Available online at www.sciencedirect.com
ScienceDirect
International Journal of Project Management xx (2016) xxx–xxx
International Journal of Project Management
www.elsevier.com/locate/ijproman

Analysis of interacting uncertainties in on-site and off-site activities: Implications for hybrid construction

Mehrdad Arashpour [a,*], Ron Wakefield [a,1], E.W.M. Lee [b,2], Ricky Chan [c,3], M. Reza Hosseini [d,4]

[a] School of Property, Construction and Project Management, RMIT University, 360 Swanston St, Melbourne, VIC 3000, Australia
[b] Department of Architecture and Civil Engineering, City University of Hong Kong, Kowloon, Hong Kong
[c] School of Civil, Environmental and Chemical Engineering, RMIT University, 360 Swanston St, Melbourne, VIC 3000, Australia
[d] School of Architecture and Built Environment, Deakin University, Deakin University, Geelong, VIC, Australia

Received 23 June 2015; received in revised form 20 January 2016; accepted 1 February 2016
Available online xxxx

Abstract

Interaction and integration of uncertainties in on-site and off-site project activities often result in the risk of delays and schedule overruns in hybrid construction projects. To address this problem, a holistic risk analysis approach that assesses the integrating impact of uncertainties on completion times is proposed. The results of the analysis show that growth in project size and work quantities intensifies pair and group interconnection of tasks within and between groups of on-site and off-site activities, resulting in lengthened completion times and deviations from project plans. Unavailability of resources, risk seeking attitudes, and workflow variability are other major contributors to the risk of late completion in hybrid construction. While project managers often analyze on-site and off-site uncertainties separately, practical implications of the research results suggest adoption of a holistic approach in which risk management practices in the two environments are integrated. This approach significantly improves tangible performance measures in projects.

Keywords: Decision making; Delay; Discrete event simulation; Integration; Performance measures; Prefabricated building elements; Project management; Resource availability; Workflow variance

1. Introduction

The effect of uncertainty is significant in hybrid construction projects where a combination of on-site and off-site activities is concurrently in progress (Blismas et al., 2010, Boyd et al., 2013). In hybrid construction projects, some structural elements such as foundations/footings and main columns are site-built. The remaining building components are prefabricated in the controlled environment of a factory and are shipped to the worksite for installation. This working arrangement in hybrid construction imposes risks, defined as the effect of uncertainty on project objectives (ISO31000, 2009). On-site project activities are often undertaken under uncertainty in weather conditions, quality of work, and safety (Loosemore and Andonakis, 2007). Similarly, there is uncertainty in off-site construction in availability of resources, compliance of the manufactured elements with on-site requirements, and equipment failure (Polat et al., 2006).

The interactions of above uncertainties in on-site and off-site construction result in risk of delays and lengthened completion times (Porwal et al., 2012, Lu and Yan, 2013). As an example, despite the fact that many on-site house building operations such as framing and building roof trusses have been shortened

* Corresponding author. Tel.: +613 99253513; fax: +613 99251939.
E-mail addresses: Mehrdad.arashpour@rmit.edu.au (M. Arashpour), ron.wakefield@rmit.edu.au (R. Wakefield), ericlee@cityu.edu.hk (E.W.M. Lee), ricky.chan@rmit.edu.au (R. Chan), reza.hosseini@deakin.edu.au (M.R. Hosseini).
[1] Tel.: +613 99253448.
[2] Tel.: +852 3442 2307.
[3] Tel.: +613 99259975.
[4] Tel.: +613 52272333.

http://dx.doi.org/10.1016/j.ijproman.2016.02.004
0263-7863/00

by using off-site manufactured elements, the average house completion time in Australia has not decreased. Fig. 1 illustrates the increasing trend in house completion times for an average Australian suburban house in different states (Australian Bureau of Statistics, 2015).

Although the literature supports combined benefits of on-site and off-site construction in hybrid projects (Zika-Viktorsson et al., 2006, Yung and Yip, 2010; Meiling et al., 2012), combination and interaction of uncertainties in hybrid construction and implications for project planning remain overlooked areas of research (Jaillon and Poon, 2009).

In order to understand effects of uncertainty interactions in hybrid construction projects, this paper focuses on off-site and on-site construction activities. In particular, this study analyzes the effects of combined risks on project completion times. The paper consists of an extensive review of project risk analysis in the construction context and development of four propositions based on empirical research.

2. Research background

Growing complexity of projects has exposed them to interacting uncertainties that cannot be efficiently addressed by existing management methods (Fang et al., 2012, Gagarina et al., 2015, Marle, 2015). The interaction and integration of uncertainties in off and on-site construction result in risk of deviations from plans and late completion of hybrid projects (Krane et al., 2012). Effective modeling of interacting uncertainties needs to reflect the propagation behavior in the project risk network (Marle, 2012; Fang and Marle, 2015). As an example in hybrid construction projects, a structured process to analyze complex interactions between off-site and on-site project risks can significantly improve the performance of the classical methods of risk analysis (Zhang et al., 2014b).

2.1. Risk analysis in construction projects

The high failure rate of construction projects is a result of underestimating the extent of uncertainty and risk (Hwang et al., 2014). Construction projects are often considered risky as they are one-off enterprises with numerous stakeholders, entailing substantial interactions between internal and external environments (Zwikael et al., 2006, Mu et al., 2014). The reputation of construction industry in terms of risk analysis is not as good as other sectors such as insurance or finance. This stems from the traditional risk perception in the construction industry as an estimation variance rather than a major project attribute (Lehtiranta, 2014). Gradually, however, there has been a paradigm shift in construction towards systematic and more sophisticated risk management practices.

In terms of tools and techniques, additional dimensions have been added to the traditional probability–impact (P–I) model of risk analysis. These dimensions include but are not limited to the risk exposure extent (Jannadi and Almishari, 2003), risk manageability level (Aven et al., 2007, Chan et al., 2015), influence of the surrounding environment and interdependencies among risks (Zeng et al., 2007), and risk significance (Han, Kim et al., 2008). These added dimensions aim to improve the traditional P–I model to better analyze the interacting risks in increasingly complicated construction projects.

As can be seen in Fig. 2, risk modeling and analysis with all above mentioned improvements have been used to assess different risk problems in construction project management. The bidding price estimation for projects is a widely investigated risk-related problem in the construction literature (Paek et al., 1993, East et al., 2009, Abdul-Rahman et al., 2012). Furthermore, risk of cost and schedule overrun has been modeled and analyzed using a range of tools and techniques (Love et al., 2013, Shehu et al., 2014, Williams and Gong, 2014). Project risks have been quantitatively analyzed using monetary equivalents in order to

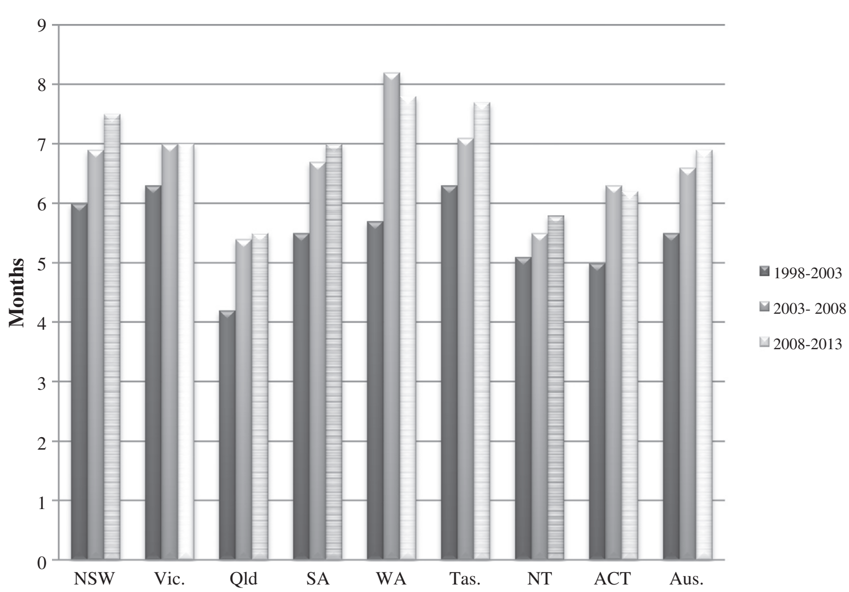

Fig. 1. House completion times in Australian states.

Please cite this article as: M. Arashpour, et al., 2016. Analysis of interacting uncertainties in on-site and off-site activities: Implications for hybrid construction, Int. J. Proj. Manag. http://dx.doi.org/10.1016/j.ijproman.2016.02.004