



Activity based risk assessment and safety cost estimation for residential building construction projects



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ABSTRACT

Fatal construction accidents are major problem in Turkish construction industry. Although new comprehensive legislation has been inured recently; level of consciousness in the industry is unsatisfactory and safety is perceived as an extra cost. Small or middle scaled residential projects have a big share in the industry and majority of the fatal accidents usually occur on such work sites. Focus of this study is small and middle-scaled residential construction sites. Drawings, technical specifications, bill of quantities of 25 concrete residential buildings with total areas that vary between 230 and 118,200 m² in Istanbul were examined. Site visits and information gathering were performed from site engineers. This study aims to give an approach for safety cost estimation for the early stages of construction bidding phase using risk assessment activities and construction project scheduling by focusing on construction activities. Additionally, a cost analysis was performed and the results were compared and analyzed with a former project that focused on 30 concrete residential projects in Istanbul. Primavera P6 was utilized for scheduling, and risk assessment was conducted using the techniques applicable for construction projects (i.e., L matrix and Fine-Kinney). Finally, activity-based techniques were used for cost estimation. The results of this study reveal that the percentage of safety cost to the total construction cost is 1.92%. Also, to comply with the current legislation and minimize risks; 0.85 USD per man-hour should be spent according to 2013 rates and safety cost per unit area was found as approximately 5.68 USD.

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1. Introduction

In recent years, not only in Turkey, but also all around the world, safety in the construction industry has become a matter of grave concern to government bodies and private enterprises. When safety assessments are required in construction sites, there is often insufficient data or imprecise information available (Gurcanli and Mungen, 2009). Additionally, different companies tend to have different scales in various safety management systems because of resource limitations (Tam et al., 2002). Thus, the construction industry has a higher fatal accident rate than other industries (Waehrer et al., 2007).

The Turkish construction industry has had double-digit growth and success in recent years. Most of this growth has come since 2011 from projects of the Housing Development Administration of Turkey (TOKI). After a small increase in 2012, the industry experienced 11.5% growth in terms of GNP in 2013 and its share in total employment reached 7.4%, the highest number in the last 20 years (TUİK, 2013). As these figures show, the construction industry is

playing a significant role in the economic development of Turkey. However, the industry also has a reputation of being one of the most dangerous domestic industries. Compared with other industries, construction accidents are frequent with a diverse set of small-scale hazard sources.

Current legislation on occupational safety in Turkey provides for regulation and enforcement of employers to implement safety measures as well as safety management systems. However, the level of consciousness in the industry is unsatisfactory and safety is perceived as an extra cost and unnecessary expenditure. More specifically, in order to stay economically competitive, sustainable and to reach maximum profits, many contractors only execute basic safety measures and eliminate many important hazard prevention-training programs during construction project implementation (Cheng et al., 2010a).

This paper provides the results of a project conducted by the authors, which was supported by The Scientific and Technological Research Council of Turkey (Project Number 112M033). The aim was to combine construction project scheduling, risk assessment activities and construction cost estimation to value safety costs and its distribution throughout a project. In this way, this research provides a better understanding of safety costs

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during a building construction project. Therefore, this approach helps in efforts to reduce loss of workers' life and mitigation of the safety costs arising from severe injuries, fatalities, administrative procedures, legal obligations and litigation costs and expenses.

2. Literature

Cost estimation models are useful in the preliminary design stage of a construction project if they are able to estimate construction costs with minimum project information in the early stages (Kim et al., 2004). Such estimates allow owners and planners to evaluate project feasibility and effectively control costs in detailed project design work. However, contractors do not have any standard for cost estimation in the European Union (EU) or in other countries. Several sources mention various cost estimating implementations (Akarca, 1992; Akintoye, 2000; Arpacı, 1995; Cook, 1982; Cox, 1987; Curran, 1989; Ciracı et al., 1996; Feng et al., 2015; PMBOK, 2008; Polat, 2004; Seyyar, 2000; Usta, 1994). Some of these cost estimation methods include: Unit Method, Superficial Method, Approximate Quantities Method, Artificial Neural Networks, Fuzzy Logic, Genetic Algorithms, Regression Analysis, etc. Since the accuracy of construction cost estimates (as well as contingency for contractors) is a critical factor in the success of the project, many cost estimation models that adopt parametric methods have been developed. Approaches to cost estimation based on statistics (Singh, 1990; Wilson, 2005) and linear regression analysis (Kouskoulas and Koehn, 1974) were developed in the 1970s. During the late 1980s a new approach to cost estimation was introduced based on user experience and increased research into the potential of artificial intelligence, such as with expert systems (Kim et al., 2004).

The literature on construction project cost estimation includes research on the costs of accidents. Costs of accidents have been a focus point for safety experts and academicians in the field of occupational safety. There are numerous studies that analyze the cost of lost working days, insurance, delay in project duration, etc. In a study undertaken by the Health and Safety Executive (of England), it was shown that indirect costs could be 36 times greater than the direct costs of an accident. In other words, the direct costs of an accident or disease represent the tip of the iceberg when compared to overall costs (Cheng et al., 2010b). Panopoulos (2003) sought optimum safety cost by estimation of prevention cost, average accident cost and management failure with-no-accident cost and determined whether or not safety pays for a project. Everett and Frank (1996) reexamined the total cost of accidents and injuries in the construction industry making necessary assumptions, method changes and updating inputs. Feng et al. (2015) calculated average direct accident costs, indirect accident costs and total accidents costs of building projects in Singapore using bivariate correlation analysis and moderated regression analysis.

According to Cooper and Kaplan (1992), Activity-Based Costing (ABC) has emerged as a new approach that associates costs directly related to business activities with manufactured products. ABC gives more accurate information especially in complex structures and allows one to obtain information on cost items that are ignored in traditional methods (Rzvi and Elnathan, 1999). Furthermore, this method is flexible for all kinds of technology-intensive business systems and can be used successfully in developing countries (Alkan, 2005; Liu and Pan, 2007). ABC provides detailed information about the cost of activities in a particular process and helps decision-makers to develop reasonable decisions (Khataie et al., 2011). According to the Ríos-Manríquez et al. (2014) ABC implementation gives firms a chance to compare their profitability, productivity and cost control

with other firms. The other objectives of this system are providing cost reduction and management; determination of profitability of customers, inventory valuation, and new product and service design.

However, studies about the cost of safety measures as a part of project costs during a construction project are very rare. Tan (1999) compared the cost of safety measures during a project and costs of accidents in Turkey. Aminbakhsh et al. (2013) investigated the safety risk assessment during planning and budgeting of construction projects using an analytic hierarchy process (AHP). Chalos (1992) introduced a cost of safety model to conceptually describe the cost-benefit analysis of accident/injury prevention. Tappura et al. (2015) discussed management accounting for safety-related decision-making and valuing human life in a cost-benefit analysis. Alonso et al. (2013) studied the impact of health and safety on the investment of construction companies by applying a questionnaire in southern Spain. Sousa et al. (2014) presented an Occupational Safety and Health Potential Risk Model for estimation of the statistical costs of occupational safety and health risk. As health and safety costs are not calculated during the bidding period, the parties do not want to waste money for safety expenses or reduce their contract profits.

The objective of this paper is to offer an approach for safety cost estimation in the early stage of the construction bidding phase using construction project scheduling data, and risk assessment techniques applicable for construction projects, such as the L matrix and Fine-Kinney methods (Hughes and Ferrett, 2005; Kinney and Wiruth, 1976; Rausand, 2011) and ABC method. Using an activity-based risk assessment and activity-based cost estimation analysis would be consistent since the safety risks of every activity are analyzed and costs of these risks are investigated in this study. Furthermore, consideration of safety costs as part of project costs and calculation of safety cost using both activity-based risk assessment methods and ABC analysis will offer a new approach for determination of safety expenses in the construction industry. The approach provides a very practical way to estimate the share of safety costs in total project costs for building projects. Hence, by implementation of the approach suggested, contractors can readily prepare and implement their safety management plan while controlling costs and improving project management, and most importantly save human life and protect their workers on site.

3. Methodology

This section provides details on specific topics related with the proposed approach and methodology. Fig. 1 shows a graphical representation of the methodology.

3.1. Data collection

This paper attempts to estimate safety costs and its distribution throughout a project before construction starts. For this purpose, firstly drawings, technical specifications, bill of quantities of 25 concrete residential buildings in the region of Istanbul province were collected, construction sites were visited and information gathered from the site engineers about safety practices on site with the financial support of The Scientific and Technological Research Council of Turkey (TUBITAK). In total, the 25 concrete residential building projects vary between 230 and 118,200 m² in area. Since the costs of construction projects vary due to regional characteristics (different labor wages, different tax policies of the municipalities, variable transportation, material cost and additional cost due to site facilities), the study only focused on the projects in Istanbul province.

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