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AN APPROACH FOR SAFETY COST ESTIMATION OF BUILDING CONSTRUCTION

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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. In this study, drawings, technical specifications, bill of quantities of 25 small or middle scaled concrete residential buildings with total areas that vary between 252 and 221.979 m^2 in Istanbul were examined. The 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 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 occupational health and safety (OHS) cost to the total construction cost is 2.6%. Also, to comply with the current legislation and minimize risks; 0.95 USD per man-hour should be spent according to 2013 rates and OHS cost per unit area was found as approximately 9.37 USD.

Keywords: Construction accidents, Cost of occupational health and safety, Occupational health and safety management, Risk analysis, Scheduling.

1 INTRODUCTION

In recent years, not only in Turkey but also all around the world, safety has become a matter of grave concern to government bodies and private enterprises. Current legislative system on OHS in Turkey enforces employers to implement safety measures as well as safety management systems. However level of consciousness in the industry is unsatisfactory and safety is perceived as extra cost and unnecessary expenditure. More specifically, in order to stay economically competitive and 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 (C. W. Cheng *et al.* 2010). The aim of this paper is to combine risk assessment activities, construction project scheduling and construction cost estimation to value OHS cost and its distribution throughout a project.

2 SCOPE AND METHOD

This paper attempts to estimate OHS cost before construction starts, according to the project type using risk assessment activities, construction project scheduling and construction cost estimations. For this purpose, project-scheduling techniques by the aid of Primavera P6, risk assessment techniques L matrix and Fine-Kinney that are applicable for construction projects and activity based cost estimation techniques were performed. In the scope of the project, drawings, technical specifications, bill of quantities of 25 concrete residential buildings in the region of Istanbul province are examined, construction sites were visited and information gathered from the site engineers upon safety practices on site by the financial support of The Scientific and Technological Research Council of Turkey (TUBITAK). Furthermore the cost analysis was compared with a former project (Gurcanli *et al.* 2011) that focused on 30 concrete residential projects again in Istanbul.

2.1 Preparation of Work Breakdown Structures

Park and Kim (2012) mentioned that effective activity based risk identification is one of the most crucial topic for site safety management planning in efficiently accomplished projects. Work breakdown structures of 25 building projects were established and for each construction project all work items were listed. Sources were determined and assigned to listed work items. In this stage of the study, the authors and concerned departments of the projects were made consultations about the work items. Ultimately, a number of adjustments and assumptions were made about the work items of construction projects.

2.2 Risk Assessment with L-Matrix and Fine-Kinney Methods

The main aim to perform hazard analysis and risk assessment is to determine the safety expenditures to prevent accidents by decreasing risk scores (to the level of "acceptable") by the utilization of personnel protective equipment, collective equipment and other equipment or techniques as well as training programs. By the aid of the work breakdown structure for each work item, hazards are determined firstly. There may be used many possible hazards but all the hazards used in this study are the most frequently hazards according to the past studies (Gurcanli and Mungen 2005, Gurcanli 2006, Gurcanli and Mungen 2009, Gurcanli and Mungen 2013, Mungen 1997) in Turkey. Secondly for each construction work item and sub-item risk assessment were performed by the utilization of accident severity and accident likelihood as input parameters. For accident likelihood and severity, conceptual framework and score of a former study performed by Gurcanli and Mungen (2009) was used. Risk scores of each work item were calculated and risk assessments were completed by using two different methods: L Matrix and Fine-Kinney.

2.3 Preparation of Project Schedules and Determination of Man-Hour Values

The man-hour values which Kuruoglu and Bayoglu (2001) prepared using 69 different construction jobs were utilized. In their study Kuruoglu and Bayoglu (2001) specified these values using the man-hour values of Turkish Ministry of Environment and Urban Planning (MEUP) and averaged man-hour values obtained from several companies. Briefly, this study comprises the man-hour values from the MEUP as well as man-hours from real project scheduling tables of different companies.

Daily labor payroll information is used in this study. Payroll information and working hours information is evaluated together; hereby, direct labor costs of each work item is determined (Bozkurt 2010). Indirect labor may be defined as combination of administrative and auxiliary labor (Ustun 1996). On the other hand, indirect labor costs are distributed to the work items by using activity-based costing method as overheads.

Project schedules were prepared using the planning tables, activity durations and total number of workers for each activity. In this study, *risk score of each work item was accepted as if amount of work with a unit cost* and was assigned to the each activity when processing Primavera P6 software. In this way, risk of any activity, the distribution of risks throughout the project and the time period with highest risk level in the project could be seen from the scheduling tables and project schedules.

2.4 Calculation of Cost of Construction Activities

Since the ultimate aim of the project is to give an approximate cost of safety to the contractors before bid and award phase or before the construction phase begins, project cost including labor and material costs, service and consultancy costs for mechanical, electrical systems as well as architectural and structural services, costs for supervision and finally general expenditures for construction site facilities were calculated. The direct cost of each work item is determined from the market research. Tenders about the projects were received from subcontractors for each work items or cost data were used with the permission of the companies. Additionally, some assumptions were used in calculations but the length limit of the study prevents giving the assumptions in this paper. For these calculations also man-hour values mentioned in the previous section were used.

2.5 Cost of OHS for Residential Construction Projects

OHS costs for personal protective equipment (PPE), collective protective measures (CPM), consultancy and training were determined. In the first stage, a market research was performed to estimate the safety cost for each item and in this stage, not only costs of PPE's but also the costs of CPMs such as fences, guardrails, stairs, roof stairs and others collected from the market. In the second stage, PPE packages are established for each workers working at different jobs through the project. CPM costs were also calculated for every activity. Job details are explained according to MEUP Unit Prices and Definitions Hand Book.

In the third stage, hazard analyses and risk assessment scores were used to determine collective protection measures and calculate associated costs for related construction activity. When calculating the cost of safety measures, overall project was examined to determine mitigation and abatement techniques, equipment and tools by the aid of architectural and technical drawings, bill of quantities, specifications and construction schedule. The level of risks for each construction activity determines the level of safety expenditure to eliminate that hazard.

After these steps, consultancy and training costs were calculated. In the study, it is assumed that a safety consultancy and training service of an expert once in two weeks throughout the project for a fixed 12 months project duration and it is calculated as 3675 USD data gathered from the market research (from consultant firms). Safety Consultancy, training and expertise cost (ST_{Cost}) is the minimum price and includes auditing and training. Finally safety cost of a building project can be expressed as follows:

Table 1. PPE packages for different occupations.

		PPE	Helmet	Goggle	Dust musk Respirator	Face Shield	Protective Clothes	Reflective Work Vest	Safety Harness	Safety-toe Protective footwear	High Boots	Gloves	Cost(USD)
		Standards	CE EN 397	CE EN 166	CE EN 149	CE EN 166		CE EN 471	CE EN 361	CE EN 345	CE EN 345	CE EN 388	
PPE_1	PPE-EXC	Exc. Worker	□		□		□	□			□	□	15,28
PPE_2	PPE-FRM	Formw. Worker	□		□		□		□	□		□	47,66
PPE_3	PPE-IRW	Iron Worker	□				□		□	□		□	47,23
PPE_4	PPE-CON	Conc. Worker	□			□	□		□	□		□	49,86
PPE_5	PPE-ROF	Roof Worker	□		□		□		□	□		□	47,66
PPE_6	PPE-BRK	Exc. Worker	□				□		□	□		□	47,23
PPE_7	PPE-PPT	Brick layer	□			□	□		□	□		□	49,86
PPE_8	PPE-ELC	Painter, Plaster	□				□			□		□	23,55
PPE_9	PPE-MEK	Electrici an	□				□			□		□	23,55
PPE_{10}	PPE-FLR	Mechani cs, Plumber	□	□			□			□			24,34
PPE_{11}	PPE-WEL	Floor Jobs Worker	□	□	□		□			□		□	48,45
PPE_{12}	PPE-CAR	Welder	□	□	□		□			□		□	24,76
PPE_{13}	PPE-UNS	Unskille d	□				□			□		□	23,55
PPE_{14}	PPE-DWI	Door-Window ins.	□				□			□		□	23,55

$$Safety_{Cost} = PPE_{Cost} + CPE_{Cost} + ST_{Cost} \quad (1)$$

$$PPE_{Cost} = \sum_{i=1}^{n} (PPE_i \times N) \quad \text{(Num. of workers at that activity, n=14)} \quad (2)$$

$$CPE_{Cost} = \sum_{i=1}^{n} C_i \quad \text{(n=6)} \quad (3)$$

$$ST_{Cost} = 12 \times 2 \times 1 \times ST_{Daily} \quad (\text{STD}_{\text{daily}} = 153.13 \text{ USD }) \quad (4)$$

3 RESULTS

The share of the OHS expenditures in total project cost should be underlined especially, because this calculation will be important in the bidding phase for contractors. Table 2 shows summarized information of all the cost items calculated in this study. The calculations indicate that the percentage of OHS cost to the total construction cost is 2.6%. In terms of man-hour costs, 0.95 (USD) OHS expenditure should be spent (with the 2013 rates). OHS cost per unit construction area is found as around US$9.37.

Table 2. Cost Summary Information (USD) and Cost Rates of 25 Projects.

Project Number	Construction (Area m2)	Project Cost (Except OHS Cost)	OHS Cost	Total Cost	Project Cost per C. Area (m2)	Total Working Hours	OHS Cost/ Total (%)	OHS Cost per man-hour (USD)	OHS Cost per C. Area (USD/m2)
1	2,618	1,171,758	21,205	1,192,963	865,8	37792	1,8	0,56	8,11
2	9,75	2,038,263	27,896	2,066,159	402,6	71072	1,4	0,39	2,84
3	2,5	381,438	11,49	392,928	298,6	11264	2,9	1,02	4,58
4	1,35	386,333	13,836	400,169	563,2	10352	3,5	1,34	10,26
5	1,26	455,286	18,776	474,062	714,9	46184	4	0,41	14,89
6	11,2	2,891,402	33,899	2,925,301	496,3	95640	1,2	0,35	3,05
7	2,5	937,883	12,549	950,433	722,3	10800	1,3	1,16	5
8	11	18,458,607	143,947	18,602,554	3,213.20	118002	0,8	1,22	13,11
9	3,4	833,645	11,179	844,824	472,1	9056	1,3	1,24	3,26
10	3,7	1,089,413	45,578	1,134,991	582,8	34384	4	1,33	12,32
11	530	171,688	7,728	179,416	643,2	6728	4,3	1,15	14,58
12	7,33	1,997,605	31,649	2,029,254	526	51368	1,6	0,62	4,32
13	2	717,087	10,494	727,582	691,2	28728	1,4	0,36	5,26
14	300	111,521	7,778	119,299	755,6	9176	6,5	0,85	25,95
15	3,15	729,174	14,491	743,665	448,6	19544	1,9	0,74	4,58
16	230	107,012	6,3	113,312	936,1	15064	5,6	0,42	27,37
17	12	2,699,819	84,166	2,783,985	440,8	23728	3	3,55	5,26
18	500	263,385	6,852	270,236	1,026.90	5072	2,5	1,35	13,68
19	118,2	28,666,266	155,158	28,821,424	463,3	166128	0,5	0,93	1,32
20	1,2	239,692	8,831	248,523	393,5	7664	3,6	1,15	7,37
21	2,255	813,805	16,451	830,256	699,6	25880	2	0,64	7,32
22	439	172,102	10,858	182,961	791,9	20992	5,9	0,52	24,74
23	4,345	1,414,536	19,962	1,434,498	627,3	22760	1,4	0,88	4,58
24	3,106	1,150,106	17,592	1,167,698	714,3	18832	1,5	0,93	5,68
25	4,042	1,476,310	19,042	1,495,352	702,9	25952	1,3	0,73	4,74
						Average	**2,6**	**0,95**	**9,37**

When the results are compared with the earlier study (Gurcanli et al., 2011), the ratio of OHS cost to the total construction cost was found as 3.7%; man-hour cost was calculated as 0.4 USD and cost per unit area was obtained as 11.6 USD. Earlier research observed and focused relatively small construction projects and it can be intuitively said that the share of the OHS cost decreases when total construction area increases. OHS cost versus construction area for 25 building projects is seen in Figure 1. The most appropriate trend can be expressed by a logarithmic curve for this data set. When the Figure 4 is analyzed it can be said that as the area of construction gets larger, the OHS costs tend to decrease.

In this study a basic logarithmic regression applied to the data shown in Table 2 and relationship between total area of construction and share of safety cost in total cost was shown. Regression analysis gives relationship shown below:

$$y = -1.123 \ln(x) + 11.362 \qquad R^2 = 0.61146 \tag{5}$$

where y represents here the percentage of safety cost in total project cost and x is the total area of the construction. The logarithmic relationship of course just gives us a point of view or starting point for further analyses. However at this stage, the formula gives a practical way to estimate share of safety cost in total project cost.

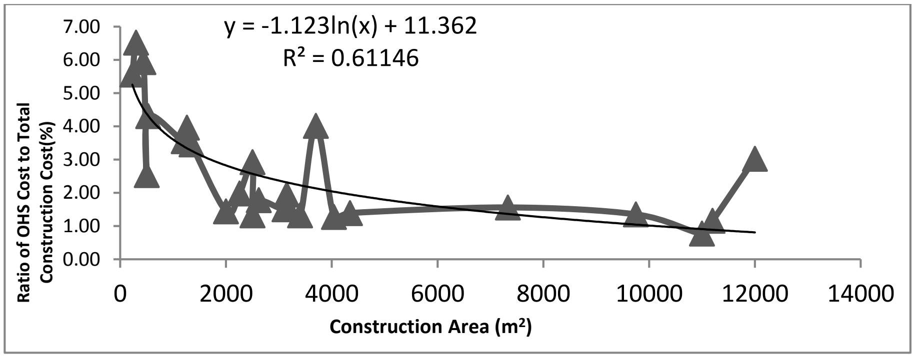

Figure 1. Variation of OHS cost based on construction area for 25 projects.

4 CONCLUSIONS

This study provides an approach for prime contractors to estimate OHS cost. Safety risks and related costs were assessed and calculated and related costs were determined for an effective OHS planning. Contractors can prepare safety plans and organization and allocate required budget to safety measures not only for cost control or project management but also save human life and protect their workers. Additionally, the results of the study may help for resource leveling attempts that means to minimize the period-by-period variations in resource loading by shifting tasks within their slack allowances. Briefly, it is thought that completely different project characteristics like duration, number of workers and similar parameters should also be considered.

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