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Effects of organizational complexity and resources on construction site risk

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ABSTRACT

Introduction: Our research is aimed at studying the relationship between risk level and organizational complexity and resources on constructions sites. Our general hypothesis is that site complexity increases risk, whereas more resources of the structure decrease risk. A Structural Equation Model (SEM) approach was adopted to validate our theoretical model. *Method:* To develop our study, 957 building sites in Spain were visited and assessed in 2003–2009. All needed data were obtained using a specific tool developed by the authors to assess site risk, structure and resources (Construction Sites Risk Assessment Tool, or CONSRAT). This tool operationalizes the variables to fit our model, specifically, via a site risk index (SRI) and 10 organizational variables. Our random sample is composed largely of small building sites with general high levels of risk, moderate complexity, and low resources on site. *Results:* The model obtained adequate fit, and results showed empirical evidence that the factors of complexity and resources can be considered predictors of site risk level. Consequently, these results can help companies, managers of construction and regulators to identify which organizational aspects should be improved to prevent risks on sites and consequently accidents.

1. Introduction

Originally, most Health and Safety (H&S) research on construction began by highlighting the problem of accident rates and the special nature of construction (Baxendale & Jones, 2000; Cheng, Leu, Lin, & Fan, 2010; Mahmoudi, Ghasemi, Mohammadfam, & Soleimani, 2014; Wu, Liu, Zhang, Skibniewski, & Wang, 2015). At the same time, it appears that something intrinsic in the construction sector produces these risks. Currently, risk level assessment research has evolved from an accident-based approach towards a more prospective and holistic one, characterized by technical analysis together with organization and human factors (Sgourou, Katsakiori, Goutsos, & Manatakis, 2010). Despite this tendency, most current studies remain based on accidents (Hollnagel, 2008; Khanzode, Maiti, & Ray, 2012). However, in a small number of studies, authors use precursor analysis as an alternative to the classical accident approach. These authors criticize reactive research techniques that use lagging indicators, and they propose different leading indicators (predictors) to obtain information before an accident occurs (Grabowski, Ayyalasomayajula, Merrick, & McCafferty, 2007; Hinze, Thurman, & Wehle, 2013; Rozenfeld, Sacks, Rosenfeld, & Baum, 2010; Sparer & Dennerlein, 2013; Toellner, 2001). In this study, we try to link organization variables with risk to propose them as another set of predictors of risk.

Organizational factors have arisen as a relevant issue for site risk research. Since Hoewijk (1988) proposed that the vertexes of the "Organization Triangle" formed by structure, culture and processes are mutually dependent and conform workers behaviour, other models and metaphors have been used to represent the accident process (Swuste, Frijters, & Guldenmund, 2012; Swuste, van Gulijk, & Zwaard, 2010) and analyse this organizational side of the problem of safety. One important approach is the Bowtie metaphor (Visser, 1998), which identifies preventive measures before the loss of control of the accident process, and mitigating measures, which can reduce injury and damage (Hale et al., 2004). This metaphor clarifies the important relationship between management and the scenarios in which hazards become in risks. Management identifies risks, selects barriers and determines their effectiveness (Swuste et al., 2012). This metaphor is the basis for developing the Workgroup Occupational Risk Model (WORM), which is based on accident scenarios to cover the full range of occupational accidents (Hale et al., 2007). For each accident scenario, the items selected for accident modelling with the "Storybuilder" (the tool to classify and analyse accidents) included among others the management failures in terms of failed control or resources (Baksteen, Mud, & Bellamy, 2007;

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Bellamy, Geyer, & Wilkinson, 2008; Bellamy, Mud, Manuel, & Oh, 2013). Using this approach for construction companies is complex because of the particular features of the sector such as, the temporary nature of sites, their physical distance from company headquarters, the low level of standardization of processes, and so on (Wilson, 1989). Moreover, the sector is also characterized by the special conditions of agent structures, business processes, and operational levels (Donaghy, 2009; Health and safety Executive, 2009). For Swuste et al. (2012), construction companies are similar to an organic structure that manifests itself in its processes. Although process can determine the organizational structure on site, the means of the head company determine sufficient site resources.

There is a certain consensus about the relationship between organizational factors and risk conditions. In fact, a selection of nonspecific construction risk condition assessment methods was analysed by Sgourou et al. (2010), and all of them include organizational features. However, few field studies, specifically on construction sites, have connected and clarified these relationships (Fang, Huang, and Hinze, 2004; Fang, Xie, et al., 2004; Mohamed, 1999; Swuste, Theunissen, Schmitz, Reniers, & Blokland, 2016; Teo & Ling, 2006; Wu et al., 2015), and even fewer have linked organizational and complexity with risk levels assessed on site (Fang, Huang, and Hinze, 2004). Q17

The normative is to use other important dimensions to analyse the relationship between H&S and firms' organization structures. H&S Laws have been incorporated in Europe since the 1990s through European Directives. These directives establish a new framework for all agents intervening in processes (Ros Serrano et al., 2013) that might generate an adaptation within a company's structure, principally for H&S human resources and the functions of contractors and subcontractors, to comply with requirements of the new preventive model. However, most companies only complied with formal aspects of the H&S Law in terms of fulfilment of required documentation. “Safety has become too bureaucratic. With the slogan ‘manage the risk, not the paper work’, Health and Safety Executive (HSE) calls for a return to the controlling of hazards and risks at construction sites …” (Swuste et al., 2012, p. 5). Q18

The remainder of the paper is structured as follows. First, we provide a literature review to build a theoretical framework to analyse the relationships among organizational aspects and risk on sites. Next, we build our theoretical model and state our specific set of hypotheses. Third, we detail the methods and materials we have used to conduct our empirical analysis. Subsequently, we report our empirical results. Finally, we end the paper with a discussion of our findings, their implications and conclusions.

2. Literature review on risk and organizational issues on construction sites

Most studies try to find connections between different aspects of safety performance (SP), safety management systems and wider organizational issues (Bellamy, 2009; Bellamy et al., 2008; Jørgensen, 2016; Niskanen, Louhelainen, & Hirvonen, 2016; Wang, Ding, Love, & Edwards, 2016). On the one hand, SP is a concept under investigation that very few empirical studies have analysed (Wu et al., 2015). According to Ghasemi, Mohammadfam, Soltanian, Mahmoudi, and Zarei (2015) SP has two aspects: risk conditions (e.g., working conditions, protections, procedures, and rules) and safety participation (e.g., motivations, safety meetings participation). On the other hand, safety management systems are a broader organizational concept that includes among others practices, policy, and meetings. Q19

Table 1 presents a summary of the literature review. Each study is described depending upon the index that the authors have created.

As seen in Table 1, SP and safety management includes several elements, depending upon an author's definition. Each study focusses on one set of issues related to these terms, e.g., Törner and Pousette (2009) noted that any study of safety management must develop a set of organizational measurements as reported in Table 1. Manu et al. (2010) defined Construction Project Features (CPFs), such as the elements that linked to accident causation. These authors wrote,

> “*These CPFs are organisational, operational, and physical attributes that characterise construction projects, and they emanate from the client's brief, project management decisions and design decisions. Like other distal/originating influences in construction accidents, the above-mentioned CPFs are high level determinates of the nature, extent and existence of immediate causes of accidents…*” (p. 688).

Despite the important connection between SP and safety management recognized in the literature, we observe a lack of empirical evidence on the relationships between these issues (Knegtering & Pasman, 2009; Körvers & Sonnemans, 2008; Swuste et al., 2016), and the different content of both them. Due to the lack of a common and narrow definition of the concept of SP, we have focused on the assessment of site risk. In relation to safety management, and considering our model of risk site assessment, we focus only on the organizational structure and resources of safety management.

Based on studies reported in Table 1, we propose in Table 2 the following factors of on-site complexity and resources.

3. Theoretical model and hypotheses

3.1. Model

Based on technical knowledge and evidence found in the literature, we propose to assess to what extent the risk on sites can be explained based on the levels of two organizational factors, complexity and resources. Our proposal is that risk on site, in addition to the classical definition of the combination of probability of exposure to the hazards and their consequences, can be explained in part as a function of both factors as reflected in expression (1):

$$\text{Risk} = f(\text{complexity}; \text{resources}; \varepsilon) \quad (1)$$

where ε contains all other factors affecting risk on site.

Our model connecting risk with organizational factors and its empirical testing are among the major contributions of our research. Table 2 shows the factor classification used in the literature review. This general classification of factors has been also confirmed by an expert panel, as we will report below in Section 4.3. We have excluded from our analyses those factors that, although considered in the literature, did not apply to our sample or research purpose or that were explicitly excluded after consulting an expert panel. The specific names of each factor and variable are only illustrative of their content according to the literature we have reviewed; we are not proposing here an accurate definition or measurement of each concept.

3.2. Hypotheses

In the following, we connect the main important elements from the literature review that are used to build the factors and the corresponding hypotheses.

3.2.1. *Hypothesis 1* on site complexity (F1) Q20 Q21

Complexity of site is an important factor affecting risk conditions. This complexity is measured by examining type of project (considering repair, maintenance, and extension projects) (Hon et al., 2010), high risk typologies (Hatipkarasulu, 2010), other project elements (type of work, site restrictions, design complexity, and the level of construction) (Manu et al., 2010), and finally, the project nature (size of site and complexity of construction) (Fang, Huang, and Hinze, 2004; Fang, Xie, et al., 2004). Some of them increase fatal accidents such as falls from height, which represented 50% of fatal accidents from 1996–1997 to 2007–2008 according to Health and Safety Executive (2009).

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