Deviations in construction projects: The contractor's perspective

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1. INTRODUCTION

The construction industry is a significant contributor to the country's economy, both in terms of Gross Domestic Product and also on the number of jobs created. However, many construction projects suffer extensive deviations and initial estimates of time and cost are often exceeded.

These deviations can have consequences on the project's success and certainly have negative impacts on the various entities involved, namely construction owners, contractors and designers. If cost deviations have a direct impact on the financial performance of companies, time deviations do so indirectly. The project owner is hampered by time deviations ie. the loss of potential revenues in the use of the development and by additional administration and supervision costs. The contractor also loses out due to fixed contract costs, such as site charges, and possible fines for delays, among others.

The main objective of this document was to quantitatively analyse the cost and time deviations in construction projects from the contractor's perspective. It also sought to identify patterns in the deviations observed in some of the project's characteristics and their underlying causes.

2. COST AND TIME DEVIATIONS

A schedule deviation can be defined as a situation where a construction project does not come to a conclusion within the timeframe envisaged (Kaliba, Muya, and Mumba 2009). This deviation may be caused by any party and may arise due to one or more circumstances. A delay in the contract has adverse effects on both the owner and the contractor, which often leads to the question the ultimate responsibility for the delay (Memon, Abdul Rahman, and Abdul Azis 2012).

Cost deviations in ventures with a large capital investment can be extremely damaging, to both investors and taxpayers, compromising key executives and their organisations (Flyvbjerg et al. 2018).

They represent the difference between the actual costs and the estimated costs in the budget. This deviation is usually measured as a percentage of the estimated cost and can be either favourable or unfavourable depending on whether the difference is negative or positive. For a positive value, it means that there has a cost overrun since the final cost is higher than estimated.

There are many factors that contribute to deviations in construction projects. Delays occur in virtually all projects and their magnitude varies considerably from project to project. It is important to define the causes of these delays in a way that minimises and prevents possible overruns. Several studies have been carried out around the world to determine the causes of delays (Kenny and Vanissorn 2012).

A study was carried out (Ling et al. 2009) where the authors investigate successful methods of project management of foreign companies in China. They have concluded that there are some fundamental cost management practices:

- high quality cost data;
- high quality financial management;
- good planning to determine the resources and quantities required;
- resource costs control;
- monitoring activities to detect cost variances;
- cost reporting and monitoring of work carried out;
- financial stability.

A company's strong financial strength is crucial to achieve a positive cash flow and project profitability. This study also indicates some practices for good time management:

- fast approval of projects and planning;
- providing adequate equipment;
- quick responses to changes in project by the developer.

There are several studies that have qualitatively analysed the causes of delays in construction from the point of view of the three main entities involved: i) the developer, ii) the contractor and iii) the designer. The causes were classified into 11 categories, identified in the Table *1*.

Table 1: Counting of causes according to the point of view of the various entities.

			Causes/Responsibilities for deviation										
Authors	**Country or region**	**Type of work in stydy**	Materials	Equipment	Labour force	Equipment management	Financial management	Owner	Design team	Contract and contractual relations	Institutional relations	Project specificity	External factors
Odeh and Battaineh 2001	Jordan	Large public and private buildings, roads and water and sewage projects			C D	C D	C D	C D					
Al-Tabtabai 2002	Kuwait	Buildings			O	O	O C	C	C				C

Frimpong, Oluwoye, and Crawford 2003	Ghana	Wastewater projects	O C			O C D	O C D	C D					D
Assaf and Al-Hejji 2006	Saudi Arabia	Public and private projects	C		O D	O D		O C D	C	O C D			D
Sweis et al. 2008	Jordan	Residential buildings			C	O D	O C D	C D	O				
Kenny and Vanissorn 2012	Austraia	Residential buildings	O D		O C D	O D	C D	C D	O C			O	
Aziz 2013	Egypt	Wastewater Project		C		D	O C	C D	O C D	O	O E	O	
Ahmed, Dlask, and Hasan 2014	Siria	Residential buildings	O C	C		C	O	O C		O C		O	
Niazi and Painting 2017	Afghanistan	Buildings, roads and industrial projects	O				O D	O C D	O C	D	O C D		O
Amare, Quezon, and Busier 2017	Ethiopia	Road projects	O	O D	O	O C D	O C D						
Herrera et al. 2020	Study perfomed in various countries	Road infrastructure				O C	O C	O D	C D	O C		D	O D

O – owner; C – contractor; D – designer

The graph in Figure 1 makes it possible to analyse the most frequent causes of the deviations from the qualitative studies analysed. The largest cause is the Owner category, due to successive project changes and delays in payments. Financial management and contractor management appear more frequently afterwards, poor contract management, financial difficulties of the contractor, inadequate budgets and planning are some of the reasons for these causes.

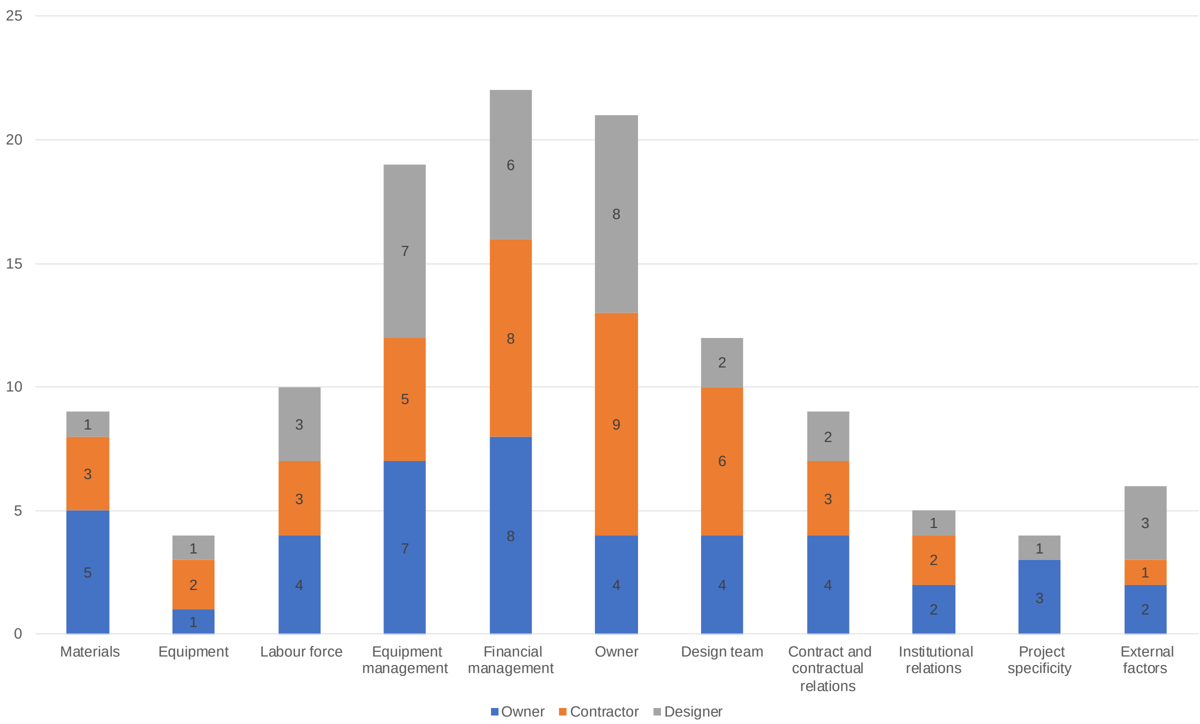


Figure 1: Counting the various categories.

3. CASE STUDY AND METHODOLOGY

3.1. COLLECTION AND ORGANISATION OF INFORMATION

The case study selected comprises a set of contracts completed by CIVILRIA. Only projects carried out from 2015 onwards have been selected in order to minimize a possible influence of the 2008 crisis and the International Monetary Fund intervention between 2011 and 2014. Since the company is building in several regions of the country, a sample involving a set of residential building works for housing in the districts of Aveiro, Porto and Lisbon was considered, where CIVILRIA has been acting as owner and contractor. The sample also aims to include new construction and (deep) rehabilitation developments, which are two of the areas of intervention of the company in the field of residential buildings. Those developments with significant gaps and/or information errors that were not likely to be eliminated in time were excluded, resulting in a sample composed of 16 developments, of which 4 concern rehabilitation and the remaining 12 new constructions.

3.2. ORGANISATION OF INFORMATION

In the selected sample, the developments show differences in terms of more general aspects, such as the size and configuration of the buildings or flats. There are also differences in more particular aspects, such as solutions and construction processes or the range of materials applied. Among this variability, it was decided to classify the typology of the developments in terms of the type of intervention (new construction or rehabilitation) and the size of the dwellings (small or large), where the following typologies result:

- small typology;
- large typology;
- rehabilitation typology.

3.3. ANALYSIS METHODOLOGY

A statistical approach is used to quantitatively analyse the cost deviations recorded in the projects within the case study. The first stage is to describe the sample using parametric approaches (e.g., mean, median, and standard deviation) and graphical approaches (e.g., box plots and histograms). The second phase compares the distributions between groups using parametric (e.g., t-test, ANOVA) and non-parametric (e.g., Mann-Whitney, Kruskal-Wallis) tests, depending on whether the data have normal or non-parametric distributions respectively.

The analysis is carried out at two levels: i) by typology (vertical analysis); and ii) by category (cross-sectional analysis). In vertical analysis, cost deviations in each category are compared by project typology. In cross-sectional analysis, the cost deviations in each type are compared by cost category. The vertical and horizontal analysis are also carried out in aggregated form, as schematically illustrated in the Figure 2.

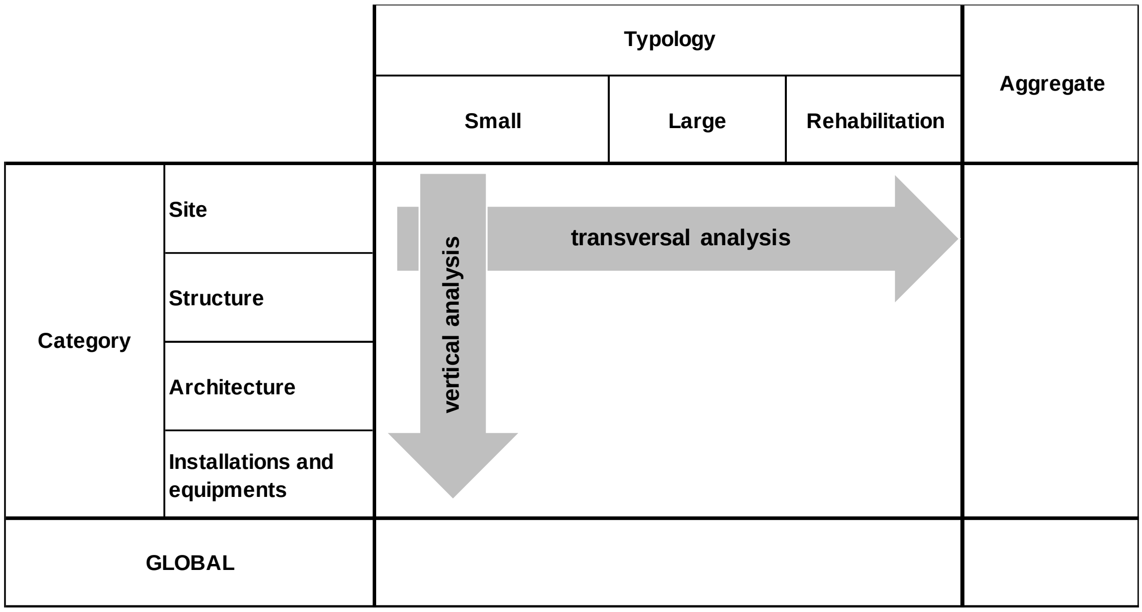


Figure 2: Analysis methodology matrix.

A correction of costs based on the starting year of the ventures was necessary to take account of inflation. This adjustment was made using the price revision formulas and through the IMPIC indices.

This correction was made for the absolute values, the initial estimate of new construction and rehabilitation projects and the values per square meter. The following variables were obtained:

- estimate;
- value per gross area;
- value per equivalent area.

The calculations of the deviations of each development are calculated by the formula (3.1). When these are negative, it means that the final price of the work was below the initial estimated price, whereas positive deviations indicate that the final price of the work was above the initial price, i.e. there was overrun.

$$Deviation = \frac{(Rebudget + W_{more} + W_{less}) - Estimate}{Estimate} \times 100 \tag{3.1}$$

In order to be able to treat the data while maintaining the company confidentiality, the variables were treated in such a way as to standardise them. Then the following expression was applied (3.2):

$$Standard\ variable_i = \frac{variable_i}{mean\ of\ variables} \tag{3.2}$$

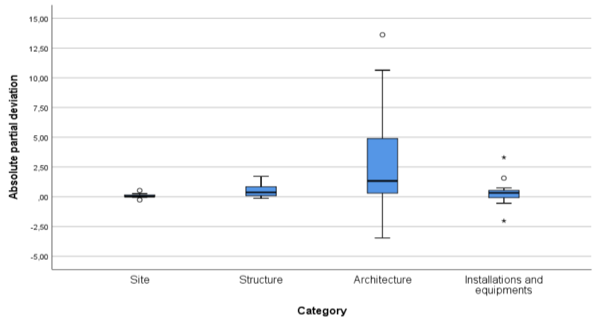
The standard variables obtained were:

- standard estimate;
- value per standard gross area;
- value per standard equivalent area;
- standard deviation.

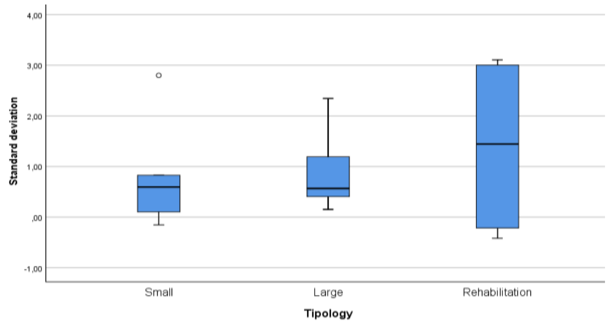
4. RESULTS AND ANALYSIS

The deviations can be analysed in an aggregate way, i.e., not dividing developments by typology. In Figure 3 (a) it is possible to observe the distribution of the absolute partial deviation in the categories. The category that suffers the most deviations is the architecture, which has an outlier value belonging to the rehabilitation typology.

Standard deviations of projects by typology can be analysed in the Figure 3 (b). The rehabilitation typology is the one with the highest variability of standard deviations.



(a)



(b)

Figure 3: (a) Distribution of absolute partial deviation; (b) Distribution of standard deviation.

Statistical analysis began by testing the normality of the distributions of the "value per normalized equivalent area", "value per standard gross area" and “standardised cost deviation" using the Kolmogorov-Smirnov and Shapiro-Wilk tests. The Shapiro-Wilk test is most suitable for small size samples (< 50 samples), so this test is used as a numerical means to assess the normality of the sample. If the significance value is greater than 0.05 then the data is normal, and if they are smaller they deviate significantly from a normal distribution. We obtained the results shown inTable *2*, where values for the 'standard deviation' variable show a normal distribution while the other variables deviate significantly from normality.

Table 2: Numerical normality tests.

Variable	Typology	Kolmogorov-Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Value per standard equivalente area	Small	0,359	5	0,034	0,692	5	0,008
	Large	0,199	7	,200*	0,879	7	0,222
	Rehabilitation	0,400	4		0,705	4	0,013
Value per standard gross area	Small	0,414	5	0,005	0,663	5	0,004
	Large	0,169	7	,200*	0,977	7	0,944
	Rehabilitation	0,268	4		0,931	4	0,598
Standard deviation	Small	0,302	5	0,153	0,841	5	0,168
	Large	0,238	7	,200*	0,880	7	0,226
	Rehabilitation	0,290	4		0,808	4	0,118

4.1. TESTS

The analysis of unidirectional variance serves to determine the existence of statistically significant differences between different typologies. Table *3* shows the result of the ANOVA test, where it is identified that the significance value of the dependent variable "value per normalized gross area" is 0.005. This value is less than 0.05 so there is a statistically significant difference in the "value per standardised gross area" between the different typologies. Still, it is not known which of the typologies differed.

The variable 'value per normalized equivalent area' has a significance value of 0.053 - just above 0.05, so for a 90% confidence interval this variable would be statistically significant.

Table 3: Results ANOVA.

Dependent variable		**df**	**F**	**Sig.**
value per standard equivalent area	between typologies	2	3,712	0,053
value per standard gross area	between typologies	2	8,361	0,005

The Kruskal-Wallis test is a non-parametric test that allows comparing small, large and rehabilitation typologies, testing the null hypothesis that all samples have equal distributions against the hypothesis that at least one typology has a different distribution from the others. The dependent variables were studied: i) value per normalized equivalent area, ii) value per normalized gross area and iii) normalized deviation with a significance level of 0.050. The summary of the hypothesis test, presented in Table 4, rejects the null hypothesis in the variable 'value per standard gross area' (p=0.008) which indicates that there are differences in distributions.

Table 4: Summary of the hypothesis test.

Null hypothesis	**Test**	**Sig.**	**Decision**
Distribution of value per standardised equivalent area is the same in both typologies	Independent samples of the Kruskal-Wallis Test	0,136	Accept null hypothesis.
Distribution of value per gross equivalent area is the same in both typologies	Independent samples of the Kruskal-Wallis Test	0,008	Reject null hypothesis.
Distribution of standard deviation is the same in both typologies	Independent samples of the Kruskal-Wallis Test	0,924	Accept null hypothesis.

The variable 'value per standard gross area' was analysed by comparing typologies from the null hypothesis - the distributions of typology 1 - typology 2 are equal with a significance level of 0.05. Table *5* presents the results obtained, in which the last column corresponds to the significance values adjusted by the Bonferroni correction. The small and large typologies reject the null hypothesis, so it is concluded that the medians are not all the same for these samples.

Table 5: Comparisons of the value per standardised gross area in typology pairs.

Typology 1 - Typology 2	Test statistics	Standard deviation	Standard deviation statistics	Sig.	Sig. Adjusted
Small-Rehabilitation	-0,050	3,194	-0,016	0,988	1,000
Small-Large	7,514	2,788	2,695	0,007	0,042
Rehabilitation-Large	7,464	2,984	2,501	0,012	0,074

4.2. CORRELATIONS

Table *6* allows us to establish correlations between the variables and draw some conclusions from the results obtained.

Analysing Table *6*, it can be seen that the "value per normalized gross area" and the "value per normalized equivalent area" show a good Pearson correlation which was statistically significant (r=0.609 and p=0.012).

The standard deviation and the number of underground floors show a negative and statistically significant correlation (r=-0.601 and p=0.014), i.e. the standard deviation tends to increase when the number of underground floors decreases.

Table 6: Pearson correlation.

		Value per standard gross area	Standard deviation
Underground floors	Pearson correlation	-0,329	-0,601
	Sig. (2 extremidades)	0,214	0,014
Value per standard equivalente area	Pearson correlation	0,609	-0,465
	Sig. (2 extremidades)	0,012	0,069

4.3. MULTIDIMENSIONAL ANALYSIS

As shown in Table *7*, the value per standard gross area is 1,253 but varies according to its location and the standard gross area. When the location is Aveiro, Estarreja or Lisbon the value is -0,231. The standardised gross area also has a negative coefficient, with the value of -0,108.

The value per standardised equivalent area is 1.060 and varies with the location as in the previous model. In this model, when the location is Aveiro, Estarreja or Lisbon the value has a decrease of -0.085. The number of underground floors also influences the value per normalized equivalent area.

Table 7: Analysis of linear regression results

	Coefficient	Std. error	t	Sig.	95% Confidence interval	
					Inferior	Superior
			Value per gross standard area			
Ordained	1,253	0,050	24,995	0,000	1,144	1,361
Localization = Aveiro, Estarreja ou Lisboa	-0,231	0,037	-6,249	0,000	-0,311	-0,151

Localization = Canidelo ou Ílhavo	0,000					
Gross standard area	-0,108	0,042	-2,590	0,022	-0,198	0,018
Value per standardised equivalent area						
Ordained	1,060	0,022	47,382	0,000	1,011	1,108
Localization = Aveiro, Estarreja ou Lisboa	-0,085	0,029	-2,939	0,012	-0,147	-0,022
Localization = Canidelo ou Ílhavo	0[a]					
Number of floors below ground = 0	-0,106	0,058	-1,838	0,089	-0,231	0,019
Number of floors below ground = 1, 2 ou 3	0[a]					

a. This coefficient is set to zero because it is redundant.

5. CONCLUSION

From a first analysis through descriptive statistics, the weight of the categories is summarized by the average of the categories in the different typologies and globally in Table 8. An analysis of these figures shows that the major difference in the comparison of the weight of the projects in terms of the type of new construction or rehabilitation intervention is the 'Stability' category. In the rehabilitation typology, the weight of these projects is much lower than the small and large typologies. This is because, in the sample, rehabilitations do not present major interventions at the structural level.

Table 8: Average weight of the categories, in the different typologies.

Typology	Site	Structure	Architecture	Installations and equipment
Small	7,61%	26,28%	45,23%	20,88%
Large	6,82%	25,87%	48,57%	18,74%
Rehabilitation	9,85%	9,46%	53,7%	26,99%
Aggregate	7,8%	21,9%	48,8%	21,5%

In Table 9, the absolute partial deviations calculated by equation 3.3 are presented, where it is possible to conclude that there is a great difference of deviations in the category 'Architecture' between the small and large typologies. This deviation is related to the flat sizes of the mentioned typologies.

Table 9: Absolute partial deviations.

		Typology			
		Small	**Large**	**Rehabilitation**	**Aggregate**
Category	**Site**	-0,03	0,08	0,2	0,07
	Structure	0,69	0,63	0,23	0,55
	Architecture	0,86	2,32	6,19	2,83
	Installations and equipment	0,97	0,17	-0,2	0,33
Global		2,48	3,2	6,42	3,78

The tests carried out on the variable "deviation per standardised gross area" allow us to conclude that there are statistically significant differences between small and large typologies, which lead us to validate the initial premise of distinguishing developments by level of the size of the dwellings. It can be concluded from Table 10 that the value per standardised gross floor area of large projects is more expensive than that of small ones.

Table 10: Distribution of the dependent variable 'value per standard gross area'.

	mean	median	variance	minim	maxim
Small	0,89	0,92	0,005	0,77	0,94
Large	1,12	1,11	0,014	0,94	1,28
Rehabilitation	0,93	0,90	0,011	0,83	1,07
Aggregate	1,00	0,94	0,021	0,77	1,28

6. REFERENCES

Ahmed, S., P. Dlask, and B. Hasan. 2014. “Deviation in the Cost of Projects.” *Construction Maeconomics Conference 2014*, 1–9.

Al-Tabtabai, H. M. 2002. “Causes for Delays in Construction Projects in Kuwait.” *Engineering Journal of the University of Qatar*.

Amare, Yosef, Emer T Quezon, and Mamuye Busier. 2017. “Causes of Delays during Construction Phase of Road Projects Due to the Failures of Contractor, Consultant, and Employer in Addis Ababa City Road Authority.” *International Journal of Scientific & Engineering Research* 8 (3): 15–25.

Assaf, Sadi A., and Sadiq Al-Hejji. 2006. “Causes of Delay in Large Construction Projects.” *International Journal of Project Management*. https://doi.org/10.1016/j.ijproman.2005.11.010.

Aziz, Remon Fayek. 2013. “Factors Causing Cost Variation for Constructing Wastewater Projects in Egypt.” *Alexandria Engineering Journal* 52 (1): 51–66. https://doi.org/10.1016/j.aej.2012.11.004.

Flyvbjerg, Bent, Atif Ansar, Alexander Budzier, Søren Buhl, Chantal Cantarelli, Massimo Garbuio, Carsten Glenting, et al. 2018. “Five Things You Should Know about Cost Overrun.” *Transportation Research Part A: Policy and Practice*. https://doi.org/10.1016/j.tra.2018.07.013.

Frimpong, Yaw, Jacob Oluwoye, and Lynn Crawford. 2003. “Causes of Delay and Cost Overruns in Construction of Groundwater Projects in a Developing Countries; Ghana as a Case Study.” *International Journal of Project Management* 21 (5): 321–26. https://doi.org/10.1016/S0263-7863(02)00055-8.

Herrera, Rodrigo F., Omar Sánchez, Karen Castañeda, and Hernán Porras. 2020. “Cost Overrun Causative Factors in Road Infrastructure Projects: A Frequency and Importance Analysis.” *Applied Sciences (Switzerland)* 10 (16). https://doi.org/10.3390/app10165506.

Kaliba, Chabota, Mundia Muya, and Kanyuka Mumba. 2009. “Cost Escalation and Schedule Delays in Road Construction Projects in Zambia.” *International Journal of Project Management* 27 (5): 522–31. https://doi.org/10.1016/j.ijproman.2008.07.003.

Kenny, Wong, and Vimonsatit Vanissorn. 2012. “A Study of the Factors Affecting Construction Time in Western Australia.” *Scientific Research and Essays* 7 (40): 3390–98.

Ling, Florence Yean Yng, Sui Pheng Low, Shou Qing Wang, and Hwee Hua Lim. 2009. “Key Project Management Practices Affecting Singaporean Firms’ Project Performance in China.” *International Journal of Project Management* 27 (1): 59–71. https://doi.org/10.1016/j.ijproman.2007.10.004.

Memon, Aftab Hameed, Ismail Abdul Rahman, and Ade Asmi Abdul Azis. 2012. “Time and Cost Performance in Construction Projects in Southern and Central Regions of Peninsular Malaysia.” *International Journal of Advances in Applied Sciences* 1 (1): 52–57.

https://doi.org/10.11591/ijaas.v1i1.537.

Niazi, Ghulam Abbas, and Noel Painting. 2017. “Significant Factors Causing Cost Overruns in the Construction Industry in Afghanistan.” In *Procedia Engineering*, 182:510–17. Elsevier Ltd. https://doi.org/10.1016/j.proeng.2017.03.145.

Odeh, A. M., and H. T. Battaineh. 2001. “Causes of Construction Delay: Traditional Contracts.” *International Journal of Project Management* 20 (1): 67–73. https://doi.org/10.1016/S0263-7863(00)00037-5.

Sweis, G., R. Sweis, A. Abu Hammad, and A. Shboul. 2008. “Delays in Construction Projects: The Case of Jordan.” *International Journal of Project Management*. https://doi.org/10.1016/j.ijproman.2007.09.009.