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Original Article/Research

Integrating a fuzzy-logic decision support system with bridge information modelling and cost estimation at conceptual design stage of concrete box-girder bridges

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Abstract

Integrating 3D bridge information modelling (BrIM) with construction technologies had inspired many researchers for the past decade. In this study, research objectives are intended to demonstrate the viability of integrating a 3D computer-aided design (3D-CAD) model with a structural analysis application and bridge cost estimation framework without compromising interoperability matters. An integrated model that relates a fuzzy logic decision support system with cost estimation for concrete box-girder bridges is presented. Model development methodology comprises an integrated preliminary cost estimation system (IPCES), and complex quality functions and deployment of a multi-criteria decision making (MCDM) approach. An actual case project is used to validate and illustrate model corresponding estimating capabilities. The proposed model is engineered to enhance existing techniques implemented by bridge stakeholders and designers to prepare cost estimates at the conceptual design stage by taking into consideration box-girder bridge project site preparations, substructure, and superstructure. The proposed model is anticipated to be of major significance to designers and its contribution resides into the integration of BrIM technologies with cost estimation approaches.

Keywords: Decision support; Complex quality functions; Bridge information model; Cost estimation

1. Brief background

Bridge information modelling (BrIM) is an approach similar to building information modelling (BIM) and may be comprehended as an innovative approach to inform downstream processes of infrastructure projects. As part of developing this research incentive, it was understood that integrating a fuzzy-logic decision support system with BrIM and preliminary cost estimation of concrete box-girder bridges is possible only if objectives were kept simple, focused, and organized. Therefore, basic BrIM processes were researched, recalled, and analysed. According to Bentley bridge solutions (Peters, 2009), the eight processes of BrIM are: (1) bridge type selection; (2) 3D-CAD model; (3) technical analysis; (4) planning for construction; (5) production; (6) phases of construction; (7) maintenance; and (8) remediation. In this study, the first two processes

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List of symbols

Greek symbols

ϕ normalization factor

Latin symbols

A^* positive ideal solution
A' negative ideal solution
C_i^* relative closeness to positive ideal solution
E measure of entropy by a discrete probability distribution for WHATs criteria
e_m weight of a WHATs criterion
g_{mk} relative importance perception on a criterion in crisp form
$\tilde{g}_{mk}$ relative importance perception on a criterion in fuzzy form
J set of beneficial attributes or criteria
J' set of negative ideal attributes or criteria
j summation counting variable
i number of bridge competitors
k bridge beneficiary
p_L probability distribution
p_{mk} probability distribution of WHATs criteria assessment on bridge competitors
r_{ij} normalized scoring value of bridge beneficiaries on bridge competitors' criteria
S_i^* separation from positive ideal solution
S_i' separation from negative ideal solution
v_j^* weighted positive scoring values of beneficiaries on bridge competitors' criteria
v_j' weighted negative scoring values of beneficiaries on bridge competitors' criteria
v_{ij} weighted normalized element of TOPSIS matrix
W_m WHATs criterion
w_i WHATs criterion weight value
X bridge beneficiaries comparison matrix
x_{ij} "m × n" matrix with 'm' bridge competitors and 'n' criteria
x_m total of bridge beneficiary assessment of all bridge competitors on each of the WHATs criteria
x_{mk} bridge beneficiary assessment on a WHATs criterion
x_{mlk} bridge beneficiary assessment of a bridge competitor on a WHATs criterion

(i.e. bridge type selection, and 3D-CAD model) were selected for development and integration with cost estimation of concrete box-girder bridges at conceptual design stage.

2. Problem statement

In the past, several attempts had been witnessed in efforts to developing computational tools for supporting various aspects of bridge design; however, these aspects were tackled independently from impediments arising due to availability of multiple data resources. Nowadays, few industries have moved forward in terms of incorporating integrated design with industrial processes in parallel with "broadly-accepted" interoperability standards. Although the deployment of object-oriented programming (OOP) approaches in the bridge construction industry supported by metadata file transfer capabilities had resulted in less error-prone data duplication, many engineers and researchers are still unaware of the benefits of utilizing such technologies in cost estimation at the conceptual design stage of bridge projects. For example, incorporating a fuzzy logic decision support system for bridge type selection assists the user in determining the economical bridge type for given site conditions. This paper presents results pertaining to the integration of an information model as a technology that incorporates a fuzzy logic decision support system with a cost estimation system at the conceptual design stage of bridges.

3. Motivation and objectives

Research motivations presented in this study underlie the deployment of an integrated preliminary cost estimation system (IPCES) with 3D BrIM for concrete box-girder bridge projects. The main objective of this paper; however, is geared towards the development of the fuzzy logic decision support system, multi-criteria decision making approach, technique of order preference by similarity to ideal solution (TOPSIS), and bridge conceptual design in order to obtain preliminary cost estimates. The subject matter presented hereby mainly emphasizes on the methodology followed to achieve the abovementioned objective while taking into consideration interoperability concerns. According to Shim et al. (2011), existing 3D-CAD solutions are not sufficient for utilizing information models of bridges since technical improvements are a necessity for the effective exchanging of information among interoperable software. In their study, a neutral file format accompanied with an extensible markup language (XML) schema is deployed via a coded-link to enhance interoperability. Furthermore, Gallaher et al. (2004) clearly state that the absence of efficient interoperability among 3D modelling solutions could substantially refrain users from reaping remarkable benefits. Up to date, there is a lack in the literature on the effect of integrating a fuzzy logic decision support system and a multi-criteria decision making approach with BrIM and cost estimation at the conceptual