Root Causes of Cost Deviation in Highway Construction Projects in Bahrain

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ABSTRACT: *In this research the cost overrun in highway construction projects in Bahrain was investigated. Fifty-two causes were identified from the literature and from interviews with highway construction engineers working at contractors, consultants, and at Ministry of Works (MoW). The causes were classified into six groups. A field survey was conducted through a questionnaire including thirty-six contractors, twenty-four consultants and eighty-four engineers working at MoW to study the frequency and severity of the causes of overrun.*

Furthermore, an ANN model was developed for this study, the data for the model were gathered from interviews with project managers working at MoW, who managed 38 highway construction projects in Bahrain between years 2005 to 2016. They were asked to rank the severity and the frequency of occurrence of the six groups that were identified earlier, which had caused cost overruns to their projects. The Artificial Neural Network (ANN) model was used to identify which group had more effect on cost overrun, and the results were compared to the ones from the questionnaire.

It was concluded that there are many causes of cost overrun related primarily to owner's group, consultants' group and contractors' group such as frequent change orders, lack of experience, and lack of communication with suppliers, respectively. However, factors related to project's characteristics, estimation, and environment were not as significant to the above groups.

Finally, recommendations were suggested in order to minimize the cost overrun in highway construction projects in Bahrain. In addition, recommendations for future research were suggested.

Keywords: *cost overrun causes, highway construction projects.*

1. INTRODUCTION

The success of every construction project can be defined as meeting the goals and objectives of the client/owner as specified in the project plan. A project is therefore said to be successful when it has accomplished the technical performance and been completed within schedule and budgeted cost.

Cost overrun is common in infrastructure projects. Researches on highway construction projects in some developing countries indicate that by the time a project is completed, the actual cost exceeds the original contract price by about 30% [1]. Cost overruns in highway projects have a serious impact on program budgeting from the view of the owner (MoW). The planning and programming of future highway construction projects are vitally important tasks in highway organizations. A construction program outlines how highway funds are to be spent over time and any deviation from the stated program often brings a quick response from the public, the press, and politicians [2]. When this occurs, the government loses creditability and will take time defending deviation from the published program [3].

It is therefore beneficial for construction parties to recognize the root causes of cost overrun in highway construction projects in Bahrain. This will help them significantly to overcome or reduce such issue in future projects.

The main objectives of this study are summarized in the following points:

- Identify the internal and external factors that cause cost overrun in highway construction projects in Bahrain.
- Establish the relationship between the cost overrun and the identified factors.
- Recommend solutions to avoid or reduce cost deviation in future road construction projects in Bahrain.

In the following sections the literature review will be presented first, where it includes related previous studies, followed by research methodology and data collection. Then results will be presented, analyzed and discussed. Finally conclusions will be presented and recommendations will be suggested in order to overcome cost overruns of future highway construction projects.

2. LITERATURE REVIEW

Several articles in scientific journals that are related to cost deviation in construction projects have been reviewed along with those related to highway construction projects in particular, which present the cost overrun in construction projects and its causes and effects. Rowland [4] ascertained that the likelihood of cost overrun increased with: The contract size; complexity; length of communication channels; and distortion of information associated with larger projects.

Al-Khaldi [5] conducted a study aims at identifying factors affecting construction cost in Saudi Arabia from contractors and consultants' view. He found that project size is one of the top five affecting factors from both contractors and consultants' view. In Indonesia, Kaming et al. [6] identified variables that have an impact on construction time and cost overruns using factor analysis techniques. In their work, time and cost overrun variables were grouped into factors, and their relationships were analyzed. It was found that the main causes of cost overruns were the complexity of the project; inflationary increases in material costs; and inaccurate material estimates. They stated that the main causes of cost overrun were related to inadequate planning; design changes; and poor labor productivity.

Akinci and Fischer [7] stated that risk factors in highway construction projects are associated with the project design, construction, and project environment. They also analyzed cost overruns associated with Washington State highway projects and found that the cost overruns, expressed as a percentage of the contract amount, tended to increase with project size.

Attalla and Hegazy [8] presented an interesting study that pioneered the comparison of the performance of different techniques by considering Artificial Neural Network (ANN) and regression in predicting cost deviation in highway construction projects. In a similar subsequent study, Williams [9] compared the performance of Neural Networks (NNs) and regression in explaining highway project cost deviations in Texas on the basis of bidding information such as bidding ratio, mean bid, and second lowest bid.

Odeck [10] found rather surprisingly as no other study has noted it previously, that smaller projects have relatively larger cost overruns compared to larger ones. The study by Flyvbjerg et al. [11] concludes conversely that cost overruns are large for all project sizes.

Azhar et al. [12] conducted a study to identify the major factors affecting cost estimating accuracy in the construction sector of Pakistan. Forty-two factors were short-listed and made part of the survey questionnaire and the survey was conducted with representatives from local general contracting firms. They found that the top ten affecting factors are: fluctuation in prices of raw materials; unstable cost of manufactured materials; high cost of machineries; lowest bidding procurement procedures; poor project management or poor cost control; delays between design and procurement phases; incorrect or inappropriate methods of cost estimation; additional work; improper planning, and unsupportive government policies.

Aje et al. [13] identified that contractors' management capability had significant impact on cost and time of building projects. Also, Koushki et al. [14] conducted a study in Kuwait to study the factors affecting cost estimation in construction projects. An interview survey of 450 randomly selected private residential project owners and developers have been done. They found that the main factors affecting cost are: contractor related problems; material related problems; and owners' financial constraints.

Mahamid [15] conducted a study to identify the factors affecting cost estimation accuracy in building construction projects in Palestine. He concluded that the top five affecting factors are: fluctuation in currency exchange rate, project financing, contract management, level of competitors, and cost of materials.

After reviewing regional and international cases of cost overrun studies related to highway construction projects, the studies showed that there are some causes of cost overrun that are important and required to be investigated in this study such as cost estimation methods; lack of communication; frequent change orders/variation by client; and estimator's experience. This study involved the identified factors from literature as well as the ones identified from interviews with highway construction project managers in MoW in the Kingdom of Bahrain.

3. RESEARCH METHODOLOGY

In order to identify the factors causing cost overrun in highway construction projects in the Kingdom of Bahrain, a comprehensive literature review was performed by reading several articles in scientific journals that are related to the topic of this study. The extensive literature review helped identifying the internal and external factors causing of cost overrun. Historical data were also gathered from MoW of highway construction projects undertaken by the ministry from years 2005 to 2016, including estimated cost, actual cost upon completion of the project, and factors that lead to cost overrun of each project.

A questionnaire was developed to evaluate the frequency of occurrence and severity of the identified factors. Moreover a model was developed using the data gathered from interviews with highway construction projects managers to describe the relationship between the cost overrun and the identified factors, and verify its validity. The ANN modeling approach was used. Significant factors of cost overrun and their severities were identified, and recommendations to overcome these factors were suggested in view of the results of the study.

4. DATA COLLECTION

The first type of data was gathered through a review of literature on cost deviation in highway construction projects. The second type of data was obtained by interviewing consultant firms, contractors and engineers from Roads Affairs in MoW to have their opinions on the general factors of cost overrun in highway construction projects in Bahrain. The identified factors will be used in the questionnaire for frequency and severity analysis. The identified cost overrun factors from literature and interviews were grouped into 6 groups as shown in Table 1.

Table 1: Causes of Cost Overrun Identified from Literature Review and Interviews with MoW Project Managers

Group	Description of Factors
1. Factors related to consultant	1. Design errors and omissions 2. Estimator's experience 3. Extent of completion of pre-contract design 4. Slowness in inspection and testing of completed works 5. Lack of communication 6. Lack of qualified project manager
2. Factors related to contractor	1. Contractor's deficiencies in planning and scheduling at tender stage 2. Effective monitoring and feedback process 3. Communication with suppliers 4. Poor procurement programming of materials 5. Low speed at decision-making 6. Staff training in the skill areas relevant to project 7. Availability and supplies of labor and materials 8. Contractor's financial difficulties 9. Inadequate contractors experience 10. Lack of project knowledge 11.Lack of qualified project manager 12.Methods/techniques of construction 13.Planning and scheduling deficiencies 14.Poor site management and supervision 15.Rework from poor materials quality
3. Factors related to estimation	1. Estimator's experience 2. Cost estimation methods 3. Deficiencies in cost estimates prepared 4. Procedure for updating cost information 5. Time allowed for preparing the cost estimate 6. Availability of data of similar projects
4. Factors related to project characteristics	1. Project duration 2. Build-ability (including on-site prefabrication) 3. Complexity of design and construction 4. Location of project 5. Services relocation costs 6. Project size 7. Construction techniques required
5. Factors related to owner	1. Delays in work approval waiting for information 2. Cash flow during construction 3. Low speed at decision-making 4. Disputes 5. Form of procurement and contractual arrangements 6. Frequent Change orders/Variation by owner 7. Payment delay 8. Specifications Change

Group	Description of Factors
6. Factors related to environment	1. Tender period and market condition 2. Cultural heritage issues 3. Escalation of material prices 4. Frequent breakdown of construction equipment 5. Government interference 6. Inflation 7. Lead times for delivery of materials 8. Monopoly of material suppliers 9. Weather 10.Unexpected geological conditions

A third type of data was collected from project managers of thirty-eight highway construction projects in Bahrain awarded over the years 2005-2016. The data comprise specific groups of cost overrun factors for each project with their frequency and severity indices based on interviews with project managers as shown in Table 2. These data will be used in the NN model.

Table 2: Summary of the Interviews Results

Factors Groups	Weight of cost overrun groups based on each project's manager response						Overrun (BD)
	Consultant	Contractor	Estimation	Project Characteristics	Owner	Environment	
Project 1	6	8	12	6	12	10	9,823
Project 2	10	12	6	8	9	9	16,749
Project 3	6	12	14	6	8	9	7,271
Project 4	9	12	4	6	8	9	68,521
Project 5	14	10	6	5	8	5	42,060
Project 6	9	9	4	12	9	8	23,220
Project 7	10	8	5	5	6	12	5,401
Project 8	8	12	5	8	12	9	329,492
Project 9	9	6	12	8	8	12	8,001
Project 10	12	9	8	5	5	10	5,891
Project 11	9	12	6	6	14	9	123,111
Project 12	12	12	8	9	14	8	252,748
Project 13	14	14	6	8	12	9	25,996
Project 14	10	10	8	6	12	8	278,008
Project 15	12	12	9	8	14	9	170,000
Project 16	12	12	8	9	8	9	4,482
Project 17	10	12	8	8	12	5	31,180
Project 18	10	8	6	12	9	12	114,565
Project 19	10	12	6	8	12	8	168,412
Project 20	12	10	6	8	12	9	242,533
Project 21	12	12	9	8	12	8	23,223
Project 22	10	12	8	9	12	5	151,651
Project 23	12	12	8	9	10	9	607,596
Project 24	9	12	9	8	9	8	407,553
Project 25	12	12	8	9	8	9	21,709
Project 26	10	12	8	8	12	5	110,362
Project 27	12	14	14	9	12	12	1,440,645
Project 28	14	14	14	8	12	12	728,521
Project 29	12	12	12	9	9	12	820,159
Project 30	12	10	9	8	12	8	201,982

Factors Groups	Weight of cost overrun groups based on each project's manager response						Overrun (BD)
	Consultant	Contractor	Estimation	Project Characteristics	Owner	Environment	
Project 31	14	14	10	10	12	8	60,221
Project 32	10	12	12	10	12	8	407,832
Project 33	12	8	10	9	10	8	1,386,212
Project 34	12	12	8	9	14	8	110,760
Project 35	14	14	6	8	12	9	110,226
Project 36	12	8	9	4	9	12	403,591
Project 37	9	10	4	3	8	10	292,201
Project 38	12	6	10	9	11	8	507,394

5. STATISTICAL RESULTS AND ANALYSIS

The factors under each group were ranked by the measurement of importance index according to the following equation.

$$IMPI(i) = FI(i) \times SI(i) \quad (1)$$

Where IMPI(i), FI(i), and SI(i) are the importance, frequency, and severity indices of factor (i), respectively. The frequency index is given by:

$$FI(i) = \frac{\sum_{j=1}^{5} w_j \, x \, f_{ij}}{5 \, x \, N} \quad (2)$$

And the severity index is given by:

$$SI(i) = \frac{\sum_{j=1}^{5} (w_j \, x \, s_{ij})}{5 \, x \, N} \quad (3)$$

Where; w_j (j=1,2,…5) is the weight given to each factor i (ranges from $w_1 = 1$ for very low up to $w_5 = 5$ for very high), f_{ij}/s_{ij} are the frequency/ severity of the responses for each factor i associated with weight w_j, and N is the total number of responses. Tables 3 to 8 summarize the ranking of each group's factors based on IMPI.

Table 3: Importance Index and Ranking of Each Factor under the Consultant's Group

Factor	IMPI%	Rank
Estimator's experience	70.55	1
Lack of communication	69.98	2
Lack of qualified project manager	68.62	3
Extent of completion of pre-contract design	67.79	4
Slowness in inspection and testing of completed works	66.13	5
Design errors and omissions	65.35	6

Table 4: Importance Index and Ranking of Each Factor under the Contractor's Group

Factor	IMPI%	Rank
Communication with suppliers	69.75	1
Lack of qualified project manager	68.77	2
Lack of project knowledge	67.20	3
Poor site management and supervision	65.89	4
Staff training in the skill areas relevant to project	64.40	5
Availability and supplies of labor and materials	63.74	6
Low speed at decision-making	62.93	7
Planning and scheduling deficiencies	61.17	8
Contractor's deficiencies in planning and scheduling at tender stage	60.65	9
Poor procurement programming of materials	59.80	10
Methods/techniques of construction	58.18	11
Effective monitoring and feedback process	57.38	12
Rework from poor materials quality	56.52	13
Inadequate contractors' experience	55.46	14
Contractor's financial difficulties	54.69	15

Table 5: Importance Index and Ranking of Each Factor under the Estimation's Group

Factor	IMPI%	Rank
Estimator's experience	73.74	1
Cost estimation methods	72.48	2
Time allowed for preparing the cost estimate	71.20	3
Availability of data of similar projects	70.38	4
Accuracy and reliability of cost information	69.75	5
Procedure for updating cost information	68.63	6

Table 6: Importance Index and Ranking of Each Factor under the Project Characteristics' Group

Factor	IMPI%	Rank
Project size	64.78	1
Project duration	62.70	2
Location of project	59.80	3
Services relocation costs	58.78	4
Construction techniques required	56.63	5
Complexity of design and construction	55.74	6
Build-ability (including on-site prefabrication)	55.91	7

Table 7: Importance Index and Ranking of Each Factor under the Owner's Group

Factor	IMPI%	Rank
Frequent Change orders/Variation by owner	78.55	1
Low speed at decision-making	77.36	2
Specifications Change	75.25	3
Delays in work approval waiting for information	74.76	4
Form of procurement and contractual arrangements	73.56	5
Disputes	71.89	6
Cash flow during construction	71.27	7
Payment delay	71.13	8

Table 8: Importance Index and Ranking of Each Factor under the Environment's Group

Factor	IMPI%	Rank
Government interference	64.85	1
Tender period and market condition	63.75	2
Cultural heritage issues	62.68	3
Unexpected geological conditions	60.82	4
Weather	59.39	5
Lead times for delivery of materials	58.75	6
Escalation of material prices	57.47	7
Frequent breakdown of construction equipment	55.89	8
Monopoly of material suppliers	54.26	9
Inflation	53.01	10

The average importance indices of all factors in each group were also calculated to determine the ranking of each group. Table 9 shows the results of group's ranking.

Table 9: Importance Indices and Ranking of Each Group

Factor	IMPI%	Rank
Factors related to owner	74.22	1
Factors related to estimation	71.03	2
Factors related to consultant	68.07	3
Factors related to contractor	61.76	4
Factors related to project characteristics	59.20	5
Factors related to environment	59.10	6

6. NN Model DEVELOPMENT AND RESULTS

Data in Table 2 were normalized for effective model training. Tests have proven that normalized data performed better for the prediction of the total construction cost [16]. Data were normalized in the range from 0 to 1 as shown in Table 10 using the following formula:

$$\text{Group normalized value for project (i)} = \frac{\text{Group original value for project (i)}}{\text{Group maximum value over all projects}} \qquad (4)$$

The developed model in this research is based on SimBrain. It is selected for its ease of use, speed of training, flexibility of building and executing the NN model. In addition, the modeler has the flexibility to specify his own NN type, learning rate, momentum, activation functions, number of hidden layers/nodes, and graphical interpretation of the results. Finally, it has multiple criteria for training and testing the model.

The available data were divided into three sets: training set, cross-validation set and test set. Training and cross-validation sets were used in learning the model through utilizing training set in modifying the network weights to minimize the network error, and monitoring this error by cross-validation set during the training process. However, test set did not enter in the training process and it hasn't got any effect on the training process, where it is used for measuring the generalization ability of the network, and evaluating network performance [17]. In this study, the total available data of 38 exemplars (projects/indices) were divided using the following ratio:

- Training set (includes 20 exemplars ≈ 52%).
- Cross validation set (includes 8 exemplars ≈ 21%).
- Test set (includes 10 exemplars ≈ 27%).

As a rule of thumb, determining the number of hidden layers/nodes is one of the main drawbacks of NNs, because there is no specific rule and it requires many trial and error processes while considerable time must be spent [18]. Hegazy and Moselhi [19] stated that one hidden layer with a number of hidden nodes as 0.75m, m, or 2m+1, where m is the number of input nodes, is suitable for most applications.

Two types of NNs were chosen Multi-layer Perceptron (MLP) and Generalized Feed Forward (GFF) to be used in the following training process due to their good initial results. Through a system of trial and error, the best model that provided more accurate results was structured of MLP, which includes one input layer with 6 input nodes (factor groups) and one hidden layer with (5 hidden nodes), and finally one output layer with one output node (cost overrun).

In terms of Goodness of Fit (GoF), it was employed to judge the overall fit of the model It is the geometric mean of the average communality and the average R^2. It represents an index for validating the NN model globally, by looking for a compromise between the performance of the measurement and the structural model, respectively. Thus, GoF is given by:

$$GoF = \sqrt{\overline{AVE}\ x\ \bar{R}^{\,2}} \quad (5)$$

The GoF calculations for MLP model are as follows:

$\overline{AVE}$ (0.781+0.856+0.841+0.785+0.890+0.872)/6= 0.837

$\bar{R}^2$ = 0.893

GoF = $\sqrt{(0.8375x0.893)} = 0.864$

Whereas, the calculations of GoF for GFF model are:

$\overline{AVE}$ (0.814+0.835+0.851+0.729+0.749+0.883)/6= 0.810

$\bar{R}^2$ = 0.861

GoF = $\sqrt{(0.810x0.861)} = 0.835$

Table 10: Normalized Indices (Weight) of Each Cost Overrun Group Based on Interviews Results

	Factors Group						
	Consultant	Contractor	Estimation	Project Characteristics	Owner	Environment	Overrun
Project 1	0.43	0.57	0.86	0.50	0.86	0.83	0.007
Project 2	0.71	0.86	0.43	0.67	0.64	0.75	0.012
Project 3	0.43	0.86	1.00	0.50	0.57	0.75	0.005
Project 4	0.64	0.86	0.29	0.50	0.57	0.75	0.048
Project 5	1.00	0.71	0.43	0.42	0.57	0.42	0.029
Project 6	0.64	0.64	0.29	1.00	0.64	0.67	0.016
Project 7	0.71	0.57	0.36	0.42	0.43	1.00	0.004
Project 8	0.57	0.86	0.36	0.67	0.86	0.75	0.229
Project 9	0.64	0.43	0.86	0.67	0.57	1.00	0.006
Project 10	0.86	0.64	0.57	0.42	0.36	0.83	0.004
Project 11	0.64	0.86	0.43	0.50	1.00	0.75	0.085
Project 12	0.86	0.86	0.57	0.75	1.00	0.67	0.175
Project 13	1.00	1.00	0.43	0.67	0.86	0.75	0.018
Project 14	0.71	0.71	0.57	0.50	0.86	0.67	0.193
Project 15	0.86	0.86	0.64	0.67	1.00	0.75	0.118
Project 16	0.86	0.86	0.57	0.75	0.57	0.75	0.003
Project 17	0.71	0.86	0.57	0.67	0.86	0.42	0.022
Project 18	0.71	0.57	0.43	1.00	0.64	1.00	0.080
Project 19	0.71	0.86	0.43	0.67	0.86	0.67	0.117
Project 20	0.86	0.71	0.43	0.67	0.86	0.75	0.168
Project 21	0.86	0.86	0.64	0.67	0.86	0.67	0.016
Project 22	0.71	0.86	0.57	0.75	0.86	0.42	0.105
Project 23	0.86	0.86	0.57	0.75	0.71	0.75	0.422
Project 24	0.64	0.86	0.64	0.67	0.64	0.67	0.283
Project 25	0.86	0.86	0.57	0.75	0.57	0.75	0.015
Project 26	0.71	0.86	0.57	0.67	0.86	0.42	0.077
Project 27	0.86	1.00	1.00	0.75	0.86	1.00	1.000

	Factors Group						
	Consultant	Contractor	Estimation	Project Characteristics	Owner	Environment	Overrun
Project 28	1.00	1.00	1.00	0.67	0.86	1.00	0.506
Project 29	0.86	0.86	0.86	0.75	0.64	1.00	0.569
Project 30	0.86	0.71	0.64	0.67	0.86	0.67	0.140
Project 31	1.00	1.00	0.71	0.83	0.86	0.67	0.042
Project 32	0.71	0.86	0.86	0.83	0.86	0.67	0.283
Project 33	0.86	0.57	0.71	0.75	0.71	0.67	0.962
Project 34	0.86	0.86	0.57	0.75	1.00	0.67	0.077
Project 35	1.00	1.00	0.43	0.67	0.86	0.75	0.077
Project 36	0.86	0.57	0.64	0.33	0.64	1.00	0.280
Project 37	0.64	0.71	0.29	0.25	0.57	0.83	0.203
Project 38	0.86	0.43	0.71	0.75	0.79	0.67	0.352

For the MLP and GFF models mentioned above with six nodes in the input layer, five nodes in the hidden layer, and one node in the output layer, the GoF indices are 0.864 and 0.835, respectively. These values exceed all the cut-off values in comparison of baseline values of GoFsmall = 0.1, GoFmedium = 0.25, and GoFlarge = 0.36. This shows that both models have substantial explaining power, however, MLP model gave better results.

Tables 11, 12 and 13 show that both models (MLP and GFF) gave relatively similar results, however, the MLP model with 6-5-1 configuration had less error and gave an accuracy of 95.2% compared to 93.7% of GFF model. Also the coefficient of determination, R^2 for MLP model was 0.893, which is higher than 0.861 of the GFF model. This means that the 6 groups in MLP model moderately explain 89.3% of the variance in cost overrun. This proves that the developed model has substantial explaining power to represent the relationship of construction groups of cost overrun towards cost overrun.

Table 11: 0.75m Hidden Layer NN Results

Model type	Network architecture	MAE	MAPE (Accuracy)	R	R^2
MLP	6-5-1	0.048	4.8% (95.2%)	0.945	0.893
GFF	6-5-1	0.063	6.3% (93.7%)	0.928	0.861

Table 12: m Hidden Layer NN Results

Model type	Network architecture	MAE	MAPE (Accuracy)	R	R^2
MLP	6-6-1	0.168	16.8% (83.2%)	0.826	0.682
GFF	6-6-1	0.193	19.3% (80.7%)	0.803	0.644

Table 13: 2m+1 Hidden Layer NN Results

Model type	Network architecture	MAE	MAPE (Accuracy)	R	R^2
MLP	6-13-1	0.184	18.4% (81.6%)	0.874	0.763
GFF	6-13-1	0.233	23.3% (76.7%)	0.831	0.690

Where: MAE is the mean absolute error, and MAPE is the mean absolute percentage error.

Based on loading results from NN model using MLP network, with six nodes in the input layer, five nodes in the hidden layer, and one node in the output layer, the two most influential groups determined by the model were “factors related to owner” and those “related to consultant”. Table 14 summarizes the main factors’ group influencing cost overrun in highway construction projects in Bahrain using NN model.

Table 14: Main Factors’ Group Influencing Cost Overrun in Highway Construction Projects in Bahrain (NN model results)

Factor	Weight	Rank
Factors related to owner	0.784	1
Factors related to consultant	0.773	2
Factors related to contractor	0.747	3
Factors related to environment	0.653	4
Factors related to project characteristics	0.642	5
Factors related to estimation	0.631	6

7. DISCUSSION

This section discusses and compares the results obtained in the previous section.

7.1 Frequency and Severity Results

Factors related to consultant: The respondents pointed out "estimator's experience" factor as the top affecting factor under this group with an importance index value of 70.55%. This result is supported by Azhar et al. [20], who confirmed that estimator's experience affects accuracy of cost estimating. "Lack of communication" is ranked in position number two with importance index value of 69.98%. "Lack of qualified project manager" is ranked in third position with importance index value of 68.62%. It can be noticed from Table 3 that all factors under this group have importance indices higher than 60%, indicating that all of them are highly affecting the accuracy of cost estimate.

Factors related to contractor: The results show that the most important factor affecting the pre-tender cost estimate is "communication with suppliers" as the top contributing factor to cost overrun with importance index value of 69.75%. This can be related to the fact that when the contractor communicates with the suppliers he will know the latest rates based on which he can prepare the cost estimate. "Lack of qualified project manager" with importance index value of 68.77% is ranked as second in this group. "Lack of project knowledge" is ranked at third position with importance index value of 67.20%. The factor ranked at the bottom of the list is "contractor's financial difficulties" with importance index value of 54.69%. This low value is related to the fact that highway construction contractors in Bahrain have good financial status, and therefore it is very rarely that they will have financial difficulties. Also, the second to last factor in the list is "inadequate contractors' experience" with importance index value of 55.46%. This can be related to the fact that MoW go through a thorough process for contractor pre-qualification and selection. All contractors who bid for a highway construction project are evaluated financially and technically, and those who don't pass the evaluation are disqualified.

Factors related to estimation: The results show that in first place with importance index value of 73.74% is the factor "estimator's experience", followed by "cost estimation methods" with importance index value of 72.48%. The top third factor in this group is "time allowed for preparing cost estimates" with importance index value of 71.20%. The factor ranked at the bottom of the list is "procedure for updating cost information" which has an importance value of 68.63%.

Factors related to project characteristic: The results show that in first place with importance index value of 64.78% is the factor "project size", followed by "project duration" with importance index value of 62.70%. The top third factor in this group is "location of project" with importance index value of 59.80%. It should be mentioned that only two factors of this group have importance index values of more than 60%. The factors "build-ability" comes at the bottom of the list with importance index value of 55.91%.

Factors related to owner: Eight factors are considered under this group. The top ranked factor is "frequent change orders/variations by owner" with importance index value of 78.55%. The second top factor in this group is "low speed in decision-making" with an importance index value of 77.36%. "Specification change" is ranked as the third top factor in this group with importance index value of 75.25%. All the factors of this group have shown importance index values of more than 71%.

Factors related to environment: The results show that in first place with importance index value of 64.85% is the factor "government interference. This factor is somehow similar to the factor "frequent changes made by the owner" in factors' group related to owner, which is intentionally added to ensure the results are accurate, i.e. for cross checking. However, it is considered here as an environmental factor. The second most ranked factor is "tender period and market condition" with importance value of 63.75%. "Cultural heritage issue" is the third top ranked factor with importance index value of 62.68%. Four factors have importance values of more than 60%, whereas, the remaining six have values of less than 60%.

Groups ranking: The results show that the top-affecting group is the owner related group (IMPI = 74.22%), followed by estimation related group (IMPI = 71.03%) and consultant related group (IMPI = 68.07%). The table also shows that the groups' importance indices are ranging from 59% to 74%, and the environment group is the one with the lowest importance index.

7.2 NN Model vs. Frequency and Severity Results

Both the model and the statistical results show that the owner's group factors are the most contributing factors to cost overrun in highway construction projects in Bahrain. However, the "consultant related factors" are ranked second by the model whereas the statistical approach ranked the "estimation related factors" in second place. This difference can be explained by the fact that statistical approach is based on opinions of stakeholders, the participants in the questionnaire, who believe that "estimation related factors" come as second. However, highway construction experts, who were interviewed about the causes of cost overrun in their 38 projects (data entered in the model), have agreed that the "estimation related factors" are ranked as the last factor contributing to cost overrun, whereas the "consultant related factors" are ranked as second.

Moreover, Table 15 shows that both approaches determined that "project characteristics related factors" group is ranked as fifth in contributing to cost overrun of highway construction projects in Bahrain.

Table 15: Comparison of Results Using Frequency and Severity, and Modeling Analysis

Factor	Model Ranking	Statistical Ranking
Factors related to owner	1	1
Factors related to consultant	2	3
Factors related to contractor	3	4
Factors related to environment	4	6
Factors related to project characteristics	5	5
Factors related to estimation	6	2

The contractor's contribution to cost overrun as determined by the model comes after the owner's and the consultant's. Thus, the model had identified that external factors leading to cost overrun such as environment, project characteristics, and estimation methods are not as significant as those related to the stakeholders of the highway construction project.

8. CONCLUSION AND RECOMMENDATIONS

8.1 Conclusion

This work identified and studied the factors causing cost overrun in highway construction projects in Bahrain. It studied the frequency and severity of the cost overrun factors as well as it had established a relationship between the factors' group and cost overrun.

Both the model and the statistical results show that the owner's group factors are the most contributing factors to cost overrun in highway construction projects in Bahrain. The top ranked factors in this group are "frequent change orders/variations by owner", "low speed in decision-making" and "specification change". The model results show that projects' stakeholders are the main contributors to cost overrun. External factors however such as: "factors related to environment"; "factors related to project characteristics"; and "factors related to estimation" have the least effect on cost overrun as determined by the model as they are ranked 4, 5, and 6 respectively.

However, frequency and severity results show that estimation is ranked as the second most influencing factor (ranked 6 by the model). This difference can be explained by the fact that frequency and severity approach is based on opinions of stakeholders, the participants in the questionnaire, who believe that "estimation related factors" come as second. However, highway construction experts, who were interviewed about the causes of cost overrun in their 38 projects (data entered in the model), have agreed that the "factors related to estimation" are ranked as the last factor contributing to cost overrun, whereas the "consultant related factors" are ranked as second.

8.2 Recommendations

This section presents general recommendations to minimize cost overrun in highway construction projects in Bahrain as follows:

1. Minimizing change orders during construction.
2. Selecting the bidder whose resources, capabilities and experience qualify him to construct the project, not necessarily the one who provides the lowest offer.
3. Considering the contractor financial status and level of experience before awarding the job. Contractors with strong financial status have the ability to do their duties on time, on budget, and with required quality.
4. Using risk assessment when estimating construction projects to help decision makers to define unforeseen situations more reliably ahead of time, so that corrective measures can be better taken into account in project design and estimating.
5. Prioritizing cost overrun factors in projects to have better risk contingency weightings in budget estimates.
6. Developing human resources through continuous training programs.
7. Using managers with high level of work experience and knowledge on managing the critical conditions. Good managers have the ability to run the project successfully with cost limitations.
8. Keeping unqualified and inexperienced staff under supervision, because unskilled employees impose slow progress of work, thus increases the cost overrun chances of occurrence.
9. Managing of financial resources and planning cash flow by utilizing progress payment.
10. Planning and scheduling should be done properly by the contractor, to ensure continuous progress of the project, and to match allocation of resources to the schedule requirements to avoid cost and time overruns.
11. Evaluating of total cost before undertaking a construction project contract. A contract price should not be over the financial ability of the company. Any financial problem in the project expenditures and payments will cause delay and cost overrun accordingly.
12. Staying in touch with the latest updates of construction technology and review the lessons learned from the previous successful projects. Take successful contractors as benchmarks.
13. Considering a detailed feedback from similar previously constructed projects is required from consultant and contractors.

The cost overrun developed model showed that stakeholders groups (owner, consultant and contractor) have a significant effect on cost overrun such as communication with suppliers, lack of experience, change orders,...etc. Construction managers should not overlook these basic elements as they have significant influence on cost overrun.

8.3 Future Work

The following can be recommended for future studies in the field of this research:

1. A comprehensive study can be done for all G.C.C. countries, on the highway construction projects cost overruns' causes and effects.
2. A cost estimation model can be developed, which estimates the cost of highway construction projects with acceptable accuracy.
3. A similar type of research can be done for other government infrastructure projects in Bahrain, such as sanitary and schools construction.

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