PROJECT PERFORMANCE CONTROL IN RECONSTRUCTION PROJECTS

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ABSTRACT: Cost, schedule, and quality are the main indicators of performance in construction projects. These indicators are highly interrelated and require some balance and trade-off among them to achieve efficient overall control over project performance. Focusing on these performance indicators, the primary objective of this study is to investigate the use of conventional control techniques in projects involving reconstruction of occupied buildings. To facilitate this analysis, performance data have been collected, using a questionnaire survey, from 25 reconstruction and 15 new construction projects. The survey was followed by structured interviews with construction practitioners and project participants to elicit success-related factors and to identify some of the unique problems affecting the control of reconstruction projects. Using the collected data, performance comparison was conducted between new and reconstruction projects along with a detailed analysis of the suitability of existing techniques for the control of the cost, schedule, and quality in reconstruction projects.

INTRODUCTION

The construction industry is one of the largest industries in North America and worldwide. In Canada, for example, investments in the construction industry amount to about 6% of the total investments in all industries (Statistics Canada 1998). In recent years, a larger portion of all construction work has been shifting from new to reconstruction projects. Lee (1996), for example, reported that during the last decade, up to 50% of the total construction budget in the United States has been spent on a form of renovation, remodeling, or reutilization of existing buildings.

Whereas Statistics Canada groups the addition, renovation, or conversion of existing facilities under a broad category of ''new construction projects,'' this study defines reconstruction projects as a distinct category that includes the modification, conversion, or phased complete replacement of an existing facility (McKim and Attalla 1998). The importance of studying reconstruction projects in particular stems from the following two main reasons:

- Large investments are being directed to reconstruction projects. In the United States, for example, the national average spending on reconstruction is approximately 25% of new construction spending (U.S. Census Bureau 1998).
- Reconstruction projects are gaining increasing attention as owners, such as metropolitan governments, face huge problems with aging infrastructure projects that have large demographical, environmental, social, technological, and economical impacts (Sanvido and Riggs 1993; Attalla 1996).

Reconstruction projects vary extremely in scope, from simple interior renovation to major phased replacement of occupied facilities. The latter is understandably more complex and challenging. As an example of a typical large city in North America, the average percentage of spending on various reconstruction activities, according to one interviewed organization, is shown in Table 1.

The uniqueness of new construction projects and their increasing complexity make them highly challenging, and it is very difficult to control their cost, schedule, and quality of construction. This situation becomes even more complicated in the case of reconstruction projects due to various additional factors, including space constraints, safety regulations, and coordination requirements (Krizek et al. 1996). As various techniques are available to control the cost, schedule, and quality individually, these three indicators of performance are highly interrelated and affect one another. Excessive lack or exceptional excellence in the performance of one aspect (e.g., quality) may both lead to poor performance in another aspect (e.g., cost). It is, therefore, desirable to determine the balanced combination of techniques that provide efficient control for the three aspects, simultaneously, considering the specific environment of reconstruction projects.

The main objective of the present research is to determine if conventional control techniques are adequate for reconstruction projects of occupied buildings. In this research, the unique characteristics and good performance requirements of these types of projects are first identified. Using the construction cost, schedule, and quality as the three main performance indicators, the research investigates the external factors that interact with these indicators and need to be considered in an efficient control system. The present research also studied the conventional methods of project control and discussed their applicability to both new and reconstruction projects.

QUESTIONNAIRE SURVEY

Very little usable information was found in the literature concerning reconstruction projects. Most organizations that are involved in reconstruction projects of occupied buildings develop their own management tools, which they keep modifying through experience. Therefore, to gather information about these types of projects, a questionnaire survey was prepared.

TABLE 1. Expenditures on Reconstruction Activities

Type of reconstruction (1)	Expenditure (%) (2)
Expansion and phased replacement	38.6
Upgrading the functional performance of the facility (e.g., exterior walls, windows, reroofing)	29.2
Retrofit	24.5
Interior renovation	7.7

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The objectives of the survey were to (1) identify the project control techniques that correlate with high-performance projects; (2) compare and analyze the performance of reconstruction projects as compared to new construction projects; and (3) identify performance-related factors that apply specifically to reconstruction projects, other than cost, schedule, and quality. The survey was followed by structured interviews with construction managers and contract administrators to discuss the performance of particular projects.

To develop the questionnaire, a comprehensive review of the principles of project controls was conducted. Preliminary interviews were conducted to examine the validity of the questions and to observe the flow of questions. Accordingly, the questionnaire was refined to its final format. The questions were structured in a way that avoids subjective answers as much as possible and elicits quantitative data that directly relate to the cost, schedule, and quality performance. Data were obtained for a number of reconstruction and new construction projects. All selected reconstruction projects were executed within or near an occupied operational facility. An effort was made to reduce or eliminate the effect of external factors such as weather, local bylaws, etc., on the performance comparison. Thus, all selected projects were in the same geographical area of southern Ontario, Canada, and were institutional type buildings with the exception of one commercial building. Also, all project contracts were lump sum, except for one turnkey project.

The results of the selection process are 40 projects out of 45 originally recommended by the survey participants. These included 25 reconstruction and 15 new construction projects. The total value of the 40 projects is in excess of $100,000,000. Thirteen interviews were then conducted with construction professionals from participant organizations, owners, architects, and contractors. The interviewees provided factual information and knowledgeable opinions about the control processes and the actual performance experienced in the 40 projects.

SURVEY RESULTS: COMPARATIVE PERFORMANCE ANALYSIS

To analyze and compare between the performance of new construction versus reconstruction projects, quantifiable measures of the cost, schedule, and quality performances were established. In consistency will previous researches, cost overrun, schedule overrun, and the cost of rework have been used to measure cost, schedule, and quality performance, respectively (Sanvido et al. 1992; Weston and Gibson 1993; Gibson and Hamilton 1994; Ledbetter 1994). The comparative performance with regard to cost, schedule, and quality is discussed in the following subsections.

Cost Performance Factor (CPF)

According to survey respondents, cost performance can be measured by analyzing the actual project's cost overrun at any reporting period during construction. At the overall project level, respondents have also suggested the use of the total value of change orders as a reasonable indicator of the cost overrun. A CPF was then developed to be used as a measure of the cost performance in the surveyed projects and as a benchmark for comparing the cost performance of different projects. The CPF was calculated for the surveyed projects as follows:

$$\text{CPF}(\%) = \frac{Ct}{\text{original contract value}} \times 100 \qquad (1)$$

where Ct = total value of change orders issued during construction. Based on the CPF calculations, the mean and standard deviation of the CPF values are 19.9 and 18.37%, respectively, in the reconstruction projects and are 4.55 and 4.3%, respectively, in the new construction projects. This large difference in cost performance shows that new construction projects have better cost performance history than reconstruction projects of occupied buildings.

Schedule Performance Factor (SPF)

Survey respondents suggested the use of the schedule overrun as a good indicator of a project's schedule performance. An SPF was, therefore, created to measure the schedule performance and to establish a benchmark for comparison purposes. The SPF was calculated for the surveyed projects as follows:

$$\text{SPF}(\%) = \frac{St}{\text{original project duration}} \times 100 \qquad (2)$$

where St = total project delay. The results indicate that reconstruction projects have a higher tendency for schedule slippage (mean SPF value is 22.3%) and are more volatile (standard deviation is 26.2%). New construction projects, on the other hand, are more stable (mean SPF value is 12.6% and standard deviation is 14.2%).

Reasons for Cost and Schedule Overruns

The respondents' answers related to the reasons for cost and schedule overruns are compiled in Table 2. Although the questionnaire was structured to obtain factual information in a numeric format, details of the specific elements that contribute to cost and schedule overruns were obtained in the interviews. In reconstruction projects, it appears that the most cited factor contributing to cost overruns is unforeseen site conditions (mean value of 52.8%). Responses from the participants indicated that removal of concealed hazardous materials such as asbestos is a major element of unforeseen existing site conditions. Concealed services such as piping or ductwork and inaccurate as-built drawings are also major elements of unforeseen site conditions. Table 2 also shows that scope changes and design coordination add up to 26.8% of cost overruns. It was reported that in most reconstruction projects, the end-users often discovered during construction that the proposed design did not support the intended use of the facility. This triggered a considerable amount of change orders. Unlike reconstruction projects, unforeseen site conditions are not the highest contributors to cost overruns in new construction projects. Table 2 shows that the change of scope by the owner is the highest contributor for new construction.

With respect to the reasons for the delays, the participants were asked to assign a percentage to each contributing factor. These percentages were then grouped and mean values calculated. Unforeseen site conditions were reported as the biggest contributing factor to schedule overruns in reconstruction projects. This was followed by scope and design change. Table

TABLE 2. Factors Contributing to Cost and Schedule Overruns

	Reconstruction		New Construction	
Factor (1)	Cost (%) (2)	Schedule (%) (3)	Cost (%) (4)	Schedule (%) (5)
Unforeseen site conditions	52.8	50.4	21	27.5
Scope change by owner	16	13.8	52	47.1
Design change	13	14.7	23.6	16.7
Procurement problem	3.8	11.6	—	4.4
Design coordination	10.8	8.2	3.4	3.3
Regulatory requirement	3.6	1.3	—	7.0

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2, on the other hand, shows that the critical factors that cause schedule delays in new construction are the change of scope by the owner followed by unforeseen site conditions. Overall, this study revealed that, to some extent, the cost and schedule performance of reconstruction projects are sensitive to the same factors. These identified factors can be focused upon when establishing a project control mechanism to achieve significant improvements in performance.

Quality Performance

For the purpose of this research, quality has been defined as the degree of compliance with contract specifications (Gibson and Hamilton 1994; Ledbetter 1994). Whereas it was relatively simple to develop quantitative measures of performance in terms of cost and schedule, an effort was made to elicit practitioners' opinions on a suitable quantitative measure of performance with regard to quality. Accordingly, three quantifiable measures to quality performance were used: (1) Estimated cost of rework and/or repair; (2) number of rework and/or repair requests; and (3) number of users' complaints related to noise, dust, smoke, etc. The results are shown in Table 3, with the cost of rework being a good indicator of the quality performance factor (QPF).

As shown in Table 3, reconstruction projects experienced substantially more users' complaints (average of 7.8 complaints per project) as compared to new construction projects (average of 1.0). This is also consistent with a higher cost of rework and larger number of rework requests in the case of reconstruction projects. This analysis indicates that new construction projects outperform reconstruction projects in terms of quality performance.

SURVEY RESULTS: PROJECT CONTROL TECHNIQUES

One objective of the present survey is to investigate the use of conventional control techniques in new construction versus reconstruction projects. Using the survey data, the techniques to control the cost, schedule, and quality are analyzed in the following subsections. The control techniques associated with successful projects are also identified.

Cost Control Techniques

Based on a literature search during survey preparation, 11 techniques most commonly used to control the cost of a project were identified. These techniques are budget baseline, work packages costing, cost breakdown structure, unit costing, cost ratio, earned value, cost variance, cash flow analysis, schedule of values, trend analysis, and forecast analysis (*Project* 1987; CII 1988, 1991; Ahuja et al. 1994; Parker 1994; *A guide* 1996; McMullan 1996). In the conducted interviews, the participants were asked to identify which of the 11 techniques, or any additional ones, were used in their projects. The survey results indicate that the most frequently used cost control techniques, shown in Table 4 are budget baseline and cost breakdown structure for cost planning and unit costing, cost variance, cash flow analysis, and schedule of values for cost control during construction. Surprisingly, no forecasting techniques were reported in the surveyed projects.

TABLE 3. QPF

Quality criteria (1)	Reconstruction (2)	New construction (3)
Average cost of rework (percentage of total cost)	1.6%	0.27%
Average number of rework requests	7.4	1.3
Average number of users' complaints	7.8	1.0

TABLE 4. Most Frequently Used Cost Control Techniques

Technique (1)	Frequency (2)
Cost planning	
Budget baseline	22
Cost breakdown structures	19
Control measurement/control	
Unit costing	14
Earned value	5
Cost variance	21
Cash flow analysis	15
Schedule of values	23

TABLE 5. Cost Control Techniques Associated with High Cost Performance

Control techniques (1)	CPF reconstruction (2)	CPF new construction (3)
Group 1—High-performance projects: budget baseline, cost breakdown structure, schedule of values, and cost variances	6.7	2.9
Group 2—Low-performance projects: work packages, unit costing, and cost ratios	27.2	9

To identify the cost control techniques associated with high cost performance in the surveyed projects, the projects were divided into two groups. One group for projects with high cost performance (small CPF value, as calculated earlier) and the other group for projects with low cost performance. A correlation analysis for each group was then performed. The result was the identification of two sets of cost control techniques that produced high correlation with the CPF in the first and second groups of projects, respectively. The results of this analysis are summarized in Table 5.

Table 5 indicates that cost control planning using the cost breakdown structure and a budget baseline render better results than using work packages alone. It also indicates that better cost performance is associated with the use of the schedule of values and cost variances during construction to measure performance and identify any deviation from the original cost. On the other hand, the use of unit costing and cost ratios alone did not render high cost performance. It is also noted that the CPF for reconstruction projects, shown in Table 5, indicates that new construction projects outperform reconstruction projects when the same conventional control techniques are utilized.

One interesting approach to improve cost performance in reconstruction projects was indicated in the survey. It suggested the use of cash allowances to assist in reducing the cost overruns. In this approach, any undetermined scope of work at the time of tendering may be included in the contract through a cash allowance. When the scope becomes more defined during the construction process, the owner is then able to solicit prices from vendors or subcontractors to carry out this portion of work under the supervision of the general contractor. This method can be applied to demolition work, rerouting of existing services, or removal of hazardous material. This approach eliminates or reduces the painful and costly change orders. It is recommended that further research be conducted in this area to discover other performance improvement techniques.

Schedule Control Techniques

Similar to the case of cost control, the literature search identified the 11 most commonly used techniques to control the

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TABLE 6. Most Frequently Used Schedule Control Techniques

Technique (1)	Frequency (2)
Schedule planning	
Work breakdown structure	14
Bar chart	27
CPM analysis	10
Schedule measurement control	
Percent complete	25
Incremental milestone	19
Time variance	11

TABLE 7. Schedule Control Techniques Associated with High Schedule Performance

Control techniques (1)	SPF reconstruction (2)	SPF new construction (3)
Group 1—High-performance projects: detailed bar charts, percent complete, CPM analysis, incremental milestones	7.17	6.6
Group 2—Low-performance projects: WBS, time variance	100	21.5

schedule of a project. These techniques are work packages, work breakdown structure (WBS), bar charts, forecasting, critical path method (CPM) analysis, precedence method, program evaluation and review technique, percent complete, incremental milestone, S-curves, and time variance (Cole 1991; Popescu and Charoenngam 1995; ''A guide'' 1996). The survey participants were asked to identify which schedule control techniques were used in their projects. The results are summarized in Table 6. For planning purposes, WBS, bar charts, and CPM analysis were the most frequently used techniques in the surveyed projects. Also, for measuring and monitoring the schedule, the percent complete, incremental milestone, and time variances were most frequently used.

Using the same grouping of high-performance and low-performance projects, a correlation analysis was conducted to identify the schedule control techniques that contributed the most to schedule performance. The results of this analysis are summarized in Table 7.

For planning purposes, the use of detailed bar charts and CPM analysis techniques yield good schedule performances. Also, for schedule control during construction, the use of incremental milestones and percent complete resulted in higher schedule performances. One approach suggested by respondents for reconstruction projects is to integrate the operation schedule of the existing facility into the construction schedule. In large reconstruction projects, the operation of the occupied facilities during construction may require special consideration to provide a safe environment for users and a productive environment for construction as well. Providing temporary access and fire routes and moving equipment from and to the operational facilities are two situations that may cause delays to construction if not planned in advance. The integration of these tasks into the construction schedule keeps all parties informed of the different aspects of the project and ultimately enhances the schedule performance.

Quality Control Techniques

Three questions were included in the questionnaire to examine quality control planning in the surveyed organizations. Responses to the questionnaire indicated the following: (1) All reconstruction and new construction projects had the quality control organizational structure clearly defined; (2) responsibilities of individuals toward quality were also clearly defined; (3) all organizations interviewed did not have a quality controller position (rather, it is the responsibility of the site superintendent or the project manager to oversee and coordinate the quality control process); and (4) independent inspection firms were used to the same degree in both construction environments.

OTHER PERFORMANCE-RELATED FACTORS IN RECONSTRUCTION PROJECTS

An effort was made to explore additional factors that affect the performance of projects involving reconstruction of operating facilities, other than cost, schedule, and quality. Very useful information was obtained from the interviewees regarding the factors that contribute to the success or failure of reconstruction projects. Four aspects were reported as essential control functions: communication control, scope control, site control, and safety control.

Several interviewees cited communication control as one key to the success of reconstruction projects. In addition to the architect, the owner, and the contractor, other players become heavily involved in reconstruction projects, including facility users, facility operators, and, in most cases, the public. The involvement of these parties early in the process eliminates unexpected interruptions to the existing services of the building (water, power, etc.) and to the construction operations. One recommendation by some respondents in this regard is to conduct regular meetings with the users and operation staff to keep them informed and receive their feedback.

Early documentation and communication of the scope to all parties increases the chances of success. One important aspect to defining the scope of reconstruction work is the availability of adequate as-built drawings for the existing facility. In addition to proper scope definition, site control becomes significant in the case of occupied buildings. Space congestion introduces a variety of challenges particularly for storage and hoisting of material and equipment. In many cases, providing enough parking spaces or alternate parking for users is one of the problems that has an influence on the sequencing of reconstruction work.

Health and safety risks are more in reconstruction projects than in new construction. Working in, or in the vicinity of, an occupied building imposes additional constraints for safe practices. These constraints come from two sources: (1) Existing building components, as it is likely that these components contain hazardous materials such as asbestos, polychlorinated biphenyl, and lead; and (2) the occupants, because their existence in the building imposes limitations on activities that produce odors, smoke, or noise. These concerns should be included in the contract documents to avoid possible future disputes that may result in cost or schedule overruns.

SUMMARY AND CONCLUDING REMARKS

Projects involving reconstruction of occupied buildings are becoming increasingly more important. These projects have a unique environment that is different from new construction projects and imposes larger limitations on the owner, engineer, contractor, operator, and user. By means of a questionnaire survey, the use of conventional control techniques in both construction environments was investigated in this paper. Three different performance factors were described in order to obtain a quantifiable measure and establish benchmarks for comparison: CPF, SPF, and QPF. Using these factors, a comparative study revealed that new construction projects perform much better than reconstruction projects that exhibited higher schedule overruns and cost overruns.

Analysis of the factors contributing to schedule and cost

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overruns in reconstruction projects indicated that unforeseen site conditions is the biggest contributing factor to both cost and schedule overruns followed by the change in scope of work. Two interesting approaches were reported in the survey as means of reducing cost overruns and schedule overruns: cash allowances and integration of the operational facility's schedule into the construction schedule. The survey identified several factors that contributed to the success of reconstruction projects and also identified some problems that are unique to reconstruction projects. The reported problems included lack of information about the operating facility, space limitations for construction, maintaining health and safety of the occupants, and involving more players such as building users. Therefore, site control, communication control, safety control, and scope control become essential elements in the planning and control of reconstruction projects. Research efforts to develop a predictive model of the performance in reconstruction projects are currently being carried out by the writers.

APPENDIX. REFERENCES

Ahuja, H. N., Dozzi, S. P., and Abourizk, S. M. (1994). *Project management techniques in planning and controlling construction projects*. Wiley, New York.

Attalla, M. (1996). ''Reconstruction of occupied buildings, project control techniques,'' MS thesis, University of Waterloo, Waterloo, ON, Canada.

CII. (1988). ''Work packaging for project control.'' Publ. 6-6, Construction Industry Institute, Austin, Tex.

CII. (1991). ''Organizing for project success.'' Publ. 12-2, Construction Industry Institute, Austin, Tex.

Cole, L. J. R. (1991). ''Construction scheduling: Principles, practices, and six case studies.'' *J. Constr. Engrg. and Mgmt.*, ASCE, 117(4), 579–588.

Gibson, G. E., and Hamilton, M. R. (1994). ''Analysis of pre-project planning effort and success variables for capital facility projects.'' *Rep. Source Document 102*, Construction Industry Institute, Austin, Tex.

A guide to the project management body of knowledge. (1996). Project Management Institute, Drexel Hill, Pa.

Krizek, R. J., Lo, W., and Hadavi, A. (1996). ''Lessons learned from multiphase reconstruction project.'' *J. Constr. Engrg. and Mgmt.*, ASCE, 122(1), 44–54.

Ledbetter, W. B. (1994). ''Quality performance on successful projects.'' *J. Constr. Engrg. and Mgmt.*, ASCE, 120(1), 34–42.

Lee, J. H. (1996). ''Statistical deterioration models for condition assessment of older buildings,'' PhD thesis, Wayne State University, Wayne, Nebr.

McKim, R., and Attalla, M. (1998). ''Reconstruction of occupied buildings, project control techniques—A Canadian study.'' *Proc., 1st Int. Conf. on Civ. Engrg.*, Helwan University Press, Egypt, 439–453.

McMullan, L. E. (1996). ''Cost forecasting—Beyond the crystal ball.'' *Proc., AACE Int. 40th Annu. Conf.*, AACE International, Morgantown, W.Va.

Parker, D. E. (1994). ''Project budgeting for buildings.'' *Cost Engrg.*, 36(12), 13–18.

Popescu, C. M., and Charoenngam, C. (1995). *Project planning, scheduling and control in construction*. Wiley, New York.

Project controls: Needs and solutions. (1987). ASCE, New York.

Sanvido, V., Grobler, F., Parfitt, K., Guvenis, M., and Coyle, M. (1992). ''Critical success factors for construction projects.'' *J. Constr. Engrg. and Mgmt.*, ASCE, 118(1), 94–111.

Sanvido, V., and Riggs, L. S. (1993). ''Managing successful retrofit projects.'' *Cost Engrg.*, 35(12), 25–31.

Statistics Canada. (1998). ''Gross domestic product.'' Internet Site. ⟨www.census.gov/const/www/cci/ccidef.html#cv⟩

U.S. Census Bureau. (1998). ''Construction business.'' Internet Site. ⟨www.statcan.ca/english/econoind/gdpm.htm⟩

Weston, D. C., and Gibson, G. E., Jr. (1993). ''Partnering-project performance in the U.S. Army Corps of Engineers.'' *J. Mgmt. in Engrg.*, ASCE, 9(4), 410–425.