Optimal Allocation of Project Management Resources for Achieving Success

By Edward J. Jaselskis,[1] Associate Member, ASCE, and David B. Ashley,[2] Member, ASCE

Abstract: This paper discusses important aspects that can help project managers efficiently allocate their limited resources and thus help them achieve high levels of construction project performance. Additional, previously undiscussed model outcomes are presented that focus on the impact of the project team, planning, and control efforts as they relate to achieving "overall" project success, better-than-expected schedule performance, and better-than-expected budget performance. Results demonstrate that key success factors affect project outcomes differently. For example, increasing the number of budget updates has more of an impact on achieving better budget performance than it does on achieving better schedule and overall project performance. Implementation of a constructability program seems to have a significant impact on achieving overall project success and better schedule performance—especially on fixed-price contracts. Reducing team turnover has a more significant impact on improving budget performance than it does in achieving better schedule or overall project performance. A robustness analysis of the model outcomes is presented, along with a discussion on the study limitations.

Introduction

The rather complex and uncertain nature of the construction environment presents project managers with many challenges in achieving successful construction-project outcomes. Construction projects experience much uncertainty because of shortages of material and labor, unfavorable weather conditions, unstable political environments, inadequate cash reserves, possible inflationary effects on project costs, and the short-term nature of most construction projects, which makes it more difficult to maintain a stable project organization. Despite these seemingly endless hurdles, it is nevertheless possible for a project manager to consistently achieve outstanding project results. By including project management input related to success in the execution plan, the likelihood of achieving an outstanding project can be enhanced. Thus, the premise of this research is that construction project success is repeatable. Success in this study is defined as a construction endeavor that is perceived by the project manager, and hence by his organization, to have "outstanding" results for all significant parties involved in the project (such as the designer, owner, and contractor).

This paper presents further analysis of three models developed by the writers to help predict the probability of success for a construction endeavor before it begins based on key management resources applied to the project. In previous research, the writers (Ashely and Jaselskis 1988) identified differences in management-related inputs between average and outstanding construction projects and developed discrete choice models from these data re-

---

[1]Asst. Prof., Civ. and Constr. Engrg. Dept., Town Engrg. Bldg., Room 455, Iowa State Univ., Ames, IA 50011.

[2]Prof. of Civ. Engrg., Univ. of California at Berkeley, Berkeley, CA 94720.

Note. Discussion open until November 1, 1991. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on September 29, 1989. This paper is part of the *Journal of Construction Engineering and Management*, Vol. 117, No. 2, June, 1991. ©ASCE, ISSN 0733-9364/91/0002-0321/$1.00 + $.15 per page. Paper No. 25907.

J. Constr. Eng. Manage., 1991, 117(2): 321-340

lating to: (1) Achieving overall project success; (2) achieving better-than-expected schedule performance; and (3) achieving better-than-expected budget performance. Average results refer to projects that performed marginally but were not considered failures. The better-than-expected notation refers to projects that perform better than originally anticipated. These models are applied during the early stages of a project and can help predict the probability of success for a construction project; the models are based on certain inputs related to the project manager, project, team, and expected planning and control efforts. Model results demonstrate that the success of a construction project depends on many characteristics relating to the project manager's experience level, project team stability, level of control effort, and planning efforts (Ashley and Jaselskis 1988).

Further analysis of these models is accomplished in this discourse so that the impact of the project team, planning effects, and control efforts can be assessed in terms of their overall effect on a specific project outcome. In other words, an investigation of the relative importance of the project team, planning, and control efforts on each of the three measures of success will be discussed. This paper reviews pertinent project sample characteristics, as well as provides a robustness analysis of these results. The usefulness of these model results and some of the study limitations also will be discussed.

Project Characteristics

Characteristics of the project data are summarized in Table 1. The data base includes 75 construction projects. Approximately half of the projects are classified as average and half as outstanding, by the manager ultimately responsible for the project. About two-thirds of the projects are from contractor organizations and one-third are from owner organizations. Most of the construction projects are in the United States; the remainder are in various other countries. About half of the projects are process-plant–related projects, and the other half are a combination of manufacturing, office, power, pipeline, dam, tunnel, and other types. Cost-reimbursable projects account for 60%, 34% are fixed price, and 6% are unit price. The average size for the outstanding projects is $154,000,000, with a mean duration of 31 months. Average projects typically are smaller in size compared with outstanding projects; the mean size for the average projects is $86,000,000 and the mean duration is 27 months.

Table 2 displays a listing of the important factors, as well as their typical values for average and outstanding projects, representing both owner and contractor perspectives (refer to Appendix I for a definition of each factor). It is interesting to note some of the similarities and differences that exist between factor characteristics for both owner and contractor organizations. For example, the level of team turnover is approximately the same for owner and contractor organizations for both average and outstanding projects. Additionally, owner and contractor project managers have approximately the same number of formal project meetings per month (about eight to nine). It is also interesting to note that contractor project managers spend a greater percentage of their time on the outstanding projects compared with owner project managers (97% versus 72%).

Many other significant observations can be drawn from Table 2. Owner project managers appear to have more expertise than contractor managers in

J. Constr. Eng. Manage., 1991, 117(2): 321-340

TABLE 1. Average versus Outstanding Project Characteristics

Variable description (1)	Sample Characteristics: Average (N = 34) (2)	Outstanding (N = 41) (3)	Total (N = 75) (4)
Company and project under review:			
Contractor companies	65%	63%	64%
Owner companies	35%	37%	36%
Respondents' individual roles:			
Project manager	64%	61%	63%
Construction manager	18%	17%	17%
Project engineer	3%	5%	4%
Other	15%	17%	16%
Project location:			
Domestic	91%	80%	85%
International	9%	20%	15%
Construction industry type:			
Industrial	73%	80%	77%
Commercial	12%	10%	11%
Civil	15%	10%	12%
Residential	0%	0%	0%
Technology type:			
Process plant	47%	48%	47%
Manufacturing	6%	7%	7%
Office	12%	5%	8%
Power	3%	10%	7%
Pipeline	3%	2%	3%
Dam	9%	0%	4%
Tunnel	0%	3%	1%
Other	20%	25%	23%
Nature of contract or agreement:			
Fixed price	28%	39%	34%
Reimbursable cost	66%	55%	60%
Unit price	6%	6%	6%
Project cost ($, millions):			
Mean	86	154	124
Project duration (months):			
Mean	27	31	29

several respects: education level, total years of experience, years of experience as project manager, and number of projects worked on with similar scope and technology. Furthermore, owner organizations budget higher contingencies on their projects than do contractor firms. Owners tend to expend more effort in terms of monitoring and appraising the performance of the construction project, especially in the areas of quality and safety. In these two areas, owners had conducted about twice as many quality and safety inspections per month on their outstanding projects as the contractor organizations. Moreover, both owners and contractors seem to have more budget and schedule updates on their outstanding projects.

An assessment of the percentages of construction projects that fall into the

TABLE 2. Average versus Outstanding Project Input Characteristics

Factor	Contractor		Owner		Combined	
	Average (2)	Outstanding (3)	Average (4)	Outstanding (5)	Average (6)	Outstanding (7)
(1)						
Project manager meetings (number/month)	9.1	8.3	8.8	9.5	8.9	8.7
Project manager time devoted (%)	88	97	82	72	86	88
Project manager site visits (number/month)	21.0	20.5	8.9	11.4	16.6	17.4
Project manager subordinates (number)	5.1	7.7	8.2	7.9	6.2	7.8
Project manager levels to craftsmen (number)	3.8	4.1	4.8	5.1	4.1	4.5
Project manager education level (number of years after high school)	3.8	3.6	4.5	4.0	4.1	3.8
Project manager total years construction experience (number years)	18.8	20.0	23.1	24.5	20.2	21.8
Project manager experience as project manager (number years)	8.0	8.4	15.4	17.5	10.5	12.0
Project manager scope experience (number of projects w/similar scope)	2.3	2.6	6.2	4.8	3.6	3.5
Project manager technical experience (number of projects with similar technology)	1.7	2.6	4.7	4.0	2.8	3.1
Project manager scope experience other than as project manager (number of projects)	4.8	5.7	6.2	6.0	5.3	5.8
Project manager technical experience other than as project manager (number of projects)	3.5	6.4	6.5	3.9	4.5	5.4
Team turnover (%/year)	14	7	18	5	15	6.6
Design incentives (% budget)	1.0	1.0	0.6	1.0	1.0	1.0
Design complete at construction start (%)	69	60	47	52	61	57
Activities in execution plan (number)	10.5	11.9	8.3	10.0	9.7	11.2
Budgeted contingency (%)	6.0	6.0	9.2	10.0	7.3	7.9
Constructability program (% projects with programs)	45	77	75	60	56	71
Modularization (% total budget)	8.0	10.0	6.3	11.0	7.5	10.2
Progress inspections (number/month)	7.5	5.9	10.9	7.9	8.7	6.7
Quality inspections (number/month)	15.8	10.9	17.0	19.9	16.2	14.6
Safety inspections (number/month)	11.8	7.6	14.0	17.5	12.5	11.2
Control system budget (% total budget)	2.0	2.0	1.2	1.0	1.6	1.8
Control meetings during design phase (number/month)	4.4	3.7	3.2	4.9	3.9	4.2
Control meetings during construction phase (number/month)	3.0	4.9	3.3	5.6	3.1	5.2
Schedule updates (number/year)	6.1	7.8	6.4	11.7	6.2	9.3
Budget updates (number/year)	10.0	15.0	7.1	9.0	8.9	12.8

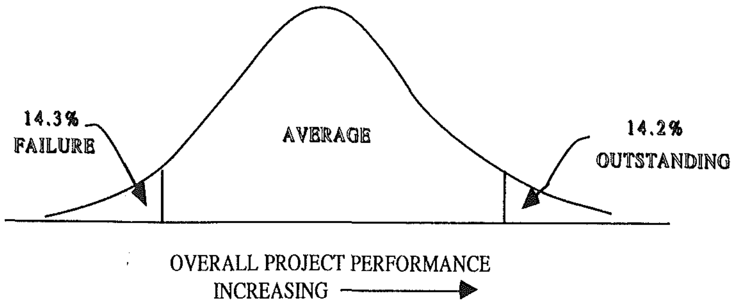

FIG. 1. Percentage of Outstanding, Average, and Failed Projects

outstanding, average, and failure categories was made. Nine project managers were asked what percentage of their projects fell into these three project classifications. About 14% of their projects fell into the outstanding category and approximately the same percentage were considered failures. A majority of the projects, about 72%, had an average classification (see Fig. 1). This suggests that a relatively small percentage of projects actually end as outstanding. At the same time, a small number of construction projects are considered failures—at least from the perspective of the project management organization. Not surprisingly, a rather large percentage of the projects fall into the average category.

To better understand how project managers rated the performance char-

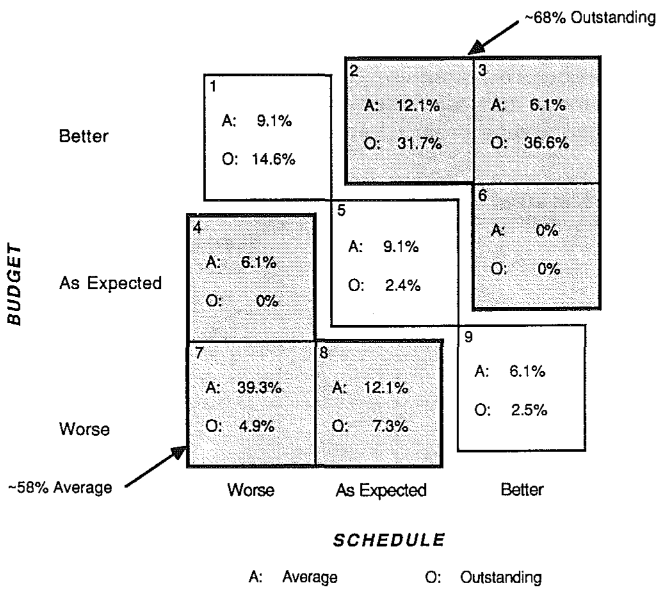

FIG. 2. Proportion of Average versus Outstanding Projects based on Budget and Schedule Performance

J. Constr. Eng. Manage., 1991, 117(2): 321-340

acteristics of the projects, a three-by-three matrix was created to show the proportion of average and outstanding projects that fall into the better, as-expected, and worse-than-expected categories for budget and schedule performance (refer to Fig. 2). Notice that about 68% of the outstanding projects have better-than-expected or as-expected performance in terms of budget and schedule (refer to boxes 2, 3, and 6). About 58% of the average projects have worse-than-expected or as-expected performance in terms of budget and schedule (refer to boxes 4, 7, and 8). It is interesting to note that some of the average projects (~6%) have better-than-expected budget and schedule performance. This is probably because other criteria (aside from budget and schedule) are used to rate the performance of the project. For example, a contractor might not have received any follow-on work from the owner, or perhaps the project did not go as smoothly as desired by the project manager.

Model Development and Robustness

Individual model results were previously discussed by Ashley and Jaselskis (1988) and are briefly summarized here. Three discrete choice models were developed using the data described herein. Each model relates to a different category of project success defined as follows: (1) Overall project success: project is considered outstanding by all major participants; (2) schedule success: project experiences better-than-expected schedule performance (better excludes as-expected project outcomes); (3) budget success: project experiences better-than-expected budget performance (better excludes as-expected project outcomes).

The models are presented in Tables 3–5 for a matter of convenience to the reader, and they include the actual project sample size used to formulate them. Each of the models has been adjusted for choice-based sampling bias because a disproportionate number of the "better" projects were collected. The adjustment involves summing the natural logarithms of the ratio of the sample fraction and the population fraction for each alternative (e.g., average versus outstanding projects) and subtracting this value from the inter-

TABLE 3. Statistical Significance of Average versus Outstanding Model[a]

Effect (1)	Estimate (2)	Standard error (3)	Chi-square (4)	Probability (5)
Intercept	0.11	0.47	3.23	0.0724
Respondent (owner or contractor)	−5.02	1.84	7.42	0.0065
Team turnover (%/year)	−6.44	2.61	6.11	0.0135
Respondent · Constructability program (yes or no)	2.07	0.92	5.08	0.0242
Respondent · Project manager subordinates (number)	0.43	0.22	3.73	0.0536
Respondent · Control meetings during construction (number/month)	0.28	0.16	3.20	0.0737

[a]Model adjusted for choice-based bias.
Note: Sample size equals 71 projects.

TABLE 4. Statistical Significance of Schedule Model[a]

Effect (1)	Estimate (2)	Standard error (3)	Chi-square (4)	Probability (5)
Intercept	−4.72	1.49	8.34	0.0039
Respondent (owner or contractor) · contract type (fixed price or reimbursable cost) · Project manager education (number of years after high school)	0.90	0.40	4.99	0.0254
Constructability program (yes or no)	3.41	1.37	6.17	0.0130
Respondent (owner or contractor) · team turnover (%/year)	19.31	11.06	3.05	0.0808
Budget updates (number per year)	0.06	0.04	2.21	0.1372

[a]Model adjusted for choice-based bias.
Note: Sample size equals 65 projects.

cept term in the model. A more complete description of this process can be found in Ben-Akiva and Lerman (1985); Ashley and Jaselskis (1988); Jaselskis (1988).

The probability of success is defined by the logit function as follows

$$\text{Probability of success} = \frac{e^y}{(1 + e^y)} \quad \text{(1)}$$

The value of y in the logit equation is estimated by the equations derived from Tables 3, 4, and 5. Other models were considered, such as the trun-

TABLE 5. Statistical Significance of Budget Model[a]

Effect (1)	Estimate (2)	Standard error (3)	Chi-square (4)	Probability (5)
Intercept	−3.79	2.05	3.34	0.0675
Control system budget (% of total budget)	113.40	84.03	1.82	0.1773
Respondent (owner or contractor) · Control meetings during design phase (number/month)	−0.83	0.43	3.65	0.0562
Control meetings during construction (number/month)	0.94	0.44	4.63	0.0315
Budget updates (number/year)	0.18	0.09	3.83	0.0505
Team turnover (%/year)	−10.07	6.58	2.34	0.1257
Respondent (owner or contractor) · Project manager technical experience (number of projects with similar technology)	0.78	0.47	2.71	0.1000

[a]Model adjusted for choice-based bias.
Note: Sample size equals 35 projects.

cated linear probability model, angular, Gompertz, Burr, Urban, right-truncated exponential, and normal, but were not used for various practical reasons. Models developed in this paper use the logistic function because the logit assumptions are mathematically tractable and there are many software packages that perform logistic regression. A description of the logit function and its relevance to discrete choice modeling can be found in Ben-Akiva and Lerman (1985).

As an example using these models, consider the probability of achieving budget success from the owner's perspective. The equation is as follows (refer to Table 5 for a tabular form of the budget model equation)

$$y = -3.79 + 113.4 \cdot (\text{Control system expenditure \%}) - 0.83 \cdot (\text{Respondent})$$

$$\cdot (\text{Number of engineering control meeting}) + 0.94$$

$$\cdot (\text{Number of Construction control meetings}) + 0.18$$

$$\cdot (\text{Number of budget updates}) - 10.07 \cdot (\text{Team turnover}) + 0.78 \cdot (\text{Respondent})$$

$$\cdot (\text{Project manager technical experience}) \qquad (2)$$

The inputs for a typical average project, from an owner's perspective, are as follows (refer to Table 2).

1. Respondent = 0 (0 = owner, 1 = contractor).
2. Control system expenditure = 0.012 (1.2% of total budget).
3. Construction control meetings = three per month.
4. Budget updates = seven per year.
5. Team turnover = 18% per year.

These inputs are substituted into (2) and the value of y is calculated as follows

$$y = -3.79 + 113.4 \cdot (0.012) + 0.94 \cdot (3) + 0.18 \cdot (7)$$

$$- 10.07 \cdot (0.18) = -0.16 \qquad (3)$$

Thus, the probability of achieving better-than-expected budget performance is

$$\text{Probability (success)} = \frac{e^{-0.16}}{(1 + e^{-0.16})} = 46\% \qquad (4)$$

If the owner project management organization doubles the control system expenditure to 2.4%, the probability of success increases to 77% (y increases by 1.36). Therefore, there is a much better chance of achieving better budget performance when more monetary resources are applied to the control effort. A higher probability of success also could have been attained by changing values of the other factors in the budget model as well.

Robustness

The issue of robustness is one of great importance in understanding the applicability of these models, and thus the conclusions drawn from the models. The definition of robustness is the degree to which a model is sensitive to

TABLE 6. Classification of Outstanding Projects based on Predicted Values (All Entries in Percent)

Factor (1)	$P < 19.9\%$ (2)	$20\% < P < 39.9\%$ (3)	$40\% < P < 59.9\%$ (4)	$60\% < P < 79.9\%$ (5)	$P > 80\%$ (6)
Respondent:					
Owner	7[a]	50	71	83	100
Contractor	20	67	63	NA[b]	NA[b]
Industry:					
Industrial	17	100	100	NA[b]	100
Commercial	0	100	67	NA[b]	100
Civil	10	50	63	83	100
Technology:					
Process	17	44	60	67	100
All other projects	8	71	69	100	100
Classification:					
Grass roots	8	69	67	75	100
Revamp	14	0	50	100	100
Contract type:					
Lump sum	17	80	75	NA[b]	100
Reimbursable cost	8	45	64	80	100
Project duration:					
<2 Years	13	50	100	80	100
>2 Years	10	60	70	100	100

[a]Seven percent of the owner projects with a predicted probability of less than 19.9% were actually outstanding; conversely, 93% of the projects in this cell were actually classified as "average."

[b]Not applicable (NA) implies that no outstanding projects were classified in this cell.

its assumptions. For example, can these models be applied to many types of construction projects (e.g., oil refinery, highway, building projects)? Can these models be applied to projects of all sizes, grass-roots or revamp projects, and fixed-price or reimbursable-cost projects? There are many methods of determining robustness of the models. A very simple, straightforward approach is to compare predicted model values with actual outcomes for various project characteristics. This process is described in the next section.

Classification Rate by Project Characteristic

Tables 6–8 demonstrate the percentage of classifications for each of the three models on the basis of six different project characteristics. It is difficult to draw specific conclusions about the robustness of these models for each category of project success, but certain trends can be observed. These tables represent the percentage of outstanding projects in each category of possible probabilities. There are five probability categories: (1) $P < 19.9\%$; (2) $20\% < P < 39.9\%$; (3) $40\% < P < 59.9\%$; (4) $60\% < P < 79.9\%$; and (5) $P > 80\%$. The value of P represents the predicted probability from the regression model. One would expect to see a higher percentage of outstanding projects in predicted probability categories close to 1.0, and very few outstanding projects in categories closer to 0. A "not applicable" symbol (NA) is applied where there are no projects in a specific probability category.

J. Constr. Eng. Manage., 1991, 117(2): 321-340

TABLE 7. Classification of Projects with Better Schedule Performance Based on Predicted Values (All Entries in Percent)

Factor (1)	P < 19.9% (2)	20% < P < 39.9% (3)	40% < P < 59.9% (4)	60% < P < 79.9% (5)	P > 80% (6)
Respondent:					
Owner	3[a]	20	NA[b]	100	100
Contractor	11	41	NA[b]	NA[b]	NA[b]
Industry:					
Industrial	4	38	NA[b]	100	100
Commercial	0	NA[b]	NA[b]	NA[b]	NA[b]
Civil	17	0	NA[b]	NA[b]	100
Technology:					
Process	0	44	NA[b]	100	NA[b]
All other projects	8	17	NA[b]	NA[b]	100
Classification:					
Grass roots	7	50	NA[b]	100	100
Revamp	0	13	100	NA[b]	100
Contract type:					
Lump sum	11	40	100	NA[b]	100
Reimbursable cost	4	35	100	NA[b]	NA[b]
Project duration:					
<2 Years	0	40	NA[b]	100	100
>2 Years	10	38	NA[b]	NA[b]	100

[a]Three percent of the owner projects with a predicted probability of less than 19.9% experienced better-than-expected schedule performance; conversely, 97% of the projects in this cell experienced poorer-than-expected schedule performance.

[b]Not applicable (NA) implies that no projects with better schedule performance were classified in this cell.

Table 6 demonstrates that model predictions greater than 80% will most likely result in outstanding project performance. All of the projects in this category were correctly classified as outstanding projects for every project characteristic. This model appears to be robust in that it is capable of predicting all types of projects: industrial, commercial, civil, grass roots, revamp, lump sum, reimbursable cost, and projects with durations less than or greater than two years. A small percentage of outstanding projects fall into the $P < 19.9\%$ category. This means that even if the model predicts a probability of less than 20%, there is still a possibility that this project really is an outstanding one. For predicted probabilities between the two extreme categories, it is difficult to draw any definite conclusions on the outcome of the project. To be assured of a successful outcome, it would be best to increase the level of project resources to the point where the probability of success is greater than 80%.

Table 7 reveals the robustness of the schedule model. Notice that all of the projects with predicted values greater than 80% are the ones that performed better in terms of schedule performance. The schedule model appears to be insensitive to the selected project characteristics and, thus, can be applied to different types of construction projects: grass-roots or revamp projects, lump-sum–versus–reimbursable-cost projects, and projects with dura-

TABLE 8. Classification of Projects with Better Budget Performance based on Predicted Values (All Entries in Percent)

Factor (1)	$P < 19.9\%$ (2)	$20\% < P < 39.9\%$ (3)	$40\% < P < 59.9\%$ (4)	$60\% < P < 79.9\%$ (5)	$P > 80\%$ (6)
Respondent:					
Owner	0[a]	100	NA[b]	NA[b]	83
Contractor	0	33	33	67	100
Industry:					
Industrial	0	67	33	67	100
Commercial	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]
Civil	NA[b]	NA[b]	NA[b]	NA[b]	NA[b]
Technology:					
Process	0	100	0	NA[b]	100
All other projects	0	0	100	67	90
Classification:					
Grass roots	0	67	0	67	91
Revamp	0	0	100	NA[b]	100
Contract type:					
Lump sum	0	67	NA[b]	NA[b]	100
Reimbursable cost	0	0	33	50	90
Project duration:					
<2 Years	0	50	50	0	88
>2 Years	0	50	0	100	100

[a]None of the owner projects with a predicted probability of less than 19.9% experienced better-than-expected budget performance; conversely, 100% of the projects in this cell experienced poorer-than-expected budget performance.

[b]Not applicable (NA) implies that no projects with better budget performance were classified in this cell.

tions less than or greater than two years. A small percentage of better projects fall into the less than 20% category. A slightly larger percentage of projects fall into the $20\% < P < 39.9\%$ category. This model appears to predict successful project schedule performance especially well when the predicted probability of success is greater than 60%.

Table 8 demonstrates the robustness characteristics of the budget model. Note that none of the projects with better budget performance are classified in the less than 19.9% category. A small percentage of projects that performed worse than expected have probabilities greater than 80%. The budget model is different in that not all of the data could be used in its development because of missing information; this may be why this model follows a slightly different trend compared with the previous two models (refer to sample-size data in Tables 3–5). Only about half of the project data were used to develop this model. Also, note that there are many categories that simply do not include any predicted values.

In general, these models appear to perform reasonably well in predicting outstanding project performance when the predicted probability is greater than 80%. It is uncertain, however, whether a project will reach this highly successful plateau when the probability is less than 80%. For these cases, it would be advisable to adjust the level of project resources to obtain a predicted probability of success greater than 80%. These models appear to be useful for many different types of project characteristics. For example, the models can be used by both owner and contractor respondents on lump-sum or reimbursable-cost projects. Additionally, they can be used for different types of construction projects (industrial, commercial, and civil) and for smaller projects (less than two-year project duration) and for larger ones lasting more than two years.

RESULTS

This section investigates the relative importance of each factor on each of the three measures of success; for example, the effect of team turnover on budget, schedule, and overall project performance. Unlike the team-turnover factor, most of the variables are not found in every model. The constructability-program factor, for example, is only found in the average-versus-outstanding and schedule models; it is not included in the budget model. For cross-comparisons, this analysis is performed on those factors that are found in at least two of the three models. Factors relating to the project manager are not included in this discussion because these variables are not carried over to more than one of the models. The reader is referred to Ashley and Jaselskis (1988) for analysis and discussion of all factors found in only one of the three models. Thus, this section investigates the impact of factors related to the project team, project planning, and control efforts on achieving various types of project success.

Project Team

Fig. 3 reveals the impact of team turnover on the three categories of project performance for the contractor organization. In all three categories (average/outstanding, schedule, and budget), the probability of success decreases as the team turnover increases for the contractor organization. This probability, however, appears to be more sensitive for achieving better budget performance than for realizing better schedule performance or outstanding project performance. Assuming that typical project values are used for the budget model (refer to Table 9), approximately a 3% team turnover can be experienced before the probability of success falls below 80%—when the

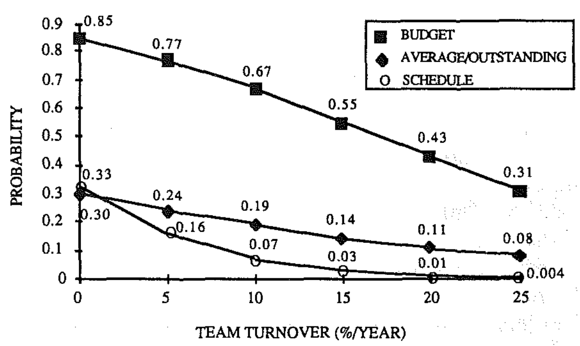

FIG. 3. Impact of Team Turnover on Project Performance for Contractor Organization

TABLE 9. Typical Factor Responses for Cross-Model Comparisons

Factor (1)	Value (2)
Project manager education level (number of years beyond high school)	4.0
Project manager technical experience (project manager experience as a project manager, before this project commenced, on projects with similar technology type) (number of projects)	3.8
Project manager subordinates (number)	7.5
Team turnover (%/year)	16
Constructability program	No
Budget updates (number/year)	7.5
Control meetings during construction (number/month)	3.1
Control meetings during design phase (number/month)	3.4
Control system cost (% total budget)	1

probability is greater than or equal to 80%, the results indicate a confidence associated with success. Reducing team turnover for the other two categories will not necessarily ensure a successful project. Other factors in the model will need to be altered in order to increase the project's chances for success.

Fig. 4 demonstrates the impact of team turnover on project performance for the owner organization. In this case, only two of the models were affected by the team-turnover rate: budget and overall success. The curves slope downward for both, suggesting that the probability of success decreases as team instability increases. In an absolute sense, it appears that budget performance is less sensitive to team turnover compared with overall success because the probability of achieving better budget performance is greater for all levels of team turnover. In a relative sense, the slope of the budget-performance curve appears steeper than the slope of the overall success curve. This implies that for every incremental decrease in the owner organization's team-turnover rate, there is a greater impact on the probability of achieving better budget performance compared with obtaining outstanding project stature.

Project Planning Effort

Fig. 5 demonstrates the impact of a constructability program in the exe-

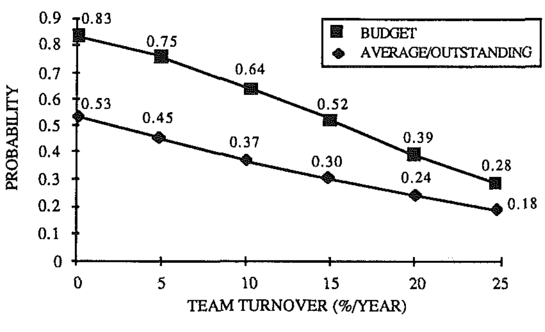

FIG. 4. Impact of Team Turnover on Project Performance for Owner Organization

J. Constr. Eng. Manage., 1991, 117(2): 321-340

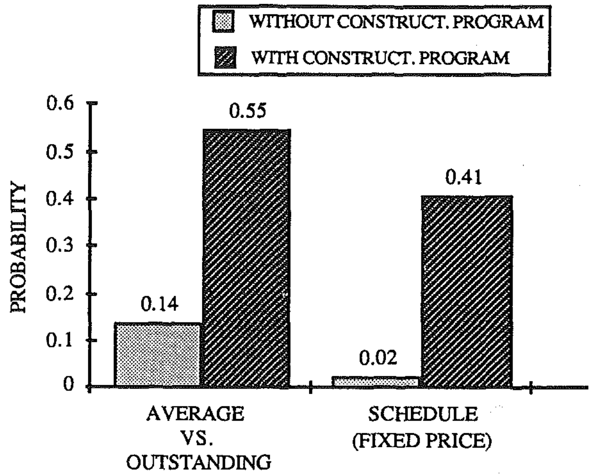

FIG. 5. Impact of Constructability Program on Project Performance for Contractor Organization

cution plan on project performance for the contractor organization. Overall, there appears to be substantial improvement in the probability of achieving overall success and schedule success when a constructability program is implemented (particularly on fixed-price projects). The probability of success increases by 41% (0.14 → 0.55) for the average/outstanding model. Similarly, the probability of success increases by 39% (0.02 → 0.41) for the schedule model representing lump-sum projects. Thus, constructability programs appear to have the greatest effect on achieving outstanding project performance.

Project Control Effort

Fig. 6 demonstrates the impact of the number of budget updates on project performance for the contractor organization. Budget updates seem to have a greater impact on achieving better budget performance than on attaining

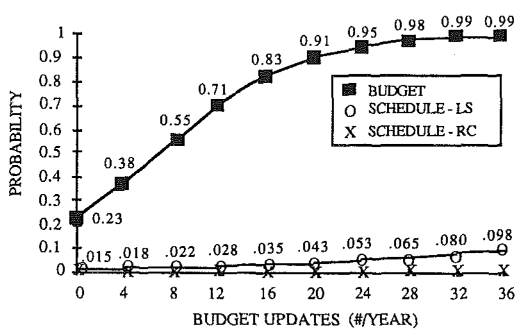

FIG. 6. Impact of Number of Budget Updates on Project Performance for Contractor Organization

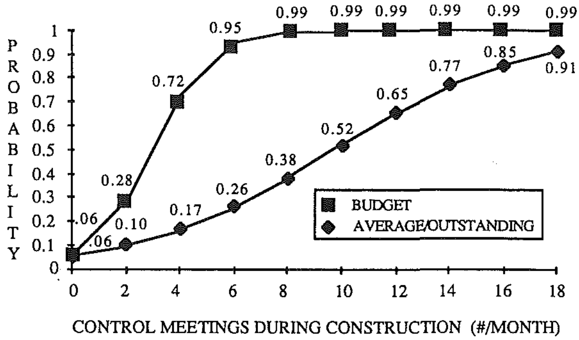

FIG. 7. Impact of Number of Control Meetings during Construction Phase on Project Performance for Contractor Organization

better schedule performance for both lump-sum and cost-reimbursable–type projects. In an absolute sense, the contractor needs to have 12 to 16 budget updates per year to surpass expected budget performance. No number of budget updates will maintain a strong likelihood of achieving better-than-expected schedule performance (for lump-sum and reimbursable-cost projects) without altering the resource level of the other variables in the model. Increasing the number of updates per year does not seem to significantly affect the probability of achieving better schedule performance. Schedule performance on lump-sum projects seems to be affected slightly more than on reimbursable-cost projects.

Fig. 7 demonstrates the impact of control meetings on project performance during construction for the contractor organization. Control meetings during the construction phase seem to have a rather dramatic effect on the probability of achieving better budget performance when in the range of two to four control meetings per month; here, the probability of success increases by 44% (0.28 → 0.72). The contractor organization substantially improves its chances of achieving better budget performance by increasing the number of control meetings to between four and six per month. After this point, the marginal return on improving probability of success diminishes (this may be an artifact of the logistic curve and the fact that a linear relationship was assumed in the discriminant function). Most of the projects experienced at least four control meetings per month; there were, however, a few projects that experienced six to eight meetings. Three projects experienced 20 to 25 control meetings per month, as necessitated by the intense project schedule.

A slightly different picture is portrayed in the average/outstanding model. In this case, the number of control meetings does not seem to affect the probability of success in the same dramatic way as the budget performance model. The contractor needs to maintain a higher level of control meetings in order to ensure a probability of success greater than 80%.

Industry Recommendations for Achieving Construction-Project Success

The following is a list of recommendations for achieving construction-

J. Constr. Eng. Manage., 1991, 117(2): 321-340

project success. Recommendations are divided into three main categories: achieving outstanding project performance, achieving better schedule performance, and achieving better budget performance. Within each of these categories, recommendations for contractor and owner organizations are made.

Achieving Outstanding Project Performance

Both contractor and owner organizations improve the likelihood of achieving an outstanding project by reducing team turnover. However, reducing this factor alone (while maintaining the other variables at their typical project levels) is not necessarily sufficient for achieving outstanding project performance; other variables in these models will need to be increased or decreased accordingly. Team turnover appears to be less sensitive for the owner organization than the contractor organization. Providing a constructability program for the contractor organization can significantly improve the project's relative expectation for achieving an outstanding project outcome; but, then again, other factors in the model will need to be altered to ensure a greater likelihood for success. Additionally, increasing the number of construction control meetings for the contractor organization appears to have a positive effect on achieving overall project performance.

Achieving Better Schedule Performance

Reducing team turnover alone in the contractor organization will not ensure better-than-anticipated schedule performance; other factors in this model will need to be modified. Constructability programs for the contractor organization appear to enhance the likelihood of success, but do not in themselves lead to successful projects. Furthermore, increasing the number of budget updates does not significantly affect schedule success for either lump-sum or reimbursable-cost projects for the contractor organization. To ensure better project performance, other factors in the model need to be increased or decreased accordingly.

Achieving Better Budget Performance

Reducing team turnover to less than 3% for both contractors and owners can promote better budget performance without modifying other variables in the model. Furthermore, increasing the number of budget updates for the contractor organization significantly improves the probability of success. Results also demonstrate that four to six formal control meetings per month during the construction phase is sufficient for providing better-than-expected budget performance.

Limitations

The robustness analysis demonstrated that the models can be applied to many kinds of construction projects, but there are limitations to their use. Most of the projects in the data base, for example, are multimillion-dollar projects, as opposed to smaller ones with less than 12,000 construction man-hours. To apply these results on smaller construction projects might be misleading because there could be significant differences betwen large and small projects that have not been identified in this research. Further work in this area might provide beneficial information.

The models may produce misleading results because of the small number of data collected for some of the variables. The second-stage sampling plan showed that statistically significant multivariate logit models could be developed with a modest amount of data (70–90 projects) (Jaselskis 1988). Data were collected on 75 projects, but because of missing values, not all of the models could use this complete set of data. Various tests were performed to identify the statistical significance of each model (likelihood ratio statistic, individual coefficient estimates, and misspecification rates) and were found to be acceptable. The misleading aspect associated with these models is the variance associated with the choice probabilities. When the model predicts 90%, this is the most likely value for the probability. There is a variance associated with this value that can be calculated using maximum likelihood estimation techniques. In a test of the average-versus-outstanding model, we found that the true probability can be +/−20% on a four-variable model (10% more than we anticipated from the second-stage sampling plan). This needs to be considered when interpreting the model results.

Furthermore, the outcomes can be naïvely interpreted if the other variables are not considered in the project execution plan. It is important to maintain all of the project management factors at their average or typical project levels and modify only those factors that are found to be important for achieving construction project success (refer to Tables 2 and 9 for typical values). The impression from interpreting these results is that the factors in the models are the only ones necessary for achieving success. It is true that these variables are significant because they demonstrated a statistical difference between the better and worse projects, but these are not the only factors that need to be considered if one expects to obtain an outstanding construction project.

Conclusions

The purpose of this paper was to provide resource allocation strategies to help project managers achieve various forms construction-project success. Three quantitative models developed by Ashley and Jaselskis (1988), related to: (1) Achieving outstanding construction project performance; (2) achieving better-than-expected schedule performance; and (3) achieving better-than-expected budget performance, were further analyzed in this paper. Results demonstrate that key success factors affect project performance in different ways. Important relationships were discovered pertaining to the effects of increasing or decreasing key management-related resources on the three performance levels described. Some relationships were as could be expected; for example, increasing the number of budget updates has more impact on achieving better budget performance than it does on achieving better schedule and overall project performance. Other interesting relationships were also discovered; for example, the effects of reducing team turnover on the three measures of project performance and the effect of a constructability program on overall success and better schedule performance.

Project managers can use the models to help predict their chances of achieving successful project outcomes based on anticipated resource allocation strategies. These models can be used in an absolute and relative sense. In an absolute sense, the probability values are interpreted at face value. In a relative sense, project managers can identify the incremental differences in the probability of success by altering the level of project management

J. Constr. Eng. Manage., 1991, 117(2): 321-340

resources. Managers can also compare how these changes in resource allocation affect the budget, schedule, and overall project performance.

By using the management tools and results presented in this paper, it is hoped that project managers will be better able to plan and execute their construction projects to maximize the project's chances of success. Owners can use this information to supplement their existing procedures to select contractors during the bidding phase of the construction project. Both owners and contractors can use these models during the strategic planning phases when crucial management resources are being allocated to the project.

Acknowledgments

The writers sincerely thank Argonaut AEC-General Motors Corp., Exxon Education Foundation, and the National Science Foundation (grant CEE 8352354, Presidential Young Investigator Award) for financial support of this effort. Their continued interest and support further enhances the value of the work. The knowledge and experience of the numerous individuals interviewed are the unique contributions to this work; we thank those people for sharing their insight and expertise.

Appendix I. Factor Descriptions and Abbreviations

The abbreviations we employed in the study are listed in the following with their definitions.

1. Respond: Contractor or owner perspective (contractor = 1; owner = 0).
2. Contrac: Type of contract (lump sum = 1; reimbursable cost = 0).

Project Manager Commitment and Involvement

1. PMMTGST: Average number of meetings project manager had with other project personnel during lifetime of the project—includes time before and during construction (number/month): N = 73; range: 1 to 36; average of all project responses: 8.8.

2. PMSCHED%: Percentage of time project manager devoted to project: N = 75; range: 6% to 138%; average of all project responses: 87%.

3. PMSITVIS: Frequency of project manager field visits (site tours) during construction phase (number/month): N = 71; range: 1 to 120; average of all project responses: 17.

4. PMSUBORS: Number of subordinates personally supervised by project manager: N = 75; range: 0 to 27; average of all project responses: 7.1.

Authority

1. PMLEVS: Number of organizational levels between project manager and craftsmen: N = 73; range: 1 to 10; average of all project responses: 4.3.

Capabilities and Experience

1. PMEDLEV#: Project manager education level (years): Employer training = 0.5 years; associate degree = 2 years; bachelor's degree = 4 years; master's degree, engineering = 5.5 years; master's of business administration = 6 years; Ph.D. = 8 years; N = 70; range: 0.5 to 5.5; average of all project responses: 3.9.

2. TOTCONEX: Project manager total years of experience in area of construction before project commenced (years): N = 70; range: 7 to 35; average of all project responses: 21.1.

3. PMPMEXP: Project manager total years of project management experience before project commenced (years): N = 71; range: 1 to 35; average of all project responses: 11.3.

4. PMSCPEXP: Project manager experience as a project manager (before this project commenced) on projects with similar cost and duration (number of projects): N = 71; range: 1 to 30; average of all project responses: 3.5.

5. PMTECEXP: Project manager experience as a project manager (before this project commenced) on projects with similar technology type (number of projects): N = 70; range: 0 to 20; average of all project responses: 2.9.

6. OTHSCPEX: Project manager experience other than as project manager (before this project commenced) on projects with similar cost and duration (number of projects): N = 69; range: 0 to 30; average of all project responses: 5.6.

7. OTECHEXP: Project manager experience other than as project manager (before this project commenced) on projects with similar technology type (number of projects): N = 68; range: 0 to 30; average of all project responses: 5.

Project Team Motivation

1. TMTURN: Project-team-turnover rate (% per year): N = 71; range: 0 to 85%; average of all project responses: 11%.

2. DESINC%: Monetary incentive to designer (% of design contract): N = 59; range: 0 to 16%; average of all project responses: 1%.

Planning Scope and Work Definition

1. DES%STAR: Percentage of detailed design complete at construction start (%): N = 75; range: 3% to 100%; average of all project responses: 59%.

2. ACTEXPLN: Number of activities in project execution plan (options available: job descriptions, cash flow, manpower loading, personnel assignments, critical equipment, contracts, detailed schedule, risks or uncertainties, activity planning, project inspections, quality control program, safety program, equipment yard, procurement, tool control, and incentive program): N = 75; range: 0 to 16; average of all project responses: 10.6.

Risk Identification and Management

1. BUDCON%: Percentage of contingency budgeted for project (%): N = 72; range: 0% to 16%; average of all project responses: 8%.

Constructability

1. MOD%: Level of prefabrication and modularization on project (percent of total construction cost): N = 74; range: 0% to 80%; average of all project responses: 9%.

2. CONSTRUC: Implementation of constructability program during design and construction phases (yes or no): N = 75; average percentage of projects with constructability programs: 64%.

Controls: Control Systems

1. PROGINSP: Number of formal progress inspections made during construction phase (number/month): N = 74; range: 0.92 to 25; average of all project responses: 7.5.

2. QUALINSP: Number of formal quality inspections made during construction phase (number/month): N = 65; range: 0 to 60; average of all project responses: 15.1.

3. SAFINSP: Number of formal safety inspections made during construction phase (number/month): N = 70; range: 0 to 60; average of all project responses: 11.6.

4. CTRLSYS%: Control system budget for project (percent of total budget): N = 48; range: 0 to 10%; average of all project responses: 2%.

5. ENGCTRMT: Frequency of control meetings during the engineering phase (number/month): N = 63; range: 0.92 to 20; average of all project responses: 4.1.

6. CONCTRMT: Frequency of control meetings during the construction phase (number/month): N = 75; range: 0.92 to 20; average of all project responses: 4.2.

7. SCHDUPD: Frequency of project schedule updates (number/year): N = 73; range: 0 to 48; average of all project responses: 7.9.

8. BUDUPD: Frequency of project budget updates (number/year): N = 75; range: 0 to 48; average of all project responses: 11.1

Safety

1. LOSTIMRA: Lost-time accident rate (refer to OSHA for calculation): N = 61; range: 0 to 28.2; average of all project responses: 7.8.

2. LOSTIMSE: Severity accident rate (refer to OSHA for calculation): N = 55; range: 0 to 10,259; average of all project responses: 270.5.

Appendix II. References

Ashley, D. B., and Jaselskis, E. J. (1988). "Achieving construction project success through predictive discrete choice models." *Proc. of the Ninth World Congress on Project Management, INTERNET*, Glasgow, Scotland, 1, 71–86.

Ben-Akiva, M., and Lerman, S. R. (1985). *Discrete choice analysis: Theory and application to travel demand.* The MIT Press, Cambridge, Mass.

Jaselskis, E. J. (1988). "Achieving construction project success through predictive discrete choice models," thesis presented to the University of Texas, at Austin, Tex., in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

Appendix III. Notation

The following symbols are used in this paper:

y = discriminant function; and
e = 2.7183.

J. Constr. Eng. Manage., 1991, 117(2): 321-340