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Nonlinear influence on R&D project performance

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ABSTRACT

This study applies artificial neural network (ANN) to explore the relationships between the performance of R&D projects and its determinants. The results indicate that the quality of project environment has an inverse U-shaped effect on the performance of R&D projects, and both project managers' skills and the effectiveness of teamwork have monotonic positive influences on it. Besides, this study utilizes self-organizing map (SOM) to classify the Taiwanese information and electronics companies into three groups and further provides some suggestions. In addition, this paper uses an in-depth interview of qualitative research to explore why the quality of project environment has an inverse U-shaped effect on the R&D project performance, and finds out the main reason. There are two managerial implications in this study. First, the relationships between the performance of R&D projects and its determinants are not always linear in the complex and uncertain environment nowadays. Second, companies must care about the inverse U-shaped effect of the quality of project environment on the performance of R&D projects, although they can enhance the extent of project managers' skills and the effectiveness of their teamwork as much as possible.

1. Introduction

Prior literature argues that firms implement strategies through projects, and thus project management contributes much to the field of management [1]. Because project management is important for the performance of organizations, exploring the topic of project performance is necessary [2]. Projects have predetermined objectives and often face a lot of complexity and uncertainty, because they have finite timelines [3–5]. Besides, projects have finite resources and limited timeframes, so firms have to clearly communicate the objectives of projects to project members [4]. There are four purposes in this study: first, this study verifies whether the antecedents – the quality of project environment, project managers' skills, and the effectiveness of teamwork – influence the performance of R&D projects; second, this study explores whether the relationships between the performance of R&D projects and its antecedents have interesting nonlinear patterns, such as inverse U-shaped relationships; third, this study focuses on the R&D application and applies artificial neural network (ANN) and self-organizing map (SOM) in the area of project management; and fourth, this paper applies an in-depth interview of qualitative research to explore why the inverse U-shaped influence on the R&D project performance happens and to find out the main reason.

Complexity and uncertainty play an important role not only in business level, but also in project level. Because of the environment with high extent of complexity and uncertainty, traditional forms of hierarchical design and managerial mindset are not always effective [5,6]. Although the patterns of the relationships between the project performance and its antecedents are not

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always linear in the complex and uncertain environment, no prior study about project management explores whether the patterns of these relationships are linear or not. Therefore, this study would like to explore the nonlinear effects between the project performance and its antecedents to fill the research gap.

This study utilizes both artificial neural network (ANN) and self-organizing map (SOM) in the field of project management. This study concentrates on the R&D application and uses ANN to explore the R&D project performance in the Taiwanese information and electronics industry by means of the three explanatory variables — quality of project environment, R&D project manager's skills, and effectiveness of teamwork. Highlighting the R&D application, this study also uses self-organizing map (SOM) to classify the sample into several groups and discusses the managerial implications.

2. Literature review

2.1. Artificial neural network (ANN) and self-organizing map (SOM)

Artificial neural network (ANN), a computational model based on the biological nervous system, is often applied to prediction and pattern classification [9]. In addition, ANN that approximates the way man processes information has been a popular research field for the last decade [10]. ANN models could be used to find solutions for complex problems. The hidden layers give critical computational capabilities to neural networks. Besides, ANN models import a set of inputs and generate a corresponding set of outputs according to internal mapping relationships encoded in their structure and connection weights [11]. There are two stages in ANN models: "learning (or training)" and "predicting (or testing)". In the learning (or training) stage, the network "learns" by altering the weights between its nodes [12]. Data are divided into two files. The first file is utilized to train the network and the second one is applied to test the network's predictive ability. In the training stage, the network weights are saved at many intervals in order to test the network's forecasting ability. The best weights for each element of the network can be obtained via thousands of iterations to derive convergence of ANN models [13]. The back-propagation network proposed by Rumelhart et al. [14] is adopted by this study because it is one of the most popular neural network techniques among various ANN paradigms [15].

There are several prior studies applying ANN models to test, predict, and classify in the area of management. For instance, Carson et al. [16] use ANN to provide recommendations in career assessment. Wanous et al. [17] demonstrate high extent of accuracy of neural network as a powerful tool for modeling the bid decision making process to help contractors consider the important bidding determinants and to improve the process of the bid decision making. In addition, Collins and Clark [18] apply ANN to discuss workplace behaviors and demonstrate that the predictive ability of ANN is better than that of regression model. Furthermore, prior research utilizes ANN to support novice nurses' triage task based on a telephone interview [19], and to test the effect of changes in product line width in the American factories [20]. Moreover, previous literature uses ANN to evaluate the association between work attitudes and individual job performance [21], to investigate the relationship between a salesperson's actions and customer perception of the salesperson [13], to improve the accuracy of flexible manufacturing system (FMS) scheduling [22], to implement finance management [23], and to undertake strategic planning [24].

Since regression analysis is applied under a specific specification of the relationship between dependent and independent variables, other relationships may be ignored. Comparing with regression analysis, ANN has three advantages to explore the relationships between variables as follows [13,17].

- There is no prior knowledge of the underlying relationships between the input and output variables in ANN models, since the complex relationships could be discovered by the weights connecting the nodes of the network [25].
- ANN is not restricted by the assumption of linearity adopted in many quantitative approaches, so there is no multicollinearity problem in ANN models [26].
- ANN can work even when the data are incomplete, though regression analysis cannot tolerate missing data and performs poorly when the data are inaccurate [27].

Self-organizing map (SOM) proposed by Kohonen [28] is a clustering ANN approach by means of unsupervised learning. The assumption about the structure of SOM in space is that there is some topology among the inputs [29,30]. Unlike traditional ANN that is calculated by supervised learning, SOM is calculated by unsupervised learning to achieve auto classification, data segmentation, or vector quantification [31,32]. Although several units that compete for the current object performs the SOM clustering, the unit whose weight vector is closest to the current object is selected as the winning unit [33]. The weight of the winning unit is altered as well as those of its neighbors. Projecting a high-dimensional input space on a low-dimensional topology, SOM enables one to visually determine the number of clusters directly [34]. Compared to the supervised ANN, SOM does not need to know in advance the exact objects that users are looking for. Since the advantage of SOM is that users can effectively identify some patterns by visual examination rather than based on mathematical descriptions, this research uses SOM to classify the sample into several groups [35].

2.2. The influence of the quality of project environment on the performance of R&D projects

Prior literature on project management widely concerns about the issue pertaining to the success and failure of projects. For example, several previous studies on project management explore the key successful factors of the project performance [36–39]. Besides, some prior studies of project management discuss how to manage a project successfully [8,40,41]. In addition, the