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Multi-criteria analysis using latent class cluster ranking: An investigation into corporate resiliency

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ABSTRACT

In this paper, we introduce a multi-stage multiple criteria latent class model within a Bayesian framework that can be used to evaluate and rank-order objects based on multiple performance criteria. The latent variable extraction in our methodology relies on Bayesian analysis and Monte Carlo simulation, which uses a Gibbs sampler. Ranking of clusters of objects is completed using the extracted latent variables. We apply the methodology to evaluate the resiliency of e-commerce companies using balanced scorecard performance dimensions. Cross-validation of the latent class model confirms a superior fit for classifying the e-commerce companies. Specifically, using the methodology we determine the ability of different perspectives of the balanced scorecard method to predict the continued viability and eventual survival of e-commerce companies. The novel methodology may also be useful for performance evaluation and decision making in other contexts. In general, this methodology is useful where a ranking of elements within a set, based on multiple objectives, is desired. A significant advantage of this methodology is that it develops weighting scheme for the multiple objective based on intrinsic characteristics of the set with minimal subjective input from decision makers.

1. Introduction

Performance measurement within organizations typically relies on analyses of multiple factors (Clivillé et al., 2007). The use of multiple factors and relative performance of units are critical for managerial planning and decision-making at both operational and strategic performance levels (Suwignjo et al., 2000; Bititci et al., 2001; Sarkis, 2003). A variety of multiple-criteria, quantitative approaches, and techniques have been developed over the years to address performance analysis issues within increasingly complex organizations. These techniques run the gamut of multiple-criteria decision modeling approaches and frameworks including the balanced scorecard method (BSC) (Kaplan and Norton, 1992); the analytical hierarchy process (AHP), data envelopment analysis, outranking, simple scoring, and numerous other techniques (Koksalan et al., 2011). Each methodology has its own strengths and weaknesses. Many factors such as amount of data required, theoretical robustness, transparency of the approach, level of acceptance by management, amount of time necessary for a solution affect the eventual decision whether or not to adopt a multi-criteria technique.

Given the rich history of the linkage between multiple-criteria analysis and performance measurement, we introduce a novel and relatively robust technique for multiple-criteria evaluation technique based on Bayesian and latent class analysis. The technique is advantageous since it requires very little input from management decision makers, a limited set of data, and has strong theoretical foundations in Bayesian statistical analysis. There are, however, a few disadvantages, which will also be discussed in this paper.

We utilize real world data and an established, well-known managerial technique to demonstrate the usefulness, validity, and flexibility of our methodology. This case example is on the performance evaluation of e-commerce or e-business companies. We utilize the BSC factors in the case example for a number of these organizations. We apply the methodology developed in this paper to rank these e-businesses. We also show how the technique can identify the most salient BSC performance measures that can help predict overall performance. This ranking process is validated by the real-world outcome for the companies in terms of whether they were resilient (remained in operation) or went bankrupt.

Thus, not only do we seek to contribute to the general multiple-criteria analysis literature, but we also seek to contribute to the performance management literature to show how the BSC can be used to evaluate organizational resilience. The approach we introduce uses a statistical model, latent class analysis within a Bayesian framework, to form ranked clusters and then determine

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company ranks within those clusters. Monte-Carlo simulation is used to estimate the parameters of interest and to assess the goodness of fit of the model.

This paper has three major objectives that are each a contribution to the literature. We develop a multiple-criteria ranking analysis method that requires only a minimal amount of subjective, managerial input. We apply the technique to a performance evaluation using aggregate financial and non-financial measures. We also examine the extent to which different BSC perspective measures are predictive of e-commerce companies' future performance and resilience through a metric we have called the displacement index.

The remainder of this paper begins with a brief review of relevant literature on performance measurement tools in general. Then we introduce the integrative multi-stage performance analysis methodology that rank-orders the companies based on a set of performance objectives. At this stage, we concurrently use real-world data to describe the methodology in detail. This methodology includes simulation using a Gibb's sampler to extricate latent variable used to determine the cluster ranks and to assess the goodness of fit of the model. Next, we introduce a validity measure called the displacement index that is used to determine the ability of a BSC perspective to gauge future viability of a firm. Finally, we present some overview of the results, limitations, and potential extensions of the methodology.

2. Multiple-criteria analysis and performance measurement: methods and applications

The performance evaluation of companies, departments, or individuals (generically referred to as objects) is necessary for managerial operations and decision-making. Outside the fields of engineering and management, performance measurements are necessary for research and practice, and the need to measure performance has not been lost to other disciplines from the sciences to the humanities. The development of tools and models for those areas also has been a continuous research endeavor for decades (Koksalan et al., 2011). In this section, we briefly review performance measurement tools, discuss one particular application, the BSC technique in more detail. This review sets the stage for the next section, which introduces the latent class ranking model with an application to e-business resilience.

The variety of tools available for performance measurement has increased greatly as new algorithms, problem situations, and supporting technology have evolved. Various tools and techniques have been developed or refined over the years. A summary of multiple criteria evaluation tools is presented in Table 1. There are various tradeoffs associated with each approach, ranging from level of decision maker effort, to inclusion as well as flexibility of inclusion of various factors.

Various types of multiple criteria evaluation classifications can be found in the literature (e.g., see Figueira et al., 2005; Wallenius et al., 2008). The classifications include the types of tools used, the level of involvement in the technique, or other characteristics.

The research on organizational performance has relied on many of the techniques mentioned in Table 1. Multiple dimensions have been used to determine strategic and operational success potential in organizations. For example, when seeking to identify or select suppliers the multiple performance dimensions are used (Sarkis and Talluri, 2002; Agarwal et al., 2011). Multiple-criteria performance evaluations have been developed for strategic purposes and applied for issues such as the long-term resilience and bankruptcy evaluation (Ravi Kumar and Ravi, 2007). Many of these models in bankruptcy evaluation have focused on financial dimensions. We believe that considering only financial dimensions in these evaluations may be shortsighted and not encompass many intangible factors that can prove to be better predictors of overall corporate resilience. This latter area of investigation is where we seek to apply our modeling technique.

Thus, utilizing a tool such as BSC, which has been applied to management performance evaluations, to determine the strategic resilience of an organization may be an important opportunity for managers and analysts. Extant research on BSC follows several major streams. Kaplan and Norton (1996) have put a great deal of emphasis on linkages of outcomes from lower level (operational) perspectives to higher-level performance drivers. Without such linkages, BSC reverts to stand-alone sets of performance measures. Several papers in this area try to establish such linkages using different types of multivariate regression analyses. A BSC model that has linkages spanning a greater strategic perspective helps explain a firm's revenues, costs, profits and total assets better than a model that only has linkages to the next higher (typically operational) perspective (Bryant et al., 2004).

Generally speaking the different perspective used in a BSC model do interact with each other and the result observed are compounded outcomes of more than one perspective (for example: the financial perspective in our example is impacted by customer service perspective). Studies by Tjader et al. (in press), Hsu et al. (2011) and Kaplan and Norton (2008) have helped clarify the structure of perspective interactions. According to the research, it is not possible to account completely and correctly for the perspective interaction without an overly complex model. However, in many practical situations the main effects of the perspectives are robust enough that a manager can glean useful information without considering the compounding interactions between perspectives.

Another stream of research has focused on whether measures that are common to all business units of a firm receive more weight in

Table 1
Summary of multiple criteria evaluation technique characteristics and exemplary references. H=high, M=medium, L=low.

Evaluation technique	Cost of implementation	Data requirements	Ease of sensitivity	Economic rigor	Decision maker involvement	Management understanding	Mathematical complexity	Parameter mixing–flexibility
AHP	M	M	L	L	H	M	L	H
DEA	M	M	L	M	L	L	H	M
Expert systems	H	H	L	H	M	M	H	H
Goal Program	M	M	M	H	M	L	H	L
MAUT	H	H	M	M	H	M	M	H
Outranking	M	M	L	M	H	L	M	M
Simulation	H	H	H	H	L	H	H	M
Scoring models	L	L	L	L	H	H	L	H
Latent class Cluster model	H	L	L	M	L	L	H	H

Adapted from Sarkis and Sundarraj (2000) except for the last row, the information for which is provided by the authors.