Optimal Allocation of Construction Planning Resources

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Abstract: Efficient allocation of resources for construction planning activities requires construction planning resource requirements to be determined on a cost-effective and value-adding basis. However, although some research studies have indicated that increasing resource allocations to construction planning activities will lead to improved project performance, other research studies have indicated that investing in construction planning beyond an optimum point will lead to a deterioration in project performance. This study explored the concept of optimal planning of construction projects by examining 52 building projects undertaken in Australia. The relationships between planning input (ratio of planning costs to total project costs) and the probabilities of achieving poor performance and good performance were modeled using logistic, linear, and curvilinear regression analyses. A probable optimum planning input based on the sample studied was derived. It is suggested that any additional planning efforts beyond this optimum point would be essentially wasted because the additional planning costs would not achieve any savings in project cost but merely add to the overhead costs and therefore increase the overall project cost. A model for optimal planning is presented and discussed.

INTRODUCTION

Construction project planning has a significant impact on the ability of construction firms to achieve success in the implementation of construction projects (Arditi 1985; Clayton 1989; Syal et al. 1992; Hamilton and Gibson 1996). Nevertheless, although researchers in construction management and practitioners in the construction industry realize the importance of construction planning, there is a divergence of opinion on how much effort should actually be invested in construction planning activities and how construction planning efforts should be organized to achieve success in the performance of construction projects. Findings from some research studies have indicated that construction planning effectiveness, and hence construction project performance, can be improved by increasing the amount of resources invested in construction planning activities (Laufer and Cohenca 1990; Faniran et al. 1994a, 1998). However, other studies suggest that investing in construction planning activities beyond an optimum point results in an increase in overall project costs (Neale and Neale 1989).

The study reported in this paper focuses on the construction planning undertaken within a construction firm for the purpose of determining appropriate strategies (methods, timing of operations, and required resources) for achieving construction project objectives. This paper addresses the issue of how much effort is required to be invested in construction project planning to achieve success in project performance. This would be of benefit to top management of construction firms in determining how much investment is required to achieve cost-effectiveness in construction planning activities within the firm. This paper also presents and discusses the conceptual framework of a construction planning model that is being developed to address the issue of optimal planning for construction projects. Specific objectives of the paper are (1) to explore the concept of optimal planning for construction projects; (2) to derive a probable value for optimum planning inputs into construction projects; and (3) to present and discuss preliminary stages of a proposed construction planning model that incorporates optimal planning concepts.

CONCEPTUAL FRAMEWORK OF STUDY

Efficient allocation of resources for construction planning activities requires that the determination of resource requirements should be undertaken on a value-adding and cost-effective basis. Firdman (1991) proposed the relationships illustrated in Fig. 1 to demonstrate the value of investing the ''correct'' amount of planning effort into a project. The relationships illustrated in the figure indicate that too little planning effort results in implementation failures, delays, and reworks. Consequently there is a high probability that the project will not achieve its intended objectives. When the correct amount of planning effort is invested, the project implementation time is optimized, and there is a high probability that the project will achieve its intended objectives. Additional planning effort beyond the optimal level also results in a high probability that the project will achieve its intended objectives. However, this effort is essentially wasted because of the implementation delays that inevitably arise due to the additional time required to complete the planning and the increasing number of planning loops that occur as planners plan and replan minute project details.

Neale and Neale (1989) proposed the relationship between project cost and planning input shown in Fig. 2. The figure indicates that as the planning input increases from 0 to (X)%, project costs are reduced. However, as the planning input goes beyond (X)%, project cost begins to increase. Neale and Neale described the low point (X) of the total cost curve as the saturation point of planning beyond which further spending on planning does not achieve any savings in project cost but merely adds to the overhead and therefore increases the overall project cost.

The studies outlined above have been mainly qualitative in their approach to exploring the concept of optimal planning. The intention of this study is to adopt a quantitative approach to explore the concept of optimal planning inputs for construction projects. In this study, project performance is based on Ashley et al.'s (1987) definition of project success that is summarized as: ''results much better than expected or normally observed in terms of cost, schedule, quality, safety, and participant satisfaction.'' Furthermore, it is recognized that there is a high degree of uncertainty in construction project environments, and therefore several other factors apart from construction planning contribute to project success (or failure). Consequently, this study examines the impact of planning efforts on the probability of achieving project success rather than on the actual achievement of project success. It is expected

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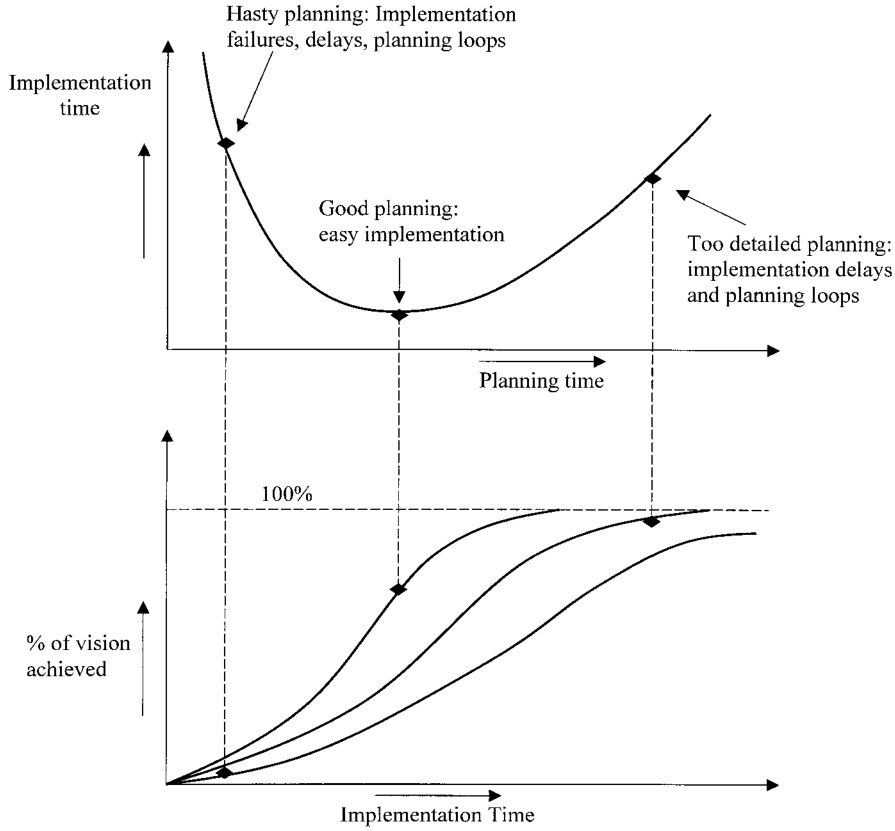

FIG. 1. Correct Planning

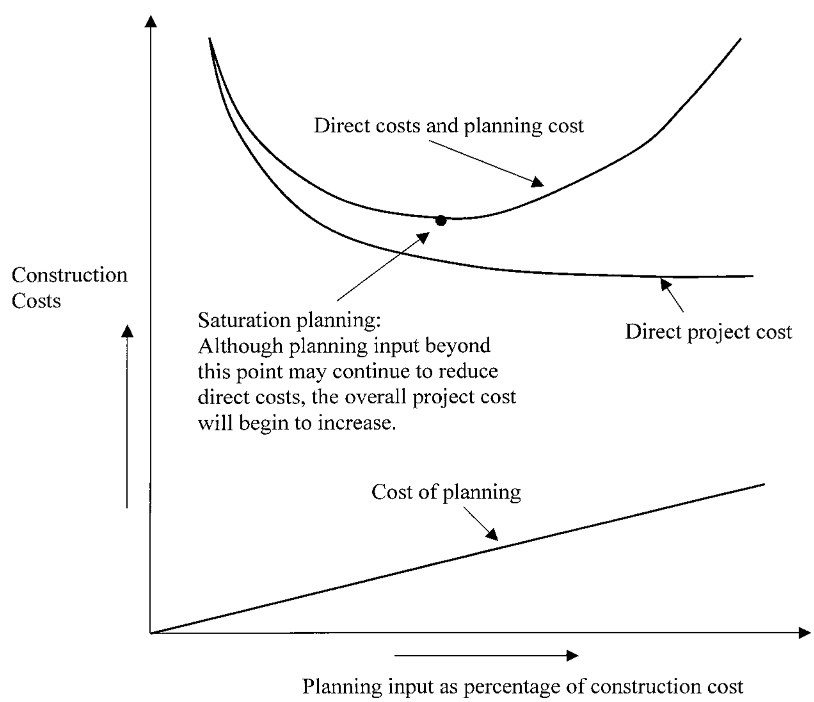

FIG. 2. Saturation Planning

that the relationship between the probability of project success and planning efforts could take either of the forms shown in Fig. 3: a linear relationship with the probability of project success increasing (or decreasing) at a constant rate as the planning input increases; or a curvilinear relationship with the probability of project success increasing (or decreasing) at a changing rate as the planning input increases. By examining the nature of the relationships, optimum values for planning input can be derived.

METHODOLOGY

Data Collection

A structured questionnaire was used to collect data for the study. The questionnaire contained questions relating to the amount of time invested in construction planning, the amount of time invested in project control, planning engineers' salaries, composition of construction planning team, and project costs. The questionnaire was pretested in a pilot study and

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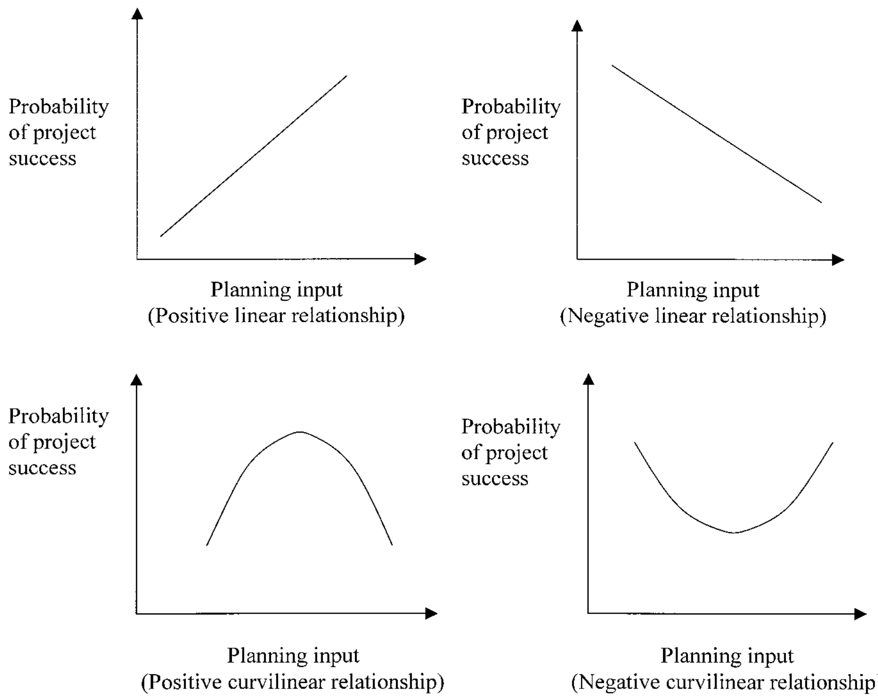

FIG. 3. Possible Relationships between Probability of Project Success/Failure and Planning Input

TABLE 1. Project Characteristics: Type of Project by Type of Contract and Type of Client

Project characteristics (1)	Type of Project: Commercial building (2)	Industrial building (3)	Educational building (4)	Health institution (5)	Government administrative building (6)	Defense facility (7)	Airport building (8)	Museum (9)	Sports/ recreation center (10)	Others (11)	Total (12)
(*a*) Type of contract											
Lump sum	11	3	8	3	3	1	1	—	—	5	35
Cost plus	—	—	1	—	—	—	—	1	1	—	3
Design/construct	9	2	1	—	2	—	—	—	—	—	14
Total	20	5	10	3	5	1	1	1	1	5	52
(*b*) Type of client											
Public	4	1	7	1	4	1	1	1	1	1	22
Private	16	4	3	2	1	—	—	—	—	4	30
Total	20	5	10	3	5	1	1	1	1	5	52

TABLE 2. Project Characteristics: Project Size Distributions

Project characteristics (1)	Range: Minimum (2)	Maximum (3)	Mean (4)
Project cost (dollars)	350,000	240,000,000	17,400,000
Project duration (weeks)	13	135	57.5
Total floor area (m^2)	250	156,000	12,067.5
Cost per square meter (dollars)	435.6	7,500	1,830.6

subsequently modified before a final version was produced. Eighty-five construction firms located in New South Wales, Australia, were approached to participate in the study. Fifty-two of the firms agreed to participate. Participating construction firms were asked to nominate a building project completed within the last 5 years and to provide responses to questions contained in the questionnaire with respect to the nominated project. Tables 1 and 2 show the characteristics of the projects included in the sample.

The following research variables were used in the study: planning input, cost variance, and time variance. Planning input is a measure of the effort invested in determining appropriate strategies for achieving the project's predefined objectives prior to the commencement of construction work on site. This includes the determination of construction methods, sequence and timing of construction operations, and required resources for project implementation. Cost variance is the extent to which the actual construction cost differs from the value stipulated in the contract documents at the time of award of the contract. Time variance is the extent to which the actual construction time varies from the time originally stipulated in the contract documents at the time of award of the contract.

Planning input was measured as the percentage ratio of planning costs to total project cost. Expressing planning costs as percentages of total project costs normalizes differences in planning efforts that may occur due to differences in project size. The cost of planning includes personnel costs, training costs, data processing costs, and administration costs. However, because of scarcity of relevant data available in construction firms, planning costs in this study were computed only on the basis of the cost of employing planning engineers for the projects (i.e., personnel costs). Cost variance was measured as the percentage ratio of the final project cost to the original project cost. Time variance was also measured as the percent-

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TABLE 3. Descriptive Statistics for Research Variables

Research variables (1)	Mean (2)	Standard deviation (3)	Coefficient of variation (4)	Range	
				Minimum (5)	Maximum (6)
Planning input (%)	0.20	0.37	185	0.01	1.71
Cost variance (%)	105.14	6.44	6.13	91.00	126.21
Time variance (%)	110.13	17.20	15.62	83.33	185.71

TABLE 4. Quartile Values for Cost Variance and Time Variance

Research variables (1)	Q1 (first quartile) (2)	Q2 (second quartile/ median) (3)	Q3 (third quartile) (4)
Cost variance	100.04	104.08	108.17
Time variance	100.00	108.33	115.39

age ratio of the final project duration to original project duration. Descriptive statistics for the research variables are shown in Table 3.

Cost variance and time variance measures were later transformed into three project performance categories: (1) Poor; (2) average; and (3) good. Jaselskis and Ashley (1991) measured project performance in three discrete categories: (1) Achieving overall project success; (2) achieving better-than-expected schedule performance; and (3) achieving better than expected budget performance. However, in Jaselskis and Ashley's study, the performance parameters were measured subjectively on the basis of respondents' assessments. In this study the project performance parameters—poor performance, average performance, and good performance—were derived statistically from the data collected.

Data Analysis

The data were analyzed using normality tests, logistic regressions, and linear/curvilinear regressions. Normality tests are used to examine the assumption that data come from a normal distribution. Normality testing can be done visually with a normal probability plot and a detrended normal plot or computed with a statistical test such as Shapiro-Wilks' test (Norusis 1994). Regression analysis is a statistical technique used to model the relationship between a dependent (or outcome) variable and independent (or explanatory) variables. In logistic regression the dependent (or outcome) variable is discrete and binary with only two values—an event occurring or not occurring. Logistic regression is used to estimate the probability that an event occurs (Hosmer and Lemishow 1989; Norusis 1994). The logistic regression model can be defined as

$$\text{Probability(event)} = 1/(1 + e^{-y}) \cdots \quad (1)$$

where y = outcome variable, expressed as the linear combination

$$y = b_0 + b_1x_1 + b_2x_2 + \cdots + b_nx_n \quad (2)$$

where $x_1, x_2, \ldots, x_n$ = covariates or explanatory variables; and $b_0, b_1, b_2, \ldots, b_n$ = constants.

Unlike the logistic regression model, the linear/curvilinear regression model does not predict the probability of occurrence of a discrete dependent (or outcome) variable but instead indicates the relative effects of independent variables on a continuous dependent variable and the strength of the relationship between the variables. In linear/curvilinear regression the dependent variable is assumed to be continuous. The linear regression equation can be expressed in the same form as (2). The curvilinear regression equation can be expressed in the form shown in the following:

$$y = b_0 + b_1x + b_2x^2 \quad (3)$$

where y = dependent (outcome) variable; x = independent (explanatory variable); and b_0, b_1, and b_2 = coefficients of regression.

The concept of optimal planning inputs for construction projects was explored in a four-stage analysis. In the first stage of the analysis, the project performance parameters used in the study—cost variance and time variance—were tested to determine whether the performances of the construction projects included in the sample followed a normal distribution. It was particularly important to determine whether the cost variance and time variance were normally distributed so that a valid basis could be established for statistically classifying the project performance into discrete categories. The second stage of the analysis consisted of converting the continuous project performance measures into discrete categorical variables. Project performance was classified into the following categories: (1) Poor cost performance; (2) poor time performance; (3) average cost performance; (4) average time performance; (5) good cost performance; and (6) good time performance. Projects with cost variance falling in the interquartile range (i.e., between the first and third quartiles) were classified into the category of ''average cost performance.'' Projects with cost variance exceeding the third quartile were classified into the category of ''poor cost performance,'' whereas projects with cost variance falling below the first quartile were classified into the category of ''good cost performance.'' Time performance was similarly categorized with time variance falling in the interquartile range (i.e., between the first and third quartiles) classified as ''average time performance,'' time variance exceeding the third quartile classified into the category of ''poor time performance,'' and time variance falling below the first quartile classified into the category of ''good time performance.'' Quartile values of cost variance and time variance are presented in Table 4. The categorization of the project performance parameters is illustrated in Fig. 4.

In the third stage of the analysis, bivariate logistic regression analyses were performed, and the probabilities of achieving good cost performance, good time performance, poor cost performance, and poor time performance for the planning input of each case in the sample was computed. Linear and curvilinear regression analyses were performed in the fourth stage of the analysis to examine the nature of the relationship between project performance and planning inputs into construction projects. A probable value for optimal planning input was also derived.

RESULTS

Fig. 5 shows the histograms (with superimposed normal curves) for cost variance and time variance. Figs. 6 and 7 show the normal and detrended normal plots for cost variance and time variance, respectively. Table 5 shows Shapiro-Wilks' test statistics for the cost variance and time variance variables. The results from the normality tests indicate that the cost variance and time variance of the projects in the sample can be considered to be approximately normally distributed. The pattern of performance of the projects in the sample can therefore be said to be a good representation of the population from which the sample was selected. Consequently, the classification of the performance of the projects in the sample into the categories of poor performance, average performance, and good performance can be considered to be valid.

Figs. 8 and 9 show the fitted regression lines for the relationship between the probability of good cost performance and

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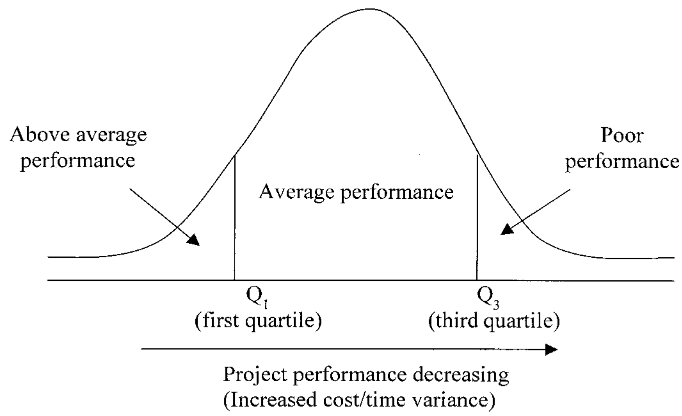

FIG. 4. Categorization of Project Performance

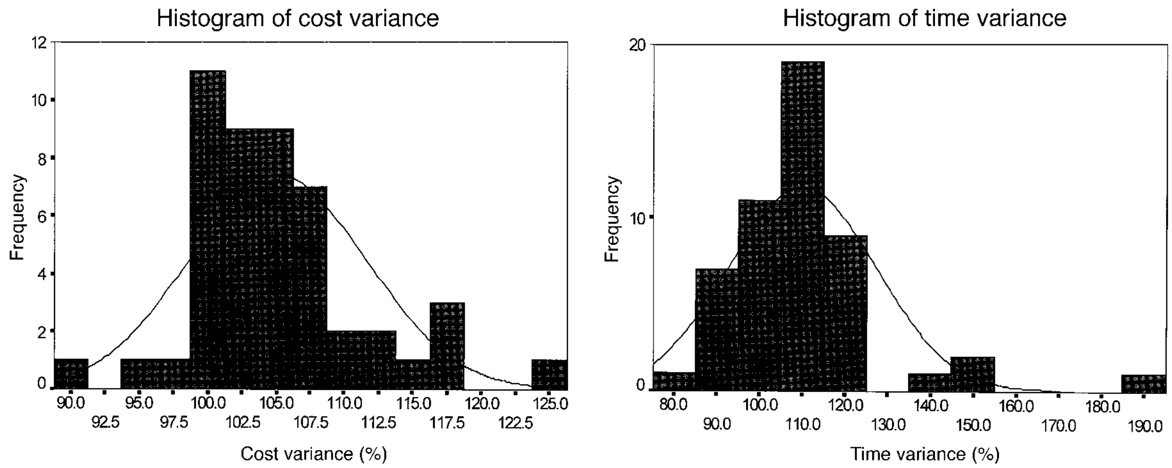

FIG. 5. Histogram (with Superimposed Normal Curves) of Cost Variances and Time Variances

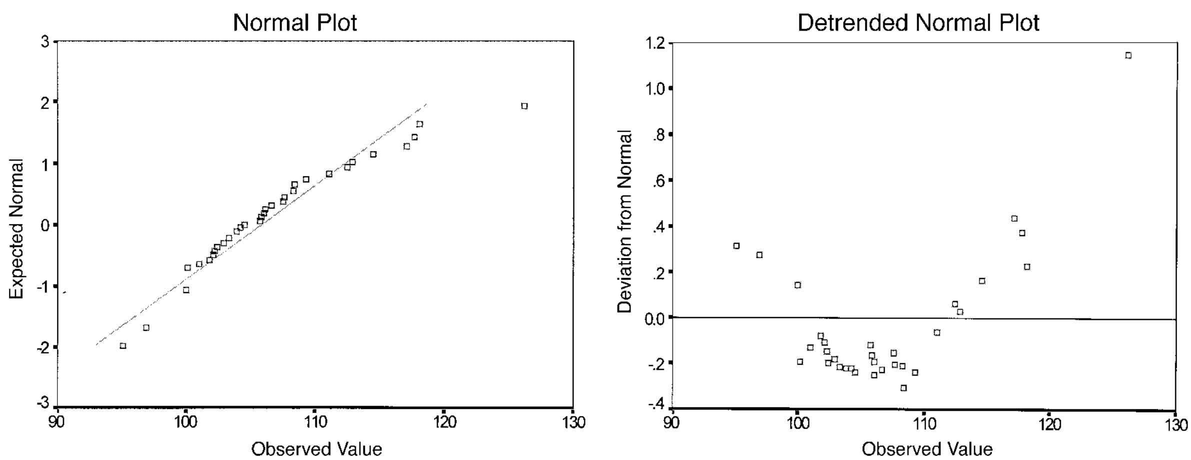

FIG. 6. Normal Probability Plots for Cost Variance

planning input and the relationship between the probability of poor cost performance and planning input, respectively. Figs. 10 and 11 show the fitted regression lines for the relationship between the probability of good time performance and planning input and the relationship between the probability of poor time performance and planning input, respectively.

DISCUSSION

It is interesting to note that none of the projects in the middle spread of the sample had cost or time variances that were below 100%. This is an indicator that cost and time overruns are a norm and confirms the prevalent high level of uncertainty associated with construction projects. Previous research studies have also reported similar findings. In Britain, a study by the Building Cost Information Service (BCIS 1988) found that 47% of projects exceed their planned cost and 71% of projects overrun their planned times. In New Zealand, Soetrick and Foster (1976) reported that time overruns on contract completion are 20% on average.

The relationships found between planning input and the probabilities of good cost performance, poor cost performance, good time performance, and poor time performance reveal very interesting trends and provide a useful basis for examining the concept of optimal planning for construction projects. The relationships suggest that the major impact of construction planning efforts is on the cost performance of construction projects rather than the time performance. The relationships

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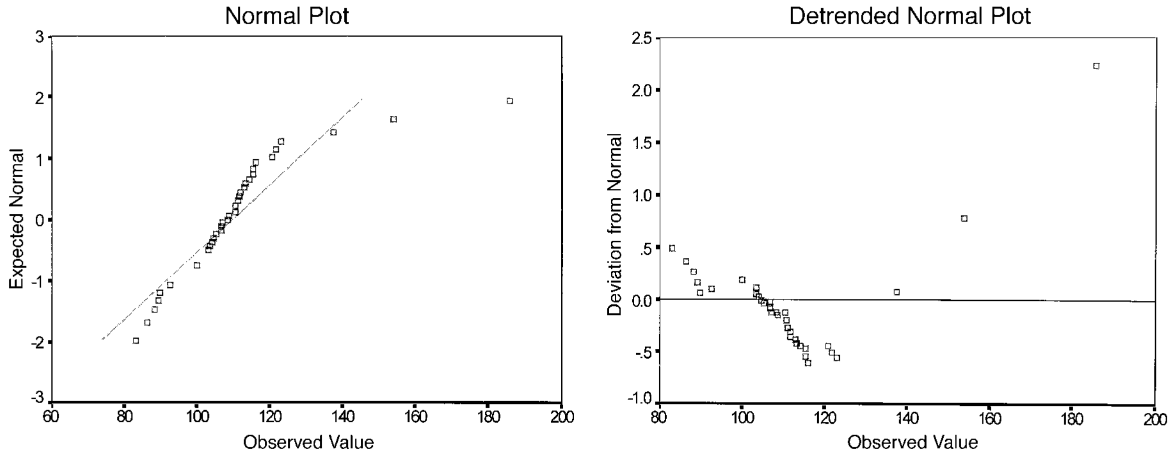

FIG. 7. Normal Probability Plots for Time Variance

TABLE 5. Shapiro-Wilks' Test for Normality

Research variables (1)	Statistic (2)	*df* (3)	Significance (4)
Cost variance	0.923	40	0.014
Time variance	0.808	40	0.010

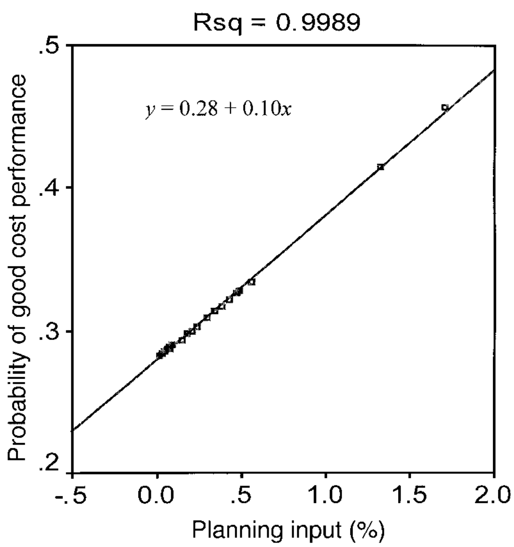

FIG. 8. Fitted Regression Line for Relationship between Planning Input and Probability of Good Cost Performance

shown in Figs. 8 and 9 indicate that the probability of achieving good cost performance increases as the planning input into a construction project increases. However, after the planning input passes beyond the minimum point of the curve in Fig. 9, the probability of achieving poor cost performance also begins to increase. The relationships shown in Figs. 10 and 11 indicate that increased planning input is associated with an increased probability of achieving good time performance as well as with an increased probability of achieving poor time performance. This implies that construction planning efforts do not have any significant dominant effect on project time performance. These findings are in line with findings from a previous study by Faniran et al. (1998) where planning time was identified as a critical determining factor for the extent to which the actual construction cost varied from the originally stipulated project cost. In Faniran et al. (1998) study, project time performance also was not found to be affected by construction planning efforts.

A probable value for optimal planning input can be derived from the results of this study by determining the cutoff point of the fitted regression curve relating the probability of poor cost performance to planning input. The cutoff point is the minimum planning input value corresponding to a zero probability of poor cost performance (Fig. 12). This is determined as follows by solving (4) for a value of zero:

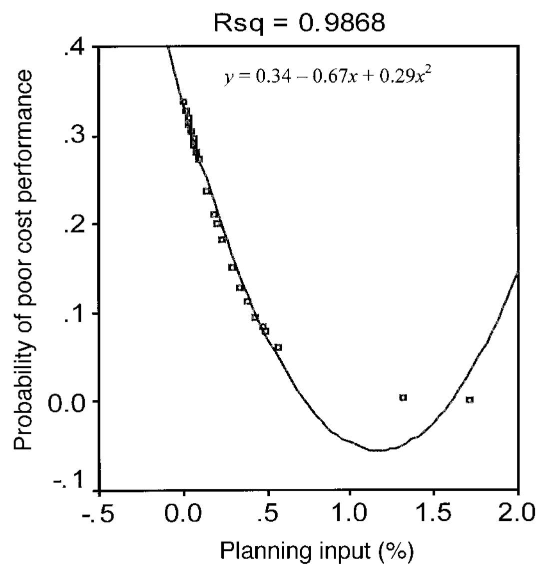

FIG. 9. Fitted Regression Line for Relationship between Planning and Probability of Poor Cost Performance

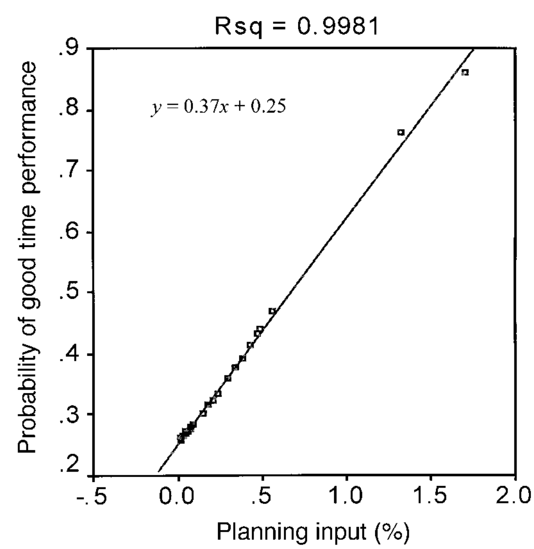

FIG. 10. Fitted Regression Line for Relationship Between Planning Input and Probability of Good Time Performance

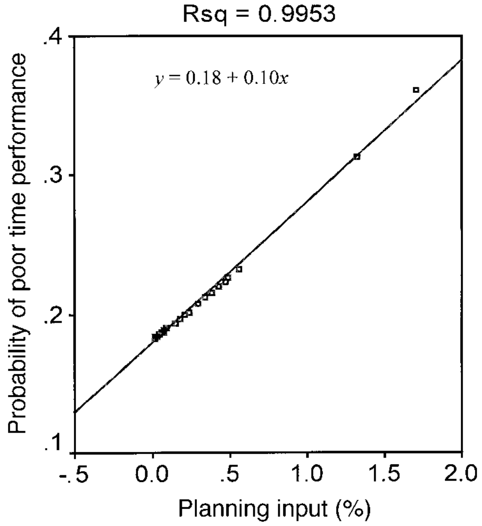

FIG. 11. Fitted Regression Line for Relationship between Planning Input and Probability of Poor Time Performance

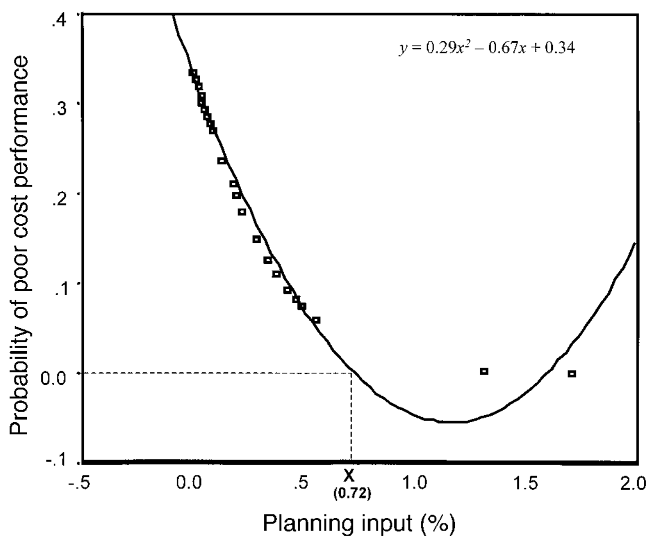

FIG. 12. Probable Value of Optimal Planning Input

$$0.29x^2 - 0.67x + 0.34 = 0 \qquad (4)$$

where $x = 0.72$; or $x = 1.59$.

The probable optimal planning input value derived from this study is therefore 0.72%. The applicability of this value has inherent limitations arising from the sample characteristics and the method of analysis. The sample was geographically restricted to the state of New South Wales, Australia, and consisted of a wide variety of building project types. Different types of buildings, and indeed different types of construction projects, would require different levels of planning input depending on the particular characteristics of the project. The amount of time invested in construction planning was also evaluated on the basis of the subjective assessments of respondents. Similarly, the computation of the planning costs was based solely on the salaries of planning engineers. Other cost factors such as data processing costs and administrative costs were not considered. Despite these limitations, the results of the study have clearly demonstrated that although too little planning is likely to result in poor project performance, and increasing the efforts invested in planning would increase the chances of good performance, excessive planning beyond an optimal level increases the probability of a deterioration in project cost performance.

The scope of the present study did not include the identification of specific planning products corresponding to an optimum level of construction planning. Nevertheless, it can be inferred from the results that an optimum planning level for a construction project would be that level of planning input that provides general direction for a project and, at the same time, provides sufficient flexibility for the project to react to change at the lowest possible level and with the least change in the original plan. This and other issues are currently being addressed in a comprehensive research study on construction project planning being undertaken at the School of Architecture and Building, Deakin University, Australia. The study is developing an optimal planning model for construction projects that addresses the issue of optimal planning and seeks to rectify some of the deficiencies in current practices in construction planning.

Fig. 13 highlights the difference between the proposed model and current practices in construction planning. Prevailing practices in construction planning can be divided into three broad phases: (1) Pretender phase—the period between the receipt of a tender enquiry by a construction firm and submission of a tender; (2) preconstruction phase—the period between the award of a contract to a construction firm and commencement of work on site; and (3) construction phase—the period between commencement of work on site and completion of site works. Construction plans prepared in the pretender phase are used for preparing the tender and consist mainly of general details of anticipated construction methods and rough estimates of anticipated resource requirements. After the contract has been awarded to the firm and prior to the commencement of work on site (the preconstruction phase), time, cost, and resource schedules are prepared on the basis of a predetermined construction method. After the commencement of work on site (the construction phase) construction planning activities consist mainly of reviewing the progress of the project at regular intervals, identifying deviations from the scheduled progress, and taking corrective measures to bring the project back in line with the original schedule. Prevailing practices in construction planning, as described above, have often been criticized for the following reasons (Erskine-Murray 1972; Laufer and Tucker 1987; Faniran et al. 1994b):

1. Attention paid to the determination of construction methods is insufficient.
2. Emphasis is on forecasting project performance before the commencement of work and controlling project performance after the commencement of work. Prospective planning (planning directed toward creating a desired future) is therefore replaced by retrospective planning (planning directed toward correcting deficiencies created by past deficiencies).

The proposed optimal planning model is a product-based model of the construction planning process that addresses the deficiencies highlighted above and incorporates the concept of optimal planning. The model focuses on the preconstruction and construction phases of a project. The objective of the model is to provide broad guidelines for project implementation prior to the start of the project and to develop detailed operational plans concurrently with project execution. In the preconstruction phase of a project, an outline schedule and budget is prepared by the contractor's contract management team to serve as a framework for the development of detailed plans (schedules and work assignments) by the site management and production teams. During the construction phase, the site management team divides the project into work packages and assigns production teams to each work package. The production teams are then responsible for developing short-term schedules and work assignments for the individual work packages and monitoring the construction process to ensure that the plans are properly implemented. A key element of the

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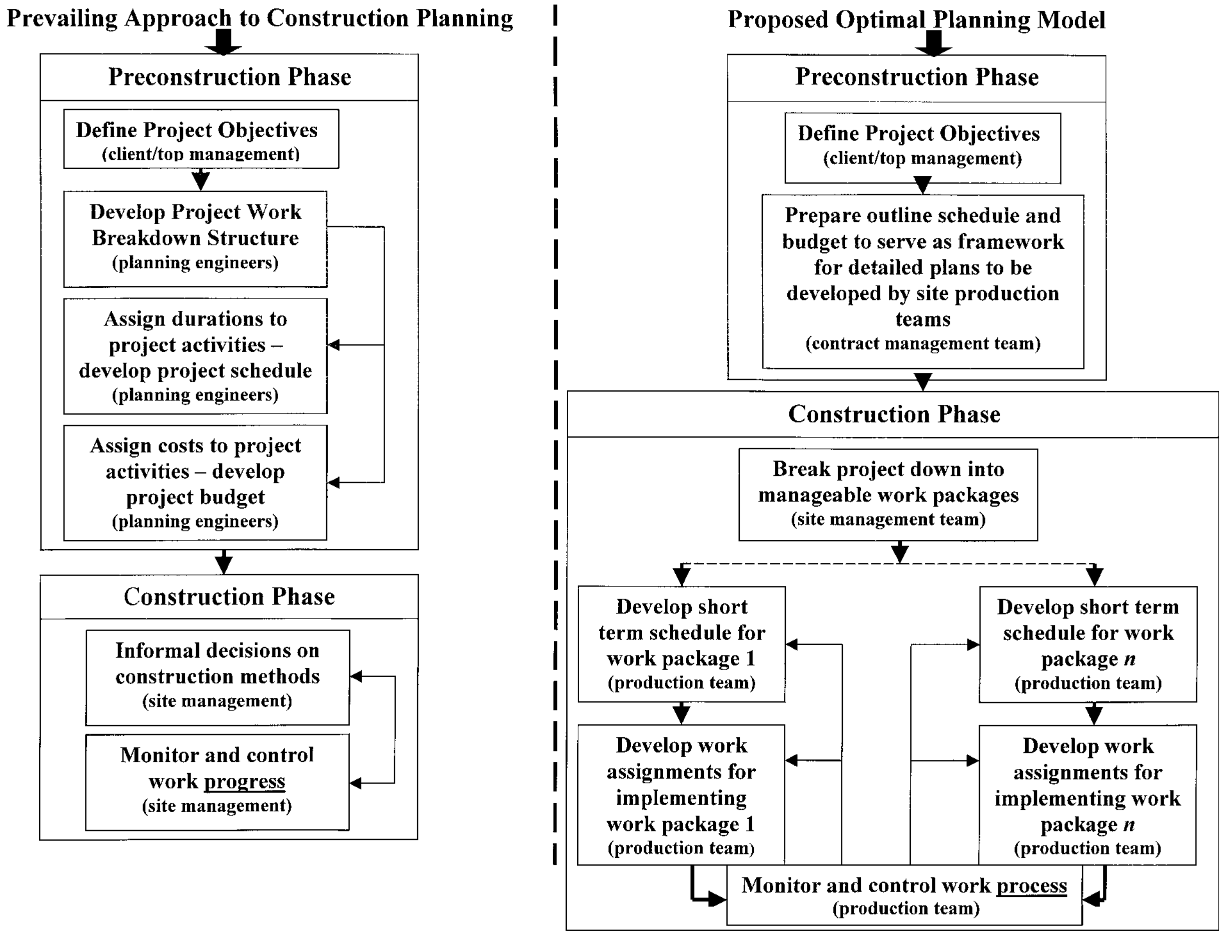

FIG. 13. Prevailing Approach to Construction Planning and Proposed Optimal Planning Model

model is that the construction plans are prepared by the people who are responsible for implementing the plans. This factor has been identified in the general planning literature as being a necessary condition for achieving effectiveness in planning (Ackoff 1970; Kudla 1976). Another key element is that the emphasis on project control in current approaches to construction planning will be replaced by an emphasis on production control. Ballard and Howell (1998) distinguished between ''project control,'' which focuses on monitoring performance against specified performance standards, and ''production control,'' which focuses on the progressively detailed shaping of the physical production process by the production unit. Further research work is being undertaken to refine and test the model.

CONCLUSIONS

This paper has explored the concept of optimal planning for construction projects and derived a probable value for optimal planning input into construction projects. Although the applicability of the derived optimum planning input value has inherent limitations, the results have nonetheless demonstrated that investing in construction planning activities beyond an optimum point increases the probability of poor project cost performance and is therefore not likely to be cost-effective. Further research work is required to validate the findings and determine globally guaranteed values of optimal planning inputs for different categories of construction projects. Based on the results obtained from this study, optimal planning can be defined as that level of planning input that provides general direction for a project and, at the same time, provides sufficient flexibility for the project to react to change at the lowest possible level and with the least change in the original plan. A planning model based on the concept of optimal planning was presented and discussed. The model is still under development, and further research work is being undertaken so that it can be refined, evaluated, and implemented.

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