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## Identification and Evaluation of Subcontractors' Selection Criteria in Highway Construction Projects

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**Abstract:** For decades, subcontracting has been utilized extensively in the construction industry. The contractors normally sublet large portions of the work to subcontractors in order to benefit from cost reductions, securing access to specialized services, and risk sharing. In this regard, progress in subcontracting practices, stemming from a meticulous selection of subcontractors based on appropriate criteria, leads to the improvement of project performance. The purpose of this paper is to identify and evaluate the subcontractors selection criteria according to their effects on project performance in "highway construction" projects. On the basis of an exhaustive review of literature, an opinion survey is conducted to achieve the purpose of research. Survey participants include expert subcontractors and general contractors in highway construction projects in Iran. Finally, by analyzing the results of questionnaire surveys, subcontractors selection criteria and indices in highway construction projects are identified and evaluated. Whereas subcontracting is the common practice in highway construction projects, the results of this paper can be used to improve highway construction projects performance. Obviously, performance improvement of highway construction projects, as the most important infrastructure, can play a critical role in the development of communities, especially in developing countries.

**Keywords:** Subcontractors, Selection criteria, Highway construction project, Project performance

### 1 Introduction

The construction is a widespread and complex industry which demands different specialty. When a construction firm wins the bid, in order to acquire specialized service and reduce the risk and cost of the project, it subdivides the project into parts and subcontracts most of them. Given the investigations, this is true for up to 90% of the construction projects that are carried out by subcontractors (Hinz and Tracy 1994). As such, subcontracting is more common practice in highway projects, as many other infrastructure projects, because of high cost, specialized tasks and strenuous demand for equipments.

To probe into this subject, there are different issues that are considered by researchers. As a matter of fact, actual subcontractors' bidding practices including the invitation to bid, bid submission, pre- and post bid negotiation, and the relationship with contractors were studied (Shash 1998). Sometimes because of changes in the construction schedule, conflicts will occur in subcontractors' schedule; this was the case that Kim investigated and regarding which he presented a model to resolve this conflict (Kim 2003). Accordingly, some others investigated the subcontractors' invitation methods (Cox et. al. 2006) and some others surveyed the subcontractors and general contractors' relationship (Lee et. al. 2009). Other factors such as subcontractor's safety, insurance, productivity and payment were also surveyed by Arditi (Arditi and Chotibhongs 2005). Recently, Choudhry et.al. have studied the subcontractors' position and performance and their reasons for subcontracting on construction projects (R. M. Choudhry et. al).

As for this study, investigating subcontractors selection methods that directly impact project objectives has been taken into consideration. Although the success of a project does not entirely depend on judicious subcontractors selection, choosing appropriate subcontractors is important because many drawbacks in the past have occurred as a result of the incapability of inappropriate subcontractors selected (Okra and Torrance 1999; Kumaraswamy and Matthews 2000). In addition, appropriate selection of subcontractors can facilitate other matters like management. Different researchers considered different yardsticks and proposed varied models for selection. Work experience, labourers, equipments, workload and financial situation were the first criteria that were considered (Shash 1998). In 2008, Thomas Ng et. al. categorized the criteria into different groups including resources, past experience, communication, etc. Moreover, he devised a model for evaluation of subcontractors (Thomas Ng 2008). Price, technical know-how, quality, and cooperation were other factors that Hartmann considered in his study in Singapore (Hartmann 2009). He found that just next to the offered price, quality played a significant role in subcontractor selection.

Despite the importance of subcontractors selection, little study has been done on this subject. Therefore, the aim of this paper is to identify the most significant criteria in subcontractors selection and find the relative importance of such criteria based on their impact on time, cost, quality and HSE level of highway construction projects. The result of this paper can be used to improve highway construction projects performance, as the most important infrastructure, and can play a critical role in the development of communities, especially in developing countries.

## 2 Subcontracting Practices in Highway Projects

A field survey which is conducted by authors shows subcontracting practices are utilizing in about 65% of the highway projects in Iran. However, this survey shows the satisfaction level of general contractors with subcontractor's performance is only about 45% cases is higher than medium. The main reasons of this rate of satisfaction level are some major issues, which are shown in Figure 1.

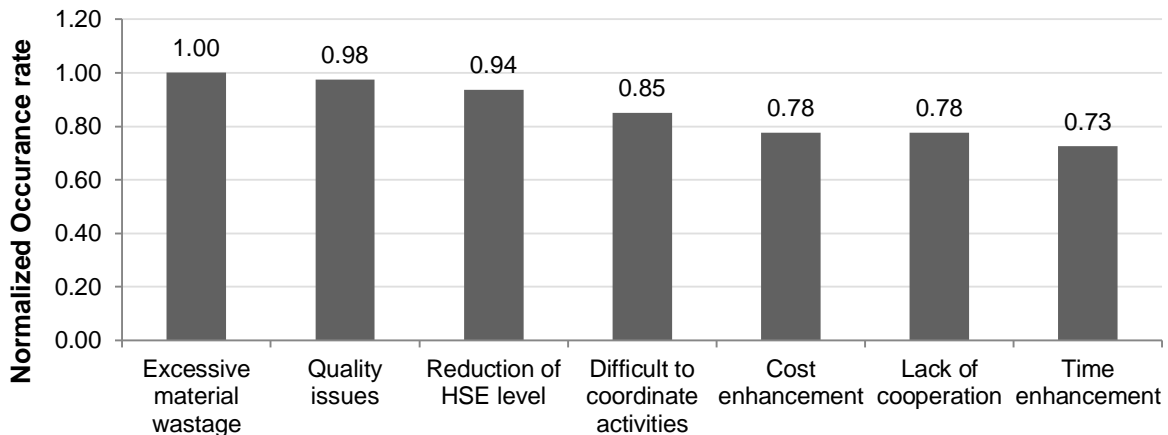


Figure 1: Subcontracting practices problems

Figure 1 shows, “Excessive material wastage” is the most problematic matter and “Quality issues”, “Reduction of HSE level”, “Difficult to coordinate activities”, “Cost enhancement”, “lack of cooperation” and “Time enhancement” followed it, respectively. Similar to these results, Choudhry et al. (2012) in their research about subcontracting in Pakistan have showed that “Difficult to coordinate activities”, “Excessive material wastage”, “Lack of cooperation”, “Progress” and “Quality issues” are the most important issues, respectively. These results emphasized that “Excessive material wastage”, “Difficult to coordinate activities”, and “Quality issues” are the most important issues of subcontracting practices in developing countries.

### 3 Methodology

Since, general contractors have to make the trade-offs between different criteria through the process of subcontractor selection, this research seeking for the most important selection criteria in highway projects. As shown in Figure 2, the methodology of this research comprises three main stages: Library studies; Field studies; and Data analysis.

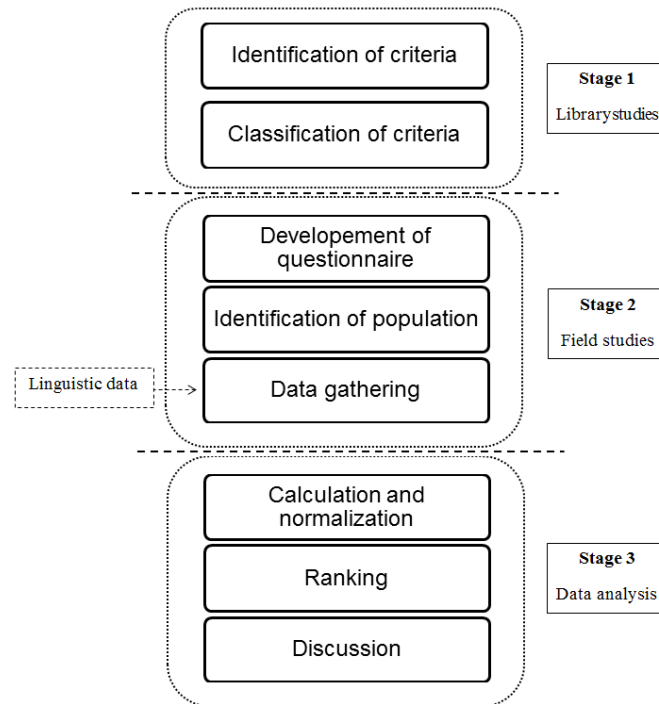


Figure 2: Research Methodology

In the following sections of this paper, the mentioned stages are pursued respectively.

### 4 Library Studies

As mentioned before, a wide variety of subcontractor selection criteria have been proposed in previous researches. Reviewing related researches and analysing the introduced criteria, we considered 27 indices in our study. The list of the subcontractor selection criteria and their references is presented in Table 1 (the phrases which are selected for the indices may not exactly be the same as the referred papers).

As illustrated in Table 1, the selected indices are classified within a three-level hierarchy. The first level is comprising of 5 main groups of "past performance", "company capability", "QHSE system", "Organizational maturity" and "workload". The second level is comprising of 10 groups of criteria and the lowest-level is comprising of 27 indices.

Obviously, above mentioned criteria should be evaluated in respect to some objectives. In this regard, time, cost, quality and HSE are considered as four major objectives of highway construction projects.

Table 1: Subcontractor selection criteria framework

Groups	Criteria	Indices	1	2	3	4	5	6	Authors
Past performance	Previous general contractor's satisfaction (previous owners)	Completion time of previous projects						*	
		Quality of completed project							*
		HSE level of completed projects							*
		Subcontractors claim							*
		Communication with main contractor				*			
		Communication with other parties				*			
	Company background	Number of years in business				*			
		The number of relevant projects completed				*			
		Number of previous contracts with the parent contractor			*				
Financial background	Financial stability			*					
Company capability	Technical ability	Know-how and technical support capability	*	*	*		*		
		Ability of advanced construction technology usage				*			
	Financial ability	Ability to undertake the size of the work–liquidity ratio				*			
	Execution ability	Craftsmen and labourers				*			
		Experienced site supervisory staff				*			
		Equipments	*			*		*	
QHSE system	Quality system	Quality planning system							*
		Quality assurance system							*
		Quality controlling system							*
	HSE system	HSE planning system							*
		HSE assurance system							*
		HSE controlling system							*
Organizational maturity	Organizational maturity	Organizational structure			*	*			
		Specified responsibility and duties							*
		Management Information System and flow information system							*
Current workload	Current workload	Current workload with the parent contractor	*						
		Current workload with other contractors	*						

(1) Shash 1998; (2) Hsieh 1998; (3) Eom et al. 2008; (4) Thomas Ng and Luu 2008; (5) Hartmann et al. 2009; (6) Choudhry et al. 2012.

## 5 Field Studies

The population of this study consists of 185 grade-one highway contractor companies. The sampling method used in this study is accidental, which is under the classification of non-probability sampling techniques. Thirty three completed responses from the grade-one highway contractors were received,

with an overall response rate of 74%. Considering the Cochran Formula for calculating the sample size for large populations (George and Mallery 2006), based on 90% confidence level and 10% margin of error, the sample size of 33 is adequate.

A questionnaire framework based on the classified criteria, as shown in Table 1, is developed for determining the importance of criteria with respect to four major objectives, separately. Then, interviewees were asked for the importance level of criteria in their companies.

After adjusting the developed questionnaire framework based on a pilot study, 33 interviews were conducted with engineers who had experience of work with subcontractors and subcontractor selection to get more precise results. The demographic profiles of the respondents are given in Table 2.

Table 2: A brief summary of respondents' characteristics

General Information		Frequency	Percent
Job Title	CEO	5	15.15
	Project Manager	9	27.27
	Engineer	19	57.57
Work Experience	2-6 years	8	24.24
	6-10 years	18	54.54
	10-14 years	3	9.09
	Over 14 years	4	12.12
Education Level	Bachelors degree	22	66.66
	Masters degree	11	33.33

To measure the internal consistency or reliability of the questionnaire, the Cronbach's alpha method is applied. The Cronbach's alphas for "past performance", "company capability", "QHSE system", "Organizational maturity" and "workload" groups, are calculated as 0.93, 0.91, 0.87, 0.89, and 0.85, respectively. The desirable value is 0.7 or more (George and Mallery, 2006).

To test validity of measures, the correlation coefficient is achieved by means of the Spearman formula. Consequently the p-values (Sig.) are less than 0.01 for all results, the correlation coefficients of each item are significant at  $\alpha = 0.01$ , therefore it can show that the sections of questionnaire are valid to measure that for which they were set.

## 6 Data Analysis

The Relative Importance Index (RII) method was applied to similar studies in order to determine a group of factors' relative importance (Sambasivan and Soon, 2007). The five point scale, ranged from very low (1) to very high (5) importance, was adopted to calculate the relative importance index using the following equation (the interviewees were asked to determine importance of each index, in five point scale: 'very low', 'low', 'medium', 'high', and 'very high'):

$$[1] \quad RII = \frac{\sum W}{A \times N}$$

Where  $W$  is the weight given to each factor by the respondents and ranges from 1 to 5,  $A$  is the highest weight which is considered 5 here, and  $N$  is the total number of respondents.

Using the calculated  $RII$  for each index, these indices are ranked in order to identify the most important selection criteria of subcontractor with respect to the specified objective in highway projects. Moreover, to facile the comparison, the results are normalized and converted to the range of 0 to 1 according to the following equation.

$$[2] X_{i, 0 \text{ to } 1} = \frac{X_i - X_{\text{Min}}}{X_{\text{Max}} - X_{\text{Min}}}$$

Where:  $X_i$  = Each data point  $i$ ;  $X_{\text{Min}}$  = The minima among all the data points;  $X_{\text{Max}}$  = The maxima among all the data points; and  $X_{i, 0 \text{ to } 1}$  = The data point  $i$  normalized between 0 and 1.

The normalized weight for each criterion is shown in Table 3.

Table 3. Relative importance of subcontractors selection criteria

Groups	Criteria	ID	Indices	Time	Cost	Quality	HSE	
<b>Past performance</b>	Previous general contractor's satisfaction (previous owners)	1	Completion time of previous projects	0.94	0.64	0.09	0.22	
		2	Quality of completed project	0.48	0.98	1.00	0.09	
		3	HSE level of completed projects	0.21	0.28	0.22	1.00	
		4	Subcontractors claim	0.71	0.71	0.13	0.01	
		5	Communication with main contractor	0.58	0.32	0.19	0.28	
		6	Communication with other parties	0.51	0.21	0.11	0.33	
	Company background		7	Number of years in business	0.74	0.48	0.69	0.47
			8	The number of relevant projects completed	0.89	0.93	0.77	0.70
			9	Number of previous contracts with the parent contractor	0.56	0.75	0.50	0.36
	Financial background		10	Financial stability	0.89	0.64	0.30	0.21
<b>Company capability</b>	Technical ability	11	Know-how and technical support capability	0.73	0.78	0.83	0.35	
		12	Ability of advanced construction technology usage	0.61	0.57	0.64	0.55	
	Financial ability		13	Ability to undertake the size of the work-liquidity ratio	0.83	0.54	0.22	0.25
	Execution ability	14	Craftsmen and labourers	0.98	0.90	0.75	0.40	
		15	Experienced site supervisory staff	0.86	0.66	0.83	0.29	
			16	Equipments	1.00	1.00	0.77	0.62
<b>QHSE system</b>	Quality system	17	Quality planning system	0.28	0.52	0.57	0.03	
		18	Quality assurance system	0.25	0.54	0.59	0.00	
		19	Quality controlling system	0.23	0.63	0.65	0.05	
	HSE system	20	HSE planning system	0.09	0.11	0.03	0.65	
		21	HSE assurance system	0.00	0.00	0.00	0.62	
		22	HSE controlling system	0.03	0.07	0.01	0.63	
<b>Organizational maturity</b>	Organizational maturity	23	Organizational structure	0.32	0.45	0.38	0.21	
		24	Specified responsibility and duties	0.56	0.54	0.46	0.31	
		25	Management Information System and flow information system	0.12	0.20	0.40	0.28	
<b>Current workload</b>	Current workload	26	Current workload with the parent contractor	0.51*	0.45	0.55*	0.26*	
		27	Current workload with other contractors	0.74*	0.59*	0.69*	0.29*	

\* These indices have negative effect on improvement of specified objectives

As it is shown in Table 3, each index has specific weight with respect to each objective. The higher the weight shows the more significance in that objective. For example:

- “Equipments”, “Craftsmen and labourers” and “Completion time of previous projects” are more important indices with respect to objective of time.
- “Equipments”, “Quality of completed project”, and “Number of relevant projects completed” are more important indices with respect to objective of cost.
- “Quality of completed project”, “Know-how and technical support capability”, and “Experienced site supervisory staff” are more important indices with respect to objective of quality.
- “HSE level of completed projects”, “Number of relevant projects completed”, and “HSE planning system” are more important indices with respect to objective of HSE.

As shown in Figures 3(a) and (b), the most important indices are specified through two consecutive steps of Time-Cost and Quality-HSE importances production. In these Figures, Zones I, II, and III are specifying the areas of the high, medium, and low important indices, respectively. In the first step, the indices that are located in Zone I, as Time-Cost high importances, are selected (see Figure 3(a)), and then are classified based on Quality-HSE importances, in the second step (see Figure 3(b)). As a result, “Equipments” and “Number of relevant projects completed” are the most important subcontractors selection indices.

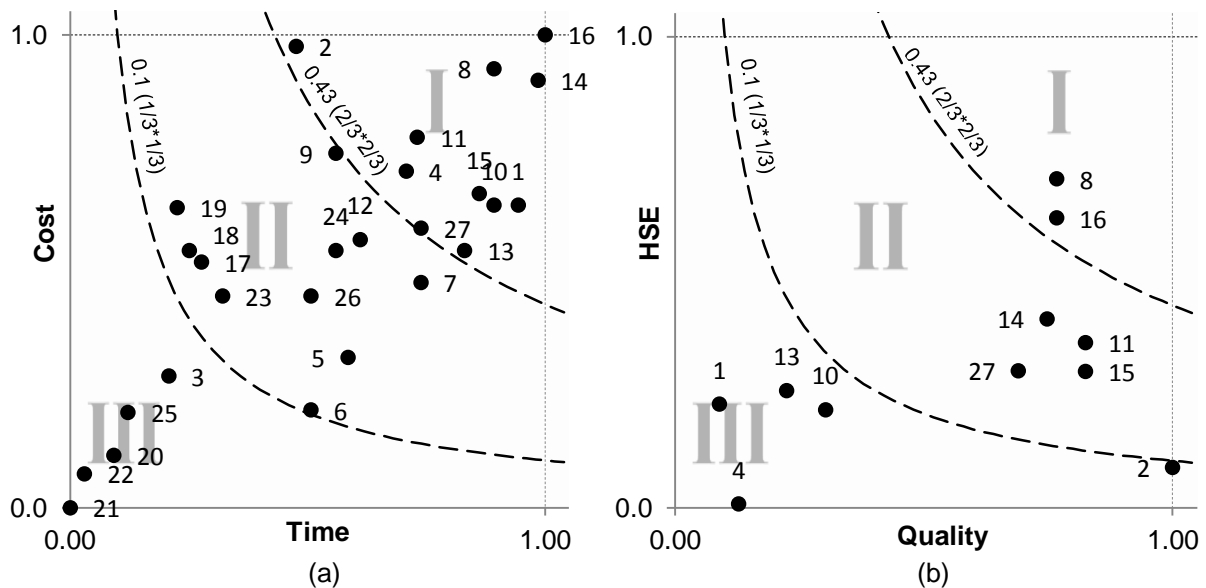


Figure 3: The importance of subcontractor selection indices (a) Time and Cost importance (b): Quality and HSE importance of more important Time-Cost indices

At one higher level, the importance of each criteria can obtain by averaging their subsets indices importances. As shown in Table 4 and Figure 4, “Execution ability”, “Company background” and “Technical ability” are three most important subcontractors selection criteria.

Figure 5 shows the relative importance of each main group of selection criteria as the average of the relative importances of subdivision criteria.

Table 4: Relative importance of criteria

Criteria	Time	Cost	Quality	HSE	Product
Previous general contractor's satisfaction	0.52	0.49	0.28	0.32	0.02
Company background	0.66	0.67	0.63	0.50	0.14
Financial background	0.80	0.60	0.29	0.21	0.03
Technical ability	0.61	0.63	0.71	0.44	0.12
Financial ability	0.75	0.51	0.21	0.25	0.02
Execution ability	0.85	0.79	0.76	0.43	0.22
Quality system	0.23	0.53	0.58	0.03	0.00
HSE system	0.04	0.08	0.02	0.61	0.00
Organizational maturity	0.30	0.38	0.40	0.26	0.01
Current workload	0.57	0.50	0.60	0.27	0.04

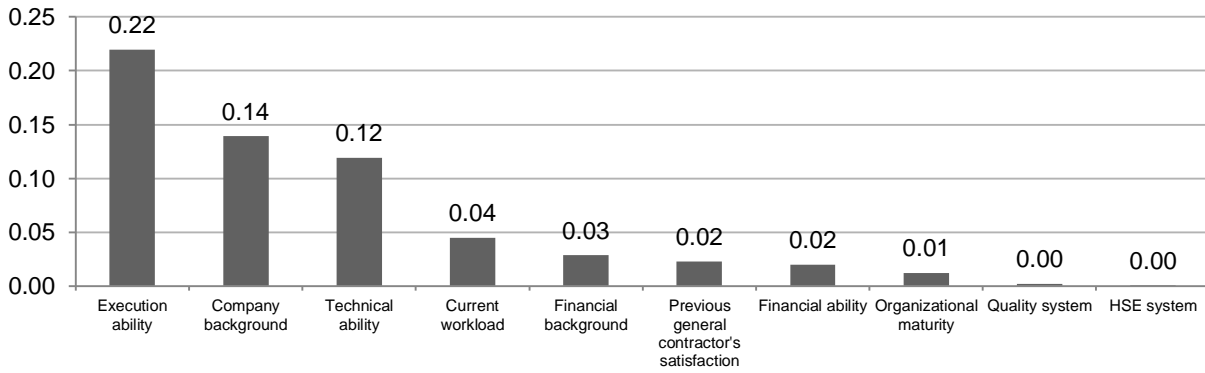
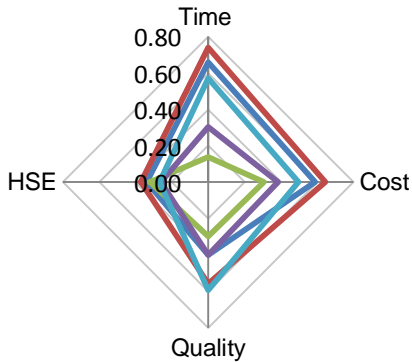


Figure 4: Results of criteria

- Past performance
- Company capability
- QHSE
- Organizational
- Current workload



Main group	Time	Cost	Quality	HSE
Past performance	0.66	0.59	0.40	0.34
Company capability	0.74	0.64	0.56	0.37
QHSEsystem	0.14	0.31	0.30	0.32
Organizational maturity	0.30	0.38	0.40	0.26
Current workload	0.57	0.50	0.60	0.27

Figure 5: Relative importance of main groups



As shown in Figure 5, “Company capability” comprising of “Technical ability”, “Financial ability” and “Execution ability” criteria is the most important group of subcontractor selection criteria. Following that, the group of “Past performance” as the second top spot should be considered in the subcontractor selection process. As the descending level of importance, three groups of “Current workload” with some negative effects on objectives, “Organizational maturity” and “QHSE system”, are placed in the third to fifth spot, respectively.

## 7 Data Analysis in SWOT Framework

Strengths, weaknesses, opportunities, and threats (SWOT) analysis is a technique that examines the project and organization from each of the SWOT perspectives to increase the breadth of identified risks. This technique identifies strengths and weaknesses of the organization and then identifies any opportunities and threats for the project that arise from organizational strengths and weaknesses (PMI 2009). In this study, the important identified criteria can be counted as a weakness and strength that can cause threats and opportunities.

In this study, we found the most important criteria with respect to their effect on project objectives. Indeed, strengths and weaknesses of these criteria can arise opportunities and threats, respectively. In Figure 6, the identified criteria (strengths and weaknesses) and arisen opportunities and threats are presented concisely. So, the firms should have special attention to these criteria in creating organizational strategies. Obviously, this analysis does not applicable for backgrounds criteria.

<p><b>Identify and List Organizational Strengths and Weaknesses (Derived from data analysis)</b></p>	<p style="text-align: center;"><b>Strengths</b></p> <ul style="list-style-type: none"> <li>• Equipments capability</li> <li>• Competent craftsmen and labourers</li> <li>• Experienced site supervisory staff</li> <li>• Know-how and technical support capability</li> <li>• Proper HSE planning and controlling system</li> </ul>	<p style="text-align: center;"><b>Weaknesses</b></p> <ul style="list-style-type: none"> <li>• Equipments incapability</li> <li>• Incompetent craftsmen and labourers</li> <li>• Inexperienced site supervisory staff</li> <li>• Know-how and technical support incapability</li> <li>• Poor HSE planning and controlling system</li> </ul>
<p><b>Derive Opportunities from Strengths and Threats from Weaknesses</b></p>	<p style="text-align: center;"><b>Opportunities</b></p> <ul style="list-style-type: none"> <li>• Ontime or ahead schedule</li> <li>• On or underrun budget</li> <li>• Proper quality</li> <li>• Proper HSE</li> </ul>	<p style="text-align: center;"><b>Threats</b></p> <ul style="list-style-type: none"> <li>• Behind schedule</li> <li>• Overrun budget</li> <li>• Poor quality</li> <li>• Poor HSE</li> </ul>

Figure 6: Data analysis in SWOT framework

## 8 Conclusion

The success of highway construction projects depends to a great extent on the performance of subcontractors. Obviously, selecting the proper subcontractor, based on some reasonable criteria, is the preliminary step that results in successful performance. The purpose of this paper was to identify the most important criteria in this regard and pinpoint their relative importance for subcontractor selection process in highway construction projects. In this respect, 27 indices as subdivisions of 10 criteria were identified and then classified in a three-level hierarchical framework. “Past performance”, “company capability”, “QHSE system”, “organizational maturity”, and “current workload” comprised the first level of this framework which was subdivided to 10 criteria such as “execution ability”, “company background”, “technical ability”, and so on. To determine the most important criteria, based on a questionnaire survey, the developed framework was evaluated with respect to four main project objectives of time, cost, quality and HSE.

The main results of data analysis were as follows: “Equipments”, “Craftsmen and labourers” and “Completion time of previous projects” are more important indices with respect to objective of time. Also, “Equipments”, “Quality of completed project”, and “Number of relevant projects completed” are more important indices with respect to objective of cost. Moreover, “Quality of completed project”, “Know-how and technical support capability”, and “Experienced site supervisory staff” are more important indices with respect to objective of quality. Furthermore, “HSE level of completed projects”, “Number of relevant projects completed”, and “HSE planning system” are more important indices with respect to objective of HSE.

In general, with respect to all objectives, “Equipments” and “Number of relevant projects completed” are the most important indices, which should be considered as selection indices of criteria in subcontractor selection process. In the criteria level of framework, as level 2, “Execution ability” and “Company background” held the top two spots. Finally, group of “Company capability” was the most important group of subcontractor selection criteria which was followed by group of “Past performance”.

The finding of this research can help general contractors in reviewing their subcontractors selection criteria, and also can be useful for subcontractors in the improvement of their performance.

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