Cost Influencing Factors on a Building Construction Site: A Delphi Study

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***Abstract*— This paper investigates and identifies the major factors which affect the construction cost of a building construction site using the classical Delphi technique in three rounds of survey. The expert panel consisted of five contractors, five consultants and ten government officials. Fifty-five factors which affect the construction cost were initially identified and after three round of survey the factors were subsequently narrowed down to ten major factors. It was inferred that the statistical approach provides an easier means to quantify the effects of different factors. From the severity index rating of all the three panels of experts it was concluded that the cost of material was the most important factor which affected the construction cost in Indian scenario; while the social and cultural factor was the least affecting.**

***Index Terms*— Delphi technique, Correlation, ANOVA analysis, Severity Index**

I. INTRODUCTION

The planning and management of a construction site and timely completion of a construction project with emphasis on economy and safety is a herculean task. There are dozens of factors around which these processes revolve. Particularly, for the timely completion of a construction project, within the stipulated budget, meticulous detailing of the intricate aspects in planning and management is required. Researchers involved in the task of planning and management typically rely on tools like the traditional survey, nominal group technique developed by van de Ven and Delbecq [1] and group brain-storming techniques. These methods have their own inherent disadvantages. Firstly, they are subjective as they pertain to the given case. Secondly, the outcome of such discussions could be biased, as it depends on the public involved in the discussion. Hence, there is a need for a step-wise, structured feedback method, which could provide reliable data for orderly execution of a construction project.

Delphi, originally developed for technological forecasting, is an iterative procedure which involves two or more rounds of expert panel discussions in a particular issue. Since each round involves brain-storming on the anonymous opinion of other experts, the deviations in the opinion are reduced, thereby decreasing the variability of responses. The first experiment using Delphi was performed to improve betting scores at horse races back in 1948 [2]. Later Kaplan, a philosopher working for the Rand Corporation coined the name "Delphi" [3]. Kaplan et al. [4] concluded that direct interaction yielded less accurate predictions than statistical understanding of experts' predictions. Delphi technique could prove to be a very useful tool in the field of construction planning and management, but the use is limited in this field due to the variables involved in the method such as poor choice of experts, lack of effort to reduce the bias, contradictions in results etc.

The primary objective of the current investigation is to provide a detailed Delphi analysis of a building construction site and identify the major factors affecting the construction cost with the unison of contractors, consultants and government officials. Furthermore, to statistically discuss the results so that this useful tool could be more effectively used in civil engineering applications.

II. PROBLEM FORMULATION

Three expert panels consisting of five contractors, five consultants and ten government officials were surveyed with a questionnaire having thirty-eight major construction factors. They were asked to rank the factors in descending order of importance and panel discussions were carried out. To begin with the research, in this particular study, building construction sites in a colony were chosen, in a small town exposed to tropical climate. The next major task involved was the constitution of an unbiased, reliable and diverse expert panel. This was constituted based on the recommendations of Hallowell and Gambatese [5] and the details of the expert panel is presented in Table 1.

Table 1. Details of Delphi technique used in this work in accordance with recommendations by ref. [5]

S.No	Characteristics	Criterions fulfilled by panelists
1	Qualifying panelists as experts	• Primary or secondary writer of at least three peer-reviewed journal articles • Invited to present at a conference • Member or chair of a nationally recognized committee • At least 5 years of professional experience in the construction industry • Faculty member at an accredited institution of higher learning • Advanced degree in the field of civil engineering, CEM, or other related fields, minimum of a BS.
2	Number of panelists	10
3	Number of Rounds	3
4	Feedback from each round	
	Round 1	Data from preliminary research
	Round 2	Median response from Round 1
	Round 3	Median response from Round 2 and reasons for outlying responses

In order to minimize the bias and thereby the range of response, the next major step was to reduce the judgment based biases. These include the bandwagon effect, contrast effect [6], Von Restroff Effect [7] and Myside effect [8].

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Other such biases include the neglect of probability, collective unconscious, dominance, primacy effect and recency effect. These effects were also controlled by cautious countermeasures suggested by Hallowell and Gambatese [5] and are presented in Table 2.

III. Researcher Methodology

Questionnaire Development:

In order to obtain an unbiased judgment, apart from anonymity of the panellists, proper selection of questions is of utmost importance. In this particular case study, the process of questionnaire development involved a two stage process. The first stage, which is reconnaissance survey, involved collection of data from literature, field visits and interviews. The second stage focused on data analysis and identification of the most relevant factors influencing construction cost in building construction. Through study of the collected data and brain-storming with the experts confirming to the criteria presented in Table 1 as recommended by Hallowell and Gambatese [5] led to the formation of a questionnaire which was distributed amongst the contractors, consultants and government officials.

Table 2. Control for bias (adapted from Hallowell and Gambatese [5])

S.No.	Bias	Countermeasures
1	Collective unconscious	Include reasons in the controlled feedback to the panel
2	Contrast effect	Randomize questions
3	Neglect of probability	The probability ratings and severity ratings for each risk are recorded independently
4	Von Restorff Effect	Include reasons in controlled feedback and conduct multiple rounds of surveys
5	Myside Bias	Include reasons in the controlled feedback and report final risk ratings as a median
6	Recency Effect	Remove individuals who have experienced recent events, remove outlying observations, conduct multiple rounds, and report results as a median
7	Primacy Effect	Randomize the order of questions for each panel member
8	Dominance	Ensure anonymity of expert panelists

There are three main parts in the Questionnaire as indicated below:

- The first part is an introduction to explain the idea and purpose of the survey as well as the definition of the interested area of study.
- The second part contains general information questions including annual volume, specialization, experience and nationality of the company.
- The third part concerns the cost factors in building construction projects. For each question, the respondents have five options .These are, “extremely severe”, “very severe”, “severe”, “somewhat severe” and “not severe”.

Classification of factors affecting construction cost:

Thirty eight essential factors which affect the construction costs are identified and categorized into five major headings. These include environmental factors; construction parties related factors; construction item related factors; cost estimating factors and financing factors. Each of the major factors is further classified into several sub-headings to yield 38 factors and each factor is represented by an alpha numeral for brevity. This is presented in Table 3. At this juncture it would be apt to mention that these factors are obtained from the second round of Delphi survey. The impact of these factors is individually dealt with elsewhere [9].

Table 3. Classification of factors affecting construction costs

S.No.	Categorization of factors	Symbol	Factors	Symbol
1	Environmental factors	A	Effects of weather	A1
			Number of construction going on at the same time	A2
			Social and cultural impacts	A3
			Project location	A4
			Lack of productivity standard in India	A5
			Level of competitors	A6
			Number of competitors	A7
			Supplier manipulation	A8
			Economic Stability	A9
			Inadequate production of raw materials by the country	A10
			Government policies (law and regulations)	A11
2	Construction parties related factors	B	Incorrect planning	B1
			Relationship between management and labor	B2
			Lack of coordination between designers and contractors	B3
			Poor financial control on site	B4
			Previous experience of contract	B5
			Disputes on sites	B6
3	Construction items related factors	C	Fraudulent practices and kickbacks	C1
			Contract management	C2
			Additional work	C3
			Duration of contract period	C4
			Contractual procedure	C5
			Frequent design changes	C6
			Inadequate labor availability	C7
4	Cost – Estimating factors	D	Cost of material	D1
			Fluctuation of prices	D2
			High cost of labor	D3
			High cost of machinery	D4
			High cost of machinery maintenance	D5
			High transportation cost	D6
			Insurance cost	D7
			High interest rates charged by banks on loans received by contractors	D8
			Long period between design and time of tendering	D9
			Bureaucracy in tendering method	D10
			Waste on site	D11
			Wrong estimation method	D12
5	Financing factors	E	Mode of financing, bonds and payment	E1
			Inflationary pressure	E2

Delphi Surveys:

One of the ways to minimize the bias listed in Table 2 and to obtain reduced range of response is to conduct the Delphi survey in more number of rounds. In the current work, three rounds of feedback were taken from the three panels of experts.

First Round*:*

In the first round, initially the panel of experts was asked to enlist the factors which could affect the construction cost along with concise explanations through emails. This process ensured avoiding the bandwagon effect, dominance and Von Restorff effect. From the list of these factors a list of fifty-five factors was prepared. The panel of experts was next asked to fill a questionnaire based on these fifty-five factors and rate the factors in order of importance in a scale of 1 to 10. A value of 10 indicated highest importance while a value of 1 indicated least importance.

At the end of the first round, based on the reply to the questionnaire the factors were narrowed down to forty-five. These factors were then ranked according to the two panel experts were dropped since the recency effect was predominant.

***Second Round**:*
In the second round of Delphi survey, the factors were arranged in the order of importance as obtained from first round and the results were presented to the three panels of experts. The experts were given an option to review the answers from the first round in order to reach to a consensus. This process helped to narrow down the range of response. At the end of the second round thirty-eight factors were selected as the thirty-ninth factor showed a marked decrease on the scale of importance.
***Third Round**:*
In this round, the panel experts were asked to rank the thirty-eight factors again based on round one and round two. The severity index as given by Mendenhall [10] was calculated and the factors were ranked accordingly. The results of ranking are presented in Table 4.

Table 4 Ranking of 38 factors by contractors, consultants and government officials

Factors	Ranking of various factors		
	Contractors(R1)	Consultants(R2)	Government officials(R3)
A1	16	12	9
A2	31	28	21
A3	37	36	38
A4	29	25	22
A5	32	29	31
A6	23	30	32
A7	24	26	33
A8	17	27	34
A9	13	4	10
A10	25	22	27
A11	6	11	6
B1	5	2	2
B2	10	6	3
B3	20	8	4
B4	7	23	20
B5	3	5	7
B6	19	24	23
C1	33	35	35
C2	11	13	12
C3	35	32	24
C4	8	19	15
C5	14	18	13
C6	9	10	11
C7	15	20	25
D1	1	1	1
D2	12	9	5
D3	21	14	16
D4	26	15	17
D5	18	16	18
D6	27	17	19
D7	36	37	36
D8	22	21	28
D9	4	7	14
D10	28	31	26
D11	38	38	37
D12	2	3	8
E1	30	33	29
E2	34	34	30

RESULTS AND DISCUSSIONS

Statistical analysis:

The stage one of the analysis starts with the calculation of the Spearman correlation coefficients amongst the ranking provided by contractors, consultants and government officials. This is presented in Table 5. Since two-tailed test of significance is used, the spearman correlations are similar in values. The scatter matrix at 95% confidence level is also shown in Fig. 1.

Table 5 Spearman Correlation for ranking

S.No.	Delphi Group	contractors	consultants	government officials
1	contractors	1	0.86147	0.79516
2	consultants	0.86147	1	0.9291
3	government officials	0.79516	0.9291	1

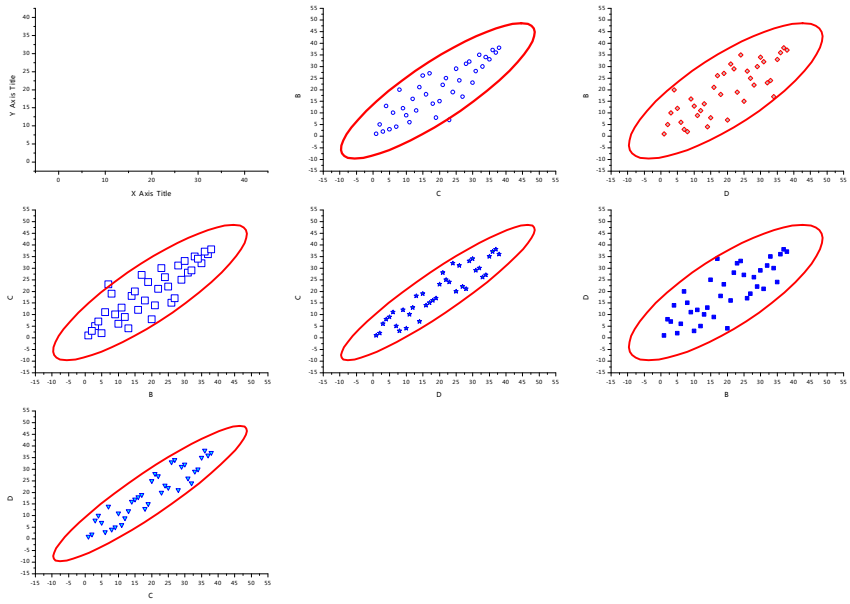

Fig. 1 Scatter matrix at 95% confidence level.

One way ANOVA analysis of the ranking of contractors and consultants showed that there is considerable variation at the 0.05 and 0.10 levels. The same was also obtained for one way ANOVA analysis of contractor versus government officials and consultants versus government officials. Based on these statistical observations it could be inferred that the three groups differ significantly in their respective priorities. Hence, the next stage of analysis involved the selection of the ten most significant factors ranked by the individuals in the three catagories. For this process, severity index as given by Mendenhall et. al. (2009) was used.

The results of the severity indices obtained are tabulated in Table 6. The overall ranking is provided by averaging the severity indices given by contractors, consultants and Government officials.

Table 6 Results of Severity indices for the 38 factors and the overall ranking of these factors

Overall Rank	Factor symbol	Severity Index			Average S.I.	Cumulative S.I.%
		Contractor	Consultant	Government official		
1	D1	100	96.66	100	98.89	5.14
2	B1	86.66	93.33	93.33	91.11	9.89
3	D12	93.33	93.33	86.66	91.11	14.63
4	B5	93.33	90	86.66	90	19.31
5	B2	66.66	83.33	93.33	81.11	23.53
6	D2	66.66	80	93.33	80	27.69
7	D9	86.66	83.33	66.66	78.88	31.79
8	A9	60	90	80	76.67	35.78

9	A11	73.33	66.66	86.66	75.55	39.71
10	C6	73.33	76.66	73.33	74.44	43.59
11	B3	46.66	80	93.33	73.33	47.4
12	A1	53.33	63.33	80	65.55	50.81
13	C2	66.66	63.33	66.66	65.55	54.22
14	C4	73.33	56.66	60	63.33	57.52
15	C5	60	60	66.66	62.22	60.76
16	D5	53.33	63.33	53.33	56.66	63.7
17	D3	46.66	63.33	53.33	54.44	66.54
18	B4	73.33	43.33	40	52.22	69.25
19	D4	40	63.33	53.33	52.22	71.97
20	D6	33.33	63.33	53.33	50	74.57
21	C7	60	53.33	33.33	48.89	77.11
22	D8	46.66	46.66	26.66	39.99	79.2
23	B6	46.66	36.66	33.33	38.88	81.22
24	A10	40	43.33	26.66	36.66	83.13
25	A8	53.33	33.33	16.66	34.44	84.92
26	D10	33.33	30	33.33	32.22	86.59
27	A4	26.66	33.33	33.33	31.11	88.21
28	A7	40	33.33	16.66	30	89.77
29	A6	40	30	16.66	28.89	91.28
30	A2	20	30	33.33	27.78	92.72
31	C3	13.33	30	33.33	25.55	94.05
32	E1	26.66	26.66	20	24.44	95.32
33	A5	20	30	16.66	22.22	96.48
34	E2	20	23.33	20	21.11	97.58
35	C1	20	23.33	13.33	18.89	98.56
36	D7	13.33	10	13.33	12.22	99.2
37	D11	6.66	6.66	13.33	8.88	99.66
38	A3	6.66	6.66	6.66	6.66	100

Based on the results of Table 6 the ten most influencing factors affecting the construction cost are listed below in Table 7 from which it is clear that these ten factors contribute to almost 44% of severity. Hence, greater emphasis should be laid on these critical factors in order to control the construction costs. Also it is worth noting that the top twelve ranked factors contribute to 50%.

Table 7 Top ten factors influencing construction cost

Overall rank	Symbol	Factor
1	D1	Cost of ,material
2	B1	Incorrect planning
3	D12	Wrong estimation method
4	B5	Previous experience of contract
5	B2	Relationship between management and labor
6	D2	Fluctuation of prices
7	D9	Long period between design and tendering
8	A9	Economic stability
9	A11	Government policies
10	C6	Frequent design changes

CONCLUSION

The Delphi technique of statistical analysis provides a new dimension towards the interpretation of results through numbers. The five factors which majorly influence cost are cost of material, incorrect planning, wrong method of estimation, previous experience of contract and relationship between management and labour. Whereas, the five factors which affect the construction cost the least are inflationary pressures, fraudulent practices and kick backs, insurance cost, wastage on site and social and cultural factors.

It is interesting to note that cost of material has been unanimously agreed upon as the most influencing factor followed by a slightly lower degree of unanimity (variation in rank less than or equal to 2) for factors like social and cultural impacts, lack of productivity standard in India, fraudulent practices and kickbacks, contract management, frequent design changes, cost of material, high cost of machinery maintenance, insurance cost and waste on site. The factors with large contradiction in ranking are lack of coordination is supplier manipulation, lack of coordination between designers and contractors, poor financial control on site and duration of contract period. It is also interesting to note that the twelve most influencing factors fall under the major categories of cost – estimating factors and construction parties related factors , hence, these should be adequately optimized.

REFERENCES

1. Delbecq. A. L., Ven van de, A. H. and Gustafson, D. H., Group Techniques for Program Planning. A Gourde to Nominal Group and Delphi Processes. Scott, Foresman and Company, Glenview, IL, 1975.
2. Quade. E. S. Cost-Effectiveness: Some Trends in Analysis, Rand Corporation, P-3529, 1967.
3. Dalkey. N. Predicting the Future. Rand Corporation, P-3948, October 1968.
4. Kaplan. A. Skogstad, A., and Cirshick, M. A., The Prediction of Social and Technological Events, Rand Corporation. P-39. April 1949.
5. Hallowell M.R., Gambatese J.A., Qualitative Research: Application of the Delphi Method to CEM Research, Journal of Construction Engineering and Management, Vol. 136, 99-107, 2010.
6. Bjarnason, T., and Jonsson, S. H. Contrast effects in perceived risk of substance use. Substance Use and Misuse, Vol.40, issue 1, 1733–1748, 2005.
7. Restorff, H. V., Über die Wirkung von Bereichsbildungen im Spurenfeld, Psychol. Forsch, Vol.18, 299–334, 1933.
8. Perkins, D. N. Reasoning as it is and could be: An empirical perspective, Thinking across Cultures: 3rd International Conf. On Thinking, Erlbaum, Hillsdale, N.J. 1989.
9. D.Soni, K. Chowdhary and Y. I. Murthy. Study of factors affecting construction cost, International Journal of Engineering Research & Technology. Vol. 4, issue 6, pp.637-642, 2015.
10. Mendenhall, W., Beaver, R. J. & Beaver, B. M. Introduction to Probability and Statistics. Boston, U.S.A: Brooks/Cole, Cengage Learning, 2009.