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Comparative study of artificial neural networks and multiple regression analysis for predicting hoisting times of tower cranes

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Abstract

This paper aims to develop a quantitative model for predicting the hoisting times of tower cranes for public housing construction using artificial neural network and multiple regression analysis. Firstly, based on data collected from crane operators and site managers in seven construction sites, the basic factors affecting the hoisting times for tower cranes are identified. Then, artificial neural networks (ANN) and the multiple regression analysis (MRA) are used to model the hoisting time, and from the results, the neural network model and the multiple regression model of hoisting time are established. The modeling methods and procedures are explained. These two kinds of models are then verified by data obtained from an independent site, and the predictive behaviors of the two kinds of models are compared and analyzed. Furthermore, the predictive behaviors of the neural network model are also investigated by a sensitivity analysis. Finally, the modeling methods, predictive behaviors and the advantages of each model are discussed.

Keywords: Hoisting time; Multiple regression; Artificial neural network; Tower cranes

1. Introduction

In most modern cities, high-rise building construction prevails. Thus, material handling and movement in construction sites have received considerable attention by site managers to ensure efficient material supply. Material hoists, which can provide fast vertical transportation, are widely used because of low cost and easy operation. However, horizontal distribution of materials to the designated work areas is required. The use of tower cranes can perform vertical and horizontal transportation at the same time and thus becomes dominating in high-rise building construction. On the other hand, the number of tower cranes installed for building sites is restricted to avoid clashing between cranes and by its high installation and running costs. Hence, the allocation of cranes for different trades is one of the critical targets in resource planning. In planning crane operations such as concreting, installing precast concrete units and fixing formwork panels, which when combined together will determine the cycling duration for structural frame construction. At present, the times for hoisting, loading and discharging are usually estimated by experience, which may vary between people and create inaccuracies.

2. Previous studies on tower cranes

Many previous studies on crane usage have been recorded. Anson and Wang [3] reported that the vertical hoisting time varied with height and occupied the cycle time of a concrete pour from 45% of cycle time at low levels to 80% at high levels. Rodriguez-Ramos and Francis [18] developed a mathematical model to determine the optimal location of a single tower crane within a construction site by minimizing the total

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crane transportation cost. Furusaka and Gray [7] studied a mathematical model of locating a crane on a construction site and selecting cranes to give the economic solution. This study revealed that it might not be necessary to use a single type of crane from the first floor up to the top, and that the least cost solution was likely to be obtained from a combination of cranes. Gray and Little [8] presented a systematic approach to the selection of an appropriate crane for a construction site. They described the process and criteria for the selection of two categories of cranes namely, tower cranes and mobile cranes. The selection process was in the form of decision flow charts, and an expert system was developed in simplifying the process. The study by Choi and Harris [6] considered the angular and radial movements which were carried out simultaneously with the hoisting movement, and suggested to locate the optimal position of a tower crane to serve the predetermined supportive facilities. Zhang et al. [27] developed a stochastic simulation model to optimize the location of a single tower crane. One of the objectives of their research was to use simulation techniques to reflect real wold practices, which is different from the deterministic models described above. Similarly to the former researchers, this model also alleged that the vertical movement time did not vary when the crane location changed. These previous works have attempted to locate the optimal position of a crane and to select the suitable cranes for a construction site by establishing a mathematical model. They could not provide a quantitative model enabling site planners to predict the hoisting time. This paper aims to establish a quantitative model to predict hoisting times based on data collected from seven construction sites.

3. Methodology and objective

In establishing a quantitative model for predicting hoisting times, the variety and complexity of factors such as discreteness, non-linearity and uncertainty of the values of the factors create difficulties in the selection of a reasonable modeling method. Over the last few decades, there has been much research directed to processing nonlinear data and establishing the nonlinear model of field data. One of the examples is artificial neural network (ANN). ANN may be considered as a data processing technique that maps some type of input stream of information to an output stream of data, and thus it belongs to the class of data-driven approaches, as opposed to model-driven approaches. Several potential advantages of ANN over statistical methods in modeling and prediction are shown below.

1. ANN can show mathematically a universal function approximator (Hornik et al. [11]), which means that it can automatically approximate whatever functional form that best characterizes the data.
2. ANN is also inherently non-linear (Rumelhart and McClelland [19]), which means not only can it estimate non-linear functions, but it can also extract any residual non-linear elements from the data after linear terms are removed.
3. With ANN using one or more hidden layers, ANN can partition the sample space automatically and build different functions in different portions of that space. This means that ANN has a modest capability for building piece-wise non-linear models.

The possible use of neural networks for construction engineering modeling was pointed out by Moselhi et al. [15] in an article that discussed potential neural network applications in construction engineering and management. Moselhi et al. [16] used back-propagation neural networks and the genetic algorithm to develop a decision-support system to aid contractors in preparing bids. The back-propagation algorithm has also been used for estimating construction productivity [4], and valuation of new construction technology acceptability [5]. Kartam [12] used neural networks to determine optimal equipment combinations for earthmoving operations. Adeli and Wu [2] formulated a regularization neural network and presented the architecture of the network for construction cost estimation. Hegazy and Ayed [9] used a neural network approach to manage construction cost data and develop a parametric cost-estimating model for highway projects. Sonmez and Rowings [23] presented a methodology based on the regression and neural network modeling techniques for quantitative evaluation of the impact of multiple factors in productivity. Yeh [26] proposed a novel neural network architecture, the logarithm-neuron network, and examined for its efficiency and accuracy in quantity estimating of steel and RC buildings. Portas and AbouRizk [17] developed a neural network model to estimate construction productivity for the concrete formwork task. On the other hand, although the future looks bright for ANN applications in forecasting and decision-making, it is still necessary to rigorously evaluate these applications in many fields.

Another commonly used modeling technique is the multiple regression analysis (MRA). It has been used extensively by researchers in social sciences, business, policy studies and other areas [22]. Mentzer and Kahn [13] reported that MRA was used commonly for sales forecasting. Sanders and Thomas [20,21] developed models in forecasting masonry productivity by using MRA. Moselhi et al. [14] established regression models for daily pour size and crew productivity for manual concrete placing and semi-automated placing.

This research aims to study modeling methods and