Small Computers and Project Management in Transportation Consulting

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Micro- and minicomputer applications to project management in transportation consulting are examined. The goals are to examine the external, organizational, and individual aspects of the implementation of small-computer-aided project management techniques in transportation consulting and to conceptualize a prototype small-computer-aided project management system for transportation consultants. Data collection efforts include mail questionnaires sent to 412 transportation consulting firms with a response rate of 56 percent. Analysis of the data shows that system/work fit (fit between small computer *system* technology and project management *work*), satisfaction with noncomputerized project management methods, organizational innovativeness, level of general computer use, and slack resources are associated with levels of adoption of small-computer-aided project management. Analysis also indicates that small-computer-aided project management is associated with the adequacy of the amount of time that project managers spend on nonquantitative elements of project management.

Transportation consultants conduct their work on a project-by-project basis and must manage these projects to ensure quality and adhere to cost budgets and time schedules. Project management is, in fact, so important to the successful execution and profitability of such projects that it has emerged as an art/science in its own right.

The small computer (micro- and minicomputer) that has evolved during the past decade is an accepted tool used by transportation consultants to help make a wide variety of engineering and planning analyses. It is also clear, however, that the small computer can be applied to elements of project management in transportation consulting. It has become apparent that the application of the small computer can improve both the ease and quality of project management in transportation consulting. Moreover, in recognition of the benefits of computerization, a growing number of software packages are being marketed for application to general-purpose (that is, not limited to transportation consulting) project management.

An overview of the elements of project management is first presented as essential background information. Then, the potential for computerization is discussed. A brief review of the state-of-the-art of small computer applications to project management follows.

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After this discussion, the research project recently completed at the University of Massachusetts at Amherst is presented. The research goals are discussed first. Second, the research model is presented. Third, data collection and analysis are described. Finally, a prototype small-computer-aided project management system is conceptualized.

The effort is believed to be one of the first major formal investigations of the integration of computer technology into the transportation consulting industry, based on a review of the literature. In fact, it may be the first such major inquiry for the greater engineering consulting service industry as a whole.

A "core" application of computer technology, as opposed to the more familiar "peripheral" applications, is the focus. Specifically, project management is at the "mission-essential" core of the transportation consulting. This contrasts with a more traditional application of computer technology such as word processing, which is more peripheral in that it automates a "support" function of transportation consulting.

A key finding of this research is that the transportation consulting industry is beginning to *depend* on computer aids to project management. However, it also found that the potential does exist for increased adoption of computer-aided project management. This finding indicates that the research has both practical value and value as exploratory theory-building.

PROJECT MANAGEMENT IN TRANSPORTATION CONSULTING

Elements of Project Management

The elements of good project management can be summarized into groups of project management objectives, tasks, and interpersonal skills, as listed below:

- Objectives
  - —Conforming to professional ethics and proper practices
  - —Providing client satisfaction
  - —Completing contractual tasks
  - —Meeting contractual schedules
  - —Meeting profit objectives
- Tasks
  - —Planning
  - —Organizing and staffing

—Directing
—Monitoring and controlling progress
—Conclusion of the project
- Interpersonal skills
—Communicating
—Leading
—Motivating
—Managing conflict
—Negotiating

The above-listed project management tasks concerning planning, monitoring and controlling progress, and conclusion of the project include quantitative measures and, therefore, lend themselves to computer applications. These tasks are discussed in more detail below. This discussion is based on the case of a traffic impact and access study, a typical project for transportation consultants. (A traffic impact and access study evaluates the traffic impacts and access requirements of a proposed land development, particularly with regard to transportation system capacity and safety.) However, the principles and methods can be transferred to other types of transportation consulting projects.

Planning

Because the key constraints imposed on the project manager are money (labor and expenses) and time (delivery dates), two key elements of the project plan are a budget and a time schedule breakdown. Both these plans can be formulated in such a way that they can function as baselines and tools to be used in the postplanning monitoring and control that may be required until the project is concluded.

Project Budget

Three key steps of formulating a detailed project budget are as follows:

- Define the project tasks and subtasks,
- Establish the labor classifications that could be employed in the project, and
- Estimate the distribution of labor hours by labor classification and task.

A sample project budget chart for a traffic impact and access study is shown in Figure 1 (data from Richard S. Bryant). Although this particular detailed project budget centers on labor hours, expenses can also be included.

Time Schedule Breakdown

The time schedule breakdown essentially establishes the planned chronology of tasks to be completed in order to meet the previously set time schedule for delivery of the final product. The first three steps of devising the time schedule breakdown are the same as the three steps in development of the project budget. All that remains to produce the time schedule breakdown is to show the relationship between the subtasks and systematically list them using a graphic tool. The two chief types of tools are bar charts (Gantt or milestone charts) and network diagrams (Critical Path Method and Project Evaluation and Review Technique networks). The simpler of the two tool types, the bar chart, is adequate for most projects in transportation consulting. An example of a bar chart for a traffic impact and access study is shown in Figure 2.

Periodic and Cumulative Labor Budgets

Project planning can be carried to a higher level of detail by establishing periodic and/or cumulative labor budgets. These budgets, which relate the rate of budget expenditure and the passage of time, require information from the detailed project budget and the time scheduling breakdown. The periodic and/or cumulative labor budgets would normally be more applicable to larger projects in transportation consulting. Sample periodic and cumulative labor budgets based on the project budget chart (Figure 1) and project bar chart (Figure 2) are shown in Figure 3.

The periodic labor budget in Figure 3 tabulates the dollar amount of labor planned for expenditure each week of the project effort. The periodic expenditures are broken down by task. The cumulative labor budget shows the cumulative dollar amount of labor planned for expenditure by the end of each week of the project effort. Because this cumulative labor budget is presented in histogram form, it is a readily comprehensible profile of anticipated labor expenditures.

Project Monitoring and Control

If properly executed, the project planning effort described above has defined valid baseline conditions and tools for project monitoring and control. With these tools in place, the next priority in project monitoring and control is to ensure that adequate and timely information is available to measure actual progress against planned progress. On the basis of this comparison, corrective action, if necessary, can be taken.

Information Needs and Monitoring Methods

To monitor progress, the project manager must have timely and adequate information on a periodic basis on the status of project tasks and subtasks and the labor hours/dollars actually expended.

This information can be used to compare actual progress with planned progress, as previously established in the project budget and time schedule breakdown. This comparison can be made graphically by marking charts similar to Figures 1, 2, or 3.

Control

In project control, the project manager takes corrective action, if necessary, on the basis of the findings from the monitoring effort. Possible findings of this effort are shown in the project control matrix depicted in Figure 4. As the figure shows, this

DISTRIBUTION OF MANHOURS BY STAFF CATEGORY AND TASK

XC: FOC/JMM/RB

Client: TASHJIAN CORPORATION
Project: YEREVAN ACRES
Budget: $9000

Job No. 1958
Prep by: KEH
Date: 1-26-1987

Tasks and Subtasks	Manhours: Prin/ Assoc	Sr Proj Mgr	Proj Mgr	Sr Proj Engr	Proj Engr	Word Proc	Draft	Tech	Task Charge
11-DATA COLLECTION 8963									
A. TMC'S	0.0	0.0	0.0	0.0	0.0	0.0	0.0	53.0	53.0
B. MRC'S	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	2.0
C. Accidents	0.0	0.0	0.0	0.0	0.0	0.0	0.0	8.0	8.0
D. Data Reduction	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.5	6.5
E. Other	0.0	0.0	0.0	1.0	0.0	0.0	0.0	4.0	5.0
Subtotal	0.0	0.0	0.0	1.0	0.0	0.0	0.0	73.5	74.5
Cost	$0	$0	$0	$51	$0	$0	$0	$1,617	$1,668
12-REPORT PRODUCTION									
A. Word Proc. - Draft	0.0	0.0	0.0	0.0	0.0	8.0	0.0	0.0	8.0
B. Word Proc. - Final	0.0	0.0	0.0	0.0	0.0	4.0	0.0	0.0	4.0
C. Report Graphics	0.0	0.0	0.0	0.0	0.0	0.0	16.0	0.0	16.0
D. Concept Plans	0.0	0.0	0.0	0.0	0.0	0.0	8.0	0.0	8.0
Subtotal	0.0	0.0	0.0	0.0	0.0	12.0	24.0	0.0	36.0
Cost	$0	$0	$0	$0	$0	$432	$600	$0	$1,032
13-BASIC ENGINEERING									
A. Project Initiation	2.0	0.0	2.0	4.0	0.0	0.0	0.0	0.0	8.0
B. Field Visit	0.0	0.0	0.0	4.0	0.0	0.0	0.0	0.0	4.0
C. Background Research	0.0	0.0	0.5	4.0	0.0	0.0	0.0	0.0	4.5
D. Background Development	0.0	0.0	0.5	4.0	0.0	0.0	0.0	0.0	4.5
E. Existing Networks	0.0	0.0	0.5	4.0	0.0	0.0	0.0	0.0	4.5
F. Trip Distribution	0.0	0.0	0.5	3.0	0.0	0.0	0.0	0.0	3.5
G. Trip Generation/Assign	0.0	0.0	0.5	4.0	0.0	0.0	0.0	0.0	4.5
H. Analysis	0.0	0.0	0.5	10.0	0.0	0.0	0.0	0.0	10.5
I. Evaluate Alternatives	2.0	0.0	1.0	8.0	0.0	0.0	0.0	0.0	11.0
J. Concept Plans	1.0	0.0	0.5	12.0	0.0	0.0	0.0	0.0	13.5
K. Documentation-Draft	2.0	0.0	3.0	16.0	0.0	0.0	0.0	0.0	21.0
L. Documentation-Final	1.0	0.0	2.0	4.0	0.0	0.0	0.0	0.0	7.0
M. Permit Preparation	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Subtotal	8.0	0.0	11.5	77.0	0.0	0.0	0.0	0.0	96.5
Cost	$760	$0	$644	$3,927	$0	$0	$0	$0	$5,331
14-MEETINGS									
A. Client Meetings	4.0	0.0	0.0	0.0	0.0	2.0	0.0	0.0	6.0
B. Public Meetings	4.0	0.0	0.0	0.0	0.0	0.0	4.0	0.0	8.0
Subtotal	8.0	0.0	0.0	0.0	0.0	2.0	4.0	0.0	14.0
Cost	$760	$0	$0	$0	$0	$72	$100	$0	$932
GRAND TOTAL	16.0	0.0	11.5	78.0	0.0	14.0	28.0	73.5	221.0
COST	$1,520	$0	$644	$3,978	$0	$504	$700	$1,617	$8,963

FIGURE 1 Sample project budget chart.

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                PROJECT BAR CHART

Client:      TASHJIAN CORPORATION                Job No:    1958
Project:     YEREVAN ACRES                       Prep by:   KEH
Budget:      $9000                               Date:      1-26-1987

                                                 Week
                            Task
Tasks and Subtasks          Charge     1     2     3     4     5     6     7     8     9    10
 11-DATA COLLECTION    8963
   A. TMC'S                 $1,166  *****  ***
   B. MRC'S                    $44  *****  ***
   C. Accidents               $176  *****  ***
   D. Data Reduction          $143  *****  *****
   E. Other                   $139  *****  *****
Subtotal Cost               $1,668
 12-REPORT PRODUCTION
   A. Word Proc. - Draft      $288                                    *  **
   B. Word Proc. - Final      $144                                       **
   C. Report Graphics         $400           *****  *****  *****  *****  **
   D. Concept Plans           $200                                       **
Subtotal Cost               $1,032
 13-BASIC ENGINEERING
   A. Project Initiation      $506  ***
   B. Field Visit             $204  ***
   C. Background Research     $232  *****  *****
   D. Background Development  $232  *****  *****
   E. Existing Networks       $232           *****
   F. Trip Distribution       $181           *****
   G. Trip Generation/Assign  $232           *****
   H. Analysis                $538                 *****
   I. Evaluate Alternatives   $654                       *****
   J. Concept Plans           $735                       *****
   K. Documentation-Draft   $1,174                             *****
   L. Documentation-Final     $411                             "     ***
   M. Permit Preparation        $0
Subtotal Cost               $5,331
 14-MEETINGS
   A. Client Meetings         $452                                   ***
   B. Public Meetings         $480                                          *****
Subtotal Cost                 $932
GRAND TOTAL COST            $8,963
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FIGURE 2 Sample project bar chart.

corrective action can include replanning the remainder of the project effort to ameliorate the effects of budget and/or schedule slips. If necessary, and justified, corrective action can take the form of an increase in fee and/or length of schedule as negotiated with the client.

Project Conclusion

The key purpose of the project conclusion is to document what happened during the project to help in future projects. In particular, the project conclusion effort can be instrumental in creating a solid data base of previous project efforts. As previously discussed, this data base can be an important aid in planning future projects.

Project conclusion documents can summarize what happened during the project in terms of task accomplishment, time schedule, and budget. The documents could include

- Project profile,
- Project budget chart,
- Project bar chart, and
- Periodic and cumulative labor budgets chart.

The project profile describes the efforts and products of the project. In the case of a traffic impact and access study, descriptive information could include

- Types and amounts of data collected;
- Format and length of report;
- Type and number of report graphics;
- Number and means of establishing traffic flow networks;
- Analysis locations, scenarios, and methodologies;
- Number of client and public meetings; and
- Names and labor classifications of primary project personnel.

The project budget and bar charts included in the project conclusion documents could simply be the bar chart used for project planning, monitoring, and control, but updated to reflect what happened throughout the project. The periodic and cumulative labor budgets charts included in the project

PERIODIC AND CUMULATIVE LABOR BUDGETS

Client: TASHJIAN CORPORATION
Project: VEREVAN ACRES
Budget: $9000
Job No.: 1958
Prep by: KEH
Date: 1-26-1987

Tasks	Task Charge	Periodic Labor Budget, by Week 1	2	3	4	5	6	7	8	9	10
11-DATA COLLECTION 8963	$1,668	$1,007	$661	$0	$0	$0	$0	$0	$0	$0	$0
12-REPORT PRODUCTION	$1,032	$0	$0	$83	$83	$83	$179	$225	$377	$0	$0
13-BASIC ENGINEERING	$5,331	$942	$232	$645	$538	$1,389	$1,174	$0	$411	$0	$0
14-MEETINGS	$932	$0	$0	$0	$0	$0	$0	$452	$0	$0	$480
TOTAL	$8,963	$1,949	$893	$728	$621	$1,472	$1,353	$677	$788	$0	$480

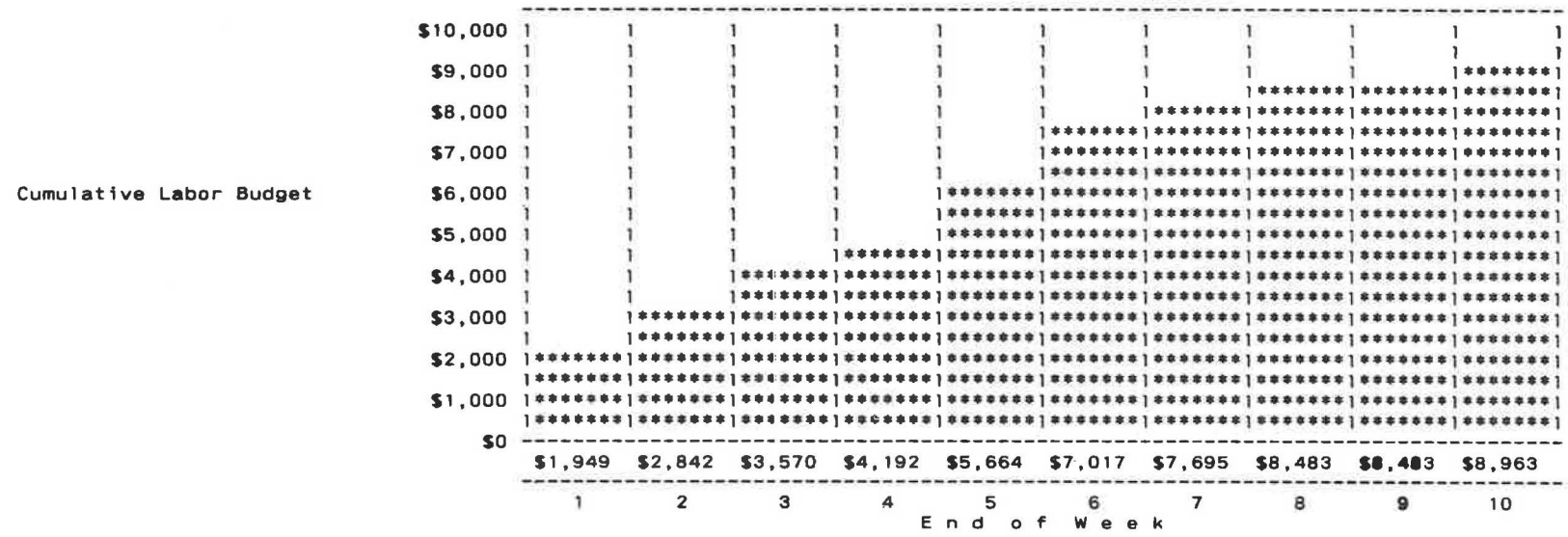


FIGURE 3 Sample periodic and cumulative labor budgets chart.

	Ahead of Schedule	On Schedule	Behind Schedule
Below Budget	• Consider replanning to make best use of the additional remaining budget and schedule.	• Consider replanning to make best use of additional remaining budget.	• Determine/rectify causes of the schedule slip. • Consider replanning to make use of additional remaining budget as a means of accelerating remaining schedule. • Consider negotiating a later delivery date.
On Budget	• Consider replanning to make best use of the additional remaining schedule.	• The remainder of the project effort will require monitoring to avoid budget or schedule slips.	• Determine/rectify causes of the schedule slip. • Consider replanning to accelerate remainder of schedule. • Consider negotiating a later delivery date. • The remainder of the project will require monitoring to avoid further schedule slips.
Above Budget	• Determine/rectify causes of the budget slip. • Consider replanning to make use of additional remaining schedule as a means of reducing remaining expenditures. • Considering negotiating a higher fee	• Determine/rectify causes of the budget slip. • Consider replanning to economize remaining budget expenditures. • Consider negotiating a higher fee. • The remainder of the project will require monitoring to avoid further budget slips.	• Determine/rectify causes of the budget and schedule slips. • Consider replanning to economize remaining expenditures. • Consider negotiating a higher fee. • Consider replanning to accelerate remainder of schedule. • Consider negotiating a later delivery date.

FIGURE 4 Project control matrix.

conclusion documents could likewise be an updated and finalized report.

SMALL COMPUTER APPLICATIONS TO PROJECT MANAGEMENT

Potential for Small Computer Applications

In the preceding discussion of project management in transportation consulting, several project management tools were presented. Each tool can be used manually or computerized. The samples depicted in Figures 1 through 3 were devised on the popular Symphony microcomputer spreadsheet (Lotus Development Corporation, Cambridge, Massachusetts 1984).

Computerization has two chief advantages. The first is that clear, legible charts can be created more quickly on the computer than with manual methods. This assumes that the software has been mastered and/or the appropriate spreadsheet template has been created. The project budget and project bar charts can be quickly built with the computer greatly speeding the normal trial and error approach. With the Symphony spreadsheet shown previously, once the project budget and project bar charts are established, the periodic and cumulative labor budgets chart is automatically constructed.

The second chief advantage of computerization is the ease with which changes can be made to any of the charts. The ability to readily change the charts facilitates project replanning, should it be necessary, and allows quick modification of the charts to convert plans of action to reports of actual action.

Another potential application of computers is the storage and management of the data base of previous project efforts. In particular, the project conclusion documents (project profile, project bar chart, and periodic and cumulative labor budgets chart) could be stored in such a manner that the material could be readily accessed to aid in future project planning efforts.

Carrying things one more step, the data base, if large enough, could be examined and manipulated by statistical means to create more powerful planning tools. For example, regression analysis could show a correlation between the number of intersections (or other independent variables) and the total project budget amount and/or shortest practical delivery schedule (or other dependent variables).

Any of the potential areas for computer application can be addressed with mainframe computers. However, small computers (micro- and minicomputers) are significantly lower in acquisition cost than mainframe computers. In fact, microcomputers are within the financial reach of small consulting firms. In light of this affordability, a review of the state-of-the-art of microcomputer applications to project management has been conducted and is presented in summary form.

Existing Software

Review of the state-of-the-art of microcomputer applications to project management indicates the availability of a number of project management software packages. Moreover, many of these packages are quite powerful, yet cost only several hundred dollars.

Existing microcomputer programs are particularly applicable to project planning, monitoring, and control. Commercially available programs have incorporated many of the standard planning, monitoring, and control tools to include Gantt-type charts, project networks, and budget control charts.

These microcomputer aids complement competent project management. In particular, they can facilitate planning of projects and help ensure timely and frequent tracking of progress. The results can be improved project plans, earlier detection of noncompliance with those plans, timely corrective action, or, if necessary, simplified project replanning.

RESEARCH PROGRAM

Preceding sections of this paper have shown that significant potential exists for applying small computers to project management in transportation consulting. A review of the state-of-the-art shows that a number of software packages are available. However, significant untapped potential also exists. Therefore, the University of Massachusetts at Amherst has conducted a research program to more fully explore the use of small computers in project management by transportation consultants.

Research Goals

The goals of the research effort are to (a) examine the external, organizational, and individual aspects of the implementation of small-computer-aided project management in transportation consulting and (b) conceptualize a prototype small-computer-aided project management system for transportation consultants.

Research Model

The first goal of this research effort is to examine the external, organizational, and individual aspects of small-computer-aided project management techniques in transportation consulting. Pre-existing research, theory, and concepts suggest the overarching research model depicted in Figure 5. The model first posits that external factors, organizational factors, and individual factors are associated with adoption/use of small-computer-aided project management systems. The model also posits that adoption/use of small-computer-aided project management systems is, in turn, associated with benefits to be realized.

Propositions

The research model suggests four research propositions:

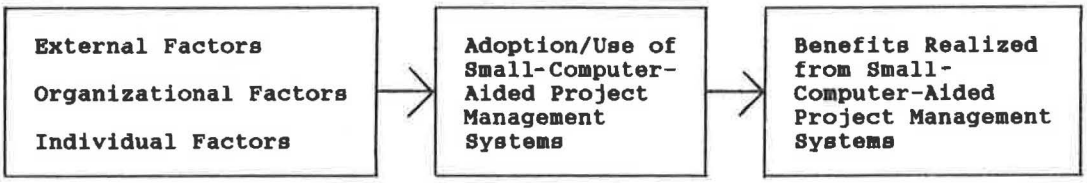
Proposition I External factors affect the adoption/use of small-computer-aided project management systems by a transportation consulting firm.
Proposition II Organizational factors affect the adoption/use of small-computer-aided project management systems by a transportation consulting firm.
Proposition III Individual factors affect the adoption/use of small-computer-aided project management systems.
Proposition IV Adoption and use of small-computer-aided project management systems have resulted in benefits to firms that have adopted those systems.

These propositions were translated into hypotheses tested by using data collected from a sample of transportation consulting firms within the United States.

Data Collection and Analysis

Mail Survey

A mail survey provided information on both current practice in the general application of small computers in transportation consulting and on the specific application of small computers to project management in transportation consulting. The study population was the 662 United States consulting firms in the consultants listing of the Institute of Transportation Engineers (ITE) *Membership Directory: 1988* (*1*). The overall response rate was considered adequate to good. Two hundred twenty-nine of the 412 total firms surveyed by mail returned useable responses representing an overall return rate of approximately 56 percent. The 229 firms represented approximately 35 per-



Note: This is an overarching research model. External factors, organizational factors, and individual factors are associated with adoption/use of small-computer-aided project management systems. Adoption/use of small-computer-aided project management systems, in turn, is associated with benefits to be realized.

FIGURE 5 Research model.

cent of the total population of 662 firms listed in the ITE *Membership Directory: 1988* (*1*).

Analysis of the mail survey data is summarized in Table 1. This analysis is structured in terms of 19 research hypotheses. As shown in Table 1, support for the hypotheses is described in qualitative terms such as "weak" or "moderate." These labels were assigned after making judgments including the data presented in Table 2, a statistical summary of hypothesis analysis. [As is standard practice in the behavioral/social sciences, characterization of strength of support for each hypothesis was based on the *significance* of the regression statistics. This was appropriate because the hypothesis analysis used regression as a tool for exploring the *existence* and *direction* of associations between variables. This differed from frequent practice in engineering analysis in which regression is used to derive equations that can be used to *predict* the value of the dependent variable given a value of the independent variable. With this practice, the explanatory or predictive power of regression (in terms of, for example, the regression coefficient r or the coefficient of determination R^2) would explicitly be important, as well as measures of statistical significance.]

A number of the 19 research hypotheses were supported in various degrees. Support was moderate or moderate to strong for the hypothesized relationship between "adoption/use of small computer-aided project management systems" and the following variables:

- "System/work fit between small computer *system* technology and project management *work*" (positive association),
- "Satisfaction with preexisting noncomputerized project management methods and tools" (negative association),
- "Organizational innovativeness" (positive association),
- "Intensity of general small-computer use within the firm" (positive association), and
- "Slack resources within the firm" (positive association).

Support was very weak, weak, or weak to moderate for the hypotheses that the following variables were associated with

TABLE 1 HYPOTHESIS ANALYSIS SUMMARY

Propositions and Hypotheses		Levels of Support*
Proposition I: External Factors**		
Hypothesis A:	Industry-Level Adoption	Weak
Hypothesis B:	System/Work Fit	Moderate to Strong
Hypothesis C:	Hardware/Software Cost	Weak***
Hypothesis D:	Pre-Existing Satisfaction	Moderate^
Hypothesis E:	Time/Effort Cost	Not Significant^
Hypothesis F:	Resistance by Personnel	Weak to Moderate^
Proposition II: Organizational Factors**		
Hypothesis G:	Organization Innovative.	Moderate to Strong
Hypothesis H:	Management Style	Weak^^
Hypothesis I:	General Computer Use	Moderate to Strong
Hypothesis J:	Number of Employees	Not Significant
Hypothesis K:	Resource Wealth	Moderate
Proposition III: Individual Factors**		
Hypothesis L:	Individual Innovativeness	Weak
Hypothesis M:	Other Individual Factors	Not Supported***
Hypothesis N:	Education/Credentials	Not Significant
Hypothesis O:	Years of Experience	Weak to Moderate^
Proposition IV: Benefits^^^		
Hypothesis P:	Financial Performance	Very Weak
Hypothesis Q:	Firm Quality	Very Weak
Hypothesis R:	Span of Responsibility	Weak
Hypothesis S:	Less Quantitative Tasks	Moderate

* Hypothesized associations are positive, unless otherwise noted.
** External, organizational, and individual factors are posited to be independent variables associated with the dependent variable level of adoption of small-computer-aided project management systems.
*** Lack of association is hypothesized.
^ Negative association is hypothesized.
^^ Firms with participative (as opposed to autocratic) management styles/structures are hypothesized more likely to adopt/use small-computer-aided project management systems.
^^^ Level of adoption of small-computer-aided project management systems is posited to be the independent variable associated with benefit dependent variables.

TABLE 2 STATISTICAL SUMMARY OF HYPOTHESIS ANALYSIS

Propositions and Hypotheses	Four-Page Questionnaire: Significant Regressions	Four-Page Questionnaire: Mean R^2 *	Two-Page Questionnaire: Significant Regressions	Two-Page Questionnaire: Mean R^2
Proposition I: External Factors				
Hypothesis A	1 of 4	0.045**	1 of 5	0.079**
Hypothesis B	3 of 4	0.130***	4 of 5	0.260****
Hypothesis C^	0 of 4	NA^^	0 of 5	NA
Hypothesis D	4 of 4	0.079***	1 of 5	0.065
Hypothesis E	0 of 0	NA	0 of 5	NA
Hypothesis F	1 of 4	0.121****	2 of 5	0.107***
Proposition II: Organizational Factors				
Hypothesis G	2 of 4	0.043**	4 of 5	0.175***
Hypothesis H	3 of 4	0.064***	0 of 5	NA
Hypothesis I	4 of 4	0.231****	5 of 5	0.172***
Hypothesis J	0 of 4	NA	Not included in this questionnaire.	
Hypothesis K	2 of 4	0.055***		
Proposition III: Individual Factors				
Hypothesis L	0 of 0	NA	4 of 5	0.130**
Hypothesis M^^^	3 of 4	0.157***	0 of 5	NA
Hypothesis N	0 of 0	NA	Not included in this questionnaire.	
Hypothesis O	2 of 4	0.086***		
Proposition IV: Benefits				
Hypothesis P	0 of 1	NA	1 of 5	0.078**
Hypothesis Q	1 of 1	0.068**	0 of 5	NA
Hypothesis R	1 of 3	0.081**	4 of 10	0.139***
Hypothesis S	1 of 2	0.078***	4 of 5	0.115**

* The mean of only the R^2 that are significant at $p < 0.05$.
** $p < 0.05$. This is the mean p for significant R^2 only.
*** $p < 0.01$. This is the mean p for significant R^2 only.
**** $p < 0.001$. This is the mean p for significant R^2 only.
^ This hypothesis posits lack of association. Because no R^2 are significant, this lack of association is at least weakly supported.
^^ NA stands for Not Applicable. No significant R^2 exist.
^^^ This hypothesis posits lack of association. Because some R^2 are significant, this lack of association is not supported.

"adoption/use of small computer-aided project management systems":

- "The perceived extent of diffusion of small-computer-aided project management systems in the transportation consulting industry" (positive association),
- "Computer hardware/software cost" (no association),
- "Resistance to the technology by organizational personnel" (negative association),
- "Participatory management style" (positive association) versus "autocratic management style" (negative association),
- "Individual innovativeness of project managers" (positive association), and
- "Project manager years of experience" (negative association).

Support was not found for the hypotheses that the following variables were associated (or, in one case, not associated) with "adoption/use of small computer-aided project management systems":

- "Time and effort for system implementation" (negative hypothesized association),
- "Number of firm employees" (positive hypothesized association),
- "Individual project manager differences other than innovativeness" (no hypothesized association), and
- "Level of project manager education and professional credentials" (positive hypothesized association).

Analysis also indicated that "adoption/use of small-computer-aided project management systems" had a moderate positive association with "adequacy of time project managers spent on nonquantitative elements of project management." Weak support was also found for the hypothesis that "adoption/use of small-computer-aided project management

systems" was positively associated with "attainment of project, budget, and schedule goals"; "quality of work at a firm"; or "increased spans of responsibility of project managers."

Field Visits

Field visits were conducted to provide qualitative data on applications of small computers in transportation consulting. These visits were important because they allowed firsthand observation of the organization and climate at several consulting firms and provided a basis for interpreting the quantitative results.

Five firms were studied. Only one person was interviewed at four of these firms. At the fifth firm, five individuals were interviewed. All visits were to southern and central New England because of the practical limits on travel. Each visit centered on a one-hour partly structured interview. Findings from the field visit effort are summarized in Table 3.

CONCEPTUAL PROTOTYPE COMPUTER-AIDED PROJECT MANAGEMENT SYSTEM

Several findings justify the conceptualization of a prototype small-computer-aided project management system. First, firms have become dependent on small-computer-aided project management systems, although it must be noted that many of these systems are oriented mainly to accounting and relatively simple project cost-tracking and reporting. Second, in consonance with the dependency that seems to have developed, the transportation consulting industry overall would like to advance, as opposed to regress, in its use of computer-aided project management. Third, room for advancement industrywide clearly does exist. Fourth, individuals within the industry have suggested specific areas for improvement and advancement.

The primary goal of a small-computer-aided project management system would be to create net benefits to transportation consultants that, in turn, would help them better serve the public. The net benefits would hopefully include improvements in firm performance.

To meet this goal, a number of objectives have been identified for such a system.

- The system should have a comprehensive range of capabilities that integrate project management and accounting applications.
- The user interface should be very flexible and "user friendly."
- The system should be very flexible with regard to computer hardware.

TABLE 3 FIELD VISIT SUMMARY

	Young Major Firm	Mature Major Firm	Young Mid-size Firm	Young Small Firm	Regional Office of Small Firm
Age in Years	10	75	6	4*	20
Number of Employees	300	270	80	5	5 **
Number of Offices	4	2	1	1	3
Number Interviewed	5	1	1	1	1
Computer-Aided Project Management	Yes	Yes	Yes	Yes	Yes
General Computer Types	Mini Micro	Mini	Micro (partial network at both these firms)	Micro	Micro
Future Plans	***	^	^^	^^^	-

* Including predecessor corporation. The corporation under its present name was on the order of two years old.
** Five employees in regional office. Twelve for firm as a whole.
*** Additional project management capabilities on minicomputer. Improved timeliness of project reporting.
^ Refinements to existing system. Tracking of direct (non-labor) expenses. Better tracking of profit/loss. Computerized invoicing.
^^ Complete the network and add new microcomputers. More comprehensive project management capabilities.
^^^ Network all microcomputers. Improved accounting software with a good interface between accounting and project management functions.
\- More comprehensive use of computer-aided project management.

- A comprehensive documentation package should be integrated with the system.
- The system should be designed to facilitate customization.
- Full training and support should be available although little should be required.
- The clear benefits of the system should encourage voluntary use.

It is important that the system *integrate* classical project management and accounting capabilities. The goal here would be to reduce duplicated effort and facilitate communication between the project management and accounting functions. Although the integrated system would have a number of sophisticated features, any of these capabilities should be easy to bypass. Some capabilities may not need to be invoked except, for example, on very large or complicated projects.

The project management capabilities should include a wide array of tools for project planning, monitoring, and control. In addition, flexible project cost summary reporting facilities should be included. The system should also be capable of managing and analyzing a data base of previous project efforts. Two key accounting capabilities should be included. The system should include automated invoicing of clients and automated tracking and reporting of aged accounts receivable.

Several classifications of transportation consulting firm personnel would have key roles in the implementation, use, and very important ongoing evaluation of the small-computer-based project management system. These classifications would include project managers and the project staff personnel, accounting personnel, computer system managers, and upper level management (*2*).

CONCLUSION

The transportation consulting industry is in the process of adopting computer technology for a number of uses. Moreover, many of these are *core* uses, such as engineering analysis, as opposed to more peripheral uses, such as word processing. The adoption of computer technology to project management in transportation consulting is slightly less advanced than these other computer applications. In addition, adoption for project management was generally more advanced for project management uses that overlapped with accounting functions, such as labor and expense tracking and billing. However, the general indication is that firms plan to expand and refine their computer use in project management.

Data analysis indicated that system/work fit, satisfaction with noncomputerized project management methods, organizational innovativeness, level of general computer use, and slack resources were associated with levels of adoption of small-computer-aided project management. The analysis also indicated that small-computer-aided project management was associated with the adequacy of time project managers spent on nonquantitative elements of project management.

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REFERENCES

1. Institute of Transportation Engineers. *Membership Directory: 1988*. Washington, D.C., 1988, pp. (C-3)–(C-34).
2. K. E. Hazarvartian. Small Computers and Project Management in Transportation Consulting. Ph.D. dissertation. University of Massachusetts, Amherst, May 1989.

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