationship between criteria requires a comparison scale designed as four levels: no influence (0), low influence (1), medium influence (2), high influence (3), very high influence (4). A team of experts is asked to make pairwise comparisons in terms of influence and direction between criteria. The results of these evaluations form a $n \times n$ matrix called direct-relation matrix $\boldsymbol{A}$, in which $\boldsymbol{aij}$ is denoted as the degree to which the criterion i affects the criterion j.

Step 2: Normalizing the direct-relation matrix
On the basis of the direct-relation matrix $\boldsymbol{A}$, the normalized direct-relation matrix $\boldsymbol{M}$ can be obtained through formulas (1) and (2):

$$\boldsymbol{M} = k \cdot \boldsymbol{A} \tag{1}$$

$$k = \mathrm{Min}\left(\frac{1}{\max_{1\leqslant i\leqslant n}\sum_{j=1}^{n}|a_{ij}|}, \quad \frac{1}{\max_{1\leqslant j\leqslant n}\sum_{i=1}^{n}|a_{ij}|}\right) \quad i,j \in \{1,2,3,\ldots,n\} \tag{2}$$

Step 3: Obtaining the total-relation matrix
Once the normalized direct relation-matrix $\boldsymbol{M}$ has been obtained, the total relation matrix $\boldsymbol{S}$ can be derived by using formula (3), where the $\boldsymbol{I}$ is denoted as the identity matrix

$$\begin{aligned}\mathbf{S} &= \mathbf{M} + \mathbf{M}^2 + \mathbf{M}^3 + \cdots = \sum_{i=1}^{\infty} M^i \\ &= \boldsymbol{M}(I - M)^{-1}\end{aligned} \tag{3}$$