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CAUSES AND EFFECTS OF VARIATIONS ON CONSTRUCTION PROJECTS

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Because of their bespoke nature, construction projects are susceptible to variations irrespective of type, size and complexity. The effects of these variations are significant and may include cost and time overrun, productivity, and waste issues at the minimum. Although variations have been widely researched, investigations into the relationship between the significant causes of variations and their effects have not. This study also considers control measures that could minimize variations in residential building projects, where significant variations are happening in the Sri Lankan construction industry. A questionnaire survey was administered to study participants with the objective of identifying significant causes and effects of variations on residential building projects. The participants were professionals across industry groups such as clients, consultants, and contractors who deal with variations on Sri Lankan construction projects. The study found that change in designs or project scope by owners or design consultants were due to owners' financial problems, errors and omissions in design, conflicts between contract documents, inadequate working drawing details, lack of coordination by consultants, differing site conditions for contractors, unforeseen problems and weather conditions. Cost and time overruns are subsequent effects of those variations. The study suggests that variations could be minimized by adopting control measures that are appropriate for both the design and construction stage.

Keywords: Productivity degradation, Procurement delay, Residential buildings, Sri Lanka.

1 INTRODUCTION

Construction processes are large and complex, and could cover a wide range of business interests and activities. The products of the industry are designed specifically for the requirement of individual customers (Rameezdeen 2006). Often this may lead to intermediate changes during both the design and construction phase (Oyedele et al. 2003). These changes hinder project success to a significant degree. According to Koushki et al. (2005), changes of this nature are the most common phenomena in the construction industry, and can lead to time and cost overruns and quality deviations in both simple and complex projects. In addition, the indirect effects of change are significant. As suggested by Bower (2000), loss of productivity, and interruption of workflows and cash flows, are examples of indirect effects that, in turn, may lead to lower morale, and claims and disputes between parties.

Variation is prevalent in construction projects, and it is becoming unlikely that a project can be completed without changes to the design or the construction process itself (Ssegawa et al. 2002). Ssegawa et al. (2002) further suggest that the existence of variation clauses in contracts is evidence that no project can be completed without changes. Variation is therefore a chronic problem in the construction industry.

In the Sri Lankan context, preliminary analysis into twenty recently-completed building projects suggests that residential buildings are mostly affected by variations. The studies indicate that residential buildings experience 15% of cost overruns, 35% of variation costs (as a percentage of the initial contract sum), and 99% of time overruns (as a percentage of the scheduled project duration). This is the highest relative to other types of buildings: commercial, educational and others. This study therefore primarily focuses on investigating the direct relationship between significant causes of variations in residential building projects and the subsequent effects of those variations. In addition, this study determines suiTable controls for variations in different project phases.

2 METHODOLOGY

The research employed a survey approach, as it provides a systematic way of primary data collection based on a sample, and it enables the assessment of information about a population (Tan 2002). The data collection was based on questionnaires sent to a wide spectrum of industry professionals operating within the Sri Lankan construction industry. Questionnaires were personally administered to 40 professionals representing contracting and consultancy organizations. The research used a five-point Likert scale, where 1 represents “never” and 5 represents “very often”, for ranking purposes. The data was analysed with the use of both descriptive and inferential statistics.

The Spearman’s rank correlation analysis was used to identify the relationship between significant causes and effects of variations. This was done only for the significant causes of variations, as identified, that held the highest seven median frequency values together with all identified effects. Significant causes that had statistically-significant positive correlation (r_s) with the effects (i.e., where the level of significance was well below the conventional threshold of $p < 0.05$), were only taken into consideration. Correlation coefficient between 0.00-0.19, 0.20-0.39, 0.40-0.59, 0.60-0.79 and 0.80-1.00 were determined as very weak, weak, moderate, strong and very strong respectively.

3 RESEARCH FINDINGS

3.1 Causes and Effects of Variations

Study participants were required to rate the 53 causes of variations identified through a literature review (Ndihokubwayo and Haupt 2009, Jawad et al. 2009). The results from analyses of the responses indicate that there are 35 causes that have median values above 3. Table 1 presents these 35 causes of variation with their frequencies as they relate to the Sri Lankan construction industry, with particular focus on residential building projects. As observed in Table 1, change of plans or scope by owner and owner’s financial problems, change in design and specifications by consultant, lack of coordination, inadequate working drawing details, and weather conditions are identified as significant causes of variations (with median values of 4). Also, causal factors with a median of 3 are responsible for occurrence of variations occasionally in residential building projects.

The most frequent causes with median values of 4 were correlated with 13 effects due to variations. Table 2 provides the correlation coefficient values and the P-value, which indicates the statistical significance of the result. It is observed that the change of design or scope by the owner, changes in design by consultant (C2), lack of coordination (C3), inadequate working drawing details (C4), and changes in specifications by consultant (C5) have significant positive correlations with completion schedule delay, increase in overhead expenses, quality degradation, productivity degradation, logistics delays, procurement delay, damage to firm's reputation, poor professional relations, disputes among professionals, hiring new professionals, complaints of one or more of the parties to the contract, wastage of resources and non-value adding activities, and saving of resources and non-value adding activities. From the analysis, change of plans or scope by owner (C1) is moderately correlated with hiring new professionals and wastage of resources and non-value adding activities, while having a weak correlation with complaints of one or more of the parties to the contract. Change in design by consultant (C2) has a strong correlation with disputes among professionals, and has moderate correlations with increase in overhead expenses, productivity degradation, procurement delay, damage to firm's reputation, and poor professional relation, while weakly correlated with quality degradation. The analyses further indicate that lack of coordination between contract parties affect productivity, and lead to disputes among professionals.

3.2 Variations in Different Project Phases and Controls for Variations

Research participants were asked to indicate the degree of contribution of each control in minimizing the variations with respect to each phase of a project. Table 3 indicates the controls for variations in different stages of a project. It is observed that freezing the design, having a clear and thorough project brief, conducting a comprehensive site investigation, having the owner's involvement at the planning and design stage, and reducing contingency sums, have more weightage, with a mean percentage contribution of over 65%, to minimize changes during the design stage.

4 CONCLUSIONS

Most variations in residential building projects arise due to changes in the quality, sequence, or timing of the execution of the work, and due to additional works to amend projects. The research findings indicated that that the top seven most frequent causes of variations in residential building projects include design or scope change by owners, owners' financial problems, change in design by consultants, lack of coordination by consultants, inadequate working drawings, change in specifications by consultants and weather conditions. Variations are expected during the course of construction process and thus it is advisable to employ suitable approaches during the design stage to control such variations and their bad implications. The research found that freezing designs, preparing clear and thorough project briefs, conducting comprehensive site investigation, involving owners at the planning and design stage, and reducing contingency sums are some of the control measures that could minimize variations.

Table 1. Causes of variations.

Code	Causes of variation	Median	Code	Causes of variation	Median
C1	Change of plans or scope by owner	4	C19	Consultant's lack of required data	3
C2	Owner's financial problems	4	C20	Ambiguous design details	3
C3	Change in design by consultant	4	C21	Unavailability of skills	3
C4	Lack of coordination	4	C22	Contractor's financial difficulties	3
C5	Inadequate working drawing details	4	C23	Differing site conditions	3
C6	Change in specifications by consultant	4	C24	Defective workmanship	3
C7	Weather conditions	4	C25	Lack of a specialized construction manager	3
C8	Change of schedule by owner	3	C26	Fast track construction	3
C9	Replacement of materials or procedures	3	C27	Design discrepancies	3
C10	Impediments to prompt decision making process	3	C28	Poor procurement process	3
C11	Change in specifications by owner	3	C29	Lack of communication	3
C12	Errors and omissions in design	3	C30	Contractor's lack of judgment and experience	3
C13	Conflicts between contract documents	3	C31	Long lead procurement	3
C14	Value engineering	3	C32	Lack of strategic planning	3
C15	Design complexity	3	C33	Contractor's lack of required data	3
C16	Inadequate shop drawing details	3	C34	Change in economic conditions	3
C17	Consultant's lack of judgment and experience	3	C35	Unforeseen problems	3
C18	Lack of consultant's knowledge of available materials equipment	3			

Table 2. Correlation between causes and effects of variation.

Effects\Causes	C1	C2	C3	C4	C5
Completion schedule delay				.452 .006	
Increase in overhead expenses		.446 .007			.421 .012
Quality degradation		.359 .034			
Productivity degradation		.446 .007	.473 .004		.433 .009
Logistics delays				.341 .045	
Procurement delay		.458 .006		.387 .022	.510 .002
Damage to firm's reputation		.445 .007			.504 .002
Poor professional relations		.474 .004	.432 .010	.364 0.32	
Disputes among professionals		.611 .000	.461 .005	.506 .022	.501 .002
Hiring new professionals	.439 .008				
Complaints of one or more of the parties to the contract	.335 .036		.397 .018		
Wastage of resources and non-value adding activities	.503 .002				
Saving of resources and no non-value adding activities					.356 .036

These strategies would control variations not only during the design, but also throughout the project from inception to completion. The study therefore recommends that professionals need to consider cause and effects and take proactive measures to mitigate the adverse impacts of variations using the identified control strategies for variations.

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Table 3. Controls for variation.

Controls for variations	Design	Construction	Completion
Design Stage			
Review of contract documents	62	32	6
Freezing design	75	21	4
Value engineering at conceptual phase	56	40	4
Involvement of professionals at initial stages of project	63	32	5
Owner involvement at planning and design phases	66	32	2
Thorough detailing of design	57	36	7
Clear and thorough project brief	71	27	2
Reducing contingency sum	65	35	0
Construction Stage			
Clarity of variation order procedures	5	86	9
Written approvals	19	73	8
Variation order scope	25	72	3
Variation logic and justification	26	69	5
Project manager from an independent firm to manage the project	24	67	9
Restricted pre-qualification system for awarding projects	14	78	8
Owner's involvement during construction phase	5	90	5
Avoid the use of open tendering	10	85	5
Use of project scheduling techniques	25	67	8
Comprehensive documentation of variations	14	77	9