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Applying Bayesian networks to performance forecast of innovation projects: A case study of transformational leadership influence in organizations oriented by projects

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ABSTRACT

The focus of this work is the analysis of the influence of transformational leadership on organizational factors, and their impacts on the project performance. The factors considered are communication, flexibility, continuous delivery and continuous improvement, overlap of activities, and maturity of the team, in projects with a high degree of innovation. Bayesian networks were chosen as a simulation tool. Results showed that for a moderate level of overlap of activities, the maximum project performance is obtained when the leadership components individual consideration, inspirational motivation, idealized influence and intellectual stimulation, are either at moderate levels. This leads to high levels of team maturity, flexibility and continuous delivery, while continuous improvement and communication tend to be moderate. It is highlighted the characterization of the individual contribution of the variables to the project performance and the empirical application of Bayesian networks, as an alternative to statistical methods commonly employed in leadership and management studies.

1. Introduction

Better and more innovative products demand technological solutions that are socially and environmentally friendly, have added value, a low production cost, and are available in the market before the competition. This demand is closely linked to good planning and the orchestration of human, financial and material resources within the organization and the vision of the early success of the projects in order to introduce these products into market quickly and meeting the requirements of performance, reliability and safety. It is known that the interaction between the leadership and organizational factors contribute to the uncertainty of the success of this process, either because of the complexity of these relationships or due to the difficulty of analysis. Moreover, from the standpoint of the organization, resources are finite and are shared. Specifically in innovation projects the question of predictability of the performance is important because of the large number of variables that are involved, such as degree of innovation of the product, the technology level that is required, investments, deployment time, the allocation, and the profile of human resources (Lebcir, 2007; Shenhar et al., 2005). These are projects characterized by high levels of uncertainty both internally and externally in the organization. A prediction model is necessary for the assessment of the development of these projects, alignment or redirection of resources, management of expectations and results for decision making.

This scenario has motivated both organizations and researchers in the search for reliable ways of predicting performance. Examples of this work are studies conducted by Hoang and Rothaermel (2005) and Zollo, Reuer and Singh, (2002), that discuss the effects of partnerships between companies in research and development (R&D) and the ways of prediction (probability) of success of these projects. However, Vandevoorde and Vanhoucke (2005) address the question of predictability of cost and duration of projects. Huchzermeier and Loch (2001) and Terwiesch and Loch (1999) discuss the uncertainties in R&D and suggest ways of modeling this environment considering market factors (payoffs and requirements) and the project (budget, product performance and delivery). Tatikonda and Montoya-Weiss (2001) add further uncertainty arising from the novelty of the product, process and market to their forecasting model. Analyses conducted by Jing and Avery (2006) show that although many studies have been conducted in this area, most of them are focused on the results of satisfaction and individual performance and not the performance of groups. Few studies have been devoted to understanding the influence of the leader about the processes and organizational performance. Examples of such analysis are the studies regarding transformational and

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transactional leadership conducted by Jung and Avolio (1999), Barling et al. (1996), Waldmann and Yammarino (1999) and Emery and Barker (2007). Moreover, there is no clear explanation about how these relationships occur, its nature and the impacts. Most of the empirical work is dedicated to the establishment of the degree of correlation between the leadership factors, processes and organizational performance, or how they account for static analysis and timely results (pictures) or a more general comprehensive view of the relationship. However, several authors have proposed alternatives that go beyond the establishment of a degree of correlation and suggest ways of forecasting performance for application in various areas. Amongst the empirical work in the military areas are Bass, Avolio, Jung and Berson (2003), on leadership in hierarchical structures and their results, where an analysis is made of applying theories of transactional and transformational leadership in military personnel as a means of forecasting performance of the squads in combat. Another example is given by Chen and Bliese (2002) by addressing aspects of leadership from the perspective of the theory of traces. In organizations there may be cited studies by Sivasubramanian, Murry, Avolio and Jung (2002), Pillai and Williams (2004), Koene, Vogelaar and Soeters (2002) and Pirola-Merlo, Härtel, Mann and Hirst (2002), examining how the leadership within teams can be used as a means of predicting the performance of groups. Whereas Keller (2001) deals with the association of transformational leadership to projects that have a better financial performance (budget versus disbursement), delivery and quality, while Xenikou and Simosi (2006) establish a relationship between transformational leadership and organizational culture and use it as a way of predicting performance of organizational units. The same applies to Politis (2004) and Jung, Chow and Wu (2003), but focusing on the assessment and forecast of the levels of creativity in the workplace. Howell and Avolio (1993) and Howell and Hall-Merenda (1999) are dedicated to assessing and predicting the individual performance of employees in organizations.

The merit of all these works is on practical and experimental aspects, on the real data collection representative of everyday life situations of the organizations. On the other hand there is a lack of sensitivity analysis of outputs (performance) to the variation of the inputs (leadership factors) and how this manifests on the means (organizational factors). Part of this limitation is associated with the choice of the validation method of the relations for the forecasting tool for conducting the studies. These limitations are comprehensive in the leadership literature mainly due to the continuous applications of traditional statistical methods. Among the most widely used statistical methods for understanding the relationship between variables in a process are the analysis of correlation and regression analysis. The first is aimed at assessing the strength of the association between variables and cannot always be used for predictions. Linear regression analysis shows the relationship that exists between different variables of a process. This tool can be used as an estimate of future results, but taking due care with the question of the linearity of the model, their relationships and the ranges considered for the extrapolation of results. Both techniques have greater limitations than the actual ability to forecast results, particularly in the case where it is necessary to evaluate the sensitivity of the influence of one or more variables on another. An alternative to this situation is the analysis of the *t*-distribution which considers the magnitude of the effect of changing a particular input variable over an output variable, associated with the level of significance for the null hypothesis (indicating the percentage of two populations that are not statistically distinct). The magnitude of the effect provides information about which variables most significantly affect the outputs of the processes that are analyzed. The prerequisite for the application of these techniques is the existence of a normal distribution of the population. From a statistical point of view, it is interesting to combine the use of the techniques described above. The major limitation of the statistical techniques mentioned (regression analysis, correlation analysis and *t*-distribution) is in its application to systems with typical nonlinear behavior, as is the case of social systems and the need for attention to the condition of normality of the population. As a way of overcoming these restrictions, techniques of artificial intelligence (AI) arise.

Bayesian networks (BNs) belong to this group of techniques. They are graphical models used to establish the causal relationships between key factors and final outcomes (cause-effect relationships). The quantitative relationships between variables in the models are expressed probabilistically. BNs work by examining the conditional independence between variables. Model parameters can be updated using Bayes's theorem. Being probabilistic, the models readily incorporate small data sets or highly variable or vague information, with uncertainties being reflected in model outputs (Pollino, Woodbery, Nicholson, Korb, & Hart, 2007). BNs are particularly useful in modeling processes where only scarce data is available, and relationships are highly variable. They have been used in many different areas as psychology, ecology, medicine, genetics, risk and bankruptcy analysis.

The purpose of this work is to analyze, via a case study how leadership affects organizational factors and which are their impacts on the project performance. After evaluating the various methods we chose to use Bayesians networks as a prediction (simulation) tool of the results. This is due particularly to the characteristics of nonlinearity of the analyzed system and the possibility of conducting a sensitivity analysis of the variables. Another advantage is the possibility of performing bidirectional inferences, i.e., from the causes to the effects or from the effects to the causes. The use of AI tool represents a new approach to the organizational leadership and management studies, since up to now, only very few references in the literature considering this application in these areas have been found. Thus, a second expected outcome of this paper is the contribution on the advance of the application of AI tools in such areas. According to Schneider and Somers (2006) the reasons why AI tools are under utilized in leadership studies are the low awareness among management scholars and confusion about their use. Following this introduction, sections dedicated to the work description are presented. Section 2 deals with the proposed method, the definition of leadership and organizational (people) factors, and performance evaluation (research questions and methodology). Section 3 is related to the empirical study, where sampling procedure and data analysis are discussed. Section 4 deals with implications and conclusions.

2. The proposed method

2.1. Research variables

The performance of an organizational is always linked to its inherent components. According to Albrecht (1988) these components are the business strategy, systems (hardware & software) and people. Leadership can be considered as the fourth one, once it is also part of every organization. The definition of leadership adopted in this work is the one given by Northouse (2004), which considers the process related to the influence among leaders and followers, where an individual influences a group of people to achieve a common goal. In this sense, the only relationship that matters for the purpose of this paper is between leadership and people. Two groups of factors are considered, one related to leadership and one associated to people.

The first group is concerned with leadership factors. Transformational leadership was chosen to be evaluated in this study. It has been one of the most studied leadership theories in recent