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Analysis of Cost Deviations in Road Construction Activities: A Case Study from Palestine

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ABSTRACT

This study investigates the statistical relationship between actual and estimated cost of road construction activities. It is based on a sample of 100 road construction projects awarded in the West Bank in Palestine over the years 2004 - 2008. Based on this data, regression models were developed. The investigated construction activities in this study are earthworks, base works, asphalt works and furniture works. The findings reveal that the average cost deviation in the investigated activities is as follows: earthworks= -15.7%, base works = 12.9%, asphalt works = 18.5% and furniture works = 36.4%. The relationship between cost divergence of each investigated activity and physical project characteristics (i.e. project size, terrain condition, ground condition and soil quality) is discussed.

KEYWORDS: Cost analysis, Deviation, Road construction, Road activities, Construction in Palestine.

INTRODUCTION

Cost deviation may be expressed as a percent difference between the final cost of the project (actual cost) and the contract award amount (estimated cost). The construction industry and its clients are widely associated with a 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, 2001). Generally, the success measure for a project is defined by accomplishing it within specified cost, time and quality. However, the construction industry is full of projects that were completed with significant time and cost overruns (Amhel et al., 2010).

In Palestine, the local construction industry is one of the main economic driving sectors, supporting the Palestinian national economy. It contributes to 26% of the Palestinian GDP (MAP, 2002). This is a relatively high proportion covered by this sector compared to what is mentioned by Chitkara (2004) stating that construction industry accounts for 6-9 % of GDP in many countries. However, many local construction projects report poor performance due to many causes such as (UNRWA 2006):

- Unavailability of materials.
- Excessive amendments of design and drawings.
- Poor coordination among participants.
- Ineffective monitoring and feedback.
- Lack of project leadership skills.

Mahamid et al. (2010) conducted a study to investigate the statistical relationship between actual and estimated cost of road construction projects using data from Palestinian road construction projects awarded over

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the years 2004 to 2008. The study was based on a sample of 169 road construction projects. The findings revealed that 100% of projects suffer from cost divergence. It was found that 76% of the projects have cost underestimation and 24% have cost overestimation. The discrepancy between estimated and actual cost has an average of 14.56%, ranging from -39.3% to 98%.

This study presents the statistical relationship between actual and estimated cost of road construction activities based on a sample of 100 road construction projects from the West Bank. The investigated construction activities in this study are earthworks, base works, asphalt works and furniture works (i.e., furniture works include concrete works, surveying, retaining walls, side walls, side walks, painting works, curb stone works, culverts, ditches, guard rails and cat eyes).

Objectives

The objectives of this study are:

- To reveal the magnitude and direction of cost deviation in major activities in road construction projects awarded in the West Bank.
- To address the relationship between estimated cost and actual cost of each investigated activity.
- To develop mathematical models that describe the cost divergence in each of the considered activities as a function of physical project characteristics.

LITERATURE REVIEW

A study by Skamris et al. (1996) compared the accuracy of traffic forecasts and cost estimates on large transportation projects in Denmark. The main conclusion from this study was that cost overrun of 50-100% is common for larger transportation infrastructure projects and that overruns above 100% are not unusual.

Al-Momani (1996) conducted a study of construction cost prediction for public school buildings in Jordan. The study covered 125 school projects carried out in Jordan in the period 1984-1994. The results indicated that the actual cost (i.e., at the time of project completion) exceeds the original contract price by 30% while change orders result in a cost overrun of 8.3%.

Al-Zarooni et al. (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 range between -28.5% and +36%.

Odeck et al. (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 of about 5% on average, but the interval was large, ranging from -210% to 170%.

Omoregie et al. (2006) reported a minimum average percentage escalation cost of projects in Nigeria of 14%; whereas the minimum average percentage escalation period of projects in Nigeria was found to be 188%.

Flyvbjerg et al. (2002) found that cost escalation strongly depends on the length of the project-implementation phase, the size of the project and the type of project ownership.

Odeck (2004) found a new finding that has not been shown before in previous studies. This finding is that cost overruns appear to be more predominant among smaller projects as compared to larger ones. Other factors found to influence the size of cost overruns include completion time of the projects and the regions where the projects are situated.

RESEARCH METHODOLOGY

After establishing the objectives of the study, the needed data to achieve these objectives were collected from road construction projects awarded in the West Bank over the years 2004-2008. Then, the data were analyzed using an array of statistical methods that include descriptive statistics, correlation analysis, t-test and statistical modeling.

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

$$\lambda_i = ((\kappa-\varepsilon)/\varepsilon)_i \qquad i = 1 \ldots n \qquad (1)$$

where κ is the actual cost and ε is the estimated cost.

A series of mathematical models were developed using linear regression analysis to describe the relation between actual cost and estimated cost of each investigated activity.

RESULTS AND DISCUSSION

Projects' Cost Distribution

Figure 1 shows the projects' cost distribution among construction activities in road construction based on statistical analysis for the cost of 100 road construction projects considered in this study. It can be seen that asphalt works represent the highest proportion of the total cost (48%), followed by base works (24%), furniture works (21%) and earthworks (7%).

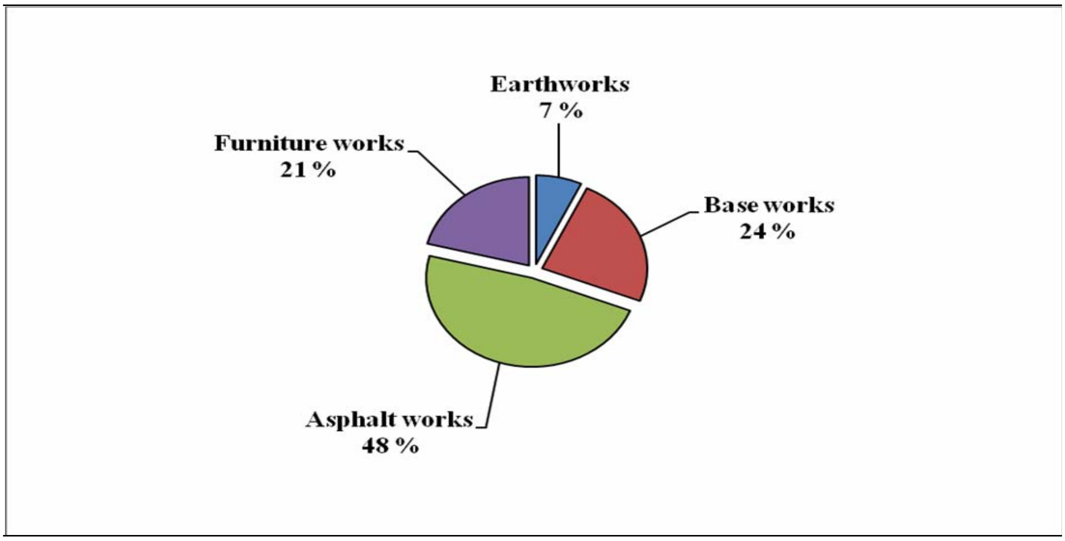

Figure 1: Projects' Cost Distribution among Construction Activities in 100 Road Projects

Table 1. Analysis of Cost Underestimation in Road Construction Activities

Activity	No. of projects	No. of projects (%)	Range (%)	Average (%)
Earthworks	37	37%	0.13 - 96.23	28.98
Base works	73	73%	1.13 - 85.50	20.75
Asphalt works	88	88%	0.83 - 92.5	22.25
Furniture works	82	82%	1.97 - 124.13	51.57

Analysis of Cost Deviation in Road Construction Activities

A statistical analysis for 100 road construction projects revealed the following findings in studying the cost deviation in road construction activities. Table 1 shows the analysis of cost underestimation in road construction activities. Table 2 shows the analysis of cost overestimation in road construction activities.

Table 3 shows the results of cost deviations in road construction activities. Figure 2 shows the summary of cost overestimation and underestimation in road construction activities.

Table 2. Analysis of Cost Overestimation in Road Construction Activities

Activity	No. of projects	No. of projects (%)	Range (%)	Average (%)
Earthworks	63	63%	0.76 – 84.73	41.48
Base works	27	27%	0.12 – 25.04	8.76
Asphalt works	12	12%	0.64 – 30.86	8.65
Furniture works	18	18%	0.84 – 73.66	21.64

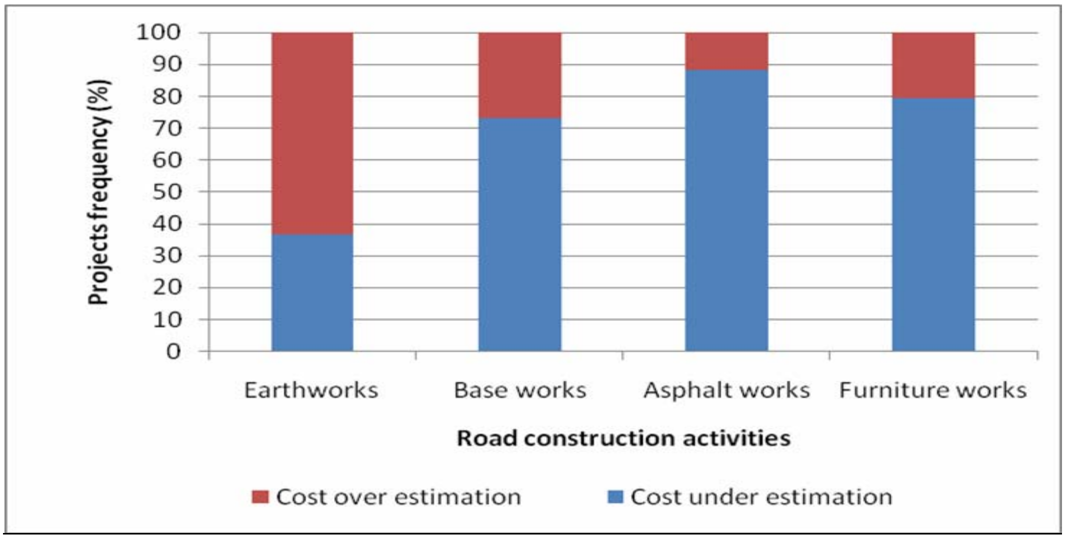

Figure 2: Frequency of Cost Overestimation and Underestimation in Construction Activities of 100 Road Projects

Table 3. Cost Deviation in Road Construction Activities

Activity	Projects with cost deviation (%)	Average of cost deviation (%)
Earthworks	100%	-15.7
Base works	100%	12.9
Asphalt works	100%	18.5
Furniture works	100%	36.4

Classification of Cost Deviation in Road Construction Activities

Classification of Cost Deviation in Earthworks

Figure 3 shows that most of the projects that have significant cost overestimation are within 10% to 70%. Figure 4 shows that most of the projects that have cost underestimation are located within the range of 10% to 30%.

Classification of Cost Deviation in Base Works

Figures 5 and 6 show the classification of cost deviation in base works. It can be seen that most of projects that have significant cost overestimation in base works are within the range of 10% to 30% and the projects that have significant cost underestimation are within the range of 10% to 20%.

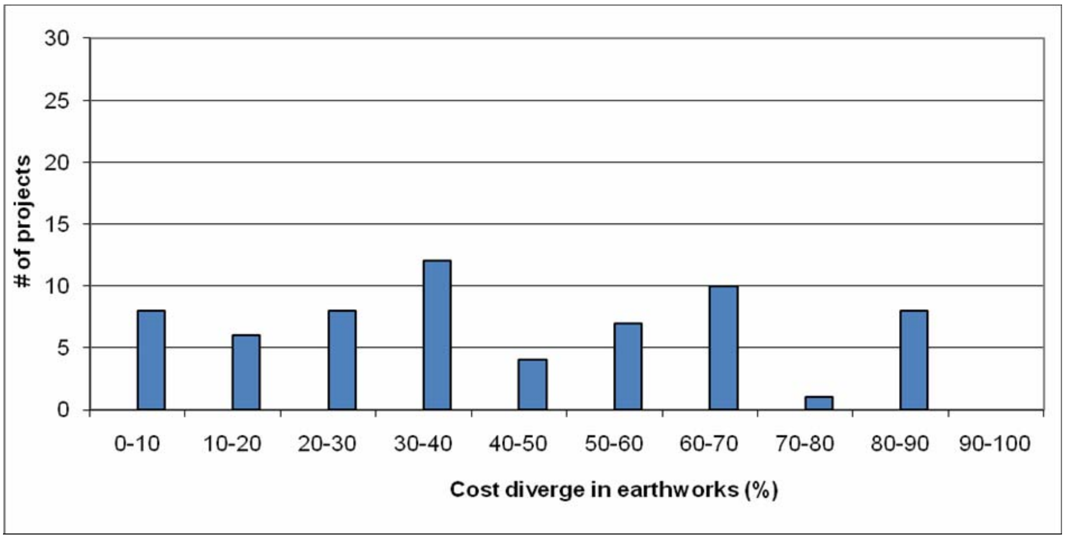

Figure 3: Classification of Cost Overestimation in Earthworks

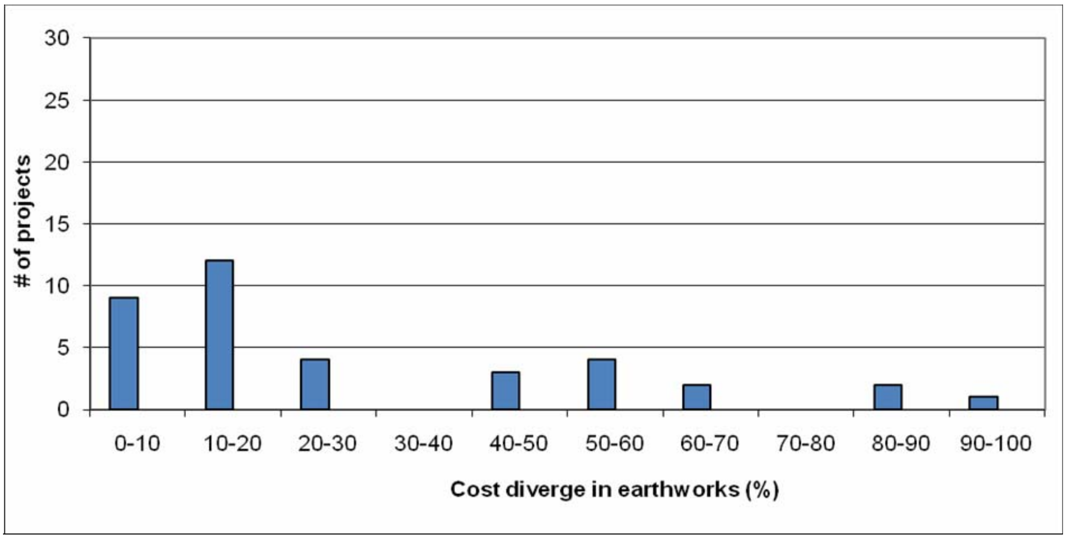

Figure 4: Classification of Cost Underestimation in Earthworks

Classification of Cost Deviation in Asphalt Works

Figure 7 shows the classification of cost overestimation in asphalt works. It shows that most of projects that have significant cost overestimation in asphalt works are within the range of 0 to 10%. Figure 8 indicates that most of projects that have cost underestimation are located within the range of 10% to 50%. The figures show that cost underestimation is more predominant in asphalt works than cost overestimation. It is clear that the cost deviation in asphalt works is alarming since its average cost proportion from the total project cost is high (48%) and the cost deviation is also high.

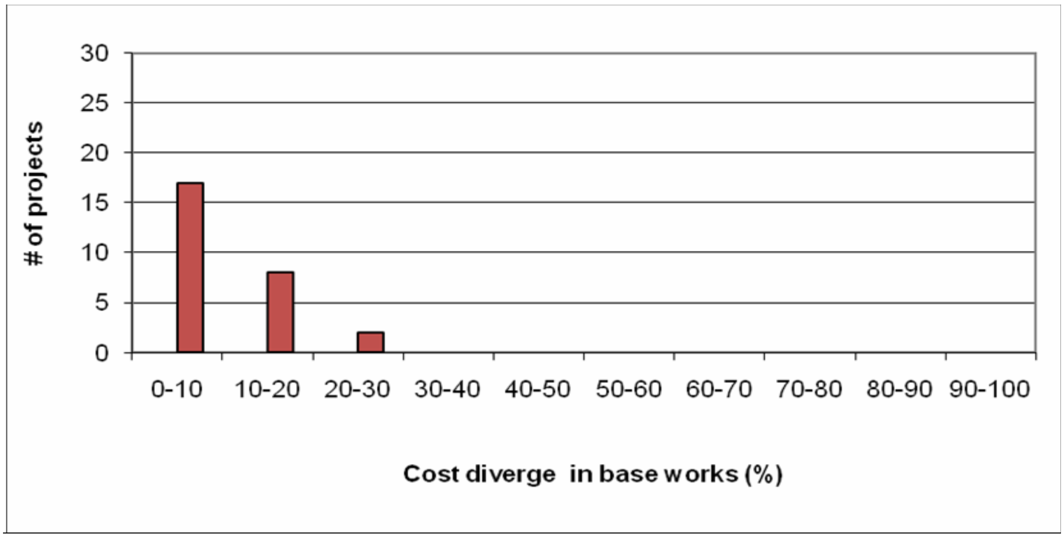

Figure 5: Classification of Cost Overestimation in Base Works

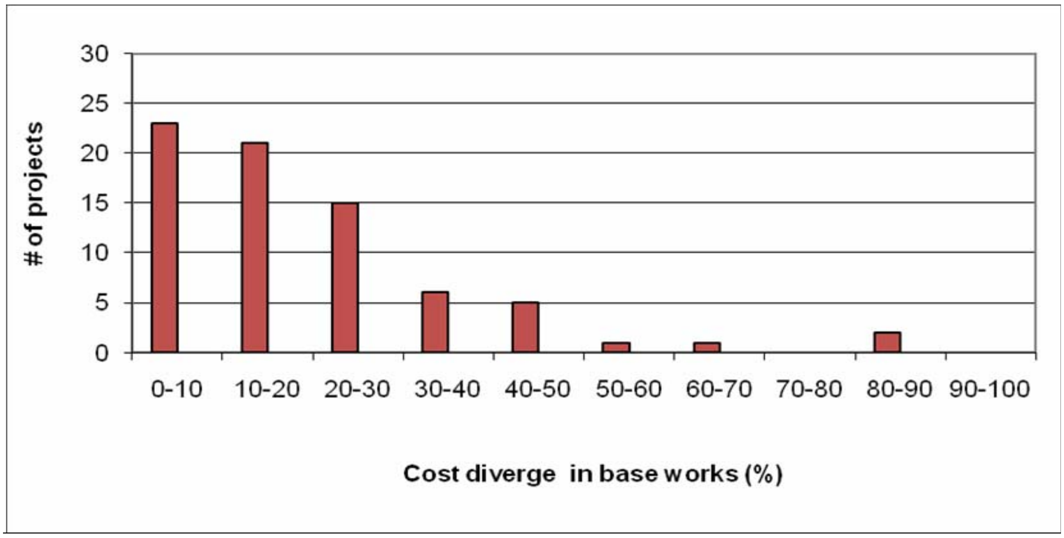

Figure 6: Classification of Cost Underestimation in Base Works

Classification of Cost Deviation in Furniture Works

Figures 9 and 10 show the classification of cost deviation in furniture works. It can be seen that most of projects that have significant cost underestimation in furniture works are within the range of 10% to 40%; while the projects that have cost overestimation are located within the range of 10% to 80%. Attention to cost deviations in furniture works should be paid since it has high frequency and value.

Cross-Tabulation for Activities' Cost Deviation

The cross-tabulation of cost deviation in road construction activities was tested. 6 groups were identified, which are:

- Asphalt works *vs* earthworks.
- Asphalt works *vs* base works.
- Asphalt works *vs* furniture works.
- Base works *vs* earthworks.
- Base works *vs* furniture works.
- Furniture works *vs* earthworks.

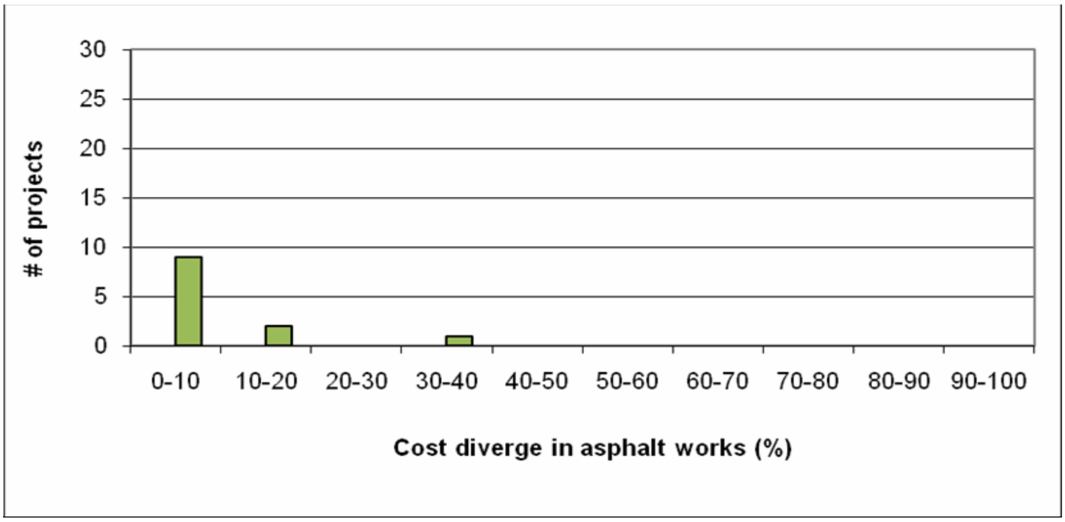

Figure 7: Classification of Cost Overestimation in Asphalt Works

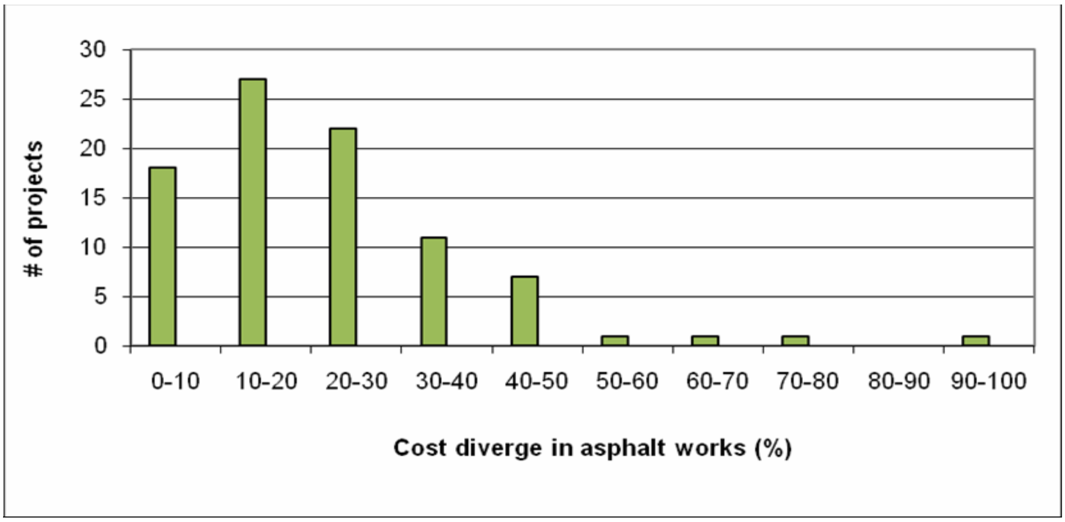

Figure 8: Classification of Cost Underestimation in Asphalt Works

The results show that there is a weak correlation between cost deviations in different activities. Figure 11 shows cost deviation in earthworks *vs*. cost deviation in base works. The result shows that $r^2 = 0.13$ which indicates a weak correlation. This r^2 value is the highest among all the mentioned groups.

Regression Models

Actual Cost *vs* Estimated Cost

A linear relationship between estimated cost and actual cost for each road construction activity is discussed in this section. Figure 12 indicates a good linear relation between actual cost and estimated cost for earthworks with $r^2 = 0.9102$. The regression equation shown on the graph indicates that actual cost is less that estimated cost for earthworks.

Figure 13 shows the relation between estimated cost and actual cost for base works. The equation shows that actual cost is higher than estimated cost for base works and $r^2 = 0.9651$, which indicates a good linear relationship between actual cost and estimated cost.

Figure 14 shows the relation between estimated cost and actual cost for asphalt works. The equation shows that actual cost is higher than estimated cost for asphalt works and r^2 = 0.9709, which indicates a good linear relationship between them.

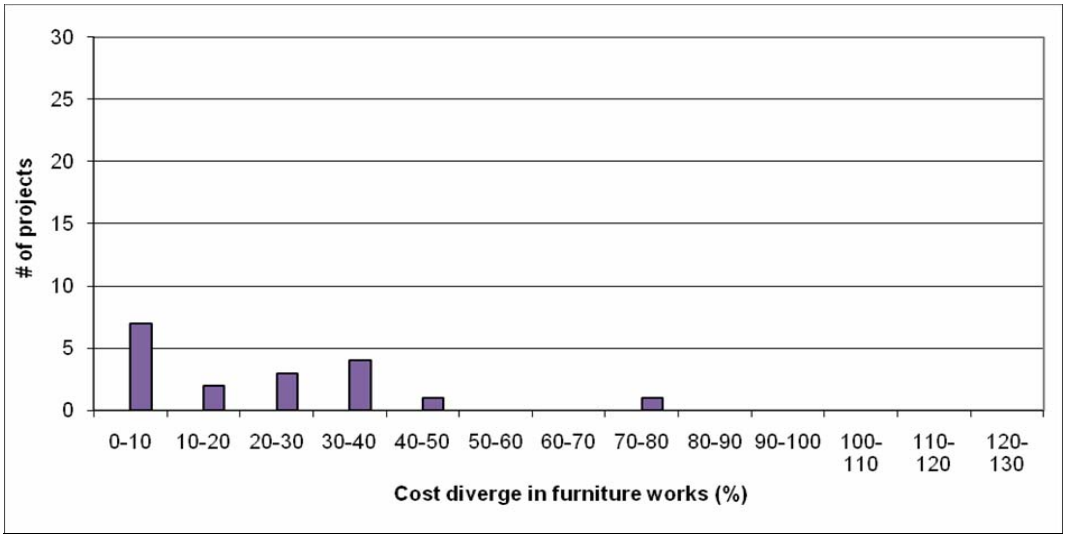

Figure 9: Classification of Cost Overestimation in Furniture Works

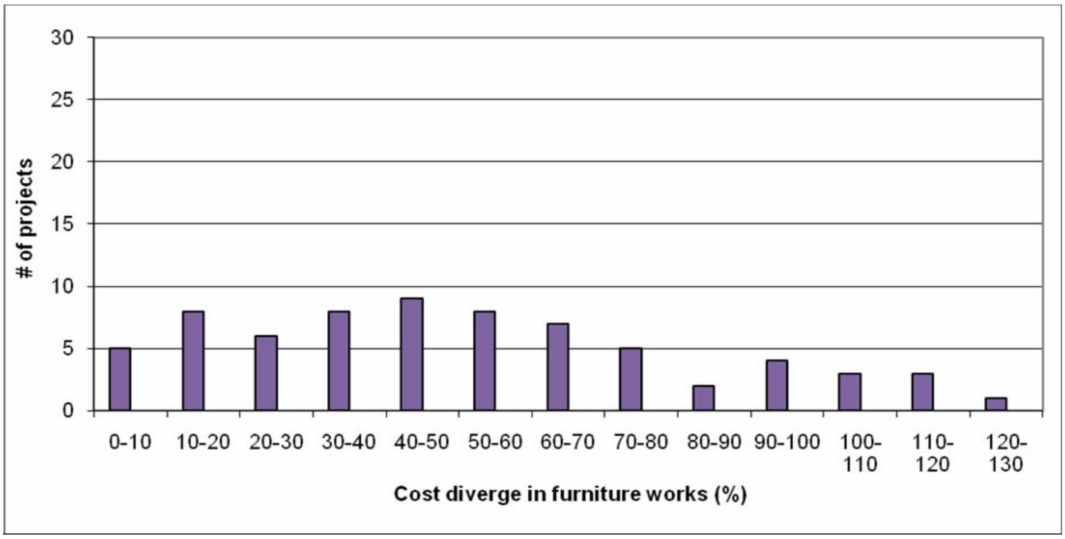

Figure 10: Classification of Cost Underestimation in Furniture Works

Figure 15 shows the relation between estimated cost and actual cost for furniture works. The equation is:

Actual cost ($) for furniture works = 24412 + 0.8284∗ estimated cost ($)

The equation indicates the following:

- When the estimated cost = $ 143600 and by substitution in the equation, the actual cost will be equal to the estimated cost (i.e., no cost deviation).
- When the estimated cost is higher than $143600, then the actual cost will be less than the stimated cost (i.e., cost overestimation).
- When the estimated cost is less than $143600, then the actual cost is higher than the estimated cost (i.e.,

cost underestimation).

- r^2=0.876, which indicates a good linear relationship.
- As many of the projects under study are small in size (i.e., furniture cost is less than $100000), the constant of 24412 in the equation indicates a high percentage of cost underestimation in furniture works.

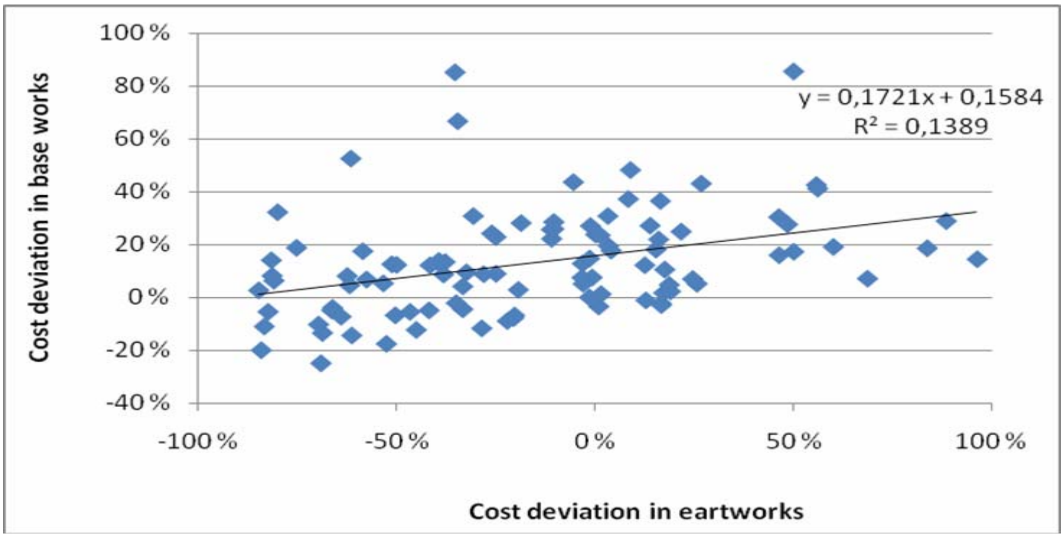

Figure 11: Cost Deviation in Earthworks *vs* Cost Deviation in Base Works

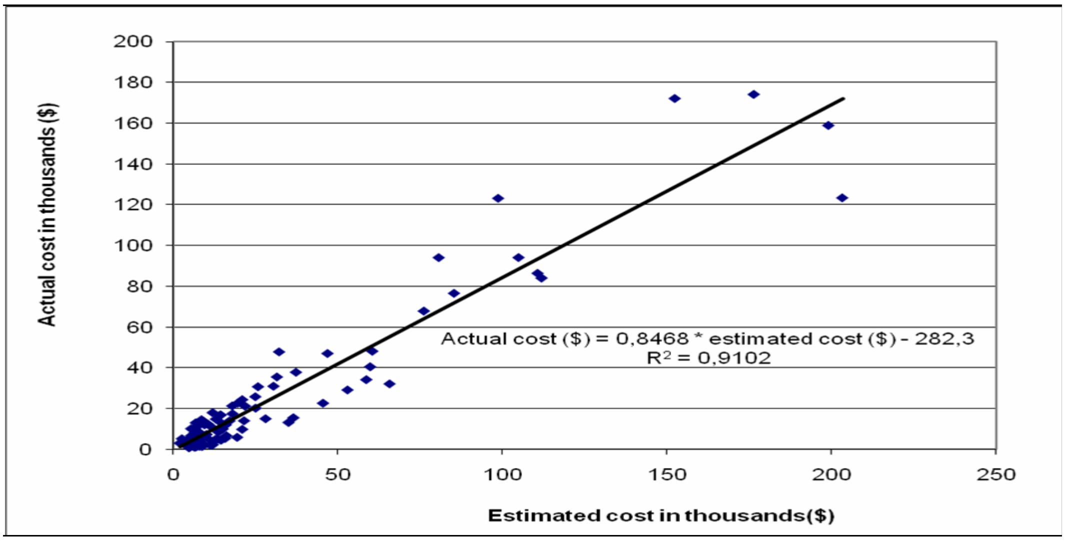

Figure 12: Actual Cost *vs* Estimated Cost in Earthworks

Cost Deviation *vs* Estimated Cost

The relation between cost deviation and estimated cost for each activity in road construction is shown in the following scatter diagrams. They reveal a weak linear relationship between cost deviation and estimated cost of road construction activities.

Linear regression models that relate cost deviation with estimated cost for each activity were developed.

The results show a weak linear relation between them. The results are shown in Table 4. The p-value for intercepts is higher than 0.05 for earthworks, base works and asphalt works, meaning that it is not significant to include them in the models; while it is less than 0.05 for furniture works. The analysis of variance test confirmed the statistical significance of the models at a significance level of 0.05.

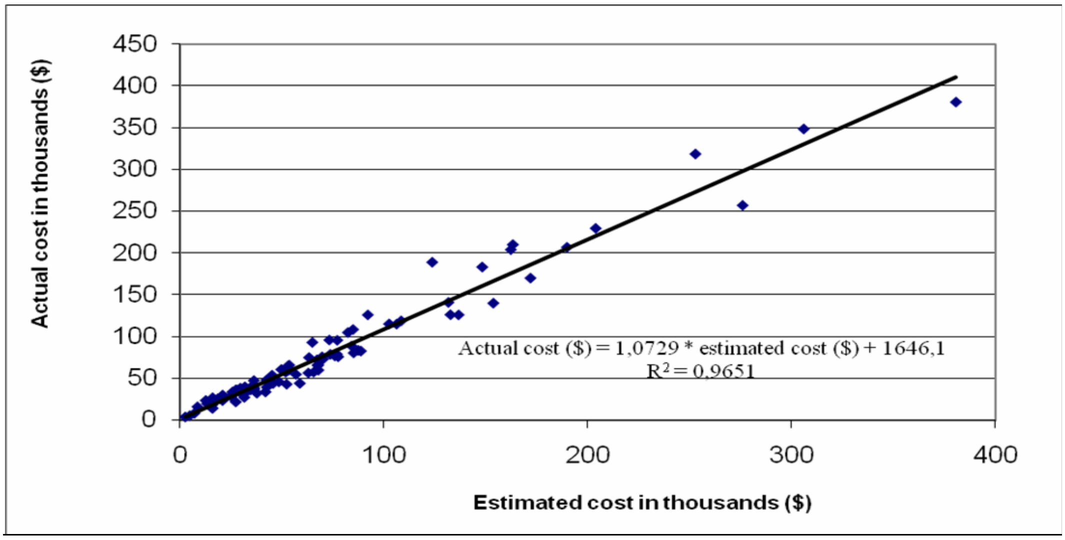

Figure 13: Actual Cost *vs* Estimated Cost in Base Works

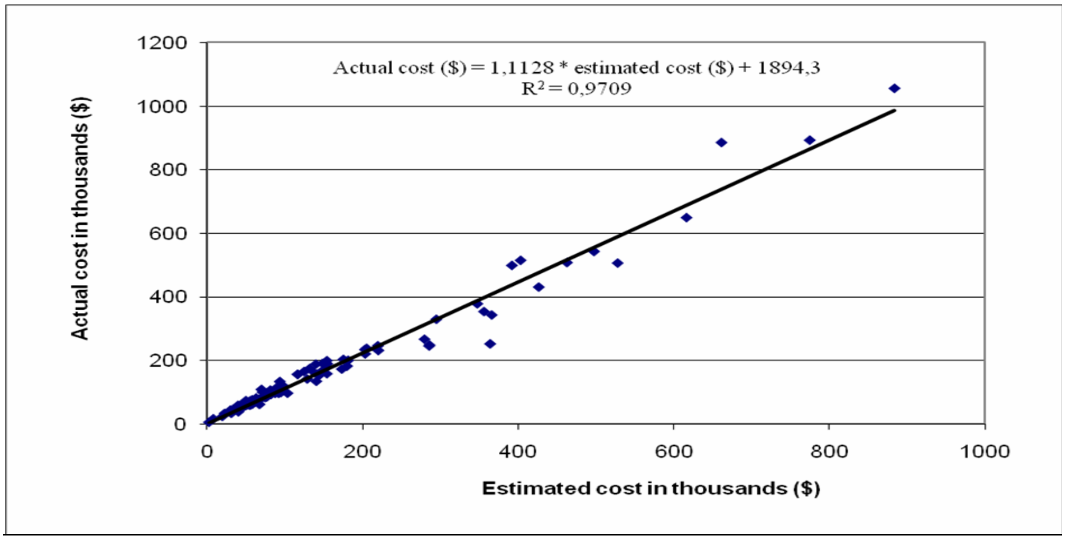

Figure 14: Actual Cost *vs* Estimated Cost in Asphalt Works

Cost Divergence *vs* Project Size

Regression models that describe the cost divergence as a function of project size for each construction activity have been discussed. Three cases were considered:

1. Models considering road length as an independent variable.
2. Models considering road length and road width as independent variables.
3. Models considering variable interaction of road

length and road width as an independent variable.

The p-value is higher than 0.05 in the first two cases, which means that the used independent variables are not significant. The p-value is less than 0.05 in the third case.

The results of the third case are presented in Table 5. The coefficients of determination r^2 of the models indicate a weak linear relation between the mentioned variables and indicate that the models cannot be used but can be concluded.

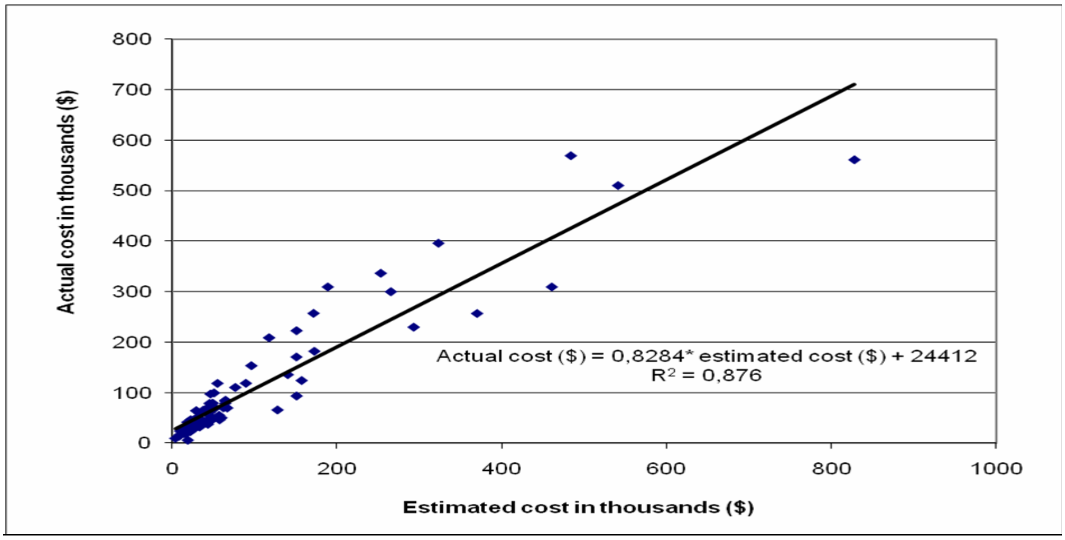

Figure 15: Actual Cost *vs* Estimated Cost in Furniture Works

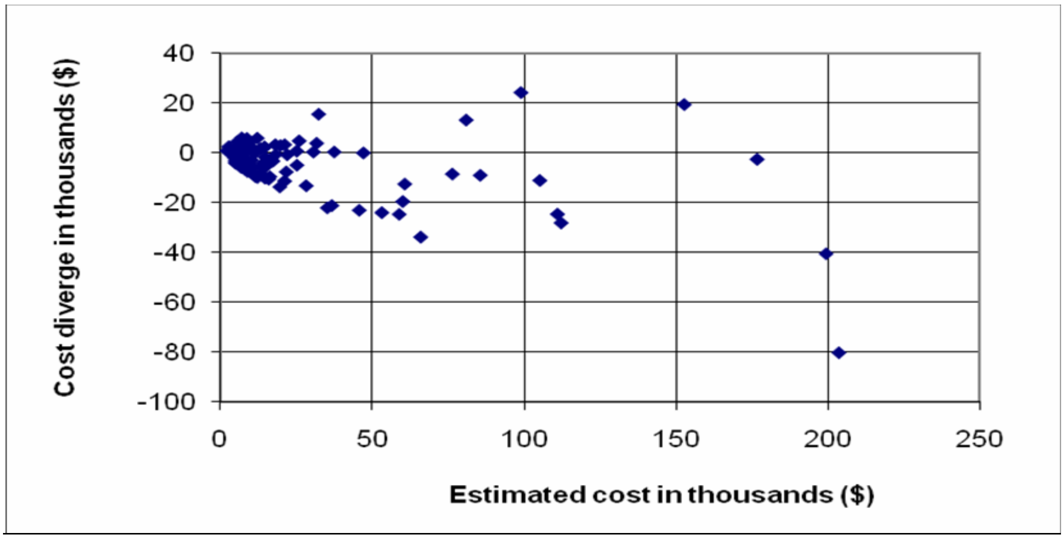

Figure 16: Cost Deviation ($) *vs* Estimated Cost (in Thousand $) in Earthworks

Cost Divergence *vs* Project Physical Characteristics

Regression models that describe the cost divergence in each of the road construction major activities as a function of project physical characteristics are presented. Three physical characteristics were considered; namely, terrain condition, ground condition and soil quality. The dummy variable technique was 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 divergence in each road construction activity in US dollars).

$D_{i's}$: qualitative variables (dummy variables) as follows:

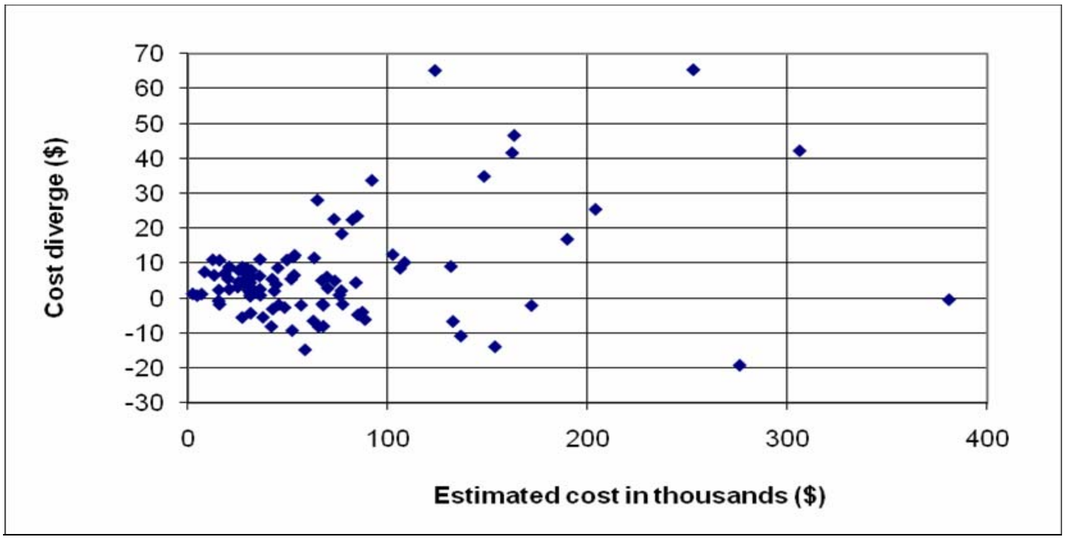

Figure 17: Cost Deviation ($) *vs* Estimated Cost (in Thousand $) in Base Works

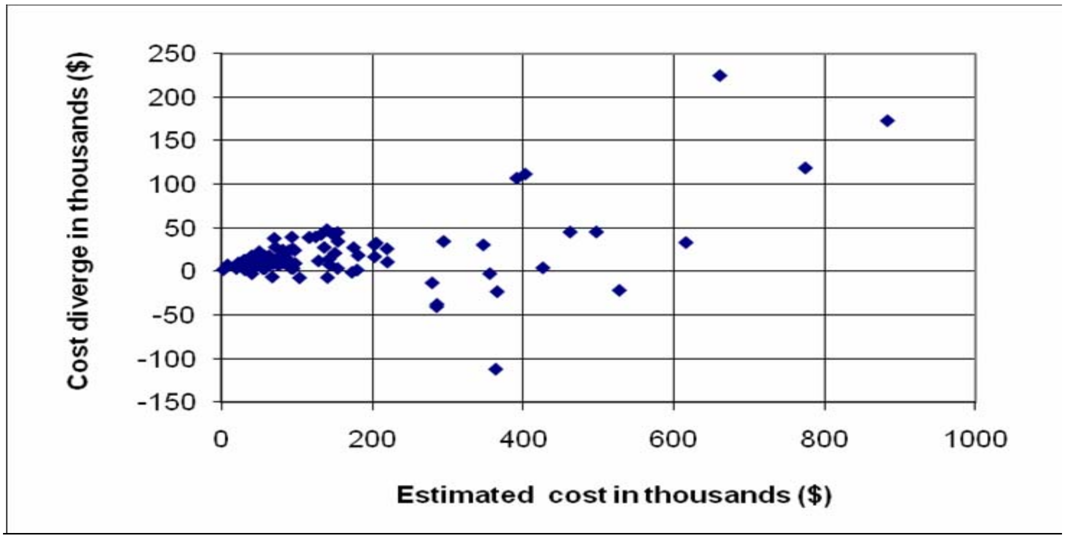

Figure 18: Cost Deviation ($) *vs* Estimated Cost (in Thousand $) in Asphalt Works

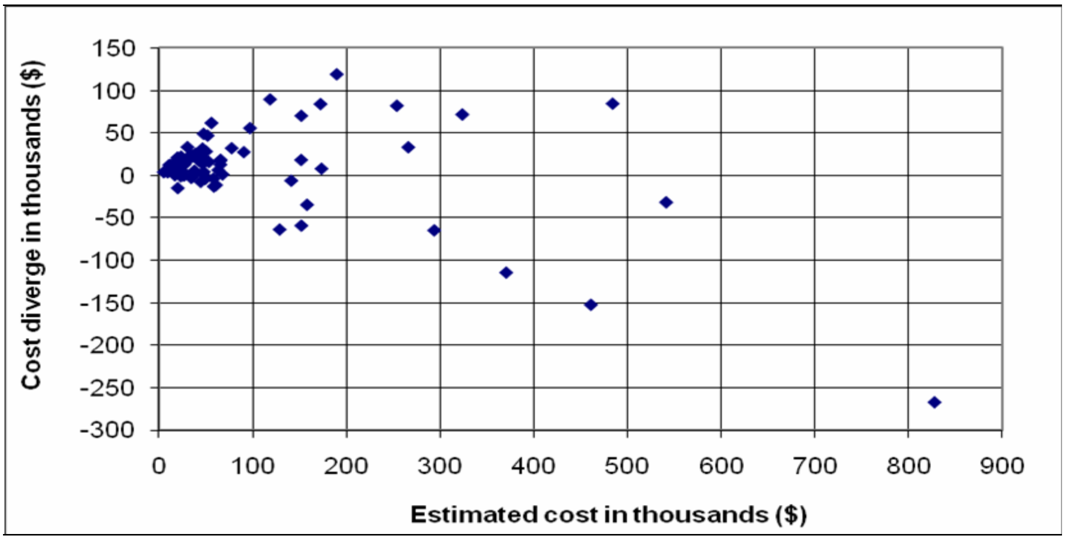

Figure 19: Cost Deviation ($) *vs* Estimated Cost (in Thousand $) in Furniture Works

Table 4. Regression Models That Relate the Cost Deviation and Estimated Cost of Each Road Construction Activity

Activity	Variables	Linear coefficient	r^2	Best fit linear model
Earthworks	intercept	0	0.34	Cost deviation ($) = - 0.16X1
	estimated cost ($): X1	-0.16		
Base works	intercept	0	0.27	Cost deviation ($) = 0.09X2
	estimated cost ($): X2	0.09		
Asphalt works	intercept	0	0.41	Cost deviation ($) = 0.12X3
	estimated cost ($): X3	0.12		
Furniture works	intercept	24411.50	0.23	Cost deviation ($) = 24411.50 - 0.17X4
	estimated cost ($): X4	-0.17		

Table 5. Regression Models That Relate the Cost Divergence in Each Construction Activity and Project Size

Activity	Variables	Linear coefficient	r^2	Best fit linear model
Earthworks	road length (m) ∗road width (m) = X1X2	-0.26	0.34	Cost divergence ($) = -0.26X1X2
Base works	road length (m) ∗ road width (m) = X1X2	0.24	0.21	Cost divergence ($) = 0.24X1X2
Asphalt works	road length (m) ∗ road width (m) = X1X2	0.94	0.42	Cost divergence ($) = 0.94X1X2
Furniture works	road length (m) ∗road width (m) = X1X2	0.08	0.003	Cost divergence ($) = 0.08X1X2
Total cost diverge	road length (m) ∗road width (m) = X1X2	1.06	0.17	Cost divergence ($) = 1.06X1X2

Table 6. Cost Divergence in Earthworks as a Function of Terrain Condition, Soil Quality and Ground Condition

Model #	Independent Variables	Coefficients	r^2	p-value
1	terrain condition	-5512.42	0.12	0.0017
2	ground condition	-5765.32	0.13	0.0010
3	soil quality	-4359.72	0.07	0.0173
4	terrain condition	-2562.44	0.14	0.3430
	ground condition	-3532.74		0.2169
	soil quality	-438.,62		0.8520
5	terrain condition	-4624.54	0.12	0.0323
	soil quality	-1533.62		0.4838
6	terrain condition	-2664.28	0.14	0.3112
	ground condition	-3732.05		0.1573
7	ground condition	-5202.21	0.13	0.0224
	soil quality	-891.58		0.6985

Table 7. Cost Divergence in Base Works as a Function of Terrain Condition and Soil Quality

Model #	Independent Variables	Coefficients	r^2	p-value
1	terrain condition	7327.64	0.13	0.0009
2	soil quality	6834.27	0.11	0.0027
3	terrain condition	4812.72	0.15	0.1548
	ground condition	691.90		0.8455
	soil quality	3431.90		0.2439
4	terrain condition	5216.59	0.15	0.0500
	soil quality	3646.36		0.1795

Table 8. Cost Divergence in Asphalt Works as a Function of Terrain Condition

Model #	Independent Variables	Coefficients	r^2	p-value
1	terrain condition	31171.79	0.22	0.0000

D_1 are regression variables of terrain condition such that:

Terrain condition	D_1
semi even	0
hilly	1

D_2 are regression variables of ground condition such that:

Ground condition	D_2
good	0
poor	1

The ground condition is considered good when it could be excavated easily with a good production rate.

D_3 are regression variables of soil quality to be used for fill and base materials such that:

Soil quality	D_3
good	0
poor	1

The following tables show the developed regression models for each road construction activity.

Table 6 shows the regression models of cost divergence in earthworks (dependent variable) as a function of project physical characteristics (independent variables). Seven models are developed. The three physical characteristics are considered since it is expected that the cost of earthworks may be affected by them. It can be seen that r^2 value for all models is small indicating a weak linear relationship between dependent and independent variables.

Table 7 shows the regression models of cost divergence in base works (dependent variable) as a function of project physical characteristics (independent variables). Four models are developed. Two physical characteristics are considered: terrain condition and soil quality since it is believed that they might affect the cost divergence in base works, but not ground condition. It can be seen that r^2 value for all models is small indicating a weak linear relationship between dependent and independent variables.

Table 8 shows the regression models of cost divergence in asphalt works (dependent variable) as a function of project physical characteristics. Terrain condition is the only variable considered in the developed models because it is the only one that might affect the cost divergence in asphalt works. It can be seen that r^2 value for the developed models is small indicating a weak linear relationship between dependent and independent variables.

CONCLUSIONS

The study investigates the statistical relationship between actual cost and estimated cost of road construction activities: earthworks, base works, asphalt works and furniture works. The regression analysis reveals a strong linear relationship between estimated cost and actual cost. Regression models describing the cost deviation in each road construction activity as a function of estimated cost are developed.

The statistical and regression analyses of cost deviation in road construction activities reveal the following:

1. The average cost deviation in earthworks is -15.67%, in base works is 12.86%, in asphalt works is 18.54% and in furniture works is 36.43%.
2. The cost underestimation is more predominant in asphalt works, base works and furniture works; while cost overestimation is predominant in earthworks.
3. Asphalt works have the highest cost proportion from the total project cost and have the highest contribution in total cost deviation.
4. There exists a low correlation between cost deviation and the estimated cost in each investigated activity.
5. The cross-tabulation reveals a low correlation between cost deviations among the investigated activities.
6. There is a weak linear relation between cost divergence in road construction activities and project physical characteristics (i.e., road length, road width, terrain condition, ground condition and soil quality).

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