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QUANTIFICATION OF DEVIATIONS IN A CONSTRUCTION PROJECT

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Abstract:- Deviations in construction have long been a debatable issue in construction projects. However, only a few formal studies have been carried out to analyse its causes and effects. This study is focused on the identification and quantification of various factors causing Deviations in construction of a multi-level commercial project. It is important for a company not only to know the deviation costs, but also to identify the most likely areas on which to focus in order to reduce these costs for the future projects. All the necessary data and information are obtained from site records along with the revised, approved site drawings, indicating the new change and addition or omission of specified work. The deviation factors are individually compared and quantified. Most of the research studies have been dealing with several factors that cause deviations in the project. The objective of this study is to identify the main cause of the cost and schedule deviation. The approach to serve the objective is achieved by collecting data regarding "Granite cladding works" from a large construction project in order to identify the cause of project cost and schedule deviation.

Keywords: Cost Deviation, Schedule Deviation, Variation costs, quantifying deviation costs

1. INTRODUCTION

The prevalence of construction errors and their resultant cumulative negative effect upon the financial performance of organizations and projects within the construction industry. Construction errors dominate the cause of accidents, and it has been revealed that gross errors cause 80 to 90% of failures to buildings, bridges, and other civil engineering structures (Matousek and Schneider 1976; Lopez et al. 2010). Bijen (2003) identified that engineering failures account for as much as 10% of the total investment in new buildings and structures. Importantly, these failures are not restricted to simple direct cost considerations because they are also inextricably linked to less tangible environmental and social costs. Despite the considerable amount of research that has addressed error causation in construction and engineering projects (e.g., Petroski 1991; Busby 2001; Andi and Minato 2003a, b; Love et al. 2009), the actual costs associated with design errors remain unknown because they are not formally measured by organizations. Even at a project level design error costs are rarely measured, although a proclivity exists for them to manifest as change orders or claims. Much of the research that has examined design error costs is anecdotal or based upon a limited number of cases (e.g., Burati and Farrington 1992; Robinson-Fayek et al. 2003; Andi and Minato 2004; Love and Josephson 2004; Love et al. 2011c, d). In addressing this issue, this paper sought experts estimate's of construction errors from projects that they had been directly involved with. This research attempts to identify the perceived causes of errors in the construction phase of residential buildings that result in waste. The reason for selecting the stage is that many of the project deficiencies could not be concentrated in construction, which will eliminate waste, and help control project cost and project schedule overrun.

2. BACKROUND OF STUDIES

The deviation play an important role because any deficiencies in the inception phase may lead to successive deviations in the construction phase (Oyedele and Tham, 2007). There is a consensus in the literature that the crucial in minimising, and "designing out waste" (Oyedele and Tham 2007, Osmani et al. 2007). Designers will develop a design solution based on the approved project requirements and constraints as outlined in the client's brief. It is the client's right to pursue the designers to fix errors that were identified in the design documents. However, there will be a notable cost increase to address these changes at later design stages. This research attempts to identify the perceived causes of errors in the construction phase that result in waste. The research focused on the architect due to his/her involvement from the initial stages of the project. Studies such as Innes (2004); cited in Osmani et al. (2006, 2008) reported that the architect is responsible for about 33% of waste generation due to design errors. Burati et al. (1992) reports that about 60% of project construction deviations are as result of design errors, which is in agreement with findings from other studies (Ransom 1987, and Kirby et al. 1988). It is well known that the costs of correcting errors in early design stages is considerably smaller compared to the cost of correcting the same errors during the construction phase. The McLeamy curve shows that design changes increase the project cost across as all phases of the project. Lam (1994) discussed that the majority of errors are originated at the initial stages and related to the poor knowledge of or lack of application of building codes. Rounce (1998) identified reasons for errors in design as lack of coordination, adding missing information, and misinterpretation of design standards. Furthermore, Rounce (1998) also discussed that the architectural quality of the design and management practices are potential sources of negative impact on projects.

Stewart (1992) defined human error as "an event or process that departs from commonly accepted competent professional practice; it excludes such unforeseen events." For the purpose of this research, Stewart definition of error was adopted. The design process needs to be organised efficiently to minimise the effects of complexity and uncertainty (Formoso et al 1998). Poor design planning may result in incomplete information to undertake design tasks, and lead to discrepancies in construction documents (Tzortzopoulos and Formoso 1999). Problems in design management, which may lead to errors or omissions, have been described in the literature. Several studies have pointed out that poor design has a strong impact on the level of effectiveness during the production stage (Ferguson 1989). A large percentage of defects in buildings arise through decisions or actions taken during the design stages (Cornick 1991). Lack of communication, insufficient documentation, missing input information, lack of coordination between disciplines are main problems in design management (Cornick 1991, Koskela et al. 1997). Coles (1990) reported that the most significant causes of design problems are poor briefing and communication. Common concerns included late approvals from clients and insufficient time for completion of design documents. Consequently, there is a clear relationship between errors and waste, e.g. if the design documents include many errors then the potential of waste generation throughout the process is high. Errors in design have negative impact on the design phase itself and also on the construction phase. More importantly, these might negatively impact the post construction/use phase of a building, with vast negative consequences for the clients.

Cho J.G., Yum B.J.U (2002) discussed a proposed methodology of modeling the software project scheduling using event chains, classification of the events and chains, identification of critical chains, analysis of effect of the chains on project duration, cost, and chance of project completion. In this paper presents a practical approach to modeling and visualizing event chains. Hr says that, the event chains methodology can contribute to reducing uncertainties in project scheduling through mitigation of philological biases and significant simplification of process of modeling, tracking, and analysis of project schedule. The research conducted by James L. Burati, Jodi J. Farrington and William B. Ledbetter (1992), to identify the causes and magnitude of quality problems in design and construction and to determine the costs associated with the quality problems. The objectives were met through the use of interviews, both in person and by telephone, visits to home offices and construction sites, and analysis of data supplied by cooperating firms. The two major areas resulting in deviations were design and construction. These results indicate that rework costs are a significant portion of total costs.

The corrective actions in the operation phase, proposed by Alin Veronika, Leni S Riantini and Bambang Trigunarsyah (2006), could be a Project Control system, consisting of cost, quality and time. Corrective action data acquired from the expert are analyzed with Delphi Method. A prototype was devised for knowledge base management system, which will yield output in terms of recommended corrective action to cost variance. Recommendation will depend on factors which have the highest risk ranking. Corrective actions towards the cause of variance are recommended by observing the risk level of material cost variance. The study performed by K. Divakar and K. Subramanian (2009), involves two phases. The first phase involved the identification of various factors causing delay. This was done through personal interviews and discussions with the project managers, project engineers and builders who are directly involved in the progress of the project. The second phase involved identification of the most critical factors, identified in the first phase. This was done by circulating a questionnaire consisting of the factors causing the delay of the project. During the progress of the work the monitoring of the project should be done with special attention to these factors. So effective monitoring of the critical factors identified in this study will ensure successful completion of the project.

Vahid Khodakarami Norman Fenton, and Martin Neli. (2000).They have represent the Project scheduling inevitably involves uncertainty. The basic inputs (i.e., time, cost and resources for each activity) are not deterministic and are affected by various sources of uncertainty. Moreover, there is a causal relationship between these uncertainty sources and project parameters: this causality is not meddled in current state-of the-art project planning techniques (such as simulation techniques). The model presented empowers the traditional critical Path Method (CPM) to handle uncertainty and also provides explanatory analysis to elicit, represent and manage different sources of uncertainty in project planning. Paulson, B.C., S.A Douglas, A. Kalk. A Touran and G.A Victor, (1983) In this journal, author outline the procedures required to perform, Monte Carlo simulation for the purpose of schedule analysis. Analysis of various steps involved in forming a network plan and estimating the characteristics of the probability distributions for the various activities. Given a plan and the activity duration distributions, the heart of the Monte Carlo simulation procedure is the derivation of a realization or synthetic outcome of the relevant activity durations, here these realizations are generated, and standard scheduling technique is applied.

Numerous definitions of error have been identified in normative literature (Lopez et al. 2010). Tucker and Edmondson (2002) define error as "the execution of a task that is either unnecessary or incorrectly carried out" (p. 3). Similarly, Reason and Hobbs (2003) define error as "the failure of planned actions to achieve their desired goal, where this occurs without some unforeseeable or chance intervention" (p. 39). The term failure is often used interchangeably with error; however, a subtle difference between error and failure exists. A failure is "an unacceptable difference between expected and observed performance" (Ayininuola and Olalusi 2004; p. 73). With a failure an implicit expectation, exists; whereas, in the case of an error an unforeseeable or chance intervention takes place. Studies that have examined design errors in construction have often treated interchangeably used the terms changes, omissions, defects, quality deviations, non-conformances, and failures (e.g., Josephson and Hammarlund 1999; Josephson et al. 2002). A lack of definition has resulted in a great deal of confusion pertaining to the underlying causes and costs of errors in projects (Love and Edwards 2004). According to Love et al. (2009), a number of latent conditions reside within project systems that influence error-provoking activities to take place and, therefore, contribute to design errors occurring downstream during construction. For example, the use of competitive tendering can result in organizations committing to undertake work at a lowest price. This can result in opportunistic behavior whereby design firms omit to undertake design audits, reviews, and verifications to maximize their fee. Moreover, when firms are placed under schedule pressure by clients to design and document, then a propensity exists for them to omit tasks to make work more efficient. This often result in errors in contract documentation, which has been identified as a major cause of disputes within construction projects (Love et al. 2011a). For the purpose of brevity, it is not the intention of this paper to examine error causation because this has been examined elsewhere (e.g., Lopez et al. 2010; Love et al. 2011a, b, c, d). Once design errors are identified rework is invariably required. The extent of the rework that arises, however, is dependent upon when it is identified in a project's life cycle. Farrington (1987) revealed that design errors occurring in nine case study projects accounted for 19.7% of the total number of deviations that arose. Farrington (1987) also revealed that design changes/errors accounted for 79.1% of the total cost of quality deviations that arose in projects. Similarly, Robinson-Fayek et al. (2003) found the engineering and review processes for an engineering project contributed to 68% of rework costs with 78% of this total attributable to design errors. Barber et al. (2000) found that design errors accounted for 50% of quality failure costs in civil engineer projects. The cost of design errors has been reported to be lower in building projects with Love and Li (2000) revealing that they accounted for 14% of rework costs. Cusack (1992) has revealed that design errors contained within contract documentation alone can contribute to a 5% increase in a project's contract value.

3. RESEARCH METHODOLOGY

This study focused on determining the influences of people, organizations, and projects on construction error costs within construction and engineering. The objectives were met through the use of data collection at a fast track construction site and analysis of data supplied by the site. Due to time constraints and to ensure meaningful comparisons, data collection was limited to a single project for which construction began before project design was completed. Data from the project were then summarized and categorized to identify the causes and number of deviations along with their associated costs.

4. DATA COLLECTION

Data were collected from Site Planning Department and Site personnel, that contained complete information concerning: (1) A description of the change (2) why the change was required (3) who initiated the change and (4) the cost of the change.
The deviation data that were collected and analyzed were limited to granite cladding works alone. The deviation data collected included the direct costs and indirect costs associated with Granite cladding activities These direct costs of deviations consists of the cost incurred to carry out the activities in accordance with the scheduled plan and the rescheduled costs in accordance with the site conditions. Other project activities were not included in the deviation costs presented herein.

5. ANALYSIS OF DATA

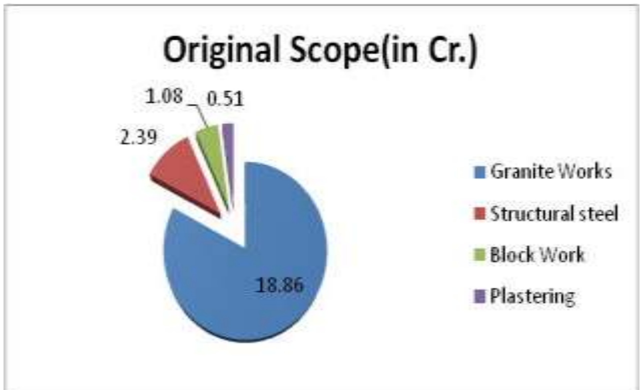
The data were analyzed both in terms of numbers and costs of deviations. Comparisons of number of deviations and deviation costs were all performed on a percentage basis. The analyses consisted of the number of deviations, deviation costs as a percentage of total project deviation costs, and deviation costs as a percentage of total project cost. Advanced scheduling techniques such as PERT and Monte-Carlo simulation, were also used in the analysis part, for identifying more accurate results on time schedule and cost of activities. Table 1 and 2 presented original and revised scope of works.

Table-1: ORIGINAL SCOPE OF WORKS

Description	Value
Granite cladding	18 Cr
Structural Steel	2.5 Cr
Concrete Block masonry	2.5 Cr
Total	23 Cr

Table-2: REVISED SCOPE OF WORKS

Description	**Value**
Granite cladding	9.5 Cr
Structural Steel	5.5 Cr
Concrete Block masonry	2.5 Cr
Total	17.5 Cr



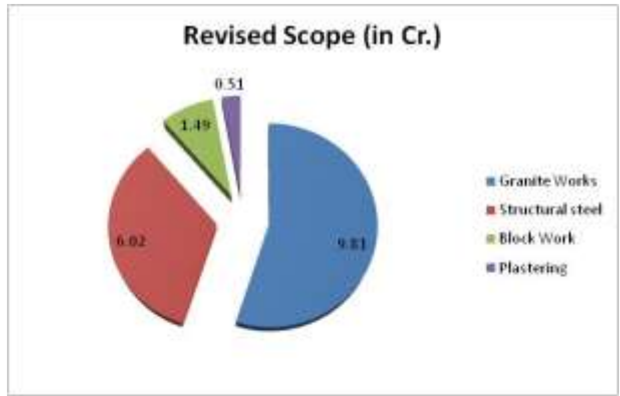


Fig-1: ORIGINAL SCOPE **Fig-2: REVISED SCOPE**

The figure 3 presented comparison of planned versus actual duration. Figure 4 and figure 5 presented in planned and actual cost. Figure 6 and 7 are shown comparison of cost by Monte Carlo simulation and PERT method. Table 3 presented in comparison of duration in Monte Carlo simulation and PERT method.

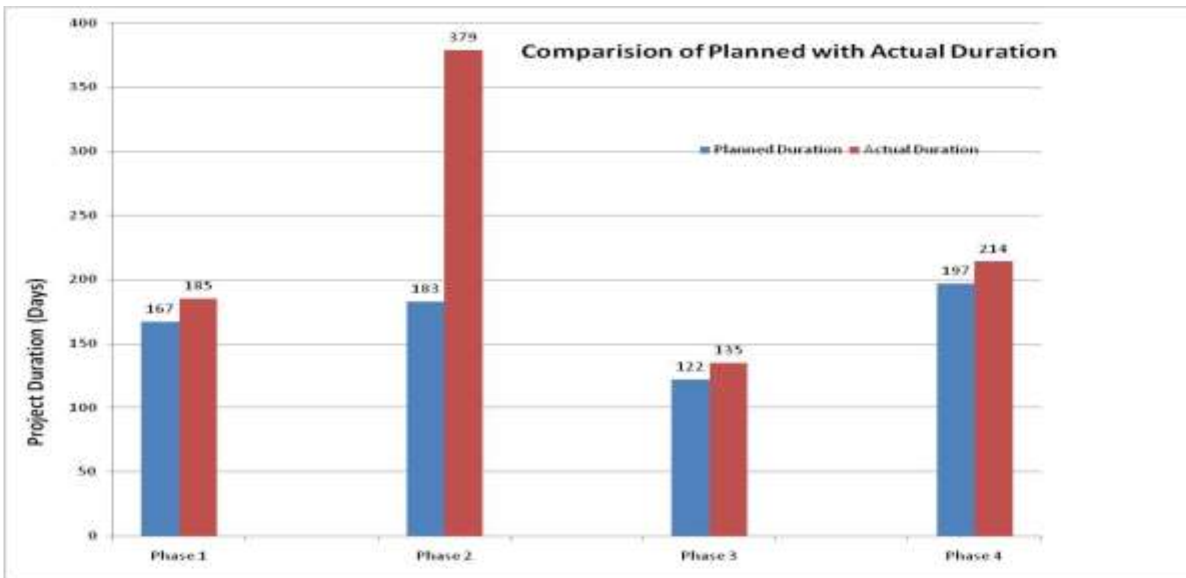
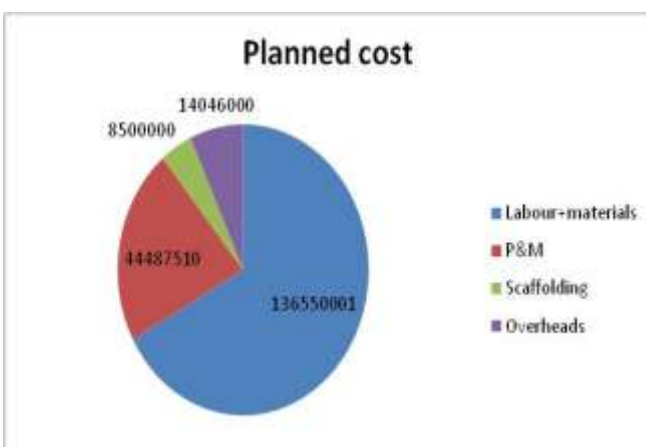


Fig 3: PLANNED VERSUS ACTUAL DURATIONS



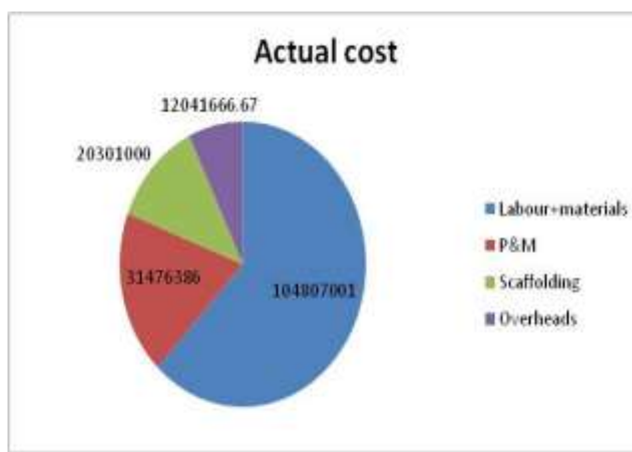
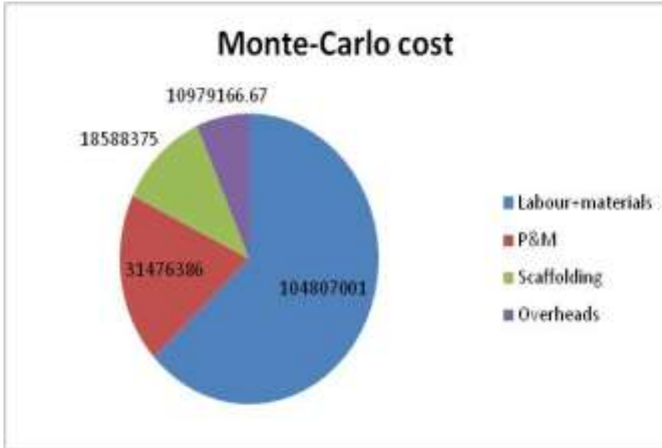


Fig 4 PLANNED COST **Fig-5: ACTUAL COST**



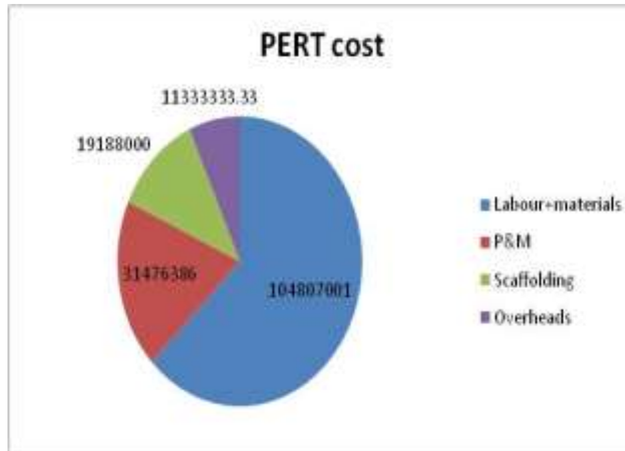


Fig-6: MONTE-CARLO DURATION RESCHEDULED COST

Fig-7: PERT DURATION RESCHEDULED COST

Table 3: PERT AND MONTE-CARLO DURATIONS

PERT and Monte-carlo Durations						
Activity Description	Optimistic Time (To = 60% of T)	Most Likely Time (Tm = 90% of T)	Pessimistic Time (Tp = 100% of T)	Average [Te = (To+4Tm+Tp)/6]	σ^2 = (Tp-To)^2/36	Monte - carlo Duration
Phase 1	123.3	185	205.6	178.1	187.8	157.9
Phase 2	252.7	379	421.1	365.0	788.1	330.2
Phase 3	90.0	135	150.0	130.0	100.0	106.2
Phase 4	142.7	214	237.8	206.1	251.3	174.1

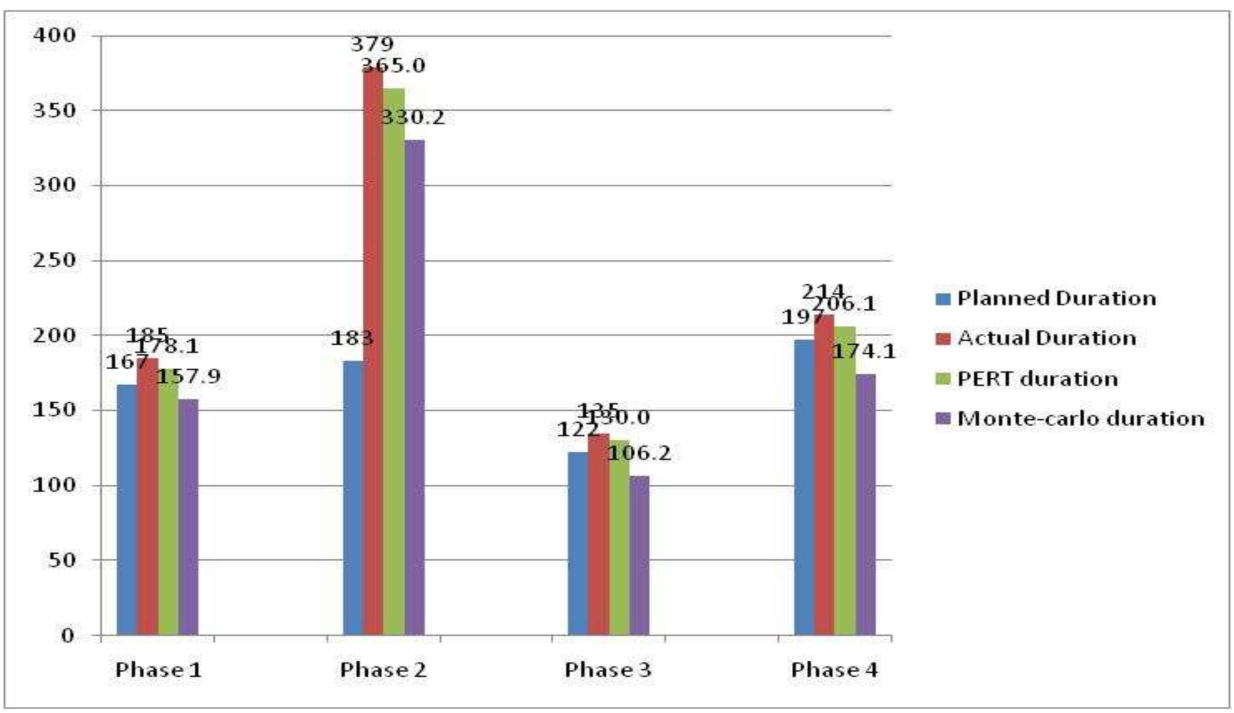


Fig-8: COMPARISON OF PLANNED, ACTUAL, PERT AND MONTE-CARLO DURATIONS

DEVIATION IN GROSS MARGIN FOR GRANITE CLADDING WORKS

Druration	Category	Cost (in Rs.)	Difference	PROFIT TARGETED %	NET IMPACT ON PROFIT %	Increase in Profit after reschedule(%)
Original	Contract amount	230,000,000	26,416,490	10.00%	-6.19%	1.58
	Planned Cost	203,583,510				
Revised	Revised amount	175,000,000	6,673,947			
	Actual Cost	168,626,053				
Monte-carlo	Revised amount	175,000,000	9,449,072		-4.61%	
	Rescheduled cost	165,850,928				
PERT	Revised amount	175,000,000	8,495,280		-5.15%	1.04
	Rescheduled cost	166,804,720				

Table 4: Deviation in Gross Margin

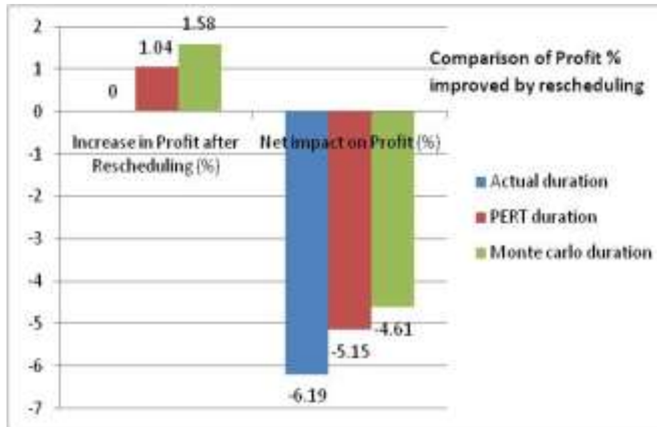


Fig-9: INCREASE IN PROFIT BY INCORPORATING PERT AND MONTE-CARLO DURATIONS

For the project's granite cladding works the activities were studied and identified the net profits were 11.49% of the original contractual amount, 3.81% of the revised contractual amount, 4.85% of the revised contractual amount (with rescheduled Monte-Carlo duration), 5.39% of the revised contractual amount (for rescheduled PERT duration). The deviation data gathered included only the schedule and cost details of granite cladding activities. Therefore, both the number and costs of deviations reported for the projects in this study are conservative estimates of the actual values. The statistics reported in this paper confirm the importance of identifying the causes of deviation costs so that they can be reduced as shown fig 8 and 9 and represted in Table 4.

6. CONCLUSIONS

Construction deviations for specified granite cladding activities considered in this study, identified net impacts on targeted profit (10%) were - 6.19% of the revised contractual amount,
- 4.61% of the revised contractual amount (with rescheduled Monte-Carlo duration), - 5.15% of the revised contractual amount (for rescheduled PERT duration). Hence for this study, by witnessing the above result interpretations, it can be concluded that Monte-Carlo simulation is best suited for fixing the activity duration, which yields maximum percentage of profit. The analyses presented in this paper demonstrate that a methodology to categorize historical data can be used to identify the number of deviations and their associated direct and indirect costs. The methods presented herein cannot only identify deviation costs, but can also identify the best suited model that can be adopted for project scheduling.

7. REFERENCES

1) Cho J.G, Yum B.J (2002), "Monte-Carlo Project Scheduling under Uncertainties", Project Management Journal, Vol. 33, No. 1, pp: 49-57
2) James L. Burati, Jodi J. Farrington and William B. Ledbetter (1996), "Causes of quality deviations in design and construction", Journal of Construction Engineering and Management, Vol.118, No. 1, pp: 34-49
3) Alin Veronika, Leni S Riantini and Bambang Trigunarsyah (2006), "Corrective action recommendation for project cost variance in construction material management", Proceedings The Tenth East Asia-Pacific Conference on Structural Engineering and Construction, Bangkok, Thailand, pp. 23-28
4) K. Divakar and K. Subramanian (2009), "Critical Success Factors in the Real-Time Monitoring of Construction Projects", Research Journal of Applied Sciences, Engineering and Technology, Vol. 1(2), pp:35-39
5) Vahid Khodakarami, Norman Fenton and Martin Neil (2000), "Project scheduling: Improved approach to incorporate uncertainty", Project Management Journal, Vol. 17, No. 4, pp: 77-81
6) Innes, S., (2004). "Developing tools for designing out waste pre-site and on-site." Proceedings of Minimising Construction Waste Conference: Developing Resource Efficiency and Waste Minimisation in Design and Construction, New Civil Engineer, London, United Kingdom.
7) Kirby, J.G., Furry, D.A. and Hiks, D.K. (1988). "Improvements in design review management." Journal of Construction Engineering and Mgmt, 114(1) 69-82.

8) Koskela, L, and Huovila, P "(1997). "On foundations of concurrent engineering", in: C, Anumba and N, Evbuomwan (eds). Concurrent Engineering in Construction CEC97,3-4 July, The Institution of Structural Engineers, London, 22-32.

9) Osmani, M., glass, J. and price, A., (2006). "Architect and contractor attitudes to waste minimization." Proceedings of the Institution of Civil Engineers, Waste and Resource Management, 159, 65–72.

10) Osmani, M., Glass, J., Price, A.D.F., (2008). "Architects' perspectives on construction waste reduction by design" Waste Management 28 (7) 1147–1158.

11) Ransom, W.H. (1987). "Building Failures: Diagnosis and Avoidance" E. & F. N. Spon, London.

12) Rounce, G. (1998). "Quality, waste and cost considerations in architectural building design management." International Journal of Project Mgmt. 16 (2) 123-127.

13) Stewart M. G., (1992). "Simulation of human error in reinforced concrete design" Research in Engineering Design Journal, 4, 51-60.

14) Tzortzopoulos, P and Formoso, C (1999). "Considerations on application of lean construction principles to design management" Proceeding of IGLC 7 Berkeley, USA.

15) Andi, A., and Minato, T. (2003a). "Representing causal mechanism of defective designs: A system approach considering human errors." Constr. Manage. Econ., 21(3), 297–305.

16) Andi, A., and Minato, T. (2003b). "Design documents in the Japanese construction industry: Factors influencing and impacts on construction process." Int. J. Proj. Manage., 21(7), 537–546.

17) Andi, A., and Minato, T. (2004). "Representing causal mechanism of defective designs: Exploration through case studies." Constr. Manage. Econ., 22(2), 183–192.

18) Bijen, J. (2003). Durability of engineering structures: Design, repair and maintenance, Woodhead Publishing, Cambridge, UK.

19) Burati, J. L., and Farrington, J. J. (1992). "Causes of quality deviations in design and construction." J. Constr. Eng. Manage., 118(1), 34–49.

20) Busby, J. S. (2001). "Error and distributed cognition in design." Des. Stud., 22(3), 233–254.

21) Love, P. E. D., Cheung, S. O., Irani, Z, and Davis, P. R. (2011a). "Causal discovery and inference of project disputes." IEEE Trans. Eng. Manage., 58(3), 400–411.

22) Love, P. E. D., Edwards, D. J., Han, S., and Goh, Y. M. (2011b). "Design error reduction: Toward the effective utilization of building information modelling." Res. Eng. Des., 22(3), 173–187.

23) Love, P. E.D, Edwards, D. J., and Irani, Z. (2011c). "Moving beyond optimism bias and strategic misrepresentation: An explanation for social infrastructure project cost overruns." IEEE Trans. Eng. Manage., 10.1109/TEM.2011.2163628 (in press).

24) Love, P. E. D., Edwards, D. J., Irani, Z., and Walker, D. H. T. (2009). "Project pathogens: The anatomy of omission errors in construction and engineering projects." IEEE Transact. Eng. Manage., 56(3), 425–435.

25) Love, P. E. D., Lopez, R., Edwards, D. J., and Goh, Y. (2011dd). "Error begat error: Design error analysis and prevention in social infrastructure projects." Accid. Anal. Prev., 10.1016/j.aap.2011.02.027 (in press).

26) Matousek, M., and Schneider, J. (1976). Untersuchgen zur struktur des sicherheitsproblem bei bauwerken, Birhäuser, Basel, Switzerland (in German).