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Construction delay: a quantitative analysis

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Abstract

Avoiding construction claims and disputes requires an understanding of the contractual terms and causes of claims. The dual underlying theme of this paper is to investigate the causes of delays on 130 public projects in Jordan and to aid construction managers in establishing adequate evaluation prior to the contract award using quantitative data. Projects investigated in this study included residential, office and administration buildings, school buildings, medical centers and communication facilities. Results of this study indicates the main causes of delay in construction of public projects relate to designers, user changes, weather, site conditions, late deliveries, economic conditions and increase in quantity. The presence of these factors have an impact on the successful completion of the projects at the time contractually specified. The findings suggest that special attention to factors identified in this study will help industry practitioners in minimising the risk of contract disputes. © 1999 Elsevier Science Ltd and IPMA. All rights reserved.

Keywords: Construction management; Project planning; Construction delay; Dispute

1. Introduction

A vital section specified in the construction contract is the performance period or time of project execution, which is established prior to bidding. The successful execution of construction projects and keeping them within estimated cost and the prescribed schedules depend on a methodology that requires sound engineering judgment.[1] The construction sector is one of the vital sectors in the development process of Jordan. The government contributes to the development of the construction industry in several ways. However, there are limitations and even draw backs to these efforts. The time required to complete construction of public projects is frequently greater than the time specified in the contract. These 'overruns' or time extensions are granted for many reasons, such as designer changes or errors, user changes, weather and late deliveries. Current construction projects are complex efforts requiring the support of the design and construction profession. Therefore, a realistic time for project execution will decrease the possibility of disputes between state agency and the contractors.

1.1. Previous work

A great deal of information concerned with project delay and overruns may be found in the literature. The increased interest in construction overruns is due, in part, to efforts by the government to reduce construction delays. There has been a considerable and continued interest in the effect of construction delays. The information available is diverse and widespread. Many construction management books[2–6] have minimum coverage on construction delays. Al-Momani[7] describe the various elements of cost upon individual public projects but does not deal specifically with construction delays.

Assaf and Al-khalil[8] outline the main causes of delay in large building projects and their relative importance. They found that 56 causes of delay exist in Saudi construction projects. According to the contractors surveyed the most important delay factors were preparation and approval of shop drawings, delays in contractor's progress, payment by owners and design changes. The architects and engineers view were cash problems during construction, the relationship between subcontractors and the slow decision making process

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Table 1
Summary of project information

Classification	Poor design	Change orders	Weather	Site condition	Late delivery	Economic condition	Increase in quantity	No delay	Total
House	4	1	3	1	0	0	2	3	14
Office	8	5	4	2	1	4	5	5	34
School	10	8	6	5	4	2	3	14	52
Medical centers	6	4	2	0	3	2	1	2	20
Communication facilities	4	2	1	0	2	0	1	0	10
Total	32	20	16	8	10	8	12	24	130

of the owner. The owners agree that the design errors, labor shortages and inadequate labor skills are important delay factors. Hancher and Rowings,[1] for example, provide a concise summary of the methodologies used by transportation agencies to establish the contract duration used for highway construction projects, and also provides a schedule guide for field engineers during construction. Similarly, Chalabi and Camp[10] conducted a review on project delays in developing countries during planning and construction stages. In their study they found that the delay and cost overruns of construction projects are dependent entirely on the very early stages of the project. Fereig and Qaddumi[11] in their study on the construction experience of the Arabian Gulf demonstrate the various components of the planning, controlling and productivity on construction delay. Their primary purpose is to alert the reader to the deviation from the project plans.

Wilson[9] examined the role of the owner and architect/engineer's roles in the prevention and resolution of construction claims. Wilson also summarised the causes of construction claims which include: extra work, project delays and acceleration, lack of management, limited site access and change in work schedule.

Despite the necessity for such research, little work has been described in the literature concerning public projects, specially in Jordan. The previously proposed factors contributing to construction delay were frequently observed in public projects. The actual frequency and magnitude of these factors is not known, which has proven to be a serious and very expensive problem to Jordan's construction industry.

1.2. Research design and objectives

The objective of this study is to determine the causes and the level of time extension of public projects and to aid construction managers in establishing adequate evaluation prior to the contract award using quantitative data. The key task is to design research so that the information obtained permits the assessment of their impact. Therefore, the best approach to assessing these potentials is to adopt randomly selected samples. The sampling population was established by selecting 130 public projects constructed in different regions of Jordan during the period of 1990–97. The data was found in contract files of several state agencies. Data collected were of 5 kinds of public projects: residential houses of public figures, office and administrative buildings, school buildings, medical centers and communication facilities. The performance and construction of these projects were recognised as being unsatisfactory to many officials, and assented to the study in order to have hard evidence as to the nature of the problems. This study will summarise the results of this research based on actual construction times experienced by public projects. The data collection was to investigate the reasons related to construction delay and overruns:

- Planned duration of contract;
- Actual completion date;

Table 2
Descriptive statistics of the public projects

Project categories	Number of projects	Duration		
			Planned	Actual
House	14	max.	450	832
		min.	75	66
		mean	221.4	297.2
		SD	102.3	192.9
Office and administrative buildings	34	max.	750	751
		min.	100	67
		mean	354.6	442.2
		SD	120.0	152.9
School buildings	52	max.	660	928
		min.	150	225
		mean	395.4	467.5
		SD	129.7	141.1
Medical centers	20	max.	720	904
		min.	90	193
		mean	313.5	444.5
		SD	162.6	231.7
Communication facilities	12	max.	360	410
		min.	195	230
		mean	268.2	308.2
		SD	58.0	59.9

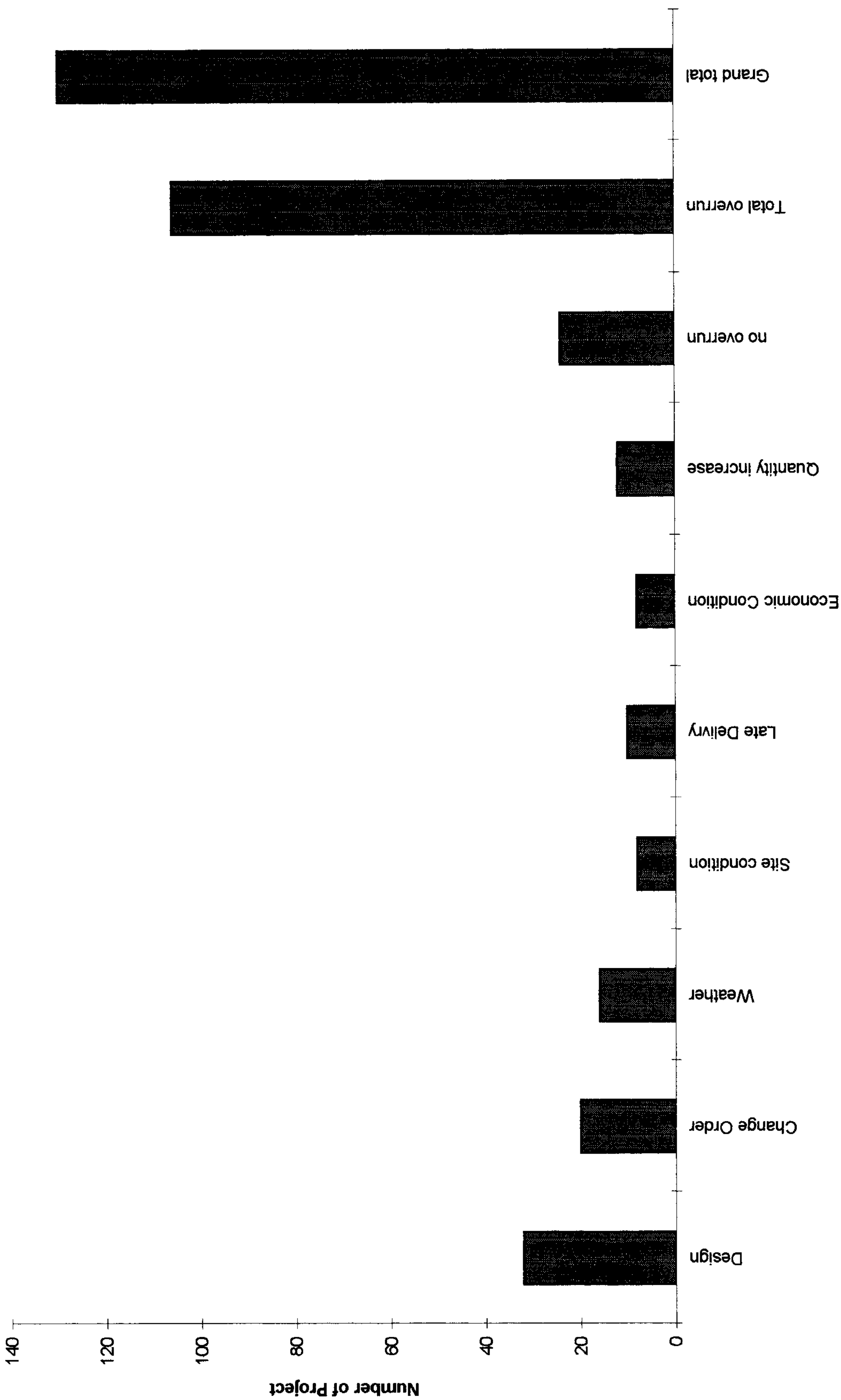

Fig. 1. Causes of delay.

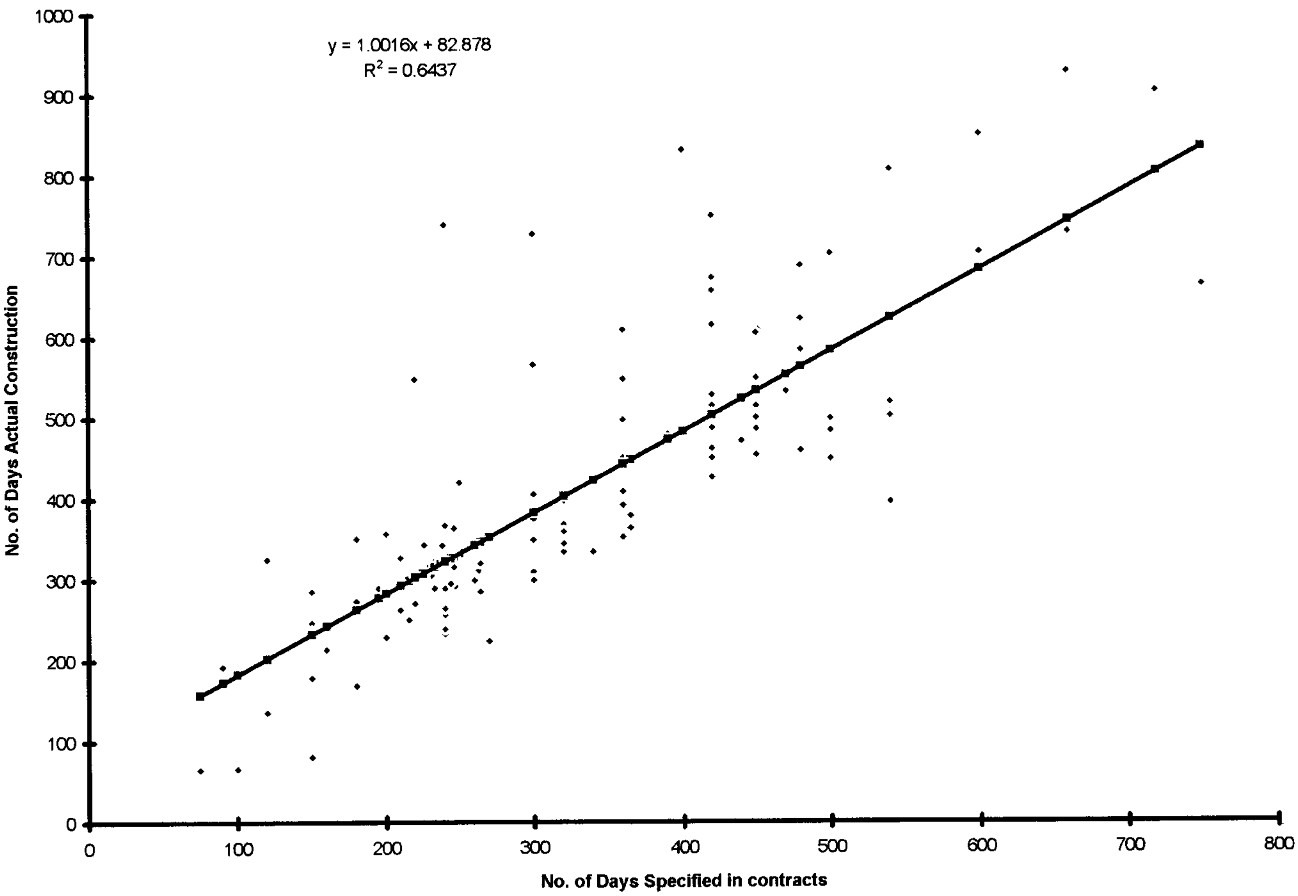

Fig. 2. Scatter plot of actual time Y versus planned time X for general model of public projects.

- Design changes;
- Disputes;
- Notification of extra work;
- Date of notice to proceed;
- Delay encountered during construction;
- Conflict of the drawings and specifications;
- Time extensions;
- Late delivery of materials and equipment.

2. Discussions

The data were entered into Excel 5 where all analysis and diagrams were developed. The first step was to explore the parameters as to causes of delay. To this effect, parameters were defined and constructed in Table 1 for public projects. These restrictions create a sample with 130 projects. The table provide frequencies for each parameter in five different construction categories. Many projects were delayed for many reasons. All extensions to the planned schedule were considered as delays. The major causes identified were: poor design, change orders, weather, site conditions, late delivery, economic conditions and increase in quantity. A breakdown of the projects by these parameters is graphically illustrated in Fig. 1. The overall delays were in 106 out of 130 (81.5%) projects. The main causes for delays were poor design in 32 projects (24.6%), while the second cause was the change orders in 20 projects (15.4%). The site conditions and the economic conditions were the least cause of delay and were found in 8 projects.

2.1. Planned and actual duration

The mean actual duration for all public projects was 426.6 days, and a standard deviation of 137 days. While the planned duration for the same projects was 343.1 days in mean, with a standard deviation of 137.4 days. The mean, maximum, minimum and standard deviation for the planned and actual time were computed as shown in Table 2 for five project classifications. It can be noticed that the actual time for each type of project vary considerably. This is illustrated by large differences between the means of the planned and

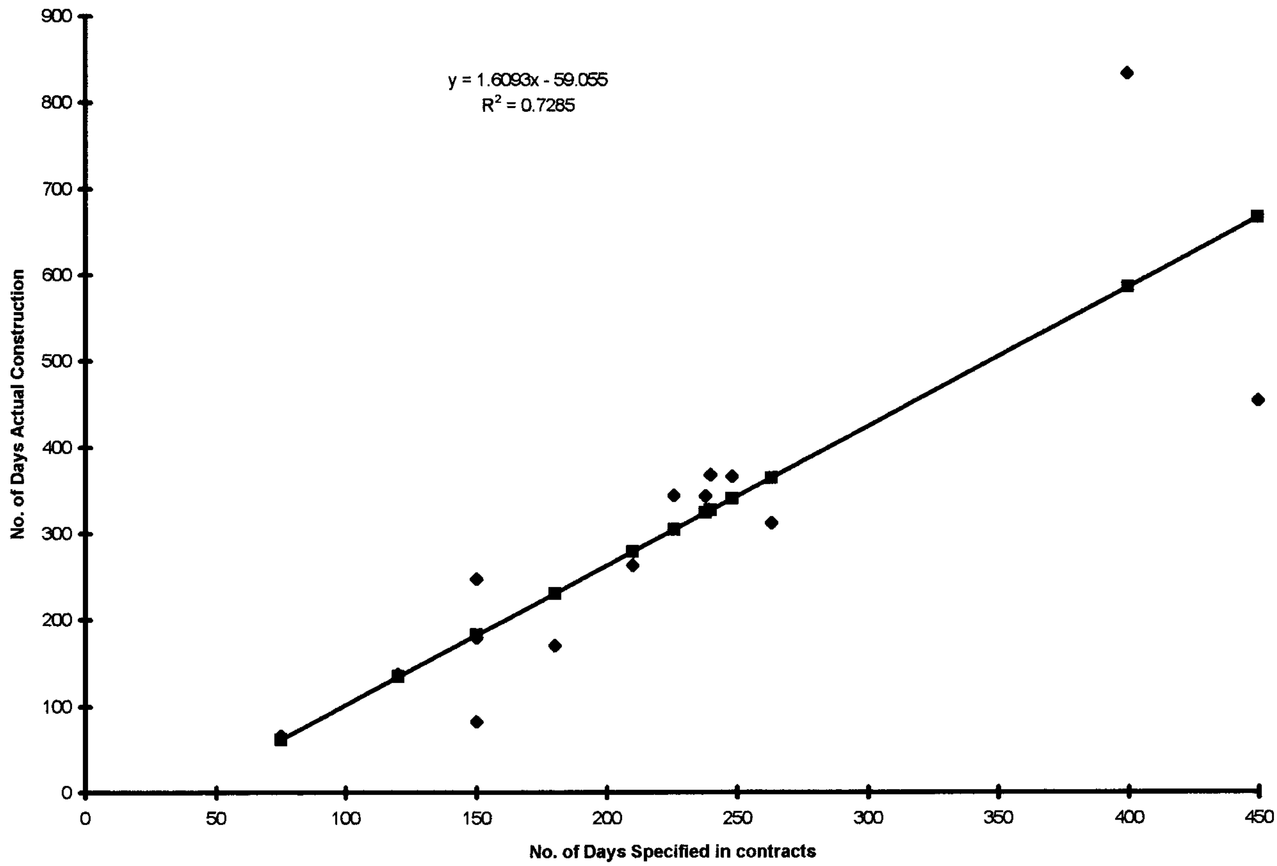

Fig. 3. Scatter plot of actual time versus planned time of the housing model.

actual times and the high values of standard deviation. For instance, the mean planned time for school buildings varied from 395.4 days to an actual of 467.5 days, while the office and adminstrative buildings varied from 354.6 planned days to 442.2 actual days. The implication is therefore, that on average during the sample period, the planned and actual duration was upward sloping. Standard deviation are reported which suggest that the variance of the actual time is considerably greater than that of the planned time, with the variance of the actual time being approximately 29 444.67 days and the variance of the planned time being approximately 18 894 days.

A mathematical structure was studied by different functions that fits the data, which indicated that the simple linear regression appears to be appropriate for this type of problem. The specification of our model is determined by one independent variable which significantly explained variations in the response variable. Correlation coefficients were used for screening the variables. Several statistical tests were conducted. Each of these was performed at 99% confidence level. It was assumed that both the actual and planned times distributions were normal and independently distributed.

3. Tests and results

Simple linear regression develops an equation that describes the relationship between two variables. In this case the equation takes the form of:

$$Y = \beta_0 + \beta_1 X + \varepsilon$$

In this model Y is the dependent variable, the parameters, β_0 and β_1 are the coefficients which are unknown and are to be estimated. X is the independent variable, and ε is a random error which is the amount of variation in Y not accounted for by the linear relationship. The theoretical models are derived and explained in the following.

For a comparison of the actual and planned time distribution, the equation developed for overall public projects is:

$$Y = 82.87 + 1.0016x$$

$$R^2 = 0.64$$

$$\text{D.W.} = 1.58 \ \text{R} = 0.80 \ \text{S.E.} = 102.8 \ \text{F} - \text{value} = 231.25 \quad (1)$$

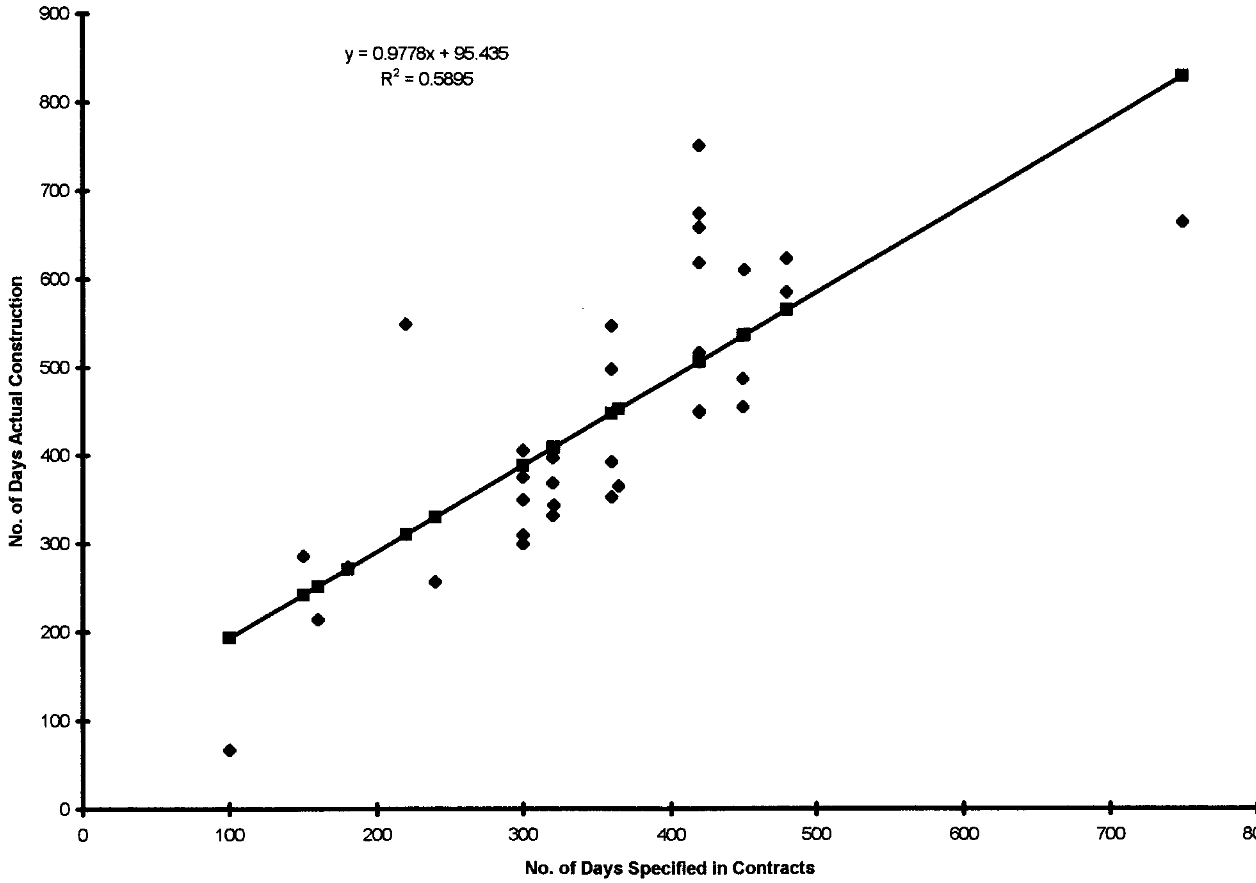

Fig. 4. Scatter plot of actual time versus planned time of the office building model.

The correlation coefficient for this relationship is 0.80 indicating that the distribution of planned time mirrors the actual time with a high degree of accuracy. The calculated F is 231.25, the higher absolute value of the F-statistics reported may reflect the observation that are powerful predictors of the measured data. Therefore, true linearity exists in the developed model.

Comparing sample means to test the agreement between the two distribution was employed. In this case the t-statistic is 9.28 which is much larger than t-value of 1.97, giving further proof of the agreement between the two distributions. The general model is valuable in that it provides a universal model of phenomena and would primarily be of interest to construction officials. The predictive equation has been developed as an aggregate model for actual construction time of a public projects.

In this setting, more specific models such as Eqs. (2)–(6) were developed, which exhibited a reasonable fit to the data. Figures 2–7 give a graphical view of how well the charts relate the actual time by project type to the planned time. Specific models are preferable and would be of particular interest to construction managers and practitioners rather than selection of the general model. The fitted equations are as follows:

3.1. Housing project

$$Y = 59.05 + 1.6X$$

$$\mathrm{R} = 0.853 \; R^2 = 073 \; \mathrm{S.E.} = 104.62 \; \mathrm{F-value} = 32.19 \tag{2}$$

3.2. Office and administration building

$$Y = 95.4 + 0.97X$$

$$\mathrm{R} = 0.76 \; R^2 = 0.59 \; \mathrm{S.E.} = 99.49 \; \mathrm{F-value} = 45.94 \tag{3}$$

3.3. School projects

$$Y = 162.05 + 0.77X$$

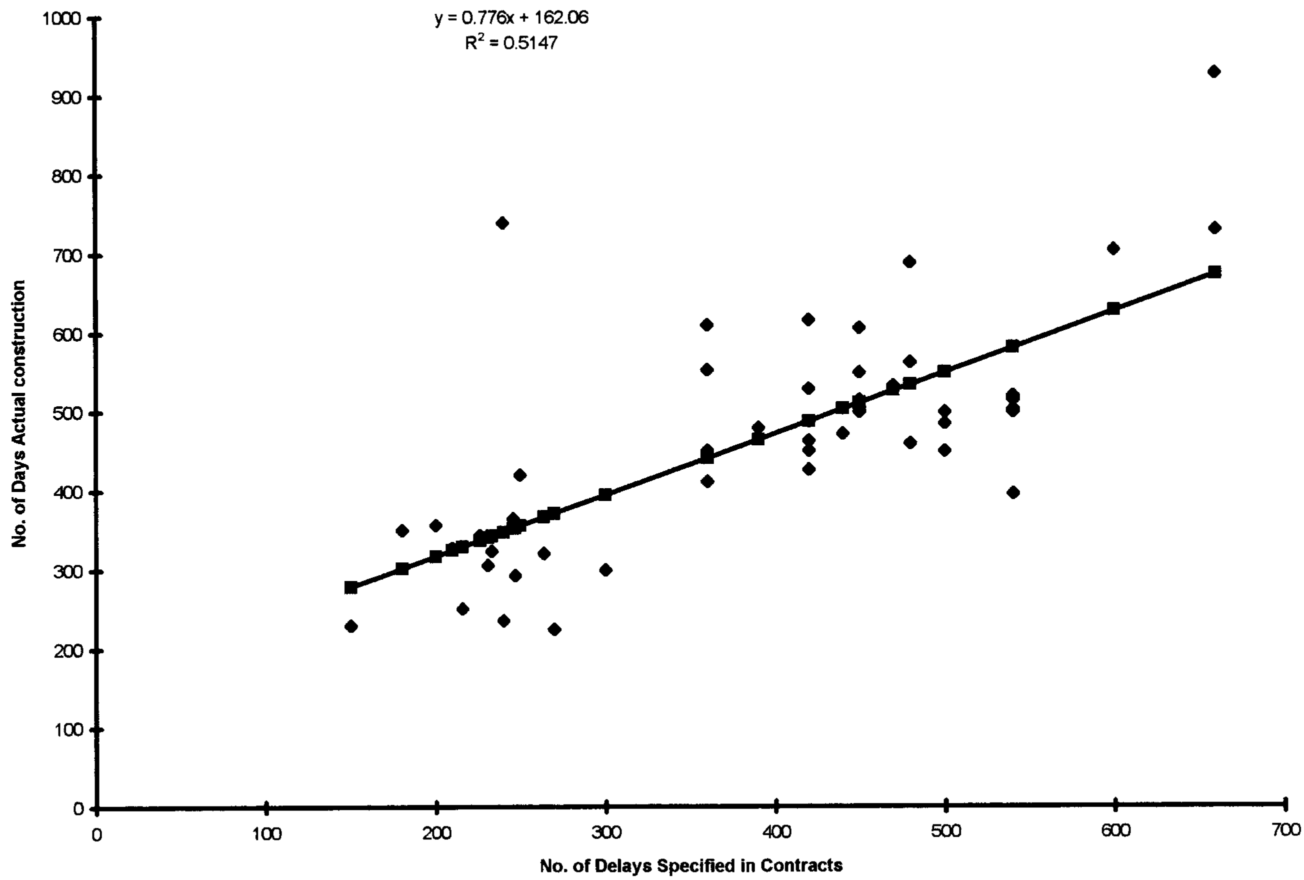

Fig. 5. Scatter plot of actual time versus planned time of the school buildings model.

$$\text{R} = 0.71 \; R^2 = 0.51 \; \text{S.E.} = 99.36 \; \text{F} - \text{value} = 51.97 \quad (4)$$

3.4. Medical centers

$$Y = 46.9 + 1.3X$$

$$\text{R} = 0.89 \; R^2 = 0.79 \; \text{S.E.} = 108.4 \; \text{F} - \text{value} = 68.71 \quad (5)$$

3.5. Communication facilities

$$Y = 85 + 0.84X$$

$$\text{R} = 0.86 \; R^2 = 074 \; \text{S.E.} = 29.27 \; \text{F} - \text{value} = 22.73 \quad (6)$$

The regression coefficients are all significantly different from zero and the expected sign and relationship between the variables is linear. Each of the tests conducted proved that, the developed equations are statistically significant at the 99% level as indicated by the t-values and appear to explain a high per cent of the variability and able to predict changes in the actual time. Other relevant regression statistics are shown below the estimates. Overall, the explanatory power ofthe estimated equations are reasonable, given that the R^2 for Eq. (1) through Eq. (6) are of a acceptable value and the corresponding F-ratios indicate very good model identifications and satisfy the diagnostic criteria. These equations can be used by engineers, planners and construction managers working in governmental agencies to estimate the actual time for construction before awarding contract.

4. Limitation and suggestion for further research

While this study is among the first to provide a full test of cause and determinants of construction delay, it is not without limitations. Several shortcomings in the data can be identified such as the actual cost of construction and construction experience of the contractors. The inclusion of the construction experience of the contractors as a predictor within the model underlines the importance of this extension of the analysis into the internal information of the firms. But this factor can be introduced only when the focus of study is moved from the construction industry to the construction firms. Such change of focus is not without difficulties. The collection of the company specific data is

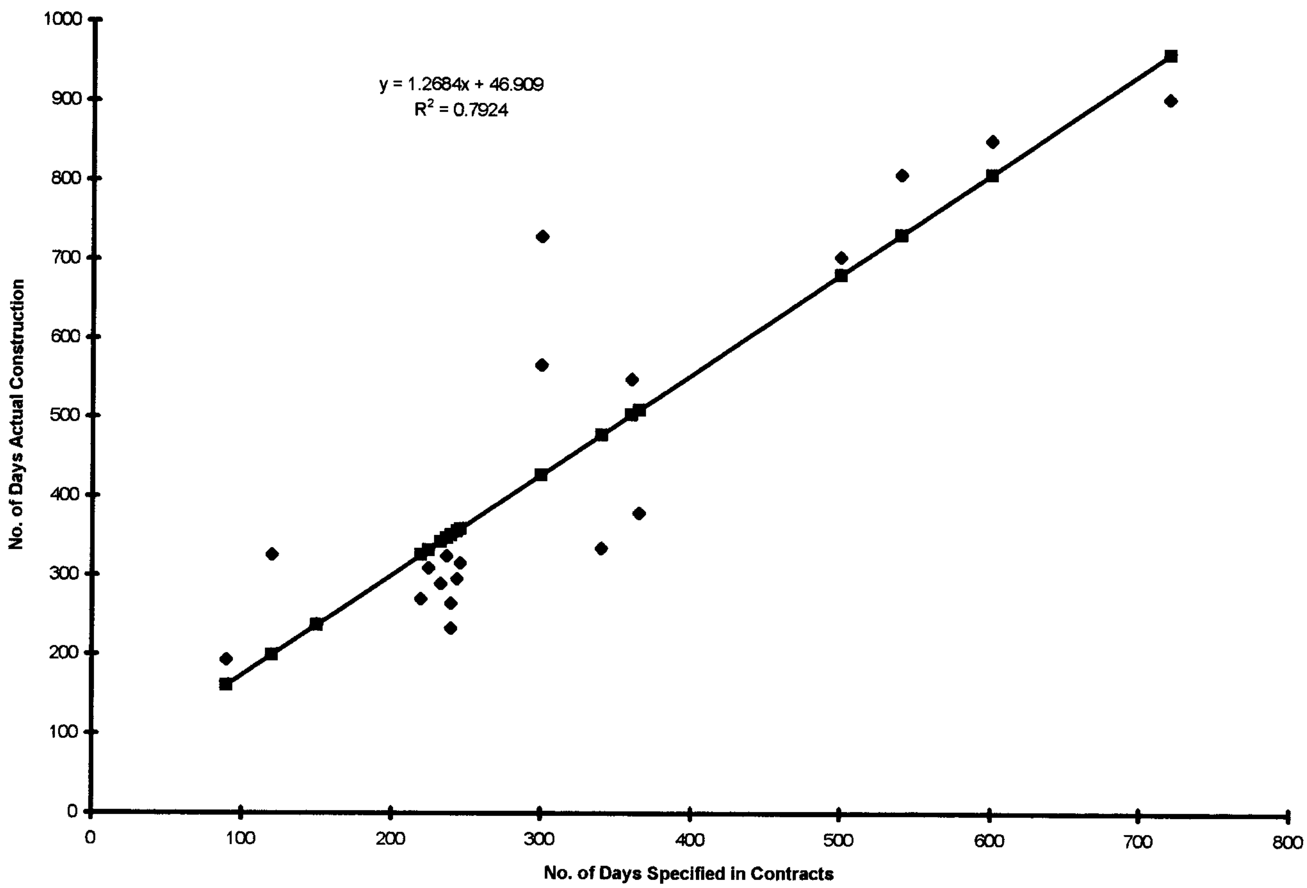

Fig. 6. Scatter plot of actual time versus planned time of the medical centers model.

costly compared with that of publicly available data. However, the quality of future studies concerning company specific data and managerial perceptions are largely dependent on the nature of the data that is available for analysis. The future emphasis should be placed on the collection of the appropriate information and this will be the subject of an additional paper.

Projectsinvestigated in this study exhibit a delay. In practice, this phenomena is expected to continue unless management actions are taken to control these causes within the planned element of the design and construction works. Thus good practice in planning, coordination, and the change of the control procedures of the public institutions needs to be recognised and the implications understood. The model still appears tenable, then it may be applied broadly for guidance and for planning further work and will prove beneficial in future projects.

5. Conclusion

Construction delay and overrun is a critical function in construction of public projects. It has been of great interest to construction researchers but has not been well understood in the case of public building projects. A survey of 130 projects indicated that poor design and negligence of the owner, change orders, weather condition, site condition, late delivery, economic conditions, and increase in quantities are the main causes of delay. In line with the reviewed research, the present investigation provides confirmation of the effect of defined parameters on construction delays.

Practically oriented research is vital for proper management of construction projects. Reliable prediction of construction duration, and then controlling cost within budget is widely used in decision making and is an essential part of successful management. To test this hypothesis, a simple linear model was used to estimate the relationship between the actual and planned time. The major implication of the foregoing have important ramifications for understanding the actual time of public projects. This has been repeatedly stated to the outstanding need of construction in Jordan. The relations obtained have the advantage of relying upon the statistical treatment of real data and could without doubt be improved by considering a larger sample of projects. The researcher believes that the arguments and findings presented in this study provide a good guidance for managerial intervention, and provide

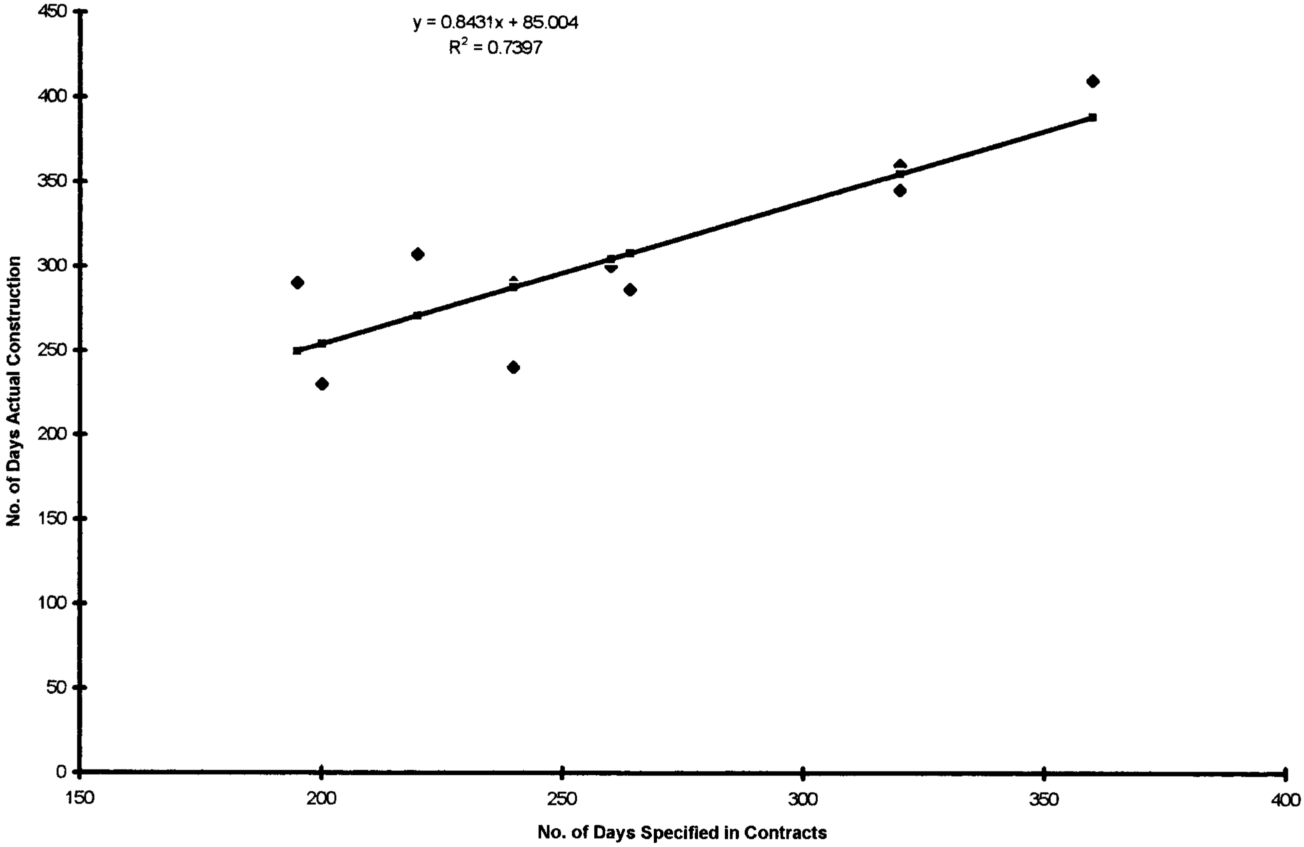

Fig. 7. Scatter plot of actual time versus planned time of the communication facilities model.

some guidelines and actionable information that managers can utilize to manage their projects.

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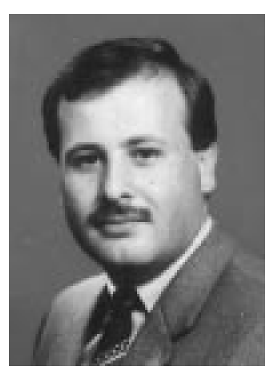

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