Analysis of Construction Duration and Cost for Public Sector Civil Engineering Projects in Libya

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Abstract: Public construction project data were analyzed to develop models for the actual construction duration and actual cost. Based on 50 civil engineering projects in Libya from the database of the Great Man-Made River System 1992-2009, the models identified extension as a main factor that affecting both the actual duration and cost of a project, while considering the contract cost and contract duration as fixed for the project. The suitability of each model was confirmed by examining RMSE (root mean squared error), NSE (Nash-Sutcliffe efficiency), and MEF (modeling efficiency factor). The models were validated with data from 17 different projects. The validation of both models demonstrated that models are very practical and accurate. The models are very effective in capturing the uniqueness of Libyan construction industry practice.

Key words: Public projects, civil engineering projects, actual construction duration, actual construction cost.

1. Introduction

The time associated with the completion of a construction project is called duration. There are two types of durations: contract duration and actual duration. The contract duration is the time to complete the project agreed at the beginning of the agreement. The actual duration is the time it takes to complete the project. If the prescribed period is exceeded, there will be a delay in the project completion. The delay of the project may also cause increase in the final cost of the project. Delay and inflated final cost of construction projects were global problems [1].

Many studies and research had attempted to investigate such problems [2-4]. However, only very few studies had explored these problems for the developing countries due to data availability and accessibility. It is important to study the problems related to the implementation of construction projects

for developing countries to enable companies, engineering offices, and all concerned parties to understand the practice of these projects and develop some tools to predict probable estimates of actual cost and duration. The objective of this study is to identify the factors affecting actual construction costs and durations for the Great Man-Made River Water Utilities Authority (GMMRWUA) projects in Libya [5].

Libya is a mostly desert and oil-rich country with an ancient history in the continent of Africa. GMMRWUA runs a strategic project in Libya which aims to transfer groundwater from the far south Libyan lakes to the north for drinking, agriculture, and other uses. The entire project contains multi-stage sub-projects of construction of roads, water reservoirs, pumping stations, water systems, fences, electrics, administrative buildings, and other amenities to be completed during each stage. About 700,000 citizens of various along the project corridor have benefited from these projects in terms of water usage for drinking,

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agriculture and industry, and in terms of the availability of jobs for engineers and workers in various disciplines [5, 6]. This country was ruled by Col Muammar Gaddafi for 42 years until 2010, when he was toppled. The chaos that followed his departure affected the entire economy of Libya. Despite the political turmoil, the project is still functioning and under construction today on and off since its start in 1984. The implementation of these projects involved many local and international companies such as Techno Farm International LTD Agriculture Company (USA), BILFINGER (Germany), and Brown & Root Consultant Company (Britain).

Construction projects in Libya, especially GMMRWUA, are subjected to delays in project implementation and overrunning the project cost like many other countries in the Middle East. It is necessary to study the cause of the delays and cost overrun to learn the lessons for future planning and implementation.

2. Literature Review

The execution of a project by the original completion date is not a trivial matter, and many construction projects are in fact neither completed by the contract completion date, nor at the contract cost. Delays in construction lead to various negative effects such as, charges between owners and contractors, enlarged total prices, loss of efficiency, increased expenses, and contract expiry.

Saleh et al. [2] rated the causes of delay in implementation of projects in the city of Benghazi, Libya in 2009. It was found that bad planning was the main reason for delays in the implementation of projects. Moreover, poor communication and relationships, lack of equipment, and design errors are important factors that contributed to the delay. Shebob et al. [3] conducted a study to identify the factors that are causing construction delay in Libyan construction industries, “the survey found that low skill workers, rise in price of material, delay in materials delivery and

changes in the scope of project were the most critical delay factors in the Libyan construction industry based on contractor point of view. Krifa [7] also stated that frequent modifications/changes were one of the most common reasons for delays in Libyan construction industries. Apolot et al. [4] conducted a study to classify and rank the reasons of construction project delays and cost overruns in Uganda’s public sector based on their frequency, severity and importance. The findings indicated that the scope of work change is one of the most important factors that influence time delay and cost overrun. Al-Hams [8] defined change order as, “the action that specifies and justifies a change of the scope of a construction contract that alters the original time of completion or the project total cost, or both”. Greenwood et al. [9] conducted a study in regards to delay in a construction project in Tripoli, Libya. Although the focus of the study was the construction of a hospital, the issues of delay and cost overrun still impact the construction sector in Libya as a whole. This study described that the project took 13 years, from the date of the contract in August 1984 to the project completion date in June 1997. During these years, the project was extended 10 times for a total of 155 months. The reason for the first extension was the new designs in line with the amendments made by the medical and engineering committees. This led to the issuance of different change orders.

Kaming et al. [10] investigated the reasons for delay in highway construction projects in the country of Libya. The study found that like other projects in Libya, highway projects are subjected to delay and cost overrun. The main causes of delay were: delays in transfer of utility services by the competent authorities, difficulty in budget availability for the project, original contract duration is too short, delay in progress payments by the owner, and effects of subsurface conditions. Frimpong et al. [11] found that the main causes of delay and cost overrun in groundwater construction projects in Ghana included monthly payment issues from organizations, poor contractor

management, material unavailability, poor technical achievements, and an increase of materials cost. It concluded that adequate project planning, proper guidance and rigor inspection should be done to improve project quality to reduce or avert construction delay and cost overruns. For the construction projects in Nigeria, Okpala and Aniekwu [12] determined that weak management skills, payment problems, and materials unavailability were the main causes for construction cost overruns in construction projects of Nigeria. Thus, the cost of labor and materials should be controlled to minimize cost overruns. Hoai et al. [13] conducted a study to identify the causes of delay in Vietnam and found that the design change was one of delay and cost overrun causes. Finally, Hatush et al. [6] conducted a qualitative study on GMMRWUA projects in 2005.

Overall, these studies examined a number of civil engineering project data of various developing countries. These studies tried to find the cause of delay and cost overrun. However, no studies have attempted to develop any models to predict the impact of various factors on project duration and project completion cost. The scope of these studies was limited due to lack of access to official data. The study presented in this paper focused on the GMMRWUA projects for a large span of time from 1984-2009. The information related to various projects was collected from the project administrative office. Deeper statistical analysis on official data has provided a better insight of the impact of various factors on the project delay and cost overrun problems. The main goal of this study is to develop models used to predict the actual cost and duration in the future.

3. Data

3.1 Preliminary Survey

Before approaching the database, a questionnaire was designed and distributed to different construction parties consisting of owners, contractors, consultants, and designers. The purpose of this survey was to get the

sense of which factors might be relating to constructions delay and cost overrun. Among several questions asked, one main question was: What do you believe is the main cause of delay in construction projects?

A total of 300 surveys were distributed via various communication methods. Out of 300 surveys sent, 215 responses were received (71.7% return rate. Result of the questionnaire survey is summarized in Fig. 1 which showed the opinion of respondents on the reasons for the delay of projects. Among all the reasons, unrealistic estimate of project topped the list with 45%, followed by the number of extensions with 15%.

3.2 Definition of System Variables

Based on the survey result, a set of system variables identified as presented below. Data that derive the values of these variables will be collected.

CODU (contract duration)

A duration of time (in days) during which a project must be completed specified by the contract (Libya holidays and weekends are not included). Thornton [13] defined contract duration as “the time agreed upon by the makers in order to complete the terms of the contract”.

COCO (contract cost)

The amount of money in LD (Libya Dina) required to complete the project written in the contract.

ACTCO (actual cost)

The total cost (LD) of the entire project upon completion. Usually, this value can be divided into several payments or invoices based on the amount of completed work.

ACTDU (actual duration)

The actual time (in days, excluding Libya holidays and weekends) spent completing the project.

CHOR (change order)

The frequency of changes applied in the project. In this specific study, the frequency of change order is an integer greater than or equal to 1.

EX (extension)

Fig. 1 Respondent opinion on reasons for project delay in percent.

Extension is defined as the frequency of extensions requested by a contractor. With the data used in this research, extensions range from one to six.

AVDC (average daily cost)

Construction cost per day (LD/Day), $AVDC = \frac{COCO}{CODU}$

3.3 Data Collection

Based on the result of the preliminary survey, data was collected for 100 projects from the database of GMMRWUA from 1992 to 2009, Data retrieved include: projects and executing companies, invoices both paid and outstanding, dates of the contract and the end of the implementation, contractual cost, number of change of order, and extensions of these projects. Out of 100 projects, only 67 projects had complete information due to the accessibility and constrains of the information system for this immense strategic project. Thus, this data set only includes 67 data points. The dataset was split into two parts randomly, three-fourth (50 projects) were selected for model

development and the remaining (17 projects) were set aside for model validation. Descriptive statistics of data for model development are presented in Table 1.

The following are highlights of the data used for model development:

- Average increase from CODU to ACTDU is 305%.
- Average increase from COCO to ACTCO is only 13%.
- Project costs change very little from contract to actual, in spite of large increase in project duration.
- 70% of projects had number of EX 2 or more.
- 92% of projects had only 1 CHOR.

The area from which the data were collected is the area extending from the city of Ajdabiya in the east through Sirte and other coastal cities to the city of Tarhona in the west and the region of Mourada to the south. Fig. 2 is a map showing the area from which projects were selected for data collection, and within the red circle are the locations in which the projects took place.

Table 1 Snap shot of model development data.

	N	Minimum	Maximum	Mean	Std. deviation
ACTDU	50	37	3680	753.72	868.24
CODU	50	18	1218	312.70	356.51
ACTCO*	50	9,115	44,703,535	4,899,492	10,141,934
COCO*	50	7,965	39,500,000	4,296,057	8,924,994
AVDC	50	204	54,110	7,899	13,077
CHOR	50	1	3	1.16	0.47
EX	50	1	6	2.22	1.25

* In Libyan Dinar.

Fig. 2 Locations of selected projects [14].

4. Methodology

4.1 Normality Test of Model Development Data

The Shapiro-Wilk test was used to determine whether the assumption of normality of data is plausible for regression analysis. This test hypothesizes that the data are from normal distribution. Low value of p -value will result in rejecting the hypothesis. Results of the test on each variable and its log transformation are presented in Table 2.

As shown in Table 2, none of variables can be assumed normally distributed and thus are not suitable for analysis with normality requirement. When the variables were transformed by log, the p -values increased significantly and the assumption of normality is plausible, except for CHOR.

4.2 Model Development and Confirmation

The goal was to produce statistical models with a vision to predict the actual duration and actual cost, but more importantly, to recognize significant influential factors that affect the actual duration and cost of GMMRWUA projects.

Based the normality test results, stepwise regression was performed on the selected 50 point of log-transformed data for model fitting. Predictors that entered the analysis were CODU, COCO, AVDC, EX, and CHOR, with the dependent variables ACTDU and ACTCO respectively. Two final models were generated with 0.05 significance by SPSS.

$$\text{Model 1: } ACTDU = 12.182 \cdot CODU^{0.51} \cdot EX^{1.2} \quad (1)$$

$$\text{Model 2: } ACTCO = 1.116 \cdot COC^{0.99} \cdot EX^{0.1} \quad (2)$$

The models developed are by the SPSS automatic procedure. To ensure these models perform at the best possible level, we will use the following measures to confirm that these are actually legitimate models before they are validated with a different set of data.

Let $\{y_i\}_1^n$ be the set of data of dependent variable, $\{\hat{y}_i\}_1^n$ be the corresponding predicted values from the model, and $\bar{y} = \frac{\sum_{i=1}^n y_i}{n}$, the measures used are described as follows.

NSE (Nash-Sutcliffe efficiency)

NSE is a normalized statistic that determines the relative magnitude of the residual variance compared to the measured data variance. This is the extension of the R -squared formula. When the data are transformed, the NSE can become negative. For better model performance, the NSE value should be close to 1. A negative NSE shows a poor model performance [15]. The formula for NSE is:

$$NSE = 1 - \frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{\sum_{i=1}^n (y_i - \bar{y})^2} \quad (3)$$

RMSE (root mean square error)

Mathematically, RMSE is a square root of the mean of the square of differences between observations and predictions [15]. The smaller the value of RMSE, the better the model is. But this value is unit and scale dependent. The formula for RMSE is:

Table 2 Test of normality.

Variable	Shapiro-Wilk test for normality	
	p -value	
	Original data	Transformed data (log)
ACTCO	0.000	0.060
ACTDU	0.000	0.063
COCO	0.000	0.034
CODU	0.000	0.082
EX	0.000	0.854
CHOR	0.000	0.000
AVDC	0.000	0.279

$$RMSE = \sqrt{\frac{\sum_{i=1}^n (y_i - \hat{y}_i)^2}{n}} \quad (4)$$

MEF (modeling efficiency factor)

MEF is a model evaluation factor; the modeling efficiency factor portrays how well a model predicts relatively to the average of the observation. This value ranges from 0 to ∞ , the smaller the MEF, the better the models perform [15]. The formula for MEF is:

$$MEF = \frac{\sqrt{\sum_{i=1}^n (y_i - \hat{y}_i)^2}}{\sqrt{\sum_{i=1}^n (y_i - \bar{y})^2}} \quad (5)$$

The values of the confirmation measures of each model are summarized in Table 3. All the measures are at satisfactory levels which demonstrate that these models are sound (legitimate).

4.3 Model Validation

Next, the models are validated by a separate set of 17 project data set aside earlier. Two methods are used to

validate the models. The first method is to calculate AAD (absolute average differences). This validation process is performed by comparing the outputs of developed models to actual collected data [16, 17]. The second method is to calculate the AVP (average validity percentage) [18, 19]. The formulas for these two measures are:

$$AAD = \frac{\sum_{i=1}^n |P_i - A_i|}{n} \quad (6)$$

$$AVP = 1 - \frac{\sum_{i=1}^n \left| 1 - \frac{P_i}{A_i} \right|}{n} \quad (7)$$

where P_i is the predicted value, A_i is the actual value, and n is the number of observations. The results of validation for these two models are presented in Tables 4 and 5 respectively.

For ACTDU model, the average absolute difference is 41 days, while the average validity percentage is as high as 91.4%. For ACTCO model, the average absolute difference is 43,794 LD, while the average validity percentage is up to 90.66%. The relative low

Table 3 Model confirmation values.

Model	NSE	RMSE	MEF
ACTDU	0.89	210	0.33
ACTCO	0.99	387,793	0.04

Table 4 Model validation for ACTDU.

Predicted duration (P) (days)	Actual duration (A) (days)	Difference P-A (days)	Percentage of difference %
1,865	1,876	11	0.61
1,138	1,145	7	0.60
1,094	1,015	79	7.81
883	865	18	2.06
1,286	1,258	28	2.24
1,184	1,145	39	3.39
633	610	23	3.81
1,003	1,123	120	10.68
923	898	25	2.75
863	876	13	1.51
696	713	17	2.38
523	548	25	4.53
278	356	78	21.98
106	120	14	11.38
195	213	18	8.43
195	219	24	10.94
159	324	165	51.05
		AAD = 41	1-AVP = 8.60%

Table 5 Model validation for ACTCO.

Predicted cost (P) (LD)	Actual cost (A) (LD)	Difference P-A (LD)	Percentage of difference %
25,956,218	25,870,250	85,968	0.33
20,004,995	20,086,543	81,548	0.41
13,967,449	13,900,000	67,449	0.49
10,032,198	9,980,523	51,675	0.52
8,574,081	8,499,424	74,658	0.88
8,337,625	8,354,971	17,346	0.21
7,282,687	7,279,521	3,166	0.04
7,365,772	7,350,235	15,537	0.21
2,546,969	2,519,064	27,905	1.11
2,376,448	2,289,229	87,219	3.81
967,925	980,551	12,626	1.29
369,237	356,981	12,257	3.43
617,027	610,001	7,026	1.15
79,463	80,421	957	1.19
74,686	70,554	4,132	5.86
74,424	170,988	96,564	56.47
22,518	120,990	98,472	81.39
		AAD = 43,794	1-AVP = 9.34%

AAD values and high AVP values indicate that these models are very accurate and can be very practical and reliable. Though in general, the models tend to perform better for bigger projects as they are more accurate.

5. Results

5.1 Model Interpretation

The models developed look simple; however, they have very interesting characteristics in addition to their accuracy. For the purpose of readability, the models are listed here again:

$$\text{Model 1: } ACTDU = 12.182 \cdot CODU^{0.51} \cdot EX^{1.2}$$

$$\text{Model 2: } ACTCO = 1.116 \cdot COCO^{0.99} \cdot EX^{0.1}$$

- For any given contract, CODU is fixed. Hence the part $12.182 \cdot CODU^{0.51}$ in Model 1 can be considered as a coefficient in the model. It leaves only one main factor, EX, to influence ACTDU. Moreover, ACTDU does not depend on COCO.

- The fact that $\frac{\Delta ACTDU}{ACTDU} = 1.2 \frac{\Delta EX}{EX}$ from Model 1

shows that the proportion of change in ACTDU is 1.2 times of the proportion of change in EX. Thus

controlling the number of extension is key to control the actual duration of a project.

- While examining Model 2, it can be seen that CODU has no impact on ACTCO.

- Model 2 also reveals that EX has minimum impact on ACTCO because the power of this factor is only 0.1. Since EX is only ranging from 1 to 6, $1 \leq EX^{0.1} \leq 1.19$, the model shows ACTCO is at most 1.33 times of COCO. Looking into the raw data, it can be seen that actual costs of the all projects were very close to the contract cost, even though actual duration of construction increased significantly. Model 2 describes this phenomenon very closely. However, it is not the construction norm in any other part of the world.

To summarize, EX is a main factor that affecting the actual duration and cost of the projects. Our models quantify such affect and give an instrument for estimation.

5.2 Findings

The interpretation of the models reveals a unique case.

- Usually, an extension on a project leads to a delay in the project, which in turn, will increase the final

project cost. But the GMMRWUA projects did not show this trend. Reviewing the data, most of the final costs were only slightly higher than the contract cost, but some projects even had actual costs lower than the contract cost. Average increase in cost due to project extension is about 13 percent (as previously stated). Couple possible explanations are: the contract cost was overestimated; it is a unique practice of this country to strictly enforce the contract cost.

- Impact on the ACTDU is very significant due to extension of project. Model 1 captures the weight of Extension in this context.

- As stated before, average increase in project duration is about 300 percent from the initial contract duration. This large difference between CODU and ACTDU is captured by the derived model. Echo back to the opinion survey, most respondents cited that the unrealistic estimate of project duration as a main reason for project delay.

6. Conclusions

Based on the results obtained in this study, the factors influencing the actual duration and actual cost of construction projects were obtained. The followings are concluded:

- This study highlighted the effect of extensions on actual duration and actual cost of construction projects.

- Since the extension factor significantly contributed to the increase in duration of a project, which affects various task completion of the project, therefore extensive planning is required as a part of contract extension. More attention should be placed on the construction management. Therefore, in order to reduce this effect, the extensions must be controlled and followed up early.

- In a country like Libya, it appears that cost of the contract is tightly controlled as a part of contraction practice, however, increase of contact duration is an acceptable norm.

- Verify accuracy when estimating contractual cost and duration to avoid significant differences between

contractual values and actual values.

- Choosing the appropriate time for data collection is one of the factors influencing any future studies in this field.

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