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Using LOD in structural cost estimation during building design stage: Pilot study

Jamin Wood[a], Kriengsak Panuwatwanich[a,*], Jeung-Hwan Doh[a]

[a]Griffith School of Engineering, Griffith University, Gold Coast campus, Queensland, 4222 Austalia

Abstract

This paper presents a pilot study attempting to harness the power of Building Information Modelling (BIM), coupled with Level of Development (LOD), for practicing structural engineers to have greater understanding of design decisions on cost, thereby giving greater control of economy. This study aimed to exploit the wealth of BIM built environment data in a framework, matching building material data with cost data, in the Microsoft Excel platform to allow for a raw design cost to be automatically determined. Level of Development (LOD) is a standard which allows for consistent comparisons between BIM models by ensuring each model covers a specified scope. There are multiple LOD's and by applying the framework at each of these, insight can be gained into the design cost over time as it is refined. To achieve the aim of the study, the tool was employed on five separate structures: two blockwork medium-rise buildings and three reinforced concrete high-rise buildings. Results indicate that similar structure types have similar design cost curves when data was standardised. By employing the process over further studies, the empirical curves will be refined with greater certainty, allowing for eventual use as benchmarks to assess economic performance of design solutions.

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Keywords: building information model; building; cost estimation; design stage; level of development

1. Introduction

Despite being the largest sector in Australia, the Architectural, Engineering and Construction (AEC) industry has historically and persistently low levels of productivity. One of the recent advances within the AEC industry is the

* Corresponding author. Tel.:+617-5552-7357
E-mail address: k.panuwatwanich@griffith.edu.au

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development of Building Information Modelling (BIM), touted as an IT-induced paradigm shift for the sector. According to Succar [1], BIM represents a methodology to manage building design and project data in a digital format throughout the buildings' life-cycle. BIM is generally applied with the notion of decreased project costs, increased productivity and quality, and reduced project delivery time [2]. These expectations of BIM provide grounding for the need to conduct research into how this may economically benefit structural design.

BIM provides a mechanism to assess structural designs in terms of economics by utilising the latest, most up-to-date project information from all participants. By extracting relevant information from a model, this can be summarised in a form comprehensible by all industry across the board. Linking this with cost information can provide for a design cost estimate. It is possible to track the design cost as the structural solution is refined, and by doing so in many cases, provides a benchmark for design. Unfortunately BIM alone suffers from a lack of clarity in communicating structure definition for the correct uses as intended by the model author. The Level of Development (LOD) concept developed by the American Institute of Architects (AIA) addresses this issue with sufficient scope to allow for BIM to be used to track design cost estimation throughout all design stages. Since LOD is stringently defined in terms of what content is modelled at each stage, comparisons can be made between different structures. By standardising this information, design cost curves can be derived for different structure types. It is intended that these, with further development, will be able to act as benchmark curves to allow project management to assess the economic performance of a design compared to a typical structure of similar construction.

2. Theoretical Background

2.1. BIM in structural design

BIM promises to synchronise the design process, especially as a result of interoperability. Linking BIM with structural analysis software allows for a workflow based on concurrent structural documentation, design and analysis, using Electronic Data Interchange (EDI) [3]. For example a structural designer may create a physical model based on existing architectural plans, or model, and apply material definitions. The physical model is essentially a model and view of the structure exactly as it is to be built. The analytical model is automatically generated from the physical model to include all the necessary parameters for analysis such as support conditions, member end releases, offsets, section and material properties, as well as loads and load combinations. Load cases are then applied and the entire analytical model is sent to a structural analysis package. An engineer then updates the analytical model as required, which in doing so updates the physical model and alerts the designer. Code checking criteria are also available inside the mainstream commercial BIM authoring tools (e.g. Autodesk Revit) for most major world standards. Since code checks and documentation use the physical structural model, in traditional workflow the drafter must wait for the structural engineer to complete the analytical model analysis before proceeding. BIM automates this process, providing for a smoother workflow. Upon completion of analysis, design documentation is then updated to reflect the latest design, a process which is repeated for every iteration of the design process in a traditional workflow. This process fragmentation in terms of design documentation and structural analysis information is addressed by BIM which helps make the process smoother through automatic coordination.

2.2. Material quantity takeoff using BIM

BIM-based quantity takeoff for cost analysis is only worthwhile when used in conjunction with rigorous, up-to-date and location specific, material cost information. This information was used by Akbarnezhad et al. [4] to calculate a design cost by extracting quantities from the BIM database and multiplying by the defined unit price. Provisions for construction, demolition, assembly, disassembly, transportation and the like were estimated automatically from the size of work required multiplied by respective unit cost factors. A similar study was put forward by Fu et al. [5] who developed an IFC based life-cycle costing tool to evaluate design options. Due to automation, BIM offers great advantages over traditional cost estimating procedures, while exerting significantly less effort [6]. Nonetheless, literature on BIM-based material quantity takeoff is scarce, most likely due to