Effects of project’s physical characteristics on cost deviation in road construction

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Abstract This study is conducted to investigate the effect of projects’ physical characteristics on cost deviation in road construction using data from road construction projects awarded in the West Bank – Palestine over the years 2007–2010. The study is based on a sample of 74 road construction projects. Based on these data, regression models are developed. A questionnaire survey is also conducted to determine the impact of projects’ physical characteristics on cost deviation in road construction. The questionnaire survey included 14 owners, 30 contractors, and 25 consultants. The considered characteristics are: project size (i.e. small, medium, and large), estimated cost, road length, road width, terrain conditions, soil and rock suitability, and soil and rock drill ability. The results reveal that the average of cost deviation in road construction is 16.73%, ranging from −20.33% to 56.01%. The correlation between cost deviation in road construction projects and the above mentioned parameters is investigated.

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1. Introduction

The construction industry is the tool through which a society achieves its goals of urban and rural development (Enshassi et al., 2006). It has a great impact on the economy of all countries (Leibing, 2001). However, it is at or near the top in the annual rate of business failures and resulting liabilities compared to other industries (Chapman, 2001). This is because of the sophistciations of the construction process itself and the large number of parties involved in the construction process (i.e. clients, users, designers, regulators, contractors, suppliers, subcontractors, and consultants). The construction industry and its parties are associated with high degree of risk due to the nature of construction business activities, processes, environment and organization. Risk in construction has been the object of attention because of time and cost overruns associated with construction projects (Kartam and Kartam, 2001). According to Daniel and Andrew (2003), poor cost performance of construction projects seems to be the norm rather than the exception particularly in most developing countries where the problem is more acute.

Cost, time, and quality have their proven importance as the prime factors for project success. A project may not be regarded as a successful endeavor until it satisfies the cost, time, and quality limitations applied to it. However, it is not uncommon
to see a construction project failing to achieve its goal within the specified cost, time, and quality (Nega, 2008). The history of the construction industry is full of projects that were completed with significant cost overruns (Ameh et al., 2010).

In Palestine, the construction sector contributes to 26% of the Palestinian GDP (MAP, 2002). This is a relatively high proportion covered by this sector comparing to what is mentioned by Chitkara (2004) in that construction industry accounts 6–9% of GDP in many countries, thus it is strongly affecting various economic, social, and educational sectors. However, many local construction projects report poor performance due to many causes such as (Mahamid, 2011):

- experience in contracts,
- insufficient time for estimate,
- incomplete drawings,
- materials price fluctuation,
- political situation.

Therefore, attention should be paid to this important industry in order to figure out its main challenges and to be able to improve it.

This study aims at investigating the effect of project’s physical characteristics on cost deviation in road construction based on data collection for 74 projects awarded in the West Bank in Palestine over the years 2007–2010, and through questionnaire survey. The considered characteristics are: project size (i.e. small, medium, and large), estimated cost, road length, road width, terrain conditions, soil and rock suitability, and soil and rock drill ability.

2. Literature review

Many studies were conducted to investigate the size and causes of cost deviation in construction projects. Al-Zarooni and Abdou (2000) conducted a survey to investigate variations in UAE public projects’ estimates. They found that the variations (positive or negative) between feasibility and contract cost, ranging between −28.5% and +36%. They stated that these variations could be explained knowing that feasibility estimates in the government agencies are usually budgeted using a Single Unit Estimating (cost per square foot) basis, regardless of the nature of projects and their associated risks or the construction complexity of each building type.

Odeck and Skjeseth (1995) assessed Norwegian toll roads to reveal whether planning procedure shortcomings experienced by Norwegian road agencies had resulted in poorer than projected financial performances for some of the toll roads. They found overestimation of traffic forecasts and underestimation of construction costs. In their small sample of 12 toll projects, they found cost overruns on average at about 5%, but the interval was large from −210% to 170%.

Kaming et al. (1997) studied factors influencing time and cost performance on high-rise projects in Indonesia and concluded that cost and time overruns were very frequent. Omorogie and Radford (2006) reported a minimum average percentage escalation cost of projects in Nigeria to be 14%.

Akintoye (1998) conducted a study to gain an understanding of the factors influencing contractors’ cost estimating practice through a comparative study of 84 UK contractors classified into four categories, namely, very small, small, medium and large firms. The initial analysis of the 24 factors considered in the study shows that the main factors relevant to cost estimating practice are complexity of the project, scale and scope of construction, market conditions, method of construction, site constraints, client’s financial position, buildability, and location of the project.

Jahren and Ashe (1990) conducted a research on predictors of cost overrun rates. They investigated the influence of the following items on construction project cost-overrun rates: project size, construction type, number of bidders, and the percent difference between the government estimate and the award amount. They found that the shape of the frequency distribution for the cost-overrun rate changed with the size of the project. Cost overruns occurred more frequently for larger projects.

Studies have shown that the size of a construction project (contract amount) influences the rate of cost overrun: Randolph et al. (1987) conducted a study on municipal contracts in Lansing; they found that cost overrun rates decreased as the contract amount increased. While Rowland (1981) found that cost overrun rates increased with increase in the contract amount of construction projects from a study of Southern United States construction contracts.

Shash and Abdulhadi (1992) have identified the factors affecting the accuracy of cost estimating in construction projects in Saudi Arabia. They found that the project characteristics are main affecting factors in cost deviation in construction projects.

Odeck (2004) investigated the statistical relationship between actual and estimated costs of road construction using data from Norwegian road construction over the years 1992–1995. The findings reveal a discrepancy between estimated and actual costs, with a mean cost overrun of 7.9% ranging from −59% to +183%. In absolute terms, cost overruns amounted to a formidable 519 million Norwegian kroner. He concluded that one particular new finding that has not been shown before in previous studies is that cost overruns appear to be more predominant among smaller projects as compared to larger ones. He also concluded that the size of cost overruns can be influenced by completion time of the projects and the regions where projects are situated.

Al-khalidi (1990) 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.

Koleola and Henry (2008) concluded that the complexity of construction is one of the top six important factors affecting the accuracy of a pre-tender cost estimate in Nigerian construction projects.

Flyvbjerg et al. (2004) conducted a study of the causes of cost escalation in transport infrastructure projects. The study is based on a sample of 258 projects worth US$90 billion. The focus is on the dependence of cost escalation on (1) the length of the project-implementation phase and (2) the size of the project.

They found that for the length of the implementation phase the main findings are:

- Cost escalation is highly dependent on the length of the project implementation phase.
For every passing year from the decision to build until operations begin, the average increase in cost escalation is 4.64%.

And for the size of the project, they found that:

- For bridges and tunnels, larger projects have larger percentage cost escalations than do smaller projects; for rail and road projects, this does not appear to be the case.
- For all project types, the data do not support that bigger projects have a larger risk of cost escalation than do smaller ones; the risk of cost escalation is high for all project sizes and types.

Mbahu and Nkado (2004) conducted a study of reducing building construction cost in South Africa. The descriptive survey method was used involving qualitative data gathering through semi-structured interviews conducted with a convenience sample of twenty principal partners/directors of consulting and contracting firms at the pilot survey stage, and regional questionnaire surveys of 130 identified from various stakeholder groups. They stated that the cost overruns have obvious negative implications for the key stakeholders in particular, and the industry in general:

- “To the client, cost overrun implies added costs over and above those initially agreed upon at the onset, resulting in less returns on investment.
- To the end-user, the added costs are passed on as higher rental/lease costs or prices.
- To the professionals, cost overrun implies inability to deliver value-for-money and could well tarnish their reputations and result in the loss of confidence reposed in them by clients.
- To the contractor, it implies loss of profit through penalties for non-completion, and negative word of mouth that could jeopardize his/her chances of winning further jobs, if at fault.
- To the industry as a whole, cost overruns could bring about project abandonment and a drop in building activities, bad reputation, and inability to secure project finance or securing it at higher costs due to added risks”.

3. Research methodology

Two methodologies were used in this research: (1) developing regression models that relate cost deviation in road construction to the project’s physical characteristics based on field data (2) ranking of related project’s physical characteristic factors according to their impact on cost deviation in road construction from owners, contractors, and consultants’ view through a questionnaire survey.

3.1. Field data

Fig. 1a illustrates the steps of methodology (1). After establishing the objectives of the study, the needed data to achieve these objectives were collected from the West Bank – Palestine. The data analysis is carried out using an array of statistical methods that include regression analysis, t-test, and statistical modeling.

Based on the collected data, the discrepancies between actual and estimated cost were studied and used to derive the magnitude and direction of the ratio \( \lambda \) of deviation defined as:

\[
\lambda_i = ((\kappa - \epsilon)/\epsilon), \quad i = 1 \ldots n
\]

where \( \kappa \) is the actual cost and \( \epsilon \) is the estimated cost.

3.1.1. Data collection

To investigate the cost deviation in construction projects, an extensive historical data are required. The data were collected from contracts awarded by the Palestinian agencies who are the clients of road construction projects in the West Bank. The collected data comprised of 74 projects to investigate cost deviation in road construction projects. The projects awarded over the years 2007–2010. The data were tabulated to ensure that all costs were considered, none is double-counted and all are clearly defined.

All the data were deflated to year 2010. The construction cost index of 2010 obtained from Palestinian Economic

<table>
<thead>
<tr>
<th>Year</th>
<th>2007</th>
<th>2008</th>
<th>2009</th>
<th>2010</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cost index</td>
<td>0.86</td>
<td>0.94</td>
<td>0.96</td>
<td>1</td>
</tr>
</tbody>
</table>
Council for Development and Reconstruction (PECDAR) is used to deflate the data. Table 1 shows the index values over the years 2007–2010, the base year is 2010 (construction index = 1).

To deflate the cost of a project in a certain year to cost in year 2010, the cost is divided by the cost index value of that year.

The collected data were classified based on their cost as shown in Table 2.

Attention was paid to the following points during data collection:

1. Distribution among year of awarding.

A consideration is taken to have an approximately equal number of awarded projects in each year over the years 2007–2010. Table 3 shows the distribution of projects over the award year in the collected data (see Table 4).

2. Projects’ category.

A consideration is taken to have approximately equal distribution for collected data based on projects size. The following table shows the distribution of projects size in the collected data.

It is worthy to be mentioned that in all road construction projects in the West Bank, the contract type is unit price contract and the followed bidding mechanism is design-bid-build mechanism. The uniformity of these parameters will decline the impact resulted from the variation of such parameters on the research results.

### 3.1.2. Model development

Once the variables to be included in the proposed models have been identified, a series of mathematical models were developed using multiple regression analysis techniques. Linear regression model is selected to find the linear combination of independent variables which best correlates with dependent variables. The regression equation is expressed as follows:

\[ Y = C + b_1X_1 + b_2X_2 + \ldots + b_nX_n \]  

\( C \): regression constant,  
\( b_1, b_2, \ldots, b_n \): regression estimates,  
\( X_1, \ldots, X_n \): independent variables,  
\( Y \): dependent variable.

Excel statistical tools were employed to perform regression analyses and to test the significance of a model.

### 3.2. Questionnaire survey

Four identified factors related to project physical characteristics that might affect cost deviation in road construction are listed in a questionnaire form. A questionnaire was developed in order to evaluate the importance of the identified factors from contractors’, consultants, and owners’ view. Data were gathered through a survey, analyzed by using importance index.

The respondents included 30 contractors, 25 consultants, and 14 owners out of 40, 35, and 20 distributed questionnaires, respectively. The respondents have an average of experience of more than 10 years. Simple random sampling was used to select the participants from an available list.

For each factor a question was asked: what is the impact level of this factor on project cost deviation? Impact level was categorized on a five-point scale as follows: very high, high, moderate, low, and very low (on 5 to 1 point scale).

The information collected from the questionnaire is analyzed statistically by using Excel statistical tools. The suggested factors are ranked by the measurement of the importance index according to the following formula.

Importance index (%) = \( \frac{\sum a(n/N) \times 100}{5} \)  

where

- \( a \) is the constant expressing weighting given to each response (ranges from 1 for very low influence up to 5 for very high),
- \( n \) is the frequency of the responses,
- \( N \) is total number of responses.

### 4. Results and findings

#### 4.1. Field data analyses

#### 4.1.1. Analysis of cost deviation

A statistical analysis of 74 road construction projects reveals the following findings in studying the cost deviation in road construction projects.

Table 5 shows the analysis of cost under estimation in road construction projects based on project’s category. It shows that
the small projects have the highest average of cost under estimation of 24.88%, while large projects have the smallest average of 15.9%.

Table 6 shows the analysis of cost over estimation in road construction projects based on project’s category. It shows that the large projects have the highest average of cost over the estimation of 8.2%, while medium projects have the smallest average of 2.15%. It can be seen that there is no small project with cost over estimation.

Table 7 shows the analysis of cost deviation in road construction projects based on project’s category. It shows that the small projects have the highest average of cost deviation of 24.88%, while large projects have the smallest average of 12.32%. The table reveals that the average of cost deviation in 74 road construction projects is 16.73%, ranging from 20.33% to 56.01%.

Fig. 1(b) illustrates the cost over and under estimation in 74 road construction projects based on project’s category. 4.1.2. Cost deviation vs project size

Linear regression models that relate cost deviation in road construction projects to the project size have been developed. The results are shown in Table 8. The analysis of variance test confirmed the statistical significance of the models at a significance level of 0.05. The results of coefficients of determination $r^2$ for both models indicate a good correlation between cost deviation and project size. Usually, as the project size increase, its resources increase. Consequently more control is required to maintain the project performance in terms of cost, time, and quality. In case of large projects, former experience and teams’ communication and coordination are considered to be key issues for project success.

4.1.3. Cost deviation vs road length and width

Regression models that describe the cost deviation in road construction as a function of road length and width were developed. Two cases were considered as shown in Table 9:

Table 8 Cost deviation in road construction vs project size.

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Variables</th>
<th>Coef.</th>
<th>$r^2$</th>
<th>p-Value</th>
<th>Best fit model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X1: project size (m²)</td>
<td>1.42</td>
<td>0.63</td>
<td>1.16E-06</td>
<td>Cost deviation ($) = 1.42X1</td>
</tr>
<tr>
<td>2</td>
<td>X2: project’s estimated cost ($)</td>
<td>0.084</td>
<td>0.71</td>
<td>2.1E-06</td>
<td>Cost deviation ($) = 0.084X2</td>
</tr>
</tbody>
</table>

Table 9 Cost deviation in road construction vs road length and width.

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Variables</th>
<th>Coef.</th>
<th>$r^2$</th>
<th>p-Value</th>
<th>Best fit model</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X3: road length (m)</td>
<td>14.74</td>
<td>0.48</td>
<td>0.001</td>
<td>Cost deviation ($) = 14.74X3 – 80.33 X4</td>
</tr>
<tr>
<td>2</td>
<td>X3: road length (m)</td>
<td>14.58</td>
<td>0.54</td>
<td>3.34E-6</td>
<td>Cost deviation ($) = 14.58X3</td>
</tr>
</tbody>
</table>

Effects of project’s physical characteristics on cost deviation in road construction 85
Model 1: it includes road length as independent variable.
Model 2: it includes road length and road width as independent variables.

The \( p \)-value of road width variable is higher than 0.05 in model 1, meaning that it is not significant to be used in the model. Therefore, model 2 is considered to develop regression model using road length only as independent variable. The analysis of variance test confirmed the statistical significance of the model at a significance level of 0.05.

The coefficients of determination \( r^2 \) for both models are 0.48 and 0.54, respectively, indicating a fair correlation between the cost deviation in road construction and road length and width.

### 4.1.4. Cost deviation vs project's physical characteristics

Regression models that describe the cost deviation in road construction as a function of project's physical characteristics are presented. Three physical characteristics are considered: terrain conditions, soil and rock suitability, and soil and rock drill ability. The dummy variables technique is used to describe the models. The explanation of the models is as follow:

The developed models are of the form:

\[
Y = \gamma_1 D_1 + \gamma_2 D_2 + \gamma_3 D_3
\]

where:
- \( Y \) is the dependent variable (cost deviation in road construction project in US dollar).
- \( D_i \): qualitative variables (dummy variables) which are:
  - \( D_1 \): regression variables of terrain conditions such that:

<table>
<thead>
<tr>
<th>Terrain condition</th>
<th>( D_1 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Semi even</td>
<td>0</td>
</tr>
<tr>
<td>Hilly</td>
<td>1</td>
</tr>
</tbody>
</table>

- \( D_2 \): regression variables of soil and rock drill ability such that:

<table>
<thead>
<tr>
<th>Soil and rock drill ability</th>
<th>( D_2 )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Good</td>
<td>0</td>
</tr>
<tr>
<td>Poor</td>
<td>1</td>
</tr>
</tbody>
</table>

The drill ability is considered to be good when it could be excavated easily with good production rate.

- \( D_3 \): regression variables of soil and rock suitability to be used for fill and base material such that:

The developed models of the form:

\[
Y = \gamma_1 D_1 + \gamma_2 D_2 + \gamma_3 D_3
\]

### Table 10 Cost deviation in road construction vs project's physical characteristics.

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Variables</th>
<th>Coef.</th>
<th>( r^2 )</th>
<th>( p )-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Terrain condition</td>
<td>54293.62</td>
<td>0.41</td>
<td>8.72E-6</td>
</tr>
<tr>
<td>2</td>
<td>Soil and rock suitability</td>
<td>42957.5</td>
<td>0.38</td>
<td>0.001</td>
</tr>
<tr>
<td>3</td>
<td>Soil and rock drill ability</td>
<td>39914.55</td>
<td>0.48</td>
<td>0.001</td>
</tr>
<tr>
<td>4</td>
<td>Terrain condition</td>
<td>53827.13</td>
<td>0.32</td>
<td>0.004</td>
</tr>
</tbody>
</table>

### Table 11 Cost deviation in road construction vs combination of road size and physical characteristics.

<table>
<thead>
<tr>
<th>Model No.</th>
<th>Variables</th>
<th>Coef.</th>
<th>( r^2 )</th>
<th>( p )-Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Project size (m²)</td>
<td>1.08</td>
<td>0.53</td>
<td>0.0005</td>
</tr>
<tr>
<td>2</td>
<td>Terrain condition</td>
<td>41797.93</td>
<td>0.021</td>
<td>0.001</td>
</tr>
<tr>
<td>3</td>
<td>Soil and rock suitability</td>
<td>2248.4</td>
<td>0.891</td>
<td>0.001</td>
</tr>
<tr>
<td>4</td>
<td>Soil and rock drill ability</td>
<td>-21360.7</td>
<td>0.258</td>
<td>0.001</td>
</tr>
<tr>
<td>5</td>
<td>Road length (m)</td>
<td>14.17</td>
<td>0.58</td>
<td>0.002</td>
</tr>
<tr>
<td>6</td>
<td>Road width (m)</td>
<td>-290.40</td>
<td>0.896</td>
<td>0.001</td>
</tr>
<tr>
<td>7</td>
<td>Terrain condition</td>
<td>33861.82</td>
<td>0.065</td>
<td>0.001</td>
</tr>
<tr>
<td>8</td>
<td>Soil and rock suitability</td>
<td>-3013.5</td>
<td>0.857</td>
<td>0.001</td>
</tr>
<tr>
<td>9</td>
<td>Soil and rock drill ability</td>
<td>-24546.9</td>
<td>0.189</td>
<td>0.001</td>
</tr>
<tr>
<td>10</td>
<td>Terrain condition</td>
<td>18,006</td>
<td>0.56</td>
<td>0.0005</td>
</tr>
</tbody>
</table>

Table 10 shows the regression models of cost deviation in road construction project (dependent variable) as a function of project physical characteristics (independent variables), four models are developed. It can be seen that \( r^2 \) values for the developed models are ranging from low to fair (i.e. 0.32–0.44), indicate weak linear relationship between dependent and independent variables.

### 4.1.5. Cost deviation vs combination of road size and physical characteristics

Regression models that describe the cost deviation in road construction as a function of a combination of project size and projects’ physical characteristics are shown in Table 11. The developed models are of the following form:

\[
Y = C + b_1 X_1 + b_2 X_2 + \ldots + b_n X_n + \gamma_1 D_1 + \gamma_2 D_2 + \gamma_3 D_3
\]

Where,
- \( Y \): dependent variable,
- \( C \): regression constant,
- \( b_1, b_2, \ldots, b_n \): regression estimates,
- \( X_1, \ldots, X_n \): independent variables (road length, road width, and road size),
- \( D_i \): dummy variables (terrain condition, soil suitability, and soil and rock drill ability).
The study of cost deviation in road construction based on 74 projects awarded in the West Bank in Palestine over the years 2007–2010, reveals that the average of cost deviation in road construction projects is 16.73%, ranging from 5.60% to 20.33%. The statistical analyses of cost deviation of 74 road construction projects indicates the following:

1. 100% of the project suffers from cost deviation.
2. The cost under estimation is more predominant in road construction projects.
3. Weak linear relation between cost deviation in road construction and project’s physical characteristics such as terrain conditions, soil rock suitability, and soil and rock drill ability.
4. Good correlation between project size and cost deviation in road construction project.
5. Moderate correlation between cost deviation in road construction and a combination of road size (m²) and its physical characteristics (i.e. terrain conditions, soil rock suitability, and soil and rock drill ability).

The questionnaire survey included responses of 30 contractors, 25 consultants and 14 owners about the impact of projects’ physical characteristics on cost deviation in road construction reveals the following:

- Project size has high impact on cost deviation in road construction.
- Soil and rock suitability has moderate impact on cost deviation in road construction.
- Soil and rock drill ability has moderate impact on cost deviation in road construction.
- Terrain condition has moderate impact on cost deviation in road construction.

It is recommended to pay attention to these parameters at the time of project cost estimating, therefore, a comprehensive investigation to the project site before and during design and bidding phases shall be conducted. More detailed studies are recommended to show how these parameters may affect the cost overrun (i.e. to build models for their impact on productivity, to test how the project size affects the construction parties communication and how it affects the resource management).

It should be kept in mind that the statistical data are never accurate as project condition. The results are just approximate assessment and are not to be taken as hard facts. This is the nature of construction projects with their inherent variability and situation dependence.

### References


