Predicting the Delivery Time of Public School Building Projects Using Nonlinear Regression

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ABSTRACT

The delay in delivering public school building projects in Iraq is one of the major problems that face the construction of new school buildings. In order to enable the concerned governmental agencies to predict the expected delivery time of these projects at the time of contract assignment, two forecasting models are developed to aid in this matter. After reviewing a wide range of literature to determine the most common causes of delay, a questionnaire is distributed to owners, consultants, supervising engineers and contractors engaged in public school building projects. The results of the questionnaire were analyzed using the relative importance index. Nine most important causes of delay in public school building projects were assured by the respondents namely; the contractor's financial status, delayed interim payments, change orders, contractor rank (classification), work stoppages, contract value, experience of the supervising engineers, contract duration and delay penalty. Historical data concerning these causes was extracted from past records of the General Directorate of School Buildings, then nonlinear regression was employed to develop two models (A & B) that can predict the final delivery time of public school building projects having (12) and (18) classes separately, where the Levenberg-Marquardt technique was used to develop the mathematical equations. The developed prediction equations show a degree of average accuracy of (97.79%) for schools having (12) classes and (97.11%) for schools having (18) classes, with (R^2) for both NLR models of (81.25%) and (87.58%) respectively.
Keywords: Delay, Delivery Time, Nonlinear Regression, School Projects.

INTRODUCTION

Unfortunately, the delay in delivering all types of construction projects in Iraq is a common phenomenon nowadays. The majority of public school building projects in Iraq are not completed within the period specified in the contracts causing drawbacks in implementing the strategic education plans of the country and lifting their costs. Many studies have been carried out to study actual factors that influence the final delivery time of construction projects. No attempts has been found to study how to use the available information at the time of contract assignment to predict

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the expected construction projects delivery time, not the one stated in the contract. Public school building is one of the most projects that need such a tool.
The expected future circumstances of any project cannot be known at the time of contract assignment. Although the hypothesis of this research is that the owner can be able to predict the final delivery time when he knows some previous information such as: the contractor's financial status, the policy of interim payments, the history of change orders, the contractor ranking, the history of work stoppages, the contract value, the experience of his supervising engineers, the contract duration and the delay penalty. All these information are available at the time of assignment and can be used as input data in the formulation of a final delivery time prediction model.
(Aibinu and Jagboro) had defined construction projects delay as "the situation where the contractor and the owner jointly or separately contribute to the non-completion of the project within the original or the stipulated or agreed upon contract period" [1].The most adopted approach to estimate construction projects delivery time is to use historical data and to find a mathematical relationship between the delay factors and their impact on delivery time (Aswed) [2]. One of the major advantages in using nonlinear regression is the broad range of functions that can be used (Mondragon) [3].

Research Objectives

The aim of this research is to:

- Investigate the main causes of delay in Iraqi public school building projects.
- Develop a model to enable the concerned governmental agencies to predict the expected delivery time of public school building projects at contract assignment.

Research Justification

Many studies have been carried out to study actual factors that influence the final completion time of construction projects either at design stage or during construction. No attempts has been found to study how to use available information at the time of contract assignment to predict the expected construction projects delivery time, not the one stated in the contract. Such predicted time is of great help to decision makers to maneuver with budget allocations, re-plan their cash flow forecasting and to keep in mind the expected date of using or occupying the completed projects.

Research Methodology

A wide range of literature is reviewed aiming at finding the most common causes of delay in construction projects. A questionnaire form is then distributed to owners, consultants, supervising engineers and contractors working at the General Directorate of school buildings in the Ministry of Education, Baghdad Governorate and Regions Development Committee of Baghdad Province. The expert opinions were analyzed to yield nine most influential factors that cause delays in delivering public school building projects. Data concerning these nine causes were obtained from the General Directorate of school buildings then used to develop nonlinear regression prediction models.

Previous Studies

(Assaf and Al-Hejji) [4] studied the causes of delays in large construction projects in Saudi Arabia, and found that (73) causes of schedule delay exist in Saudi construction projects that could be grouped into (9) major categories with different levels of importance to different parties. (Pourrostam and Ismail) [5] identified the main causes and consequences of delay in Iranian construction projects and identified the (10) most important causes of delay out of a list of (27) different causes of delay that contribute to (6) different effects of delay. (Jahanger) [6] studied the causes of delay in construction projects in Baghdad city and specify the most important causes of delay through a questionnaire that contained (58) causes of delay which were categorized in (10) groups of delay causes. (Bekr) [7] identified (65) main causes of delay in public works in Iraq and combined them into four groups according to their source. As a result of reviewing these researches and others, (73) main causes of delay are listed in a questionnaire form to obtain local expert opinions about their applicability in the case study.

Questionnaire Results

The thirty seven main causes of delay were classified into four groups; owner-related, consultant-related, contractor-related and external delay factors. These groups were listed in a questionnaire form to obtain local expert opinions about their applicability in the case study. Appendix (A) illustrates the questionnaire form used showing the (73) causes of delay in delivery time of public school building projects and their final screening and ranking based on the questionnaire results discussed later. A total of (98) out of (120) distributed questionnaire forms were collected forming a response rate of (81.6%). The respondents consist of (14) owner representatives, (10) consultants, (53) supervising engineers and (21) contractors. Nine most influential factors that cause delays in delivering public school building projects were identified by the local experts namely: the contractor's financial status, delayed interim payments, change orders, contractor rank (classification), work stoppages, contract value, experience of the supervising engineers, contract duration and delay penalty.

Verification of the Questionnaire Results

The reliability and validity of the questionnaire results is checked by employing Cronbach's alpha technique using equation (1), where the normal range of Cronbach's coefficient (alpha) value is between (0.0) and (1.0). The closer the alpha is to (1) the greater the internal consistency of data (Dawood) [8].

$$\alpha = \frac{K}{K-1}\left[1 - \frac{\sum_{i=1}^{k} S_i^2}{S_t^2}\right] \quad \ldots (1)$$

where:

K : number of items in group

S_i^2: the variance associated with item (i).

S_t^2: the variance associated with the sum of all (k) item scores.

Table (1) shows the values of reliability and validity according to Cronbach's alpha for each group in the questionnaire. It is found that the values of Cronbach's alpha were in the range of (0.853 - 0.952). This range is considered high, so it ensures the reliability and validity of each group in the questionnaire, knowing that validity is measured according to equation (2) (Dawood) [8].

$$V = \sqrt[2]{\alpha} \quad \ldots (2)$$

Table (1): Reliability and Validity of delay factors groups

Delay Factors Group	No. of Factors	Reliability *	Validity
Owner-Related Delay Factors	17	0.881	0.938
Consultant-Related Delay Factors	15	0.952	0.975
Contractor-Related Delay Factors	30	0.853	0.923
External Delay Factors	11	0.942	0.970

(Cronbach's Alpha)

In addition the relative importance of the various causes of delay is calculated according to (Ozdemir) [9] who used the relative importance index (RII) for such purpose. The five-point Likert scale ranged from (0 = not important) to (4 = very highly important) is adopted and transformed to relative importance indices (RII) for each factor in the questionnaire using equation (3).

$$RII = \left(\frac{\sum W}{A*N} \right) \quad ..(3)$$

Where:
W: the weight given by the respondents and ranges from (0 - 4),
A: the highest weight given by the respondents (for each factor), and
N: the total number of respondents which equal to (98).

It is found that values of RII were in the range of (0.217 - 0.795) as listed in Appendix (A). When considering all causes above neutrality significance of (0.5), the number of causes became (18); half of them are much near to neutrality. To take into account all (18) causes might complicate the implementation of the prediction model which ought to be simple and easy. The other nine causes were found to have correspondence with the information available at the time of contract assignment which meets the research hypothesis. Therefore it is decided to select the causes that have RII values greater than (0.60) to develop the NLR prediction models. The nine causes that were selected are listed in table (2).

Data Acquisition

The data needed to develop the nonlinear regression models are obtained from (72) school projects having (12) classes and (56) school projects having (18) classes, all completed in the period (2004-2011). Information is extracted from the records of the General Directorate of School Buildings in the Ministry of Education. The projects involved in this study are chosen to be of the same design, number of stories, gross floor area, and procurement method. Once enough information is determined, prediction of the final delivery time is performed using nonlinear regression for both types of buildings of (12) and (18) classes.

Table(2): The most influential causes of delay

	Causes of Delay	RII%	Rank
1	The contractor's financial status	79.59	1
2	Delayed interim payments	75.26	2
3	Change orders	72.45	3
4	The contractor ranking	70.92	4
5	Work stoppages	66.84	5
6	The contract value (projects size)	65.56	6
7	Experience of supervising engineers	64.80	7
8	Contract duration	64.54	8
9	delay penalty	62.24	9

The data are divided into (training, testing and validation) sets, allocating (80%) of data to the training set, (15%) to the validation (querying) set and (5%) to the testing set

for model (A) of school buildings having (12) classes. As a result, the records of a total of (57) projects are used for training, (11) for validation and (4) for testing this model. On the other hand, (75%) of the data were allocated to the training set, (20%) to the validation (querying) set and (5%) to the testing set for model (B) of school buildings having (18) classes. As a result, the records of a total of (42) projects are used for training, (11) for validation and (3) for testing this model.
The independent variables that have the most significant impact on the final delivery time of public school building projects based on the questionnaire results were treated in order to fit the analysis requirements so they become as follows:

I_1: the ratio of delay penalty to the total value of contract.
I_2: the ratio of contractor's financial status to the contract value.
I_3: the ratio of mean interim payments duration to the contract duration.
I_4: the ratio of the sum of work stoppages to the contract duration.
I_5: the ratio of mean change orders duration to the contractor duration.
I_6: the experience of the supervising engineers.
I_7: contractor rank (classification).

It was found from initial iterations that the contract value and the contract duration have insignificant effect when used by themselves, and the model become very much better when they were excluded. Nevertheless, their role still exists in calculating the ratio of other parameters.

Nonlinear Regression Models

The Levenberg-Marquardt technique is used to develop the NLR equations. This technique is based on inserting variables in a nonlinear equation built according to some values of equation parameters and checked by the "coefficient of determination" test. The best values of the equation parameters are obtained through a number of iterations. Then the equation is examined by comparing validation values with actual values. Tables (3) and (4) show the best values of the equations parameters obtained.

Table (3): Parameters estimates for model (A)*

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
β_1	-1583.240	817.445	-3225.127	58.646
β_2	1.917	0.947	0.015	3.819
β_3	2.620	1.082	0.446	4.794
β_4	0.041	1.832	-3.639	3.722
β_5	75.654	153.434	-232.527	383.835
β_6	0.804	0.215	0.372	1.235
β_7	0.858	0.238	0.381	1.336
β_8	-1.403	67.219	-136.417	133.611
β_9	7.378	67.274	-127.747	142.502
β_{10}	-0.027	0.231	-0.490	0.437
β_{11}	2.079	1.639	-1.213	5.372

*** Model (A) concerns school buildings having (12) classes**

Table (4): Parameters estimates for model (B)*

Parameter	Estimate	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
β_1	-2230.502	870.566	-3996.091	-464.912
β_2	0.010	0.009	-0.009	0.029
β_3	1.844	0.823	0.175	3.512
β_4	1.023	0.731	-0.459	2.505
β_5	0.622	0.533	-0.459	1.703
β_6	0.366	0.253	-0.146	0.878
β_7	0.978	0.265	0.440	1.516
β_8	-0.030	0.068	-0.168	0.108
β_9	6.614	0.399	5.805	7.423

*** Model (B) concerns school buildings having (18) classes**

According to the aforementioned procedure, the following final delivery time estimation equations were developed using (NLR) for models (A) and (B):

$$FDT(A) = \beta_1(I_1) + \beta_{11}(I_2)^{\beta 2} + \beta_5(I_3)^{\beta 3} + (I_7)^{\beta 6} *(I_4)^{\beta 7} + \beta_8(I_6)^{\beta 4} + \beta_9(I_5)^{\beta 10} \quad \dots (4)$$

$$FDT(A) = -1583.24(I_1) + 2.079(I_2)^{1.917} + 75.654(I_3)^{2.620} + (I_7)^{0.804} *(I_4)^{0.858} - 1.403(I_7)^{0.041}\ 7.378(I_6)^{-0.027} \quad \dots\dots\dots\dots (5)$$

$$FDT(B) = \beta_1(I_1) + \beta_9(I_2)^{\beta 2} + \beta_3(I_3+I_4)^{\beta 7} *(I_7)^{\beta 6} + \beta_5(I_5) + \beta_8(I_6)^{\beta 4} \quad \dots\dots\dots\dots (6)$$

$$FDT(B) = -2230.502(I_1) + 6.614(I_2)^{0.010} + 1.844(I_3+I_4)^{0.978} *(I_7)^{0.366} + 0.622(I_5) - 0.030(I_6)^{1.023} \quad \dots\dots\dots\dots (7)$$

Models Accuracy and Validity

One of the most important steps in developing a model is to test its accuracy and validity. It involves testing and evaluating the developed model with some test or validation data. The validation data should be some representative data from the targeted population but haven't been used in the development of the model. The predicted final delivery time of projects is forecasted using equation (5) for model (A) and equation (7) for model (B). Results are shown in Tables (5) and (6). It is evident now that the model performs well through the residual values shown in these two tables.

Table (5): Comparison of observed and predicted data of model (A)*

Ln(FDT) Observed	Ln(FDT) Predicted	Residual value
6.61204	7.03588	-0.42384
6.49072	6.53461	-0.04388
6.44095	6.41772	0.02323
6.09807	6.07318	0.02490
6.07993	5.95390	0.12603
6.07764	6.29557	-0.21792
5.93225	6.08085	-0.14860
5.91080	6.26299	-0.35220
5.89715	6.01045	-0.11329
5.73010	5.74134	-0.01124

5.69709	5.71063	-0.01353

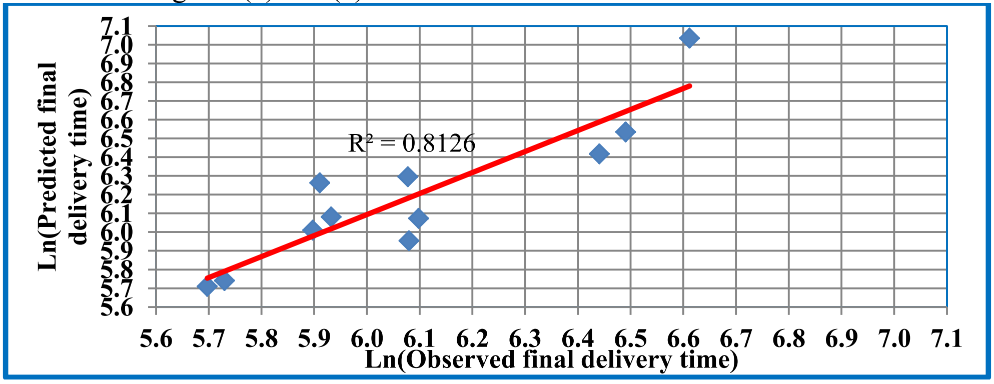
*** Model (A) concerns school buildings having (12) classes**

Table (6): Comparison of observed and predicted data of model (B)*

Ln(FDT) Observed	Ln(FDT) Predicted	Residual value
6.66185	**6.43484**	**0.22702**
6.66058	**6.30102**	**0.35956**
6.53379	**6.17834**	**0.35545**
6.49224	**6.19783**	**0.29441**
5.95584	**6.07182**	**-0.11598**
5.94803	**6.02393**	**-0.07589**
5.94017	**5.82459**	**0.11558**
5.94017	**5.95849**	**-0.01832**
5.71043	**5.84951**	**-0.13908**
5.70044	**5.82957**	**-0.12913**
5.68698	**5.85419**	**-0.16722**

*** Model (B) concerns school buildings having (18) classes**

The coefficient of determination is used to assess the validity of the derived equations of the NLR models for the final delivery time (FDT) of public school building projects. The natural logarithm (Ln) of the predicted values of (FDT) is plotted against the natural logarithm (Ln) of observed (actual) values of the validation data set as shown in Figures (1) and (2).



Figure(1): Observed vs. Predicted delivery time using NLR model (A)

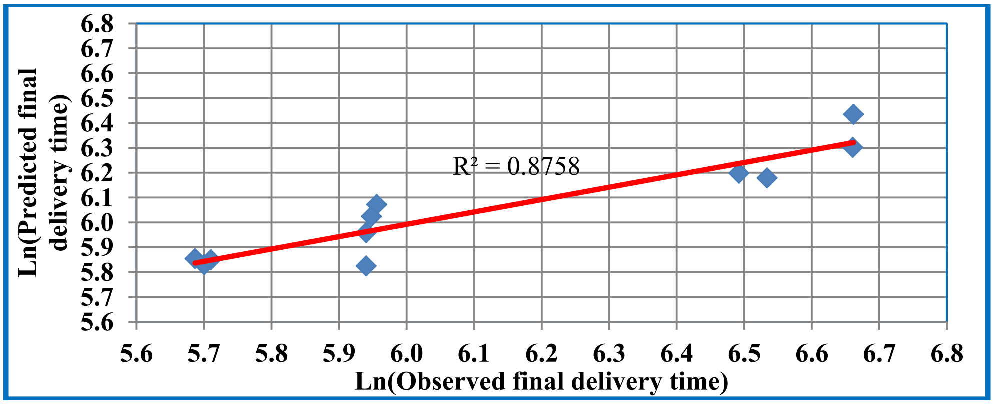


Figure (2): Observed vs. Predicted delivery time using NLR model (B)

It is clear from these Figures that there is a generalization capability in both NLR models to work in this type of data. It is found that the coefficient of determination (R^2) is (81.25%) for model (A) and (87.58%) for model (B). Therefore it can be concluded that these two models show a very good agreement with actual observations.

Models Evaluation

The statistical measures that can be used to measure the performance of prediction models include the following (Khaled, et al) [10]:

i. Mean Percentage Error (MPE):

$$MPE = (\sum \frac{A-E}{A} / n) * 100\% \quad \dots (7)$$

Where:

A: actual value

E: estimated value or predicted value

n: total number of cases (11 for validation).

ii. Root Mean Squared Error (RMSE):

$$RMSE = \sqrt{\frac{\sum_{i=1}^{n} (E-A)^2}{n}} \quad \dots .(8)$$

iii. Mean Absolute Percentage Error (MAPE):

$$MAPE = (\sum \frac{|A-E|}{A} * 100\%)/n \quad \dots . (9)$$

iv. Average Accuracy Percentage (AA%):

AA% = 100% - MAPE …. (10)

v. The Coefficient of Correlation (R).

vi. The Coefficient of Determination (R^2).

The MAPE and percentage RMSE as measures of the average error are applied only to the independent test data. The results of these statistical parameters for model (A) are given in Table (7), where the MAPE and Average Accuracy Percentage generated by NLR model (A) are found to be (2.21%) and (97.79%) respectively. On the other hand the results of statistical measures of model (B) are given in Table (8) where the MAPE and Average Accuracy Percentage generated by NLR model (B) are found to be (2.89%) and (97.11%) respectively.

Table (7): Performance measures of the NLR model (A)

Description	Statistical parameters
MPE	-1.70%
RMSE	0.191
MAPE	2.21%
AA%	97.79%
R	90.13%
R^2	81.25%

Table (8): Performance measures of the NLR model (B)

Description	Statistical parameters
MPE	0.86%
RMSE	0.211
MAPE	2.89%
AA%	97.11%
R	93.54%
R^2	87.58%

CONCLUSIONS

As a result of this research, nine causes are said to be the most influential causes of delay according to expert opinions gathered through a questionnaire form directed to owners, consultants, supervising engineers and contractors engaged with school buildings projects in Baghdad. These causes are: the contractor's financial status, delayed interim payments, change orders, the contractor ranking, work stoppages, the contract value, the experience of supervising engineers, the contract duration and delayed interim payments. When the historical data of (72) school projects having (12) classes and (56) school projects having (18) classes, all constructed in the period (2004-2011), concerning these nine causes were gathered, two models were developed using nonlinear regression to predict the final delivery time of public school building projects before the work starts. Statistical validation measures (MPE, RMSE, MAPE, AA and R^2) were used to check the validity and generalization of both models. The (R^2) for NLR models (A) and (B) were (81.25%) and (87.58%) respectively. The developed models showed an excellent performance so can be generalized in Iraq to predict the final delivery time of public school building projects of the types; having (12) and (18) classes.

Recommendations

1. Stakeholders of school buildings projects are recommended to pay attention to the nine factors that found to cause delay in school buildings delivery time in order to avoid delays in the future. Much care must be paid to the four most influential factors.
2. Where the instructions of the contractors' classification give the right to contractors to commit to a contract sum that is about six times their financial status, paying the contractors their interim payments in time become an essential issue, otherwise they will definitely face financial distress.
3. Care must be taken to the documentation of finished project data and information feedback in order to achieve efficient and effective updated information while it's better to be aided by the development of electronic database.

Future Studies

1. Additional parameters can be included relating to the causes of public school buildings projects delays in order to improve the prediction models across a wider range of data.
2. Using NLR technique to predict the delivery time of other types of construction projects with the usage of additional inputs including other factors for future analysis.

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Appendix (A) The Questionnaire form showing respondents' scores and relative importance indices

Owner-Related Causes		Impact					RII	Rank
		Nil	Low	Med.	High	V. h.		
1	Inaccurate scope definition	19	24	26	17	12	0.446	47
2	Internal conflicts in the owner's office	19	21	24	23	11	0.464	36
3	Type of contract	13	23	32	20	10	0.477	31
4	Method of procurement	7	8	22	39	22	0.656	6
5	Delayed design approvals	10	26	22	22	18	0.531	10
6	Short contract duration	10	5	20	44	19	0.645	8
7	Ineffective delay penalty	15	5	16	41	21	0.622	9
8	Lack of early completion incentives	15	29	29	13	12	0.444	48
9	Delayed site deliverance	11	23	23	26	15	0.528	11
10	Work stoppages	6	13	20	27	32	0.668	5
11	Delayed payments	7	7	12	24	48	0.753	2
12	Delayed approval of submittals	14	22	22	28	12	0.505	16
13	Delayed change orders	1	10	16	42	29	0.724	3
14	Delayed decision-making	8	10	15	46	19	0.648	7
15	Poor coordination with other parties	10	23	37	20	8	0.482	27
16	Legal obstacles	9	25	26	26	12	0.518	13
17	Delayed final acceptance certificate	10	23	35	23	7	0.485	25
Consultant-Related Causes		**Impact**					**RII**	**Rank**
		Nil	**Low**	**Med.**	**High**	**V. h.**		
18	Miss-understanding of owner requirements	17	24	25	21	11	0.462	40
19	Inaccurate or/and inadequate design data	15	25	18	25	15	0.500	19
20	Internal conflicts in the consultant office	26	26	22	19	5	0.375	65
21	Inefficiency in design management	20	23	15	22	18	0.487	24
22	Inexperienced design team	22	23	12	21	20	0.485	25
23	Lack of modern design programs	19	21	27	25	6	0.444	48
24	Delays design in completion	14	23	22	25	14	0.505	16
25	Complexity of design	21	23	31	18	5	0.406	62
26	Design mistakes or/and incompatibility	14	24	23	23	14	0.497	20

		Impact					RII	Rank
27	Vague design or/and insufficient details	18	16	28	23	13	0.492	22
28	Delay in details issuance	15	25	25	23	10	0.469	34
29	Improper supervision by the consultant	16	23	24	29	6	0.464	36
30	Delayed approval of changes	15	22	24	29	8	0.482	27
31	Consultant inflexibility	18	17	34	21	8	0.459	41
32	Poor coordination with other parties	18	23	31	17	9	0.439	52
Contractor-Related Causes		Impact					RII	Rank
		Nil	Low	Med.	High	V. h.		
33	Funding problems	1	7	14	27	49	0.796	1
34	Conflicts with other parties	22	20	24	24	8	0.439	52
35	Poor coordination with other parties	22	24	25	21	6	0.411	59
36	Poor project planning	12	29	18	17	22	0.520	12
37	Weak site management	8	1	18	43	28	0.709	4
38	Subcontractors works contradictions	35	20	16	17	10	0.365	68
39	Delayed mobilization	17	23	29	20	9	0.452	45
40	Non-suitable construction methods	25	19	19	17	18	0.459	41
41	Poor qualification of technical staff	21	18	15	24	20	0.510	15
42	Frequent defects reworks	22	14	20	24	18	0.505	16
43	Delayed subcontractors work	39	13	12	23	11	0.383	64
44	Poor quality of subcontractors work	41	9	8	25	15	0.408	60
45	Frequent change of sub-contractors	40	14	15	14	15	0.372	67
46	Shortage of materials available in market	21	22	16	30	9	0.459	41
47	Change of materials during construction	22	26	28	12	10	0.403	63
48	Delay in material processing	17	20	25	25	11	0.482	27
49	Damage of materials when needed	35	17	20	14	12	0.375	65
50	Delayed pre-manufactured components	37	16	21	12	12	0.362	69
51	Delayed materials purchasing process	16	27	28	18	9	0.441	50
52	Multitude materials alternatives available	36	19	31	10	2	0.304	71
53	Frequent breakdowns of equipment	17	27	30	19	5	0.418	58
54	Insufficient number of equipment	15	27	28	25	3	0.434	56
55	Unskilled equipment operators	17	29	30	17	5	0.408	60
56	Low equipment productivity	16	21	29	25	7	0.464	36
57	No high technology used	18	14	34	24	8	0.474	33
58	Shortage in labor	19	19	23	26	11	0.477	31
59	Unskilled labor	15	19	26	28	10	0.497	20
60	Nationality of laborers	47	27	16	6	2	0.217	73
61	Low labor productivity	15	23	29	23	8	0.464	36
62	Conflicts among laborers	35	32	19	7	5	0.283	72
External Causes		**Impact**					**RII**	**Rank**
		Nil	**Low**	**Med.**	**High**	**V. h.**		
63	Site topographic characteristics	16	29	24	22	7	0.436	54
64	Properties of site soil and groundwater	10	30	25	20	13	0.490	23
65	Hot weather	20	19	19	28	12	0.482	27
66	Rain	25	17	22	20	14	0.452	45
67	Lack of infrastructure facilities near the site	10	29	31	20	8	0.467	35
68	Delayed infrastructure facilities connection	10	30	36	17	5	0.441	50
69	Site organization	13	26	37	21	1	0.426	57
70	Work accidents and casualties	15	47	30	5	1	0.321	70
71	Delays in obtaining governmental permits	18	25	22	22	11	0.457	44
72	Changes in instructions and laws	17	26	27	21	7	0.436	54
73	Social, Cultural and Security effects	9	27	25	23	14	0.515	14