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A comparison of neural network, evidential reasoning and multiple regression analysis in modelling bridge risks ☆

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Abstract

Artificial neural network (ANN), the evidential reasoning (ER) approach and multiple regression analysis (MRA) can all be utilized to model bridge risks, but their modelling mechanisms and performances are quite different and therefore need comparison. This study compares the modelling mechanisms of the three alternative approaches and their performances in modelling a set of bridge risk data. It is found that ANN outperforms the ER approach and MRA for the considered case study. The reason for this is analyzed. The advantages and disadvantages of the three alternative approaches are also compared.

Keywords: Bridge risk assessment; Artificial neural network; The evidential reasoning approach; Multiple regression analysis; Performance measurement

1. Introduction

In British Highways Agency, bridge maintenance priorities are determined in terms of the risk scores of bridge structures. The risk score is an overall aggregation of bridge risks that are usually assessed against different criteria such as safety, functionality, sustainability and environment and characterized by risk ratings such as *High*, *Medium*, *Low* or *None*. The aggregation process involves a large number of subjective judgments of bridge experts, but there is no explicit functional relationship between risk score and risk ratings.

In order to determine the future maintenance priorities, mathematical models need to be developed to predict the risk scores of bridge structures. Artificial neural network (ANN), the evidential reasoning (ER) approach and multiple regression analysis (MRA) are three alternative approaches for modelling bridge risk data. This study compares their modelling mechanisms and performances in modelling bridge risk data.

Quite a lot of research has been done to compare the performances of ANN models and traditional statistical models. For example, Cao, Leggio, and Schniederjans (2005) utilized ANNs to predict stock price movement and compared the predictive power of linear models from financial forecasting literature to that of the univariate and multivariate neural network models. Their results showed that neural networks outperformed the linear models compared. Kumar (2005) compared regression and neural networks on a real life data and two simulated examples and found that regression was much better than neural networks for skewed data. Yim and Mitchell (2005) looked at the ability of hybrid ANN models in predicting country risk rating. The hybrid ANN models were compared with traditional statistical techniques such as discriminant analysis (DA), logit model, probit model and ordinary neural networks. Their results indicated that hybrid neural networks outperformed all the other models. Kim, An, and Kang (2004) examined the performance of three cost estimation models based on MRA, ANN and case-based reasoning (CBR) of the data of 530 historical costs and found

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that the best ANN model gave more accurate estimation results than either the MRA or the CBR models. Raaymakers and Weijters (2003) used ANN and MRA techniques to estimate the makespan of job sets in batch process industries and compared their performances. It was found that both techniques were robust for changes in the number of jobs, the average processing time, a more unbalanced workload and for different resource configurations, but the estimation quality of ANN models appeared significantly better than the quality of MRA models. Heiat (2002) compared the prediction performance of multilayer perceptron and radial basis function neural networks to that of regression analysis for estimating software development effort and found that when a combined third generation and fourth generation languages data set were used, the neural network produced improved performance over conventional regression analysis in terms of mean absolute percentage error. Alon, Qi, and Sadowski (2001) compared ANNs and traditional methods including Winters exponential smoothing, Box–Jenkins ARIMA model, and multivariate regression for forecasting aggregate retail sales. Their results indicated that on average ANNs fared favourably in relation to the more traditional statistical methods, followed by the Box–Jenkins model. It was also found that the neural network model was able to capture the dynamic nonlinear trend and seasonal patterns as well as the interactions between them. Prybutok, Yi, and Mitchell (2000) developed a neural network model for forecasting daily maximum ozone levels and compared it with two conventional statistical models, regression and Box–Jenkins ARIMA. The results showed that the neural network model was superior to the regression and Box–Jenkins ARIMA models. Baker and Richards (1999) compared the multivariate regression model developed by the National Center for Education Statistics (NCES) and ANN method for forecasting per pupil expenditures in public elementary and secondary schools in the United States. It was found that neural network results ranged from comparable to superior with respect to the NCES model. The most successful neural network procedure yielded its results with an even simpler linear form than the NCES model. Shtub and Versano (1999) described a cost estimating system based on a neural network, which learns how to modify cost estimates when a new technology is developed. Their study revealed that the proposed system outperformed traditional linear regression analysis models used for cost estimation. Ainscough and Aronson (1999) examined ANNs as an alternative to traditional statistical methods for the analysis of scanner data. The results of their study showed that ANNs could be an effective alternative to regression for modelling and predicting the effects of retailer activity on brand sales. The neural network models exhibited better performance in terms of both mean squared error and R^2 than the regression model. Arditi and Tokdemir (1999) compared ANN and case-based reasoning (CBR) for predicting the outcome of construction litigation and discussed their advantages and disadvantages. It appeared that CBR was more flexible when the system was updated with new cases and had better explanation facilities than ANN. Desai, Crook, and Overstreet (1996) explored the ability of neural networks such as multilayer perceptrons and modular neural networks, and traditional techniques such as linear discriminant analysis and logistic regression, in building credit scoring models in the credit union environment and compared their performances with customized credit scoring models. Their results indicated that customized neural networks offered a very promising avenue if the measure of performance was percentage of bad loans correctly classified. However, if the measure of performance was percentage of good and bad loans correctly classified, logistic regression models were comparable to the neural networks approach. Chang and Su (1995) compared measurement error models for computer vision inspection systems based on the statistical regression method and a neural network-based method. Their experimental results demonstrated that both of the models could effectively correct the dimensional measurements of geometric features on a part profile. It was also shown that the statistical regression method could perform excellent tasks when the functions for models were carefully selected through statistical testing procedures. On the other hand, varieties of neural network architectures all had good performance when training data were collected carefully. The explicit nonlinear relationship in neural network architectures was very effective in building a general mapping model without specifying the functional forms in advance. While statistical regression methods would continue to play important roles in model building tasks, the neural network-based method would be a very powerful alternative for precision measurement using computer vision systems. Nguyen and Cripps (2001) compared the predictive performance of ANN and MRA for single family housing sales and found that ANN performed better than MRA when a moderate to large data sample size was used. Venugopal and Baets (1994) conducted a conceptual comparison of ANN and statistical techniques such as regression analysis, discriminant analysis, cluster analysis and so on.

The above literature review clearly shows that ANN outperforms MRA in most situations. The purpose of this paper is to present a further comparison of ANN and MRA. Especially, we compare them with a newly developed evidential reasoning (ER) approach. We compare their advantages and disadvantages as well as their differences of performance in modelling a set of bridge risk data. The comparison made in this study can provide reference for the choice of the three alternative approaches and their applications.

The paper is organized as follows. Section 2 briefly reviews the basic principles of ANN, the ER approach and MRA. Section 3 presents an application of the three alternative approaches in modelling a set of bridge risk data. Section 4 compares their advantages and disadvantages and their performances in modelling bridge risks. Section 5 concludes the paper.