PROJECT MANAGEMENT IN CONSTRUCTION: SOFTWARE USE AND RESEARCH DIRECTIONS

By Matthew J. Liberatore,[1] Bruce Pollack-Johnson,[2] and Colleen A. Smith[3]

ABSTRACT: This paper focuses on future research and the use of project management software in the construction industry. Data are drawn from an empirical study of project management professionals that yielded 240 replies (35% response rate), 42 of which were from the construction industry. Data were collected on: demographics and work environment, project management software usage patterns, analytical technique usage, data management, and suggestions for future research. The results indicate that construction professionals have different characteristics, needs and preferences, as compared to the overall sample. The study shows that construction professionals are more experienced and educated than the respondents in the overall study, they tend to work on fewer projects with larger numbers of activities, and they are more likely to use Primavera (Primavera, Inc., Bala Cynwyd, Pa.) than Microsoft Project (Microsoft Corp., Redmond, Wash.). Construction respondents are heavy users of critical path analysis for planning and control, resource scheduling for planning, and earned value analysis for control. The number of activities in a typical project and the use of software for all active projects were the key determinants of the usage of specific analytical techniques. These factors are also significant determinants of the types of information entered and updated, although the effect is weaker. Although construction professionals are generally satisfied with the quality of schedules produced by the software, they still expressed a clear interest in future research on resource scheduling/leveling in general and a net present value option in particular. To maximize the impact on practice, development of new planning and control methods should include their integration into project management software.

INTRODUCTION

The use of project management (PM) software as a tool for managing and organizing work has grown and continues to grow at a rapid pace in all industries. The construction industry is one in which PM software usage is of particular importance. As heavy users of PM software, professionals in the construction industry have a strong interest in improving the tools and techniques available for better project planning and control. Several studies demonstrated that construction professionals continue to be very interested in developing better methods for project planning and control (Lee et al. 1986; Shash and Al-Abdullatif 1993). In addition, a few studies have considered the application of these tools in PM software (Choo et al., 1999; Hegazy 1999). These studies demonstrated the rise in the level of interest in effective and efficient methods for project planning and control. In this paper, patterns of PM software usage in the construction industry will be identified, addressing current usage patterns, comparing PM professionals in other industries, and finally, determining areas in need of further research and development.

THE STUDY

We conducted a random survey of professionals at the Project Management Institute (PMI), the largest professional organization of PM professionals in the world with over 43,000 members. The survey consisted of 31 questions (available on request), which served to gather information on work environment and demographic factors, PM software usage, and PM technique usage. The survey was evaluated and pre-tested by several PMI members, as well as an evaluation professional with extensive survey development experience. While the basic findings of the survey among respondents in all industries are given in Pollack-Johnson and Liberatore (1998), this study focuses on the usage of PM software by professionals in the construction industry. Where significant, we point out the differences between the results of the construction respondents and those in the full study.

RESPONSES

Of the 688 surveys sent to individuals, 240 responded. This response rate (34.9%) is significantly higher than the 10 to 20% rate usually obtained for this type of survey (Dillon et al. 1994). As discussed in Pollack-Johnson and Liberatore (1998), the distribution of respondents among industries matches closely to that of PMI as a whole, validating the randomness of the survey. A random sample of 100 nonrespondents was contacted by telephone to check for nonresponse bias. Twenty of these individuals indicated that the main reasons for nonresponse were lack of involvement or interest in the field. Of the 240 respondents in the full study, 42 (17.6%) indicated they worked with a firm or organization in the construction industry.

RESULTS

The most important findings of the survey are summarized in the discussion below, supplemented by a series of figures and tables. The demographic and work environment findings are discussed first, followed by the results pertaining to how the software is utilized. Finally, future research and software development issues are discussed.

Demographics and Work Environment

Figs. 1–5 illustrate the demographic profile of the construction respondents as compared to the respondents of the full study. Over 50% of the construction respondents work in organizations with more than 1,000 employees (Fig. 1); most work in a project work environment, and perform project/program management as their primary job function. Aside from project/program management, corporate/administrative management exceeds consulting as a primary job function for the

[1]Prof., Dept. of Decision and Information Technol., Coll. of Commerce and Finance, Villanova Univ., Villanova, PA 19085.

[2]Assoc. Prof., Dept. of Math. Sci., Coll. of Liberal Arts and Sci., Villanova Univ., Villanova, PA 19085.

[3]Grad. Asst., Coll. of Commerce and Finance, Villanova Univ., Villanova, PA 19085.

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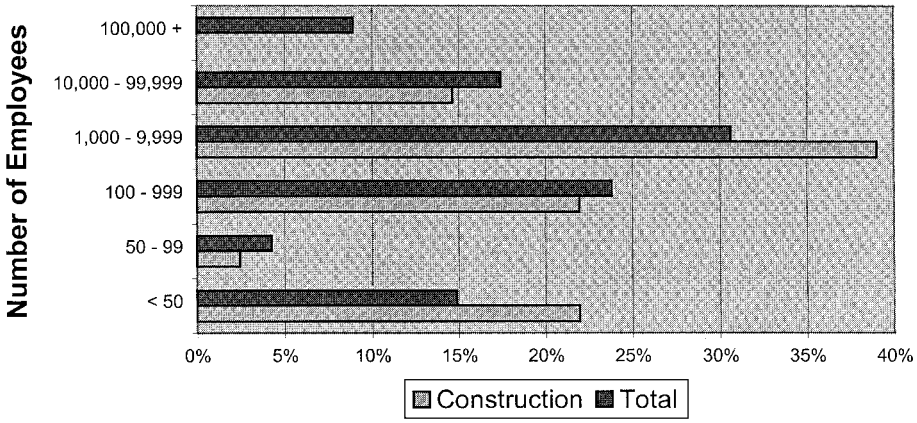

FIG. 1. Size of Firm (No Response: Total Survey—2.1%; Construction Survey—2.4%)

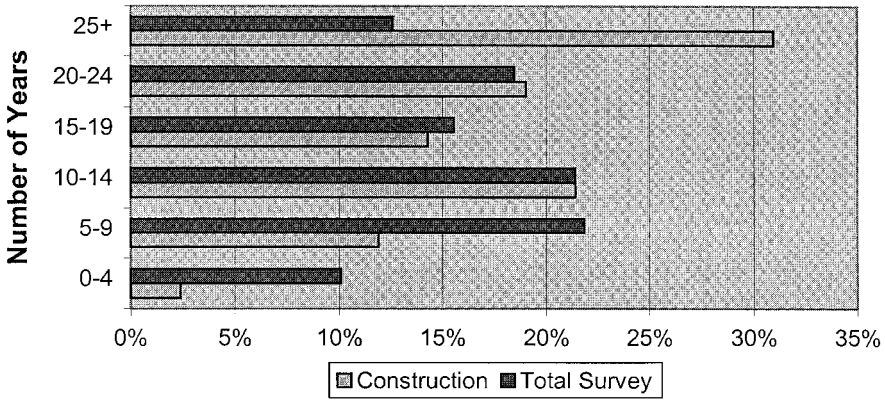

FIG. 2. Years of Experience as Member/Leader of Project Team (No Response: Total Survey—0.83%; Construction Survey—0.0%)

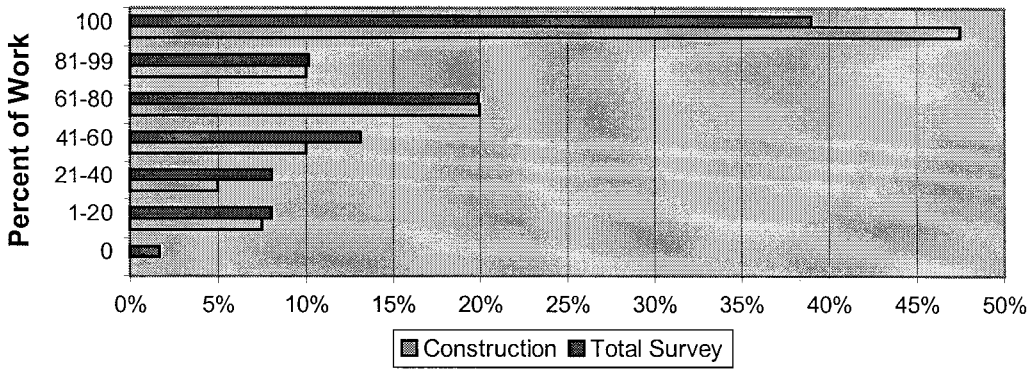

FIG. 3. Percent of Project Management Work in Past 12 Months (No Response: Total Survey—1.25%; Construction Survey—5%)

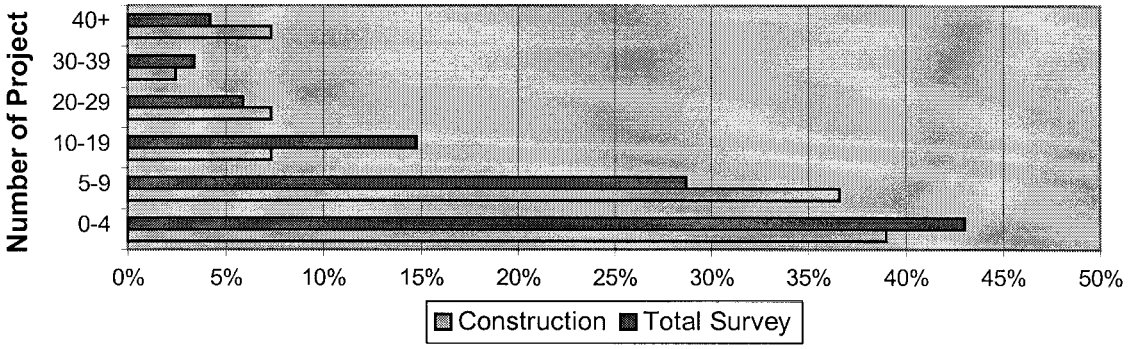

FIG. 4. Number of Projects (Active Participation) in Past 12 Months (No Response: Total Survey—0.83%; Construction Survey—2.4%)

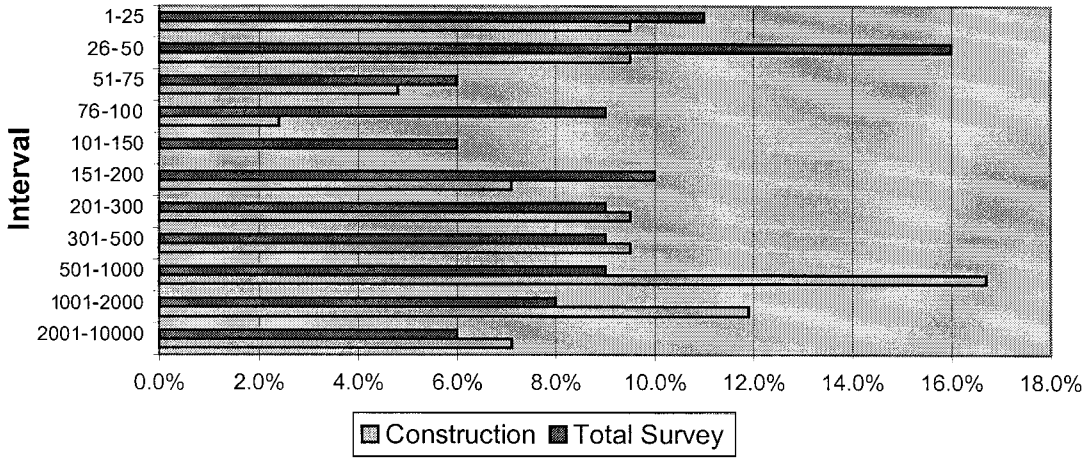

FIG. 5. Number of Activities (No Response: Total Survey—20.4%; Construction Survey—11.9%)

construction respondents, while the opposite is true for the respondents in the full study.

A notable difference between the construction and the overall respondents is the greater number of years of project experience and level of education or training possessed by the construction respondents. Over 30% of the construction respondents have 25 or more years of project experience, as compared to 13% of the respondents in the full study (Fig. 2). A large percentage of the construction respondents have undertaken postgraduate study or received a postgraduate degree (74%), which is higher than the percentage of respondents in the full study (60%).

Almost half of the construction respondents spend 100% of their time in PM, a significantly higher proportion than in the full study (Fig. 3). In addition, slightly more of the construction respondents tend to work with fewer projects compared to those in other industries (Fig. 4). Of the typical projects considered by the construction respondents, the median size of a project is a little over 300 activities, more than twice that of the respondents in the full study (Fig. 5).

Project Management Software Usage Patterns

Extent of Use over Time

Over the past five years, there has been a significant increase in the usage of PM software. Almost all construction respondents use PM software, and those using software for all of their projects has nearly doubled (Fig. 6). The initial usage of PM software by the construction respondents increased slowly until the 1980s, when it increased after the introduction of the PC. Thereafter, the growth in users grew steadily until near saturation at over 90% in 1992, several years earlier than the overall respondents (Fig. 7).

Regarding recent usage, about 97% of the construction respondents used PM software during the previous 12 months. Of those using software, a surprising 83% used it for control as well as planning. In addition, a high percentage (60%) of the construction respondents used PM software for general work planning/presentation. About 90% of the construction respondents plan to use PM software during the next 12 months, demonstrating a stable usage pattern.

Reasons for Use/Nonuse

Project complexity is the most influential factor used by construction respondents to determine when to use, and when not to use, PM software (Fig. 8). Software capabilities, size of projects and client requests are also strong influencing factors affecting usage. Interestingly, training/support is not an influential factor affecting either use or nonuse.

A striking difference between the construction and the overall respondents is found in the PM software package used most frequently during the previous 12 months. Primavera Project Planner (P3), Primavera, Inc., Bala Cynwyd, Pa., is an expen-

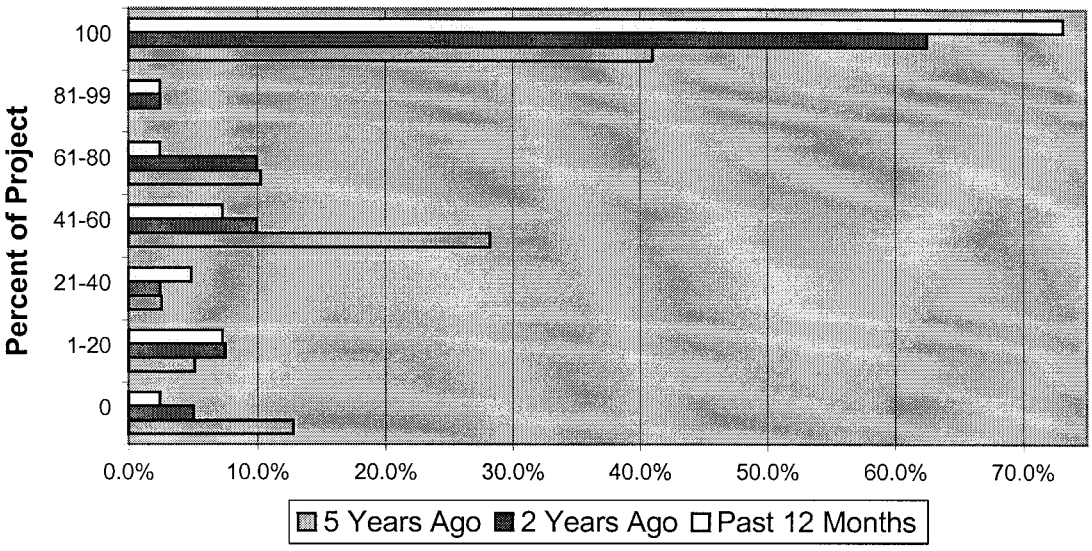

FIG. 6. Percent of Projects Using Project Management Software (No Response: Construction Survey—16.7%)

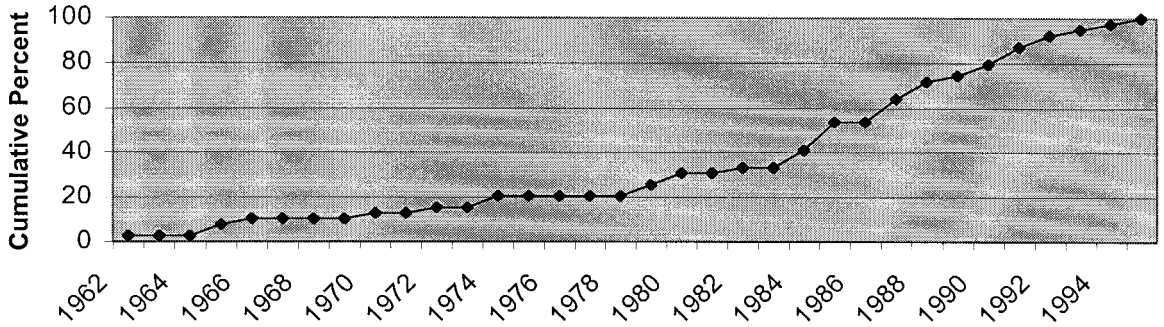

FIG. 7. Year Construction Respondents First Used PM Software (No Response: Construction Survey—7.14%)

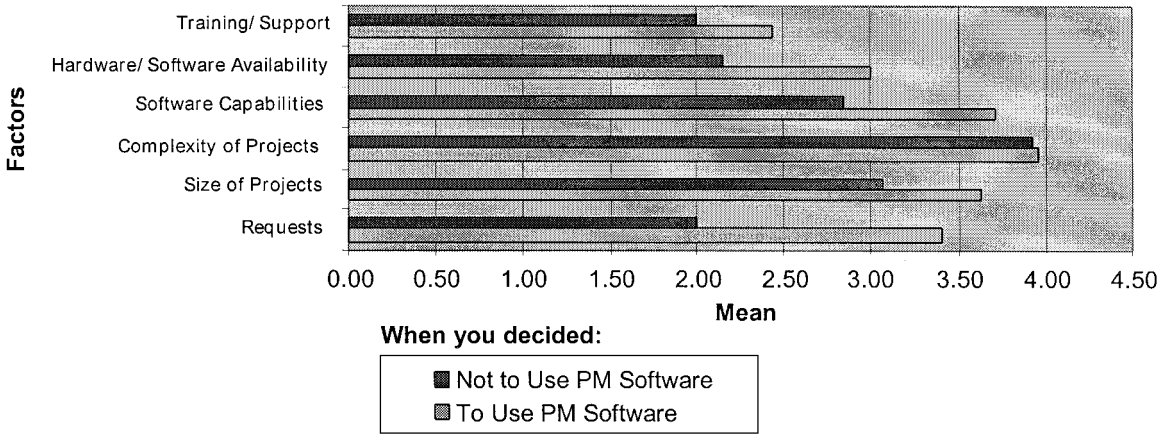

FIG. 8. Influential Factors on Decision to Use or Not to Use Software for Construction Respondents (1 = Not Influencial; 5 = Very Influencial)

TABLE 1. Comparison of PM Software Package Used in Construction versus Total Survey

Number of analytical features used (1)	MS Project (2)	Primavera (3)	All others (4)	Total construction (5)
Total construction	9 (24.3%)	19 (51.4%)	9 (24.3%)	37[a] (100%)
Total survey	102 (49%)	44 (21.2%)	62 (29.8%)	208[b] (100%)

[a]Five surveys (11.9% of 42) had no responses.
[b]Thirty-two surveys (13.3% of 240) had no responses.

sive, full-featured software package, while Microsoft Project (Microsoft Corp., Redmond, Wash.) is an inexpensive package directed toward the mass market. For the entire study, about half of the total respondents used Microsoft Project frequently followed by Primavera at less than a quarter of the total time. The opposite is found for the construction respondents. Primavera is the most frequently used software package, while Microsoft Project is used by less than a quarter of the total (Table 1). When all PM software usage over the previous 12 months was considered, Windows was the dominant primary platform at 83% of the construction respondents and 89% of the respondents in the full study.

Research Findings Concerning Technique Usage

As expected, critical path analysis is the analytical technique used most frequently by the construction respondents during both the planning and control stages of managing a project. Specifically, of those construction respondents using techniques, 89% used critical path for planning and 72% for control (Table 2). Other techniques used by over half of the construction respondents included resource scheduling for planning (although only 44% used it for control) and earned value for control.

TABLE 2. Analytical Technique Used for Project Planning and/or Control

	APPLICATION			
	Planning		Control	
Analytical technique (1)	Percentage of construction[a] (2)	Percentage of total survey[b] (3)	Percentage of construction (4)	Percentage of total survey (5)
Critical path analysis	89	87	72	66
Resource scheduling/ leveling	58	62	44	37
Earned value analysis	33	24	53	38
Multi-project scheduling	33	45	28	32
Time/cost trade-off	28	19	28	16
Probability analysis and/or simulation	33	21	22	12

[a]Six surveys (14.3% of 42) had no responses and are not included in the percentages.
[b]Forty-six surveys (19.2% of 240) had no responses and are not included in the percentages.

The earned value of work performed for project tasks in process is obtained by multiplying the estimated percent completion for each task by the planned or baseline cost for that task. The result is the amount that should have been spent on the amount of work completed. Using this information, the total project spending variance (actual cost−baseline cost) is the sum of the schedule variance (value completed−baseline cost) plus the spending variance (actual cost−value completed). This information is especially important for project control (Meredith and Mantel 1995).

Of those construction respondents using techniques, a third used multiproject scheduling, time/cost tradeoff, and probability analysis and/or simulation for planning, while only about a quarter of the respondents used those same techniques for

control. Consistent with the findings for the total survey, technique usage for control was used no more than for planning in all cases except for earned value analysis, which is used primarily for project control.

A series of chi-square tests were run to determine whether differences in specific work environment factors were related to differences in the usage of specific analytical techniques by respondents in the construction industry. The work environment factors studied included:

1. Percent of projects that used PM Software (in the preceding 12 months, 2 years before, and 5 years before)
2. Percent of work effort in PM
3. Initial year of PM software use
4. Years of experience in PM as a team member or leader
5. Number of activities in a typical project
6. Number of projects worked on during the preceding 12 months

Each work environment factor was split into two categories of approximately equal size. Separate analyses were run for the usage of each technique for planning and control. (A table, summarizing the details of the test results, is available upon request.) The principal findings are significant at the 0.10 level or better.

The number of activities in a typical project was found to be more important than the number of projects underway in identifying differences in PM technique usage among the construction respondents. Those respondents working on typical projects with larger numbers of activities were more likely to use the resource scheduling/leveling, multi-project scheduling, and time/cost trade-off techniques for both planning and control. On the other hand, construction respondents working on a larger number of projects were found to be more likely to use earned value analysis for control.

Selected technique usage is also related to the exclusive use of PM software for projects during the year preceding the study, as well as 2 and 5 years prior to the study. Our results showed that the resource scheduling/leveling technique was particularly important for those construction respondents using PM software on 100% of their projects over all three time periods (12 months, 2 years and 5 years prior to the study). In general, the effect of past PM software usage declines the further back in time one goes.

Construction respondents with higher percent of work effort in PM were more likely to use multi-project scheduling, time/cost tradeoff, probability analysis and/or simulation for control, and critical path analysis for planning. Interestingly, no significant relationships were found between years of experience and technique usage. Similarly, the only significant finding concerning initial year of PM software use is that earlier adopters were higher users of probability analysis and/or simulation for planning.

To understand overall technique usage within PM software, we formed an analytical technique index. The analytical technique index is computed by adding the number of techniques used for planning to the number used for control in PM software. Table 3 illustrates that the respondents who are the heaviest users of analytical techniques predominantly use the Primavera software package. The opposite is true for the lighest users; most use Microsoft Project and the other available packages. Those in the middle are split between Primavera, and Microsoft Project and the other available packages.

TABLE 3. Relationship between PM Software Package Used and Analytical Technique Index

Number of analytical features used (1)	MS Project (2)	Primavera (3)	All Others (4)	Total Construction (5)
0, 1 or 2	4 (50.0%)	1 (12.5%)	3 (37.5%)	8 (100%)
3, 4 or 5	4 (28.6%)	7 (50%)	3 (21.4%)	14 (100%)
6 to 14	1 (6.7%)	11 (73.3%)	3 (20%)	15 (100%)
Total construction	9 (24.3%)	19 (51.4%)	9 (24.3%)	37[a] (100%)

Note: ATI = analytical technique index.
[a]Five surveys (11.9% of 42) had no responses.

Research Findings Concerning PM Software Data Management

An analysis of information entered and updated in a typical project showed that large percentages of the construction respondents (about 55% or more) who *entered* specific types of PM information also *updated* that information (Fig. 9). As shown in Table 4, the construction respondents entered activity duration and updated actual activity start/finish dates most frequently.

Chi-square tests were conducted to determine whether differences in the work environment were related to differences in the types of information initially entered or regularly updated for a typical project. Analogous to the case with technique use, the number of activities was found to be the most important factor in identifying differences in the types of information entered and updated. The number of projects underway, initial year of PM software usage and the percent work effort in PM yielded no significant relationships to the types of information updated and entered. The results also showed that information on activity resources is particularly important for construction respondents, with higher percent of

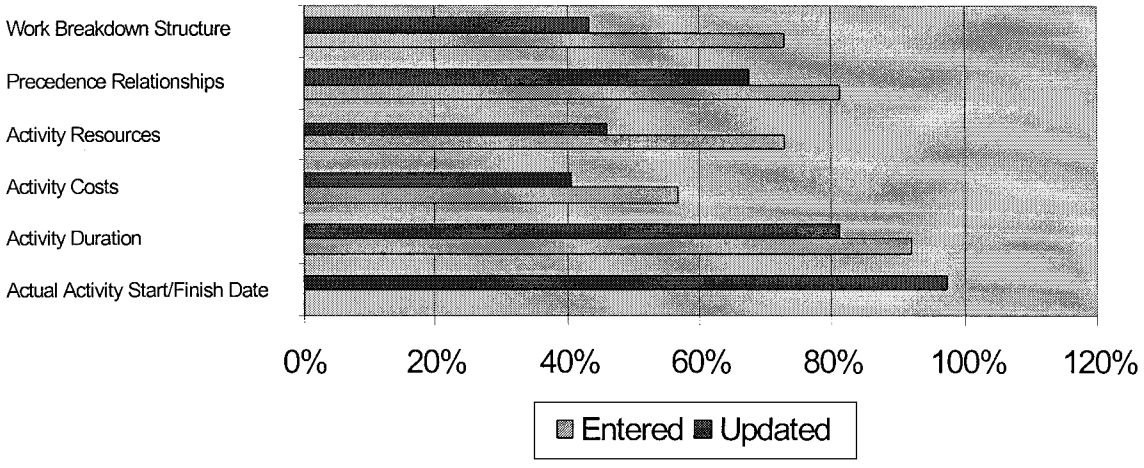

FIG. 9. Information Initially Entered and/or Updated by Construction Respondents (No Response: 11.9%)

TABLE 4. Information Initially Entered or Updated

Information type (1)	APPLICATION			
	Entered		Updated	
	Percentage of construction[a] (2)	Percentage of total surveyed[b] (3)	Percentage of construction (4)	Percentage of total surveyed (5)
Actual activity start/finish dates	—	—	97	88
Activity duration	92	90	81	74
Activity costs	57	46	41	36
Activity resources	73	74	46	47
Precedence relationships	81	82	68	59
Work breakdown structure	73	67	43	45

[a]Five surveys (11.9% of 42) had no responses.
[b]Thirty-eight surveys (15.8% of 240) had no responses.

work effort in PM. Significant relationships were found for updating activity resources during the preceding 12 months, entering and updating 2 years prior to the study, and entering 5 years prior.

Research and Software Development Issues

As the experience of software users has increased, interest has grown in the ability of PM software packages to provide near-optimal schedules, when resources are constrianed or must be leveled. A number of studies have addressed the performance of software packages on specific categories (Wasil and Assad 1988; Johnson 1992; Ozdamar and Ulusoy 1995; Hegazy and El-Zamzamy 1998). Our study addresses this issue from the perspective of the user's satisfaction with the available options rather than theoretical performance.

The construction respondents were generally more satisfied than the respondents in the full study with the quality of the resource-leveling schedules produced (Fig. 10). They also placed somewhat more value on conducting further research in this area (Fig. 11). Respondents were also asked about a leveling option (not currently available) that maximizes the net present value (NPV) of the cash flow of a project as the objective of leveling rather than minimizing project duration. Construction respondents indicated a higher level of interest in this option than those in the full study (Fig. 12).

Other Areas of Future Research

Respondents were asked to comment on what should be the focus of future research related to analytical features, project scheduling and resource management in PM software. Thirty-two of the 42 respondents (76%) provided written comments, indicating strong interest in these topics. There were three categories that contained six or more responses:

- Integration of PM software with other software packages (including PowerPoint [Microsoft Corp., Redmond, Wash.]) and with enterprise-wide systems for such activities as materials management and financial control
- Increased flexibility of PM software, including project changes, varying project sizes, and different functions supporting the project
- Ease of use issues, such as making the software more user friendly, and making training more accessible and less costly

There were a variety of additional issues addressed by more than one respondent. These include:

- Further interest in the NPV scheduling option
- Issues related to monitoring projects and performing progress calculations
- Precedence diagramming options (e.g., start-start, start-finish) that may not be available in all packages

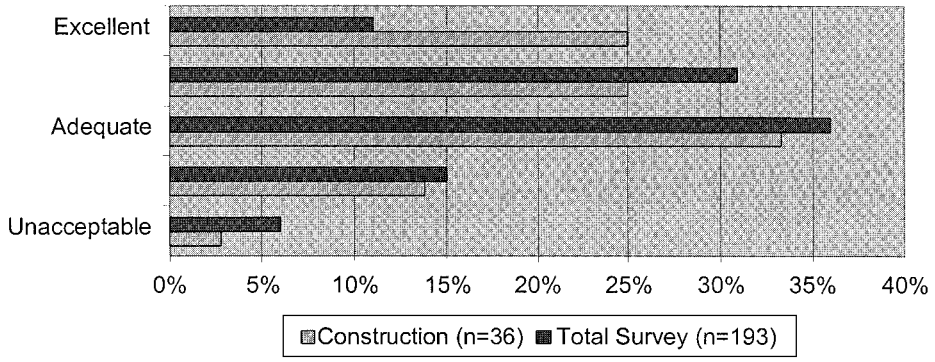

FIG. 10. Rating the Quality of the Schedules Produced (No Response: Total Survey—4.2%; Construction Survey—2.4%; No Opinion: Total Survey—16.1%; Construction Survey—12.2%)

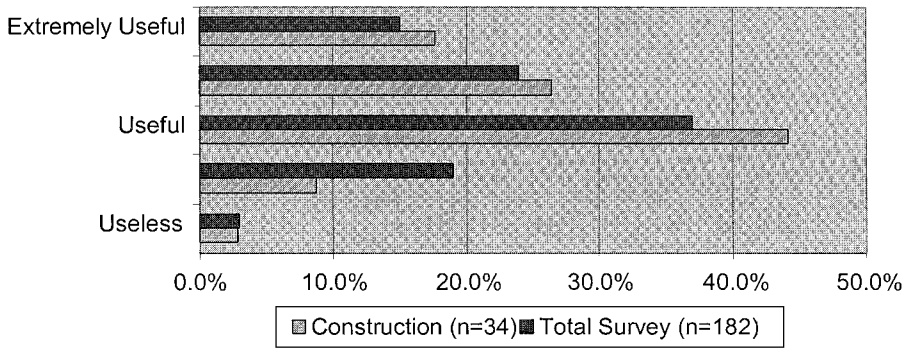

FIG. 11. Rating the Value of Research to Improve the Schedules Produced (No Response: Total Survey—6.3%; Construction Survey—4.8%; No Opinion: Total Survey—19.1%; Construction Survey–15%)

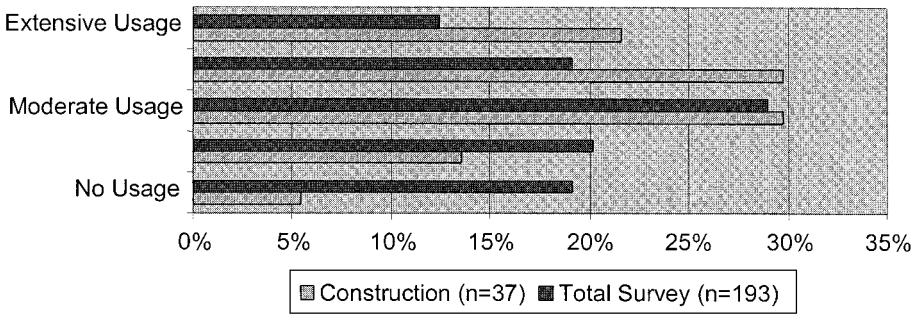

FIG. 12. Potential Usage of NPV Option (No Response: Total Survey—4.6%; Construction Survey—2.4%; No Opinion: Total Survey —15.3%; Construction Survey—9.8%)

- Improved software capabilities to communicate project information with field sites
- Improved capabilities to handle project uncertainty/risk
- Improved methods to forecast activity duration

SUMMARY AND CONCLUSIONS

The results of this study confirm that construction professionals are heavy users of PM software and differ from the respondents in the overall study concerning their usage patterns. In general, construction professionals tend to have more project experience and education than PM professionals as a whole. The construction respondents also spend more time in PM and work on slightly fewer projects than other PM professionals. Another distinguishing characteristic is that the construction professionals tend to work on typical projects that have larger numbers of activities and resources. The software package of choice among most construction respondents is Primavera, which contrasts with the total respondents' heavy use of Microsoft Project.

Not surprisingly, professionals in the construction industry, are using PM software more now than ever before. An influential factor for construction professionals when deciding when to use and not to use PM software is the complexity of the project. The results also indicate that those construction professionals who use more analytical techniques tend to choose the full-featured software package Primavera over other packages, while those who use fewer techniques chose the more basic Microsoft Project package.

Some interesting results were found concerning both technique usage and the types of information that are entered and updated in a typical project. Construction respondents are heavy users of critical path analysis for planning and control, resource scheduling for planning, and earned value analysis for control. In terms of the types of information that are entered and updated in a typical project, the results show that more than half of the construction respondents who *entered* specific types of PM information also *updated* that information. The number of activities in a typical project and the use of software for all active projects were the key determinants of the usage of specific analytical techniques. These factors are also significant determinants of the types of information entered and updated in the software, although the effect is weaker.

The construction respondents provided insightful findings and remarks for areas of future research. While they indicate a higher level of satisfaction with the quality of resource leveling schedules produced than the overall respondents in the study, they also indicate that there is value in future research in this area. The construction respondents have expressed a higher degree of interest in a net present value (NPV) option than those in the full study. A number of the construction respondents expressed interest in conducting future research on integration of PM software with other software packages, increasing flexibility of PM software, and making the use easier. Based on the growth of PM and the heavy reliance of PM software among construction professionals, improving the tools and techniques available in PM software applications remains a fruitful area for further development, especially for the construction industry. To maximize the impact on practice, development of new planning and control methods should include their integration into PM software.

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