

Effects of Inputs from the Preconstruction Activities on the Design Phase of Construction Projects

Leelanath Daluwatte and Malik Ranasinghe

Abstract: Success of the design of a project would depend on the adequacy of its inputs. The adequacy of inputs from the preconstruction activities is important to achieve effective delivery of a design and then the construction project. This study focused on identifying the relevant preconstruction activities and analyzing the adequacy of use of the outputs of preconstruction activities as inputs to the design of construction projects.

Thirty eight design phase related preconstruction activities were identified through literature review. Data was collected using a structured questionnaire regarding the adequacy of the inputs from the identified preconstruction activities to the design phase from the professionals involved in construction projects in the industry.

The data was analysed by multiple regression analysis and using the best fit, a model to predict the Relevance and Adequacy/Inadequacy of outputs of preconstruction activities (as inputs to the design phase) was proposed. Exponential relationship between Relevance (x) of the preconstruction activity and Adequacy (y) of the output of the of the carried out preconstruction activity (as the input to the design phase) was found as the best fit of the multiple regression analysis in the form of " $y = 2.6916e^{0.024x}$ ". Also, % of Inadequacy (z) = 100% - % Adequacy. Hence, a model to predict % Inadequacy, " $z = 100\% - y = 2.6916e^{0.024x}$ ", was proposed to find out the inadequacy of the use of output of a relevant preconstruction activity.

Keywords: Preconstruction activities, Construction projects, Design phase

1. Introduction

Design shortcomings were identified as the main contributory factor for cost and time overruns of construction projects [1]. Further, design related issues were found among the most problematic factors [2, 3] and significant in creating issues in construction projects [4, 5]. It was revealed, failure to identify project risks at design stages was seen as a cause for failure in construction projects [6]. It was also stated design errors [5, 7], and erroneous design work/processes including attitudes of the designer [6] created issues in construction projects. Poor designs [3, 4, 7] delay in designs [2, 4], design changes [3, 4], client driven design changes [4, 5, 7], and change orders due to design changes [4, 5] were identified as contributing to overruns in construction projects.

More time spent during early briefing stage of the design to define the scope and complexity of the project and complete design information leads to more accurate budget estimates of the projects [7]. The following literature highlighted how the effects of design phase contributed to issues in construction projects

[8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24].

Proper attention paid at the preconstruction stage [25] and proper preconstruction planning [26] was seen to contribute to the success of construction projects. Based on the above, the objectives of the study were to identify the preconstruction activities of construction projects and to analyze the adequacy of use of the outputs of preconstruction activities as inputs to the design phase of the construction projects.

Eng. Leelanath Daluwatte, B.Sc. Eng. Hons. (Moratuwa), FIE (Sri Lanka), C. Eng., P.E., M.ASCE, DBM, Dip HRM (Merit), Dip(Cleaner Production), Dip(Human Rights), Distinguished Toastmaster, Consultant in Project Management / Construction Management / Process Improvements.

Eng. (Prof.) Malik Ranasinghe, B.Sc. Eng. Hons. (Moratuwa), M.A.Sc. (BrCol), Ph.D. (BrCol), C. Eng., Int. PE, FIE (SL), FNAS(SL) Senior Professor, Dept. of Civil Engineering, University of Moratuwa.



2. Literature Review

Proper attention paid at the preconstruction phase enables the executors of construction projects to carry out professional monitoring and controlling of the two most important aspects of a project, time schedule and the budget more effectively [25]. Also it was observed when preconstruction planning was done, slippage of project schedules and overruns of the project costs could be mitigated to a great extent, if not eliminated [25]. How preconstruction planning affects cost savings and how the preconstruction planning methods promote sustainability and valuable information to investors and owners were highlighted [27]. Preconstruction planning was claimed to be a major determinant for project success [28].

Technological advancement and continuous fragmentation of the construction industry have resulted in a spiral increase in complexity of building projects. The contractors have failed to adjust their planning to more detailed level and the industry still plan the projects at the activity level. Failure to plan projects at role level, like planning for each roleplayer to carry out the activity, is widening the gap

between the contractors, subcontractors and the operatives. Hence the approach may need to be replaced by allocation of adequate time during preconstruction planning to enable the main contractors to carefully collaborate with their subcontractors, consultants and suppliers to effectively carry out the preconstruction planning required at this stage of the project [26].

It was stated that preconstruction activities were predominantly analytical and administrative but were especially important since they would set the framework of cost and schedule control of the project. Also preconstruction activities were set into four subsets; 1) job setup 2) purchasing 3) performance model and 4) job startup [29].

A three-step sequential route was identified to carry out preconstruction activities during the planning or pre-design phase: 1) initial concept and scope of the work, 2) professional evaluation of the project-feasibility report and 3) appropriate data-collection [25].

Based on above reviews information and inputs related to the preconstruction phase are listed in Table 1.

Table 1 - The Identified Preconstruction Activities based on information and inputs sought during preconstruction

#	Preconstruction Activity	(A) Information sought during Preconstruction	(B) Inputs sought during Preconstruction
P1	Carry out Preliminary survey	Technical	
P2	Carry out Engineering survey	Technical	
P3	Carry out Land survey	Technical	
P4	Carry out Geotechnical survey	Technical	Sub-soil constraints
P5	Study / record of Environmental issues	Environmental	
P6	Study / record of Rules and Regulations as applicable	Statutory authorities	Legal
P7	Record information about High flood level	Environmental	
P8	Record information about Low flood level	Environmental	
P9	Study / record the Rainfall pattern	Environmental	
P10	Study / record the Water table (variations)	Environmental	Sub-soil constraints
P11	Study / record the Wind directions	Environmental	
P12	Study / record the Variation patterns of wind	Environmental	
P13	Study / record the Locating of existing Utilities (water, power, telecom, Wi-Fi etc.)		Energy

P14	Identification of the Utility agencies		Energy, Suppliers
P15	Study availability of the Utilities (water, power, telecom, Wi-Fi etc.)		Energy
P16	Type of project : Design and Build, Tender, Proposed	Financial, Technical	Money
P17	For Tendered projects - Study of Conditions of contracts	Financial, Technical	Money
P18	For Tendered projects - Study of Special conditions of contracts	Financial, Technical	Money
P19	Investigation of Access roads (capacity, width, surface, bottlenecks, etc.)	Technical	Access
P20	Assessment of Capacities of culverts, bridges, etc. on access roads	Technical	Access
P21	Investigation on availability of Material		Materials, Suppliers
P22	Investigation on proximity of Material		Materials
P23	Identification of requirements of equipment/ machinery/ vehicles etc.	Technical	Plant Information
P24	Study / record of Availability of equipment/ machinery / vehicles etc.	Technical	Plant Information, Suppliers
P25	Study / record of Availability of Sub Contractors		Availability of skills, Suppliers
P26	Study / record of Requirement and availability of Special Sub Contractors		Availability of skills, Suppliers
P27	Study / record of Requirement and availability of Skilled Manpower		Availability of skills, Suppliers
P28	Study / record of Requirement and availability of Un-skilled Manpower		Availability of skills.
P29	Assessment of the leadership required - Project Manager etc.- to drive the project		People
P30	Study / record of Availability of knowledge to do the project - core and support areas		People
P31	Study / record of Adequacy of the skills to do the project - core and support areas		Availability of skills.
P32	Assessment of Attitude of the Individuals / Team towards delivering the project		People
P33	Identification of corrective measures, eg. Training to rectify the gaps found		People
P34	Study / record of Possible of Social issues		Social attitudes, Social expectations
P35	Study / record of Possible Neighbourhood issues		Social expectations
P36	Study / record of Possible Religious issues		Social expectations
P37	Study / record of Possible Political issues		Social expectations
P38	Study / record of Stakeholder issues		Customers, Shareholders, Suppliers

Note: Literature reviews on [25] and [26] revealed, Information sought during Preconstruction (re: Column 3; Table 1) and Inputs sought during Preconstruction (re: Column 4; Table 1) respectively.



3. Methodology and Data Collection

This study focuses on a real problem in the construction industry. As such, applied research method, a mix between quantitative and qualitative types of research methods together with descriptive methods and analytical research method [30, 31] were used to develop the research methodology.

A structured questionnaire to collect data regarding relevance of the identified preconstruction activities (Table 1) to the projects and their possible effects on the design phase of the project/s was developed. Data on the Relevance and Adequacy of preconstruction activities as inputs to the design phase of construction projects were collected from the respondents using the questionnaire which was tested through a pilot survey. The respondents reported the Relevance and then Adequacy of preconstruction activities in a Likert scale of percentages (as given in the questionnaire). Even though the Likert scale is ordinal, when the scale is symmetric and equidistant it behaves like an interval-level measurement and if well presented it approximates to an interval-level measurement.

The data was collected from different sectors of construction like; building, roads, bridge, water supply, steel construction, from responsible professionals involved in those projects.

Responses were collected from thirty two construction projects for the identified thirty eight preconstruction activities regarding their Relevance and Adequacy to the design phase of the project. Based on the responses, data from those preconstruction activities which were identified as Relevant and 100% Adequate for the projects were used (see Table 2) for the analysis which is described in section 4.

4. Analysis and Discussion

4.1 Analysis of Data

4.1.1 General

Responses received from the questionnaire were verified for clarity from the respondents and analysed to find meaningful relationships between the Relevance of preconstruction activities and Adequacy (or Inadequacy) level of their input to the design phase.

4.1.2 Relationship between Relevance and Adequacy of preconstruction activities

The data highlighted a possible relationship between the responses on Relevance of the preconstruction activities and the Adequacy of use of the outputs of preconstruction activities as inputs to the design of the construction projects. A model to predict the relationship between relevance and adequacy (or inadequacy) of preconstruction activities would be useful during the design phase to gauge the contribution of the preconstruction activities.

Table 2 - List of Projects with relevance and adequacy of analysis of preconstruction activities based on the responses from the industry.

#	Preconstruction Activity	Relevant number of Projects (X)	Percentage of Relevant number of Projects (x) %	Number of 100% Adequate inputs of a project (Y)	Percentage of 100% Adequate inputs (y) %
P1	Carry out Preliminary survey	31	97%	12	38%
P2	Carry out Engineering survey	31	97%	14	44%
P3	Carry out Land survey	30	94%	13	41%
P4	Carry out Geotechnical survey	25	78%	7	22%
P5	Study / record of Environmental issues	29	91%	9	9%
P6	Study / record of Rules and Regulations as applicable	32	100%	10	31%
P7	Record information about High flood level	20	63%	6	19%

P8	Record information about Low flood level	14	44%	2	6%
P9	Study / record the Rainfall pattern	20	63%	3	9%
P10	Study / record the Water table (variations)	19	59%	7	22%
P11	Study / record the Wind directions	13	41%	7	22%
P12	Study / record the Variation patterns of wind	8	25%	3	9%
P13	Study / record the Locating of existing Utilities (water, power, telecom, Wi-Fi etc.)	32	100%	13	41%
P14	Identification of the Utility agencies	29	91%	14	44%
P15	Study availability of the Utilities (water, power, telecom, Wi-Fi etc.)	32	100%	14	44%
P16	Type of project : Design and Build, Tender, Proposed	29	91%	11	34%
P17	For Tendered projects - Study of Conditions of contracts	29	91%	11	34%
P18	For Tendered projects - Study of Special conditions of contracts	25	78%	11	34%
P19	Investigation of Access roads (capacity, width, surface, bottlenecks, etc.)	28	88%	11	34%
P20	Assessment of Capacities of culverts, bridges, etc. on access roads	22	69%	10	31%
P21	Investigation on availability of Material	31	97%	8	25%
P22	Investigation on proximity of Material	28	88%	10	31%
P23	Identification of requirements of equipment/ machinery/ vehicles etc.	32	100%	8	25%
P24	Study / record of Availability of equipment/ machinery / vehicles etc.	31	97%	7	22%
P25	Study / record of Availability of Sub Contractors	27	84%	8	25%
P26	Study / record of Requirement and availability of Special Sub Contractors	24	75%	7	22%
P27	Study / record of Requirement and availability of Skilled Manpower	31	97%	3	9%
P28	Study / record of Requirement and availability of Un-skilled Manpower	28	88%	2	6%
P29	Assessment of the leadership required - Project Manager etc.- to drive the project	29	91%	12	38%
P30	Study / record of Availability of knowledge to do the project - core and support areas	32	100%	10	31%



P31	Study / record of Adequacy of the skills to do the project - core and support areas	31	97%	8	25%
P32	Assessment of Attitude of the Individuals / Team towards delivering the project	28	88%	10	31%
P33	Identification of corrective measures, eg. Training to rectify the gaps found	24	75%	3	9%
P34	Study / record of Possible of Social issues	24	75%	8	6%
P35	Study / record of Possible Neighbourhood issues	28	88%	8	6%
P36	Study / record of Possible Religious issues	9	28%	1	3%
P37	Study / record of Possible Political issues	10	31%	1	3%
P38	Study / record of Stakeholder issues	20	63%	1	3%

Note on Table 2 - Total number of projects considered is 32

For example, from the responses received for the preconstruction activity, (P25)from Table 2, "Availability of sub-contractors", Relevant number of Projects out of all Projects = 27 (column 3 of Table 2) and number of 100% Adequate inputs of a project out of all Projects = 8 (column 5 of Table 2), and for the number of projects considered = 32, then;

- a. Percentage of Relevant number of Projects out of all Projects, $x = (27/32)*100 = 84\%$, and,
- b. Percentage of 100% Adequate inputs to the projects, $y = (8/32)*100 = 25\%$

4.1.3 Deriving the appropriate relationship between relevance and 100% adequacy for a preconstruction activity as an input to the design

When a preconstruction activity is relevant for a construction project, it appears the output of the activity (as the input) to the design phase

has to be adequate to satisfy the purpose of an effective design. Hence finding a relationship between the two, relevance and adequacy (as explained) is done as given below.

Line fitting was utilized to test the relationship between relevance of the preconstruction activities and adequacy of the outputs of preconstruction activities as inputs to the design of the construction projects. Using regression analysis, the most appropriate relationship was determined as the exponential relationship between the variables Relevance and Adequacy, as it had the highest coefficient of determination, $R^2(=0.4)$, being the closest to the perfect fit ($=1.0$). Table 3 below gives details of gives the possible types of relationships arrived using regression analysis). Accordingly the exponential relationship between the variable 'Relevance' and dependent variable 'Adequacy' was found to be the most appropriate relationship.

$$y = 2.6916e^{0.024x} \dots\dots\dots(1)$$

Table 3 - Results of the regression analysis: Relevance % (x) and Adequacy % (y)

Relationship Relevance (x) and Adequacy (y)		
Type of Relationship	R ²	Equation
Exponential	0.4	$y = 2.6916e^{0.024x}$
Power	0.38	$y = 0.0448x^{1.3884}$
Polynomial	0.37	$y = 0.0034x^2 - 0.0785x + 6.7274$
Linear	0.36	$y = 0.3706x - 6.1054$
Logarithmic	0.33	$y = 20.88\ln(x) - 66.898$



When a designer needs to estimate the adequacy of the outcome of a preconstruction activity as input to the design he can use the model given by equation (1). For example, consider the preconstruction activity, 'Geotechnical Survey', which is 100% relevant to the project. Using equation (1) the adequacy of the preconstruction activity 'Geotechnical Survey', $y = 2.6916e^{0.024 \times 100} = 30\%$. Also, % Inadequacy (z) = $100\% - \% Adequacy(y)$.

i.e. % of Inadequacy (z) = $100\% - 2.6916e^{0.024x} = 70\%$

Figure 1 was derived using, equation (1), the most appropriate relationship for Relevance and Inadequacy, $z = 100\% - 2.6916e^{0.024x}$ as discussed above. Using the model in Figure 1, when the relevance of an activity is known, appropriate inadequacy level of the input for the design can be found. With the above finding the options available for the designer are;

- i. Improve the reliability of available data for the preconstruction activity to decrease/eliminate Inadequacy level of the activity by obtaining additional data (say data from further boreholes) before commencing the design.
- ii. Designer opts for a judgement based on his knowledge, experience, exposure etc. and continues with the design,

irrespective of the 70% inadequate value derived from the model.

If option i) was considered for the design, to rectify the identified faults, the designer would have to improve the input of the data of the activity. This would result in possible overruns in time (time the design team used in working on option ii), possible delay in construction (as a practice construction follows design until the design is rectified) and increase in costs (possible costs due to variations in a construction activity / activities).

Possible errors could surface;

- a) During the design phase before issuing drawings for the construction phase.
- b) After construction drawings were issued and design faults were identified during the construction phase.
- c) During operational phase of the project.

If option ii) was taken by the designer, and it resulted in an effective design, then there would be no issue. Such a decision would depend significantly on the knowledge, experience, exposure, etc. of the designer.

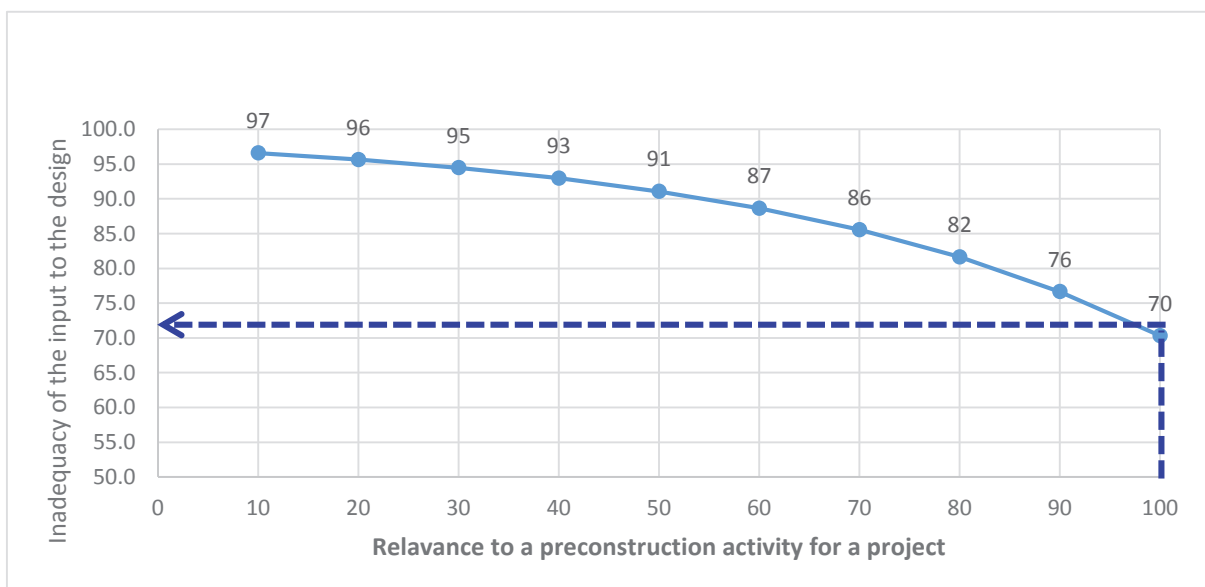


Figure 1 - Relevance of a preconstruction activity for a project vs Inadequacy of the output of the activity as the input to the design



4.2 Limitations

1. List of preconstruction activities identified and used in the study could be a subset of the possible comprehensive list of preconstruction activities that are required during the design phase.
2. The responses received from experts, based on the questionnaire survey, was limited to the professionals from the construction industry in Sri Lanka. Hence, the applicability of the results may be limited to use in the Sri Lankan construction industry.

4.3 Further research

This study focused on the 100% adequacy of the inputs of the analysis of the relevant preconstruction activities for the design phase. Hence it could be possible to carryout further research on the preconstruction activities with adequacy of inputs of the analysis is less than 100%. It is also observed that there is room for improvements on the proposed model which gives a relationship between the Relevance and Inadequacy of the inputs to the design phase by further research, for example, exploring of the limitations of this study.

5. Conclusions

Following conclusions are drawn from the study.

- Thirty eight preconstruction activities were identified from the literature review, as relevant inputs to the design phase of the construction projects. These thirty eight preconstruction activities could possibly be a subset of a number of preconstruction activities applicable to the construction industry.
- Based on the responses of the projects considered adequacy levels of the relevant inputs to the design by the outputs of the preconstruction activities were, highest at 44%, average at 23% and the lowest at 3%. Above reflects that none of the inputs from preconstruction activities hasnot even reached an adequacy level of 50%.

- Inadequacy level of the relevant inputs to the design by the outputs of the preconstruction activities of a construction project was at a minimum of 56% (%Adequacy + % Inadequacy = 100%).
- A model to predict the relationship between Relevance (x) and Adequacy (y)/ Inadequacy (z) of outputs of preconstruction activities as inputs to the design phase was developed as $y = 2.6916e^{0.024x}$ for Adequacy or $z = 100 - 2.6916e^{0.024x}$ for Inadequacy. A designer could use this model to predict the inadequacy of the output of a preconstruction activity (as the input to the design phase) for a known relevance of the preconstruction activity.

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