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Estimating OHS costs of building construction projects based on mathematical methods

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ABSTRACT

In the recent years, occupational health and safety (OHS) has become a popular topic in many sectors and holds its ground on the agenda with legal regulations. Given that work accidents occur at a higher rate in the construction industry compared to other sectors, this reality increases the importance of the topic of determining OHS costs in the construction sector. After all, it is notable that the estimation of OHS costs at the project stage is assessed as a situation that requires a great effort from the contractors' standpoint. The aim of this study is to determine the variation in health and safety costs using mathematical methods based on the size of construction areas in construction projects. Moreover, the reflection of considering or ignoring OHS to the level of occurrence of work accidents is determined. In the first stage of the study, variation in the costs of six major health and safety categories according to the size of construction area based on thirty-construction projects was determined using regression analysis. Secondly, considering four hundred-work accidents, the variation in work accidents according to the situations where relevant occupational health and safety equipment categories were considered or not was determined using Pareto analysis. Then, a comparison was made between OHS equipment category costs and work accidents. The findings showed that each category and the total OHS cost exhibited a linear variation with the size of construction area. Thereby, OHS costs could be estimated based on the size of construction areas in the construction projects. It is concluded that the effect of lacking any OHS on the rate of increase of work accidents can be provided using the results of the study.

1. Introduction

During the realization of the occupation in a work environment, any systematic and scientific work carried out to avoid conditions that would do harm to health, and behavior that could endanger safety are concerns in the scope of occupational health and safety (OHS) to ensure the continuity of the production and increase the productivity at work (Çolakoğlu, 2002; Yücel, 2007). All of the methodological works in the related literature are conducted with an aim to investigate and prevent hazards to employees that arise from the working conditions in the workplace, which are among the objectives of occupational safety given that the occupational health aims to the maintain the highest degree of social, mental and physical well-being of workers, the improvement of working environment and means of production to become conducive to health, and the adaptation of work to workers by protecting the workers from the harmful effects. Concordantly, guidelines and legal regulations are published for the goal and are updated regularly (Müngen, 2000; Milli Eğitim Bakanlığı, 2013; Official Gazette, 2013; Social Security Administration, 2014; TUIK–Turkish Statistical Institute, 2013; Official Gazette, 2012; Official Gazette, 2013; Official Gazette, 2013).

Changes in the production process depending on the innovations, modifications in the production mechanism and the increase in the business volume of the companies as a result of technology may bring about negative consequences, e.g. work accidents and occupational diseases, despite their positive effects on the development of the industry and economy. Because work accidents and occupational diseases adversely affect the profit, efficiency, brand value and the success of a company, OHS has gained importance in many sectors such as health, transportation and textile. In the construction sector, the work accidents may occur because of various reasons in a higher rate than the other sectors; the size of construction areas come to the forefront as a matter to be addressed in OHS (Haslam et al., 2005; Lopez et al., 2008). By examining the distribution of 1421 fatal work accidents in 23 activity groups, the findings indicated that the building construction activities took the first place with 264 fatal work accidents with a rate of

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18.6% (TMMOB–The Union of Chambers of Turkish Engineers and Architects, 2012). In a study, it is aimed to identify the variables that affect the occupational safety in the construction sector and provide occupational safety for the project managers, the findings showed that the most dangerous activities are on construction sites because of the occurrences of a large number of accidents (Teo et al., 2005). However, it is notable that the majority of construction companies do not have enough awareness about the occupational safety and the education level of the workers in the construction sector is low. This situation has an effect on the increase of work accidents and occupational diseases (Lingard and Holmes, 2000).

Cost estimation is defined as the estimation of actual cost which covers all kinds of costs incurred in each construction period of the building (Bostancioglu, 1992). OHS costs are evaluated in two groups: being accident prevention costs and costs associated with the occurrence of a work accident (Fellows et al., 2002). Accident prevention costs cover the expenses made to prevent the accidents while the costs associated with the occurrence of the accident are expressed as direct and indirect costs of accidents which occurred despite the health and safety that are considered (HSE, 2004; Tang et al., 2004; Ferret and Hughes, 2007). Accident prevention costs are classified into three groups as follows: being fixed prevention, variable prevention and unexpected prevention (Brody et al., 1990). The costs are called OHS or safety investment. OHS is classified as compulsory- and voluntary-investments. Compulsory investments are considered minimum protection measures which are obliged by government legally or by industrial regulations to prevent accidents during construction and involve safety costs of staffing training, equipment and facilities. Voluntary investments, in other respects, are included to be safety committee costs, safety promotion, incentive costs and costs of new technologies, methods or tools designed for safety (Feng, 2013).

In the literature, there is a limited number of scientific studies involving the comparison of the expenditures incurred for providing OHS with the total project costs in construction applications (Yılmaz and Kanıt, 2018; Alonso et al., 2013; Arpacı, 1995; Cheng et al., 2010; Everret and Frank, 1996; Heinrich, 1930; Sousa et al., 2014). In the studies on the determination of OHS costs, the cost of the categories had been considered before the work accident occurred, and the cost of expenditure after the work accident occurred were analyzed and compared (Korkutan, 2010; Tan, 1999). The studies seem to be based on the investigation of the accident costs which are considered as part of the construction industry work rather than the OHS costs. In the performed study by Health & Safety Executive on work accidents that occurred in companies in various industries to determine the accident costs, a cost methodology was developed which determines the cost of losses due to preventable work accidents. The aim was the companies can control the causes of losses they may face. In the research which was conducted in five separate lines of business and completed in approximately eighteen-weeks, the cost of each accident was calculated, and the connection between the OHS cost and the cost of the accident was investigated according to the causes of the accidents. At the end of the study, the findings showed that the rate of accident costs were 8% of the project cost in a construction company, 1.4% of the operating cost in a company engaged in dairy operations, 37% of the profit in a company engaged in transportation business, 14.1% of the potential production in a company engaged in oil exploration and 5% of the annual operating cost of a hospital providing healthcare (Tan, 2010).

In the construction companies, OHS costs in the construction process are mostly covered under general expenses item of the construction site, and sufficient financial analyses have not been performed (Sawacha et al., 1999). In the present study, with an attempt to fill this gap in the literature, the parameters that make up the OHS costs in the construction industry were classified, then, cost analyses were performed. At the first step, considering the basic work items in the projects that were examined in the context of the present study, the equipment categories were determined, and their costs were calculated according to risk factors to prevent the hazards that may occur. In the second step, the relationship of the categories, total OHS costs and the size of construction area was determined using the regression analysis in SPSS software (S.P.S.S., 2011). Finally, the effect of each category on work accidents was determined using Pareto analysis.

2. The methodology

2.1. Regression analysis

The regression analysis used to numerically express the relationship between two or more variables which have a cause-effect relationship between them is a statistical method which can make estimations or predictions about an examined subject. In this respect, Regression analysis primarily aims to determine the property of the relationship between variables, and enables making estimations about unknown facts from known findings (Orhunbilge, 2017). In the analysis technique, simple or multiple regression models were used to explain the relationship between two or more variables. In the simple regression model, a dependent variable (y) was the explained or estimated variable, and it was assumed that this variable was related to an independent variable. The independent variable (x) on the other hand was used in the model as the explanatory variable to estimate the value of the dependent variable. The general expression of a regression model with single independent variable explaining the linear relationship between the dependent variable and independent variable is given with Eq. (1).

$$y = a + bx \tag{1}$$

Here; y, denotes the value of the estimated dependent variable for the selected x value assumed to have a certain error; a, denotes the y-intercept of the regression line; b, denotes the slope of the regression line and x, denotes the value of the selected independent (cause) variable assumed to be measured error-free (Fig. 1).

While preparing a regression model, one of the two approaches known as least squares and maximum likelihood techniques tends to be used. According to whether or not there was a normal distribution of error term assumption, parameters were estimated using maximum likelihood and least squares technique respectively. R^2, being the square of the multiple correlation coefficients and defined as the coefficient of multiple determination, showed at what rate the independent variables explained dependent variables. For example, R^2 with a value of 0.7 indicated that 70% of the data could be explained by the determined regression line. The F-test used to determine the overall significance of the model gives the relationship between dependent and independent variable. In the F-test, the probability p related to the significance of regression coefficients indicated that the coefficients had p values meeting less than 0.5 limit value had a significant contribution to the model. On the other hand, t-test, was used in testing the significance of the trends of each variable, revealing the relationship of the dependent variable to an independent variable. If the t-value is different than zero indicates that the dependent variable is related to the

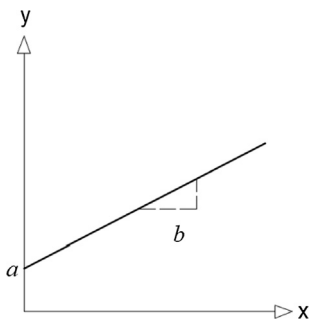

Fig. 1. Simple regression line.