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A software prototype for material handling equipment selection for construction sites

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ABSTRACT

Nowadays, every industry is experiencing demographic, economic and technological shifts, which have made innovation indispensable for them. The innovation in the construction industry can be evidenced through availability of a diverse range of new material handling equipments (MHEs) in the market having varying advanced features. An MHE is a critical investment made by a construction company that may significantly affect its future performance, competitiveness and sustainability. Therefore, selecting the best MHE with the desirable characteristics from a vast array of available alternatives is one of the most onerous tasks as often being faced by the construction engineers. In this paper, a software prototype based on quality function deployment (QFD) technique is designed and developed in Visual BASIC 6.0 for selecting two most suitable bulk-type MHEs, i.e. excavator and wheel loader for specific applications at a construction site. It is integrated with QFD method to provide due importance to the spoken and unspoken needs of the customers/construction engineers. It automates the entire MHE selection process and also performs sensitivity analysis study to investigate the effect of changing criterion weight on the alternative MHEs' ranking pattern. Its potentiality and applicability in solving bulk-type MHE selection problems is demonstrated in detail.

1. Introduction

Material handling at a construction site, where the building materials in bulk need to be transported from one place to the other, has a direct influence on transit time, resources usage and service levels. It is intrinsically associated with the flow of construction and can be time consuming, expensive, troublesome and often dangerous. Moreover, improper, inadequate or unsafe handling of materials may cause injuries and even death to the workers in many cases. Therefore, the importance of recent concepts and ongoing efforts in the development of advanced construction technologies based on automation and information sciences, material science and system engineering should be duly acknowledged [1]. Handling materials safely, smoothly and directly with proper material handling equipment (MHE) must be the primary goal of a construction company to keep the process under control at all times. It also accounts for a major percentage of the total construction cost, and thus, efficient handling of construction materials is of paramount importance in significantly reducing this cost. Having an efficient and cost-effective material handling system necessitates designing the entire system at once even though it may comprise several subsystems. Selection and configuration of MHE types are the key subsystems in the design of a material handling system [2]. In a construction company, as material handling is a cost-centered activity instead of a profit-centered one, it should be minimized as much as possible with respect to time, distance, frequency and overall cost, which can only be attained by selecting the most appropriate MHE for a given handling task. Selection of a proper MHE is also critical for its longer service life and smooth running of the construction company. Poorly selected MHE can severely affect the performance and lead to substantial losses in the construction process. Thus, to mitigate such risks, MHE selection is considered as an important issue for any construction company.

The MHEs are designed in such a way that they facilitate easy, cheap, fast, and safe loading and unloading of construction materials with the least human intervention. Various types of MHEs with diverse operational features are available in the market in these days. A quite large number of features of the available MHEs, like technical specifications, capital cost, operational efficiency etc. need to be evaluated while identifying the most appropriate MHE for a particular construction site. These evaluation criteria are sometimes interrelated to each other and may be both qualitative and quantitative in nature. So, in order to select the best-suited MHE for a given handling task, all the possible options need to be analyzed carefully with respect to various relevant factors, which requires a lot of time, sufficient knowledge and necessary skill in a particular domain. Although, technical brochures can effectively convey various MHE specifications and some level of technical performance data, they often do not provide true comparisons of a particular

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MHE with the other competing choices. Thus, lack of complete, structured and accurate information is a problem often faced by the construction engineers while selecting an MHE for a specific handling task. This creates a need for development of a systematic and rational approach that can automate the entire MHE selection procedure. In this paper, a software prototype integrated with quality function deployment (QFD) technique is developed in Visual BASIC 6.0 to select two bulk-type MHEs, i.e. excavator and wheel loader to be deployed at a particular construction site. This integration with QFD technique becomes necessary here to incorporate the dynamic, spoken and unspoken requirements of the construction engineers in the final MHE selection decision.

This paper is organized as follows. Section 2 presents a review on the past researches. Section 3 summarizes QFD technique, while the framework for the developed software prototype is outlined in Section 4. One illustrative example and advantages of the software prototype are provided in Section 5, and in the last section, conclusions are drawn.

2. Literature review

The earlier researchers already suggested various mathematical models, multi-criteria decision making (MCDM) methods and knowledge-based systems to address the issue of MHE selection for industrial applications and construction projects. Skibniewski and Chao [3] applied analytic hierarchy process (AHP) to develop a systematic approach to evaluate advanced construction technologies. The viability of the proposed approach was demonstrated while evaluating tower crane alternatives. It was claimed that the proposed approach could organize tangible and intangible factors more systematically and provide a structured solution to decision making problems for new construction technology adaption. Braglia et al. [4] developed a model integrating AHP with integer linear programming method for solving MHE selection problem for intra-cell material movement in a cellular manufacturing system. It became possible to perform selection of the 'good' set of MHEs for intra-cell material movement under the given budget and space constraints. It was also shown how the AHP weightings could be combined with integer linear programming to include possible resource and size limitations. Bhattacharya et al. [5] proposed a mathematical model based on AHP method to combine cost factor components with the importance weightings for MHE selection. Shapira and Goldenberg [6] developed a model based on AHP method to select equipment for various construction projects. The proposed selection model had two modules, e.g. evaluation of soft factors and overall evaluation of costs with respect to soft factors. A modification of AHP was also proposed to correspond with the nature of equipment selection while offering an efficient and convenient approach to MHE selection. Chakraborty and Banik [7] employed AHP method to develop systematic steps for selecting the most appropriate MHE under a specific handling environment to meet some organizational requirements. Conveying systems were selected as the most preferred MHE. Sensitivity analysis was also performed to identify the most critical and robust criteria in the MHE selection process. Vijayaram [8] presented a review on material handling technology and pointed out the role of expert systems in selecting appropriate handling equipment for engineering industries. The need for developing expert systems for guiding the decision makers in selecting appropriate MHEs was also emphasized. Lin et al. [9] proposed an adaptive AHP approach (A^3) employing soft computing and genetic algorithm (GA) to recover the real weights of various criteria in AHP methodology. Its applicability was demonstrated using a construction management example for determining criteria weights for a best-value bid. It was observed to be superior to the original AHP method with respect to cost-effectiveness, timeliness and better decision quality. Shapira and Simcha [10] implemented a non-statistical quantitative approach to assess the safety factors caused by the operation of tower cranes at a construction site. Onut et al. [11] proposed a combined fuzzy analytic network process (FANP) and fuzzy technique for order performance by similarity to ideal solution (FTOPSIS) methodology for evaluating and selecting the most efficient MHE. It was applied to a steel construction industry where rail crane system was identified as the most efficient MHE. Fuzzy TOPSIS was employed to select an MHE alternative, whereas, FANP was applied for calculating criteria weights. Ulubeyli and Kazaz [12] applied ELimination and Choice Expressing REality (ELECTRE III) method for selecting concrete pumps for a construction site. It was observed that X-52 was the most suitable concrete pump, followed by Z-52 and Y-52, respectively. A sensitivity analysis study identified no considerable change in the ranking pattern of the pump alternatives. Tuzkaya et al. [13] evaluated the performance of alternative MHEs while applying FANP and preference ranking organization method for enrichment evaluation (PROMETHEE). The proposed methodology could deal with the vagueness embedded in the MHE selection process. A sensitivity analysis showed that the derived results would become sensitive to the changes in the considered parameters. Lashgari et al. [14] combined AHP and TOPSIS methods under fuzzy environment in order to select a proper shaft sinking method in Parvadeh Coal Mine. Raise boring machine was selected as the most appropriate shaft sinking method for the mine. Using a GA-based meta-heuristic algorithm, Poon et al. [15] developed a mathematical model for effective selection and allocation of MHE for stochastic production material demand problems in a manufacturing organization. Momani and Ahmed [16] selected the most appropriate MHE while combining Monte Carlo simulation with AHP method. The applicability of the proposed model was demonstrated through a real-world problem showing its advantages over the traditional AHP method. Lashgari et al. [17] integrated fuzzy AHP, ANP and TOPSIS methods to develop a hybrid multi-attribute decision making tool for MHE selection in Gole Gohar iron mine. The fleet of cable shovel and truck was identified as the most economical loading and hauling system. It was claimed that the proposed method would also be applicable for selection of earth-moving machinery for other open-pit mining project with necessary modifications. Jiang et al. [18] adopted a fuzzy MCDM model to aid in the decision making process for choosing the best wireless technology for tracking construction materials. The results showed that Wi-Fi might be a suitable solution for optimists and neutral persons, but UWB might be the better alternative for pessimists. Yazdani-Chamzini et al. [19] applied the Takagi-Sugeno fuzzy model based on subtractive clustering method for predicting the road header performance with respect to different machine- and rock-related parameters. The performance of the developed models was evaluated in comparison with the recorded data, and the best fit model was identified based on some performance evaluation indices. Karande and Chakraborty [20] employed weighted utility additive (WUTA) method to select the most suitable MHE for a given application. Based on an illustrative example, the viability of WUTA method was tested, and it was concluded that the WUTA would be a suitable tool in solving MHE selection problems. Rossi et al. [21] developed a structured approach based on AHP methodology for selecting the best alternative for manuable material handling taking into consideration ergonomic criteria and production performance measures. Mousavi et al. [22] applied a fuzzy grey group compromise ranking method to deal with the MHE evaluation and selection problems having uncertain information. A real-time example was considered for conveyer selection in a manufacturing environment. A sensitivity analysis was also preformed to investigate the effect of strategy weight and distinguished coefficient on the derived results. Olearczyk et al. [23] proposed a methodology for crane selection and developed the related mathematical algorithms to assess the construction of multi-lift operations for the selected cranes. The developed methodology could calculate the crane rotation point and assist in modifying the boom configuration rather than relocating the unit. Yazdani-Chamzini [24] employed two fuzzy MCDM methods, i.e. FAHP and FTOPSIS to select the most suitable MHE under an uncertain environment. The effectiveness of the proposed model was validated using a real-time case study. A sensitivity analysis was also performed to study the result sensitiveness to changes