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A new approach to predict safety outcomes in the construction industry

Nariman Ghodrati[a,*], Tak Wing Yiu[a], Suzanne Wilkinson[a], Mehdi Shahbazpour[b]

[a] Department of Civil and Environmental Engineering, The University of Auckland, New Zealand
[b] Fletcher Building Ltd, New Zealand

ABSTRACT

Strategic plans play a crucial role in improving occupational health and safety (OHS) in the construction industry. The ability to predict and understand the future changes related to safety outcomes in the industry will assist the authorities and help them to design proactive strategic plans that effectively reduce and prevent accidents and occupational injuries. This study aims to construct the models to predict the safety outcome in the industry. The number of companies in liable earning classifications was used to predict the safety outcome at a macro level in the construction industry. Liable earning is defined as total gross earnings paid to employees. The study utilised data from the Accident Compensation Corporation (ACC) Canterbury rebuild database in New Zealand. The results show that in all the constructed models the number of companies in liable earning classifications is a predictor of the safety outcome including the number of claims (R^2 = 0.97) and the number of entitlement claims (R^2 = 0.76).

1. Introduction

Despite a significant improvement in Occupational Health and Safety (OHS), the construction industry still remains a high risk industry with a high rate of injury and fatality worldwide (Awwad et al., 2016; El-Sayegh, 2008; Hatami et al., 2017; Li et al., 2015; Yu et al., 2002). In 2014, over 73,000 non-fatal injuries were reported in the U.S. construction industry (Department of Labor, 2014a, 2014b). At the same time, the industry was responsible for more than 20.5% of overall worker fatalities in private industry in the United States (Department of Labor, 2014a, 2014b). Fall, electrocution, struck by objects and caught in-between were the leading causes of worker deaths on construction sites. In New Zealand, over 12% of non-fatal injuries (155,566 injuries) have occurred in the construction industry between 2003 and 2008, while only 7.8% of employees worked in the construction industry during that period (Work Safe New Zealand, 2016). The high rate of injury and fatality in the industry not only affects construction companies and their employees, it also has an adverse influence on society and on the national economy. Therefore, it is important to have a national strategic plan to improve OHS and to reduce injury and fatality in the construction industry (Department of Labour, 2011). According to SchulTz (2012), if occupational injuries can be predicted, it will lead to the reduction and prevention of accidents and injuries. The ability to predict safety outcomes such as number of occupational injuries plays a crucial role in designing a realistic and effective strategic plan for improving overall OHS in the construction industry.

An extensive literature review indicated the importance of predictive models in the construction health and safety domain (Esmaeili et al., 2015). Current predictive models in the construction literature have attempted to predict safety outcomes at the organisational level (Fang et al., 2006; Rozenfeld et al., 2010). To predict the safety outcome at the organisational level, the models have used different variables, such as, the safety climate and its components (Glendon & Litherland, 2001), the safety risk of trades or tasks (Esmaeili & Hallowell, 2013) or the number of employees in the company (Lin & Mills, 2001). Although the current models provide valuable information in terms of safety outcomes at the organisational level, they are not effective in a national context and for the purpose of strategic planning (macro level). This will be discussed in the next section of the paper.

To address this knowledge gap, this study attempts to model the safety outcome of the industry at the macro level. A subjective self-reporting approach in regard to data collection must be avoided to enhance the reliability of the model and reduce the impact of personal judgment on the final result. The model must be constructed based on the empirical data and organisation-specifications that can be measured accurately. The findings of this study will assist the authorities and decision makers in the industry to apply a pro-active approach in terms of their strategic planning. The strategic safety plans that are produced are based on both predictive and trend analyses that are more effective and realistic than those that only rely on traditional trend analyses approaches.

* Corresponding author at: Faculty of Engineering, Department of Civil and Environmental Engineering, The University of Auckland, Private Bag 92019, Auckland 1142, New Zealand.
E-mail address: ngho228@aucklanduni.ac.nz (N. Ghodrati).

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1.1. Predictive models

Different studies have used different predictors to predict project safety outcomes. The safety climate as one of these predictors has been utilised widely to predict safety outcomes in construction organisations (Glendon & Litherland, 2001; Johnson, 2007; Zohar, 1980). These studies have tried to justify the relationship between safety outcomes and safety climate by empirical evidence. Tam and Fung IV (1998) used safety management strategies to predict safety outcomes. They found safety training, post-accident investigation, safety awards and the portion of subcontracting as predictors of safety outcomes. Gillen et al. (2002) found evidence to support the relationship between severity of injuries and workers' perception of safety climate, co-worker support, decision latitude and psychological job demands. Despite the effectiveness of these models, they have the following limitations: (1) the models investigate and focus on safe work behaviours and so ignore other aspects such as environmental risks and hazards and organisational specifications; (2) subjective self-reporting method has been used for the purpose of data collection, so collected data is not free from personal bias (Donchev & Ujhelyi, 2014); (3) the information regarding safety climate and behavioural aspects that are important to construct the model is not available in early stage of projects, and (4) these models are effective at the organisational level (micro level) yet cannot be applied at the macro level that comprises several construction companies with different safety management strategies and safety climates.

To integrate predictive models in the pre-construction stage, some scholars have suggested using the safety risks of trades or tasks as a predictor of safety outcomes (Esmaeili & Hallowell, 2013). The main limitation of this approach is that, identifying all trades and tasks and their associated risks is impractical especially in large scale and sophisticated projects. The attribute-risk identification method was introduced to address this limitation (Esmaeili, 2012; Esmaeili et al., 2015). The attributes are related to the environmental specifications and physical condition of a jobsite. In this method, the risk in terms of worker injury is related to the identifiable task attribute (Esmaeili et al., 2015). Although this method is effective to predict safety outcomes at a jobsite, it has limitations in regard to large scale projects. For instance, this method cannot be applied to predict safety outcomes at the macro level with numerous environmental specifications and physical conditions since identifying all of the task attributes is impossible at such a scale and level of complexity.

Several studies in construction and other industries have identified the number of employees as a major contributor to organisation safety outcomes (Masi & Cagno, 2015; Sørensen et al., 2007; Targoutzidis et al., 2014). This organisation-specification has a significant impact on the overall operation risk level. A study in Italy between 1995 and 2000 revealed that, companies with a lower number of employees recorded an injury frequency that is higher by 47% compared to companies with over 250 employees in all sectors (Fabiano et al., 2004). Fullarton and Stokes (2007) argued that the number of employees is more accurate than safety climate indicators for the prediction of occupational injuries. In the construction sector, companies with fewer than 25 employees have experienced high accident and injury rates (Camino López et al., 2008; Hinze & Gambatese, 2003; Jeong, 1998; Shalini, 2009). A poor safety record in small construction companies is mainly ascribed to applied technologies, job design, training, limited investment in health and safety, less ability to implement health and safety in work places, unskilled employees, lack of training, wage level and inadequate management skills (Chi et al., 2004; Haslam et al., 2005; Tam et al., 2004).

Lack of economic resources has been widely cited as a clear contributor to organisational safety outcomes. According to Masi and Cagno (2015), perceived barriers to OHS negatively correlated with the availability of economic resources in organisations. The more investment in OHS, the more hindrances will be eliminated and so organisational safety performances can be improved (Hinze & Raboud, 1988; Lin & Mills, 2001). According to Cameron et al. (2008), construction companies with a minimum investment of 0.1% of their turnover on safety have a lower accident frequency rate. To achieve the best safety performance, The OHS investment should cover a wide spectrum of OHS related actions such as investment in competent practitioners, high quality of training, obtaining an OHS professional body at management or organisational level, and using external consultants (Cameron et al., 2008). Companies with limited economic resources adopt cost reduction practices in OHS or execute minimum legal requirements that lead to poor safety outcomes (Hinze & Gambatese, 2003; Tam et al., 2004). Intense competition in the construction industry obstructs organisations with limited economic resources to apply all required safety measurements and pushes the companies to make up the savings on the health and safety related activities (Cheng et al., 2010). With limited economic resources and tight budgets, it is common for construction companies to cut the budget and allocate the safety budget and resources to other undertakings as they believe OHS does not add value to production processes (Lin & Mills, 2001).

1.2. Construction industry in New Zealand

Construction is one of the most dangerous industries in New Zealand. It has made the second largest contribution to work related fatalities since 2011 (Work Safe New Zealand, 2016). The Department of Labour launched a strategic action plan in 2010 to improve OHS by 2015. The plan is based on the historical data between 2002 and 2008. Therefore, the recommendations are re-active rather than pro-active as a predictive analysis was not utilised. According to SchulTz (2012), predictive approaches are more effective than utilising historical data (traditional trend analyses) in developing safety plans. The lack of the predictive approach makes the plan less flexible to possible changes and so, it reduces the chance of success in preventing accidents and injuries. As discussed, most of the predictive models in the construction domains have been designed to predict safety outcomes at a micro level rather than at the macro level. It was expected that the number of employees can be used to predict the safety outcome of the industry. The data regarding number of employees has been collected and published by Statistics New Zealand in a yearly manner since 2000. So, the amount of data is not sufficient to construct the model. This study will identify a new way to predict the safety outcomes of the construction industry. In the process of understanding the possible changes in terms of the future safety outcomes of the industry, authorities and experts will be able to design more effective and pro-active strategic plans to enhance OHS and prevent and mitigate accidents and occupational injuries.

2. Method

2.1. Canterbury rebuild

On 22 February 2011, a magnitude 6.3 earthquake struck Canterbury region in New Zealand's South Island which injured several thousand people and resulted in the deaths of 185 people. The earthquake caused destructive damage in Christchurch particularly in the Central Business District (CBD) and eastern suburbs. The destruction level was exacerbated by the infrastructure and buildings that were weakened by the 4 September 2010 earthquake. Over 150,000 homes were damaged from the earthquake (Parker & Steenkamp, 2012). In addition, several areas that have been identified as "not fit for building" required the relocation of over 7500 residential buildings. The Canterbury rebuild is the biggest project of its kind in New Zealand. According to the Canterbury Earthquake Recovery Authority's (CERA), the cost of the rebuild, repair and improvements will be up to NZD 30 billion (Parker & Steenkamp, 2012). It is expected that the cost of health and safety could be more than NZD 80 million and over