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RESEARCH MEMORANDUM

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ESTIMATION OF THE RELATIONSHIP BETWEEN PROJECT ATTRIBUTES AND THE IMPLEMENTATION OF ENGINEERING MANAGEMENT TOOLS

K.A. Bubshait, W.J. Selen

FEW 350

Introduction

The importance of Project Management emerged after the successful trial by Dupont in 1958 to reduce the time required to perform routine plant overhaul, maintenance and construction work. The contribution to the field continues and the practices become a contractual item, especially in most of the construction projects.

An issue that has recently emerged concerns with the establishment of a relationship between project characteristics and the implementation of various project management techniques and tools, as stated by Webster (20):

> There is criticism of project management literature in regard to the inability to find guidance as to which tool and which variant to use under what circumstances.

Largely absent in project management research are studies of the relationships between specific project characteristics (uncertainty, complexity, high indirect costs, duration, etc.) and the application of project management techniques.

Tso (19) attempted to examine this area, but his research was limited to educational projects. Tso expressed the problem by stating,

> ...., the question of what aspects of techniques need to be classed under one set of project conditions has not been answered.

Avots (1) elaborated on the importance of project characteristics. According to his research, one of the reasons for project failure is that management techniques used on a project may not always suit the project's requirements or project characteristics. Bu-Bushait (2), studied the relationship between the implementation of project management techniques and some project characteristics and found a significant relationship with characteristics such as project costs, duration and number of employees directly involved in the project. Furthermore, a statistically significant difference was found between the average number of techniques used on large projects versus small projects. The above mentioned studies indicate the importance of project characteristics and their relationship to project management techniques implementation.

This study does not aim at classifying techniques for various project characteristics, but rather will elaborate on earlier work by Bu-Bshait (2,3) in identifying which project characteristics, as stated in Table 1, significantly intensify the need for a more elaborate use of project management techniques, listed in Table 2, for various project types. A regression model will be developed to estimate the number of project management techniques used, based upon a set of project characteristics. As such, this study will provide further insight in the understanding of the missing link between project attributes and the implementation of engineering management tools.

TABLE 1

PROJECT CHARACTERISTICS

1. Project Duration
2. Project Type
3. Project Total Cost
4. Number of activities
5. Resources Limitation
6. Contractual Deadline
7. Number of Employees Directly involved
8. Project Managerial Complexity

TABLE 2

EXAMINED PROJECT MANAGEMENT TECHNIQUES

1. Planning/scheduling techniques

    a. Work breakdown structure
    b. Gantt (bar) charts
    c. Milestones
    d. Project Networks

        1) Activities-on-Arrows
        2) Activities-on-Nodes
        3) Precedence Diagrams

    e. Critical Path Method (CPM)
    f. PERT statistical approach
    g. GERT/simulation
    h. Time/cost tradeoff analysis
    i. Resource leveling/allocation
    j. Computer applications (planning)
    k. Linear responsibility chart

2. Control Techniques

    a. Progress Measures
        1) Percent Complete
        2) Estimate to Complete
        3) Remaining duration.

    b. PERT/COST
    c. Structuring of costs by work type

        1) By type of work
        2) By resource type
        3) By contract

    d. Trend analysis
    e. Earned value
    f. Regular meetings and status reports

Sample Size and Selection

The sample consisted of projects that could be expected to call upon project management techniques as listed in Table 2. The majority of these projects were being conducted in the southeastern and Mid-Atlantic regions of the United States.

Forty-eight projects were selected to represent different industrial sectors. Forty-two usable responses were obtained, as six projects were excluded due to the fact that they required job shop scheduling, not project scheduling. The sample contained a wide variety of project types and project characteristics, as is shown in Table 3.

Structured interviewing was used as the data collection methodology to ensure correct interpretation of some of the research questions, due to the variety in terminology used in the field of project management.

TABLE 3

Classification of Selected Projects

A. Construction Projects

- Hotel
- Water Treatment Facility
- University Library
- Rapid Transit System
- Office Building
- Railroad Infrastructure
- Rapid Rail Station
- Fabric Manufacturing Plant
- Warehouse and Service Building
- Paper Manufacturing Plant
- Airplane Hangar
- Highway Intersection
- Park Facility
- Federal Exhibit

B. Research and Development Projects

- Automated Tube Factory Design
- Foreign Nuclear Reactor Study
- Cable Investigation
- Educational/Research Computer Facility
- Cellular Car Phone System
- Addressable Transmitter
- High Temperature Material Testing
- Laser System Training Program
- New Product Development
- Technology Alternative for Aircraft Deployment
- Advanced Digital Flight Station Simulator
- Automated Assemblies Management System
- Development of Computer Graphic Software
- Innovation Incentive Programs
- Integrated Circuit Measurement Standard
- Space Telescope Programs

C. Maintenance Projects

- Highway Resurfacing
- Product Modification
- Major Equipment Replacement

D. Administrative Projects

- Retail Marketing Planning System
- Innovation Program Evaluation
- Conference Arrangement

Model Specification

A regression model will be developed to relate the number of project management techniques used to a number of relevant project characteristics. As such the number of project management techniques used is defined as the dependent variable.

The explanatory variables to be considered for possible inclusion in the model were defined as follows:

z_i	=	a dichotomous indicator variable which classifies the project either as:
	-	construction (i=1)
	-	research and development (R & D) (i=2)
	-	administrative (i=3)
	-	maintenance (reference group)[1]
NACT	=	number of activities in the project
DUR	=	duration of the project in years
COSTPM	=	actual cost of the project (in million dollar)
NEMPL	=	number of employees directly involved with the project
DEADL	=	a dummy variable, indicating whether or not the project has a contractual deadline
SC	=	a dummy variable to classify the project as either complex or simple
RESLIM	=	an indicator variable denoting whether or not resources such as labor and equipment were limited in their availability

[1]Since a regression model with intercept is used, (m-1) dummies were used to model m classifications, due to the "dummy variable trap"

The complexity of the project denoted by SC, was determined on the response of the following survey question:

> "How much managerial/administrative complexity (not technical complexity) was involved in the project with respect to:"

	Simple	Relatively Simple	Relatively Complex	Complex
a. The number of organizational units involved	_	_	_	_
b. The amount of communication and coordination required due to inter-dependencies among activities.	_	_	_	_

If either response to a or b fell in the "complex" category or if both responses fell in the "relatively complex" category, the project was classified as complex (SC = 1); otherwise the project was classified as simple (SC = 0).

The dependent variable, project analysis complexity, is quantified as the number of project management techniques (CPM, PERT, Bar Charting, Resources Leveling and the like) the company uses to analyze the project of interest.

Analysis

The first model to be investigated was the full, non-interaction, model incorporating all regressors. As can be seen from the results, displayed in Table 4, only construction projects differ significantly from the reference category, maintenance projects. In addition, variables like number of activities, project cost, number of employees directly involved and whether or not the project has a deadline, showed up statistically non-significant. The cut-off value used in this study for determining statistical significance is a PR >¦t¦-value of 0.10 or less. In other words, when claiming that a regressor is significant we are willing to take a risk of being wrong of up to 10 percent; or being at least 90 percent confident, that is.

These initial results prompted questions like why variables as important as project cost and number of activities showed up non-significant, looking towards a full scale investigation of possible interaction effects. Interaction effects allow the partial relationships between the various regressors and the dependent variable to be different among various classifications of projects as denoted by their respective indicator variable values. Table 5 provides a list of the interaction effects that were investigated, as well as their statistical significance.

TABLE 4

Full non-interaction Model

Variable	Estimated Coefficient	Standard Error	t-value	PR >¦t¦
Intercept	0.57624			
z1	1.86652	1.93687	1.91	0.0659
z2	1.00060	1.41630	0.71	0.4852
z3	-0.41377	1.11528	-0.37	0.7132
NACT	0.002173	0.99151	1.44	0.1609
DUR	0.716313	0.36113	1.98	0.0562
SC	1.61384	0.72474	2.23	0.0334
RESLIM	2.08926	0.66851	3.13	0.0038
COSTPM	-0.00116	0.00168	-0.69	0.4935
NEMPL	-0.00030	0.000483	-0.62	0.5367
DEADL	0.12594	0.70727	0.18	0.8598
R-SQUARE = 0.702956				

TABLE 5

<u>One-way interactions</u>

Model(a)	Interaction Effect	Significance Level PR > ¦t¦
1	z1*NACT	0.3730
	z2*NACT	0.0008
	z2*NACT	0.3728
2	z1*DUR	0.4584
	z2*DUR	0.0041
	z3*DUR	0.7214
3	z1*COSTPM	0.8886
	z2*COSTPM	0.2407
	z3*COSTPM	0.9869
4	z1*NEMPL	0.2265
	z2*NEMPL	0.2671
	z3*NEMPL	0.2609
5	SC*COSTPM	0.9352
6	SC*NACT	0.0259
7	SC*DUR	0.0401
8	SC*NEMPL	0.0211
9	RESLIM*NACT	0.0259
10	RESLIM*DUR	0.6971
11	RESLIM*COSTPM	0.7185
12	RESLIM*NEMPL	0.0719
13	DEADL*NACT	0.4722
14	DEADL*DUR	0.009
15	DEADL*NEMPL	0.1019
16	DEADL*COSTPM	0.5949

(a) Each model included the significant regressors of the full non-interaction model as well as the variables needed to estimate the one-way inter-actions one at a time. These models did not include various interaction effects among different variables simultaneously because of the loss of degrees of freedom in estimation. This preliminary study only identifies possible strong interaction effects for future inclusion in a more comprehensive model, allowing for simultaneous interactions among variables.

Since none of the interactions with the z3-dummy showed any significance and the z3-dummy in the original model was non-significant, the administrative and maintenance classifications were pooled and the z3-variable was dropped from any future model. Doing so we also gained one more degree of freedom for estimation of the remaining (and more important) parameters. From the original non-interaction model and the interaction analysis, the following variables showed explanatory potential in a one-way interaction model:

- z1 and z2
- NACT
- DUR
- SC
- NEMPL
- RESLIM
- DEADL
- z2*NACT and z2*DUR
- SC*NACT, SC*DUR and SC*NEMPL
- RESLIM*NACT and RESLIM*NEMPL
- DEADL*DUR and DEADL*NEMPL

Note that the variables NACT, NEMPL and DEADL also have to appear in the model because of the respective interaction effects, although these variables by themselves were originally non-significant.

Next, a forward and backward selection stepwise regression was performed on the above model variables, resulting in the final model as displayed in Table 6, based upon a 10 percent significance level.

TABLE 6.

Final Model

Variable	Estimated Coefficient	Standard Error	Partial[a] F-Value	PR > F
Intercept	-0.53830			
z1	1.78981	0.38915	21.15	0.0001
z2	7.41187	1.90778	15.09	0.0006
NACT	0.00387	0.00179	4.65	0.0398
DUR	1.41470	0.27351	26.75	0.0001
SC	1.64162	0.64796	6.42	0.0172
RESLIM	1.74233	0.54532	10.21	0.0035
DEADL	2.43492	0.85135	8.18	0.0079
z2*DUR	-1.62744	0.57060	8.13	0.0081
SC*NACT	0.00644	0.00173	13.83	0.0009
SC*NEMPL	-0.00710	0.00205	12.01	0.0017
RESLIM*NACT	-0.00492	0.00184	7.12	0.0125
RESLIM*NEMPL	0.00658	0.00205	10.27	0.0034
DEADL*DUR	-1.39414	0.39682	12.34	0.0015

R-Square = 0.90796

(a)Note the statistical relationship $t_a^2 = F_{1,a}$ or PR>¦t¦=PR>F

CONCLUSIONS

The results indicate the importance of some of the project characteristics to the implementation of project management techniques, as is shown in table 6. Construction projects call for more techniques than non construction projects. This result is consistent with previous research (2) that shows the familiarity of the construction industry with project management techniques.

Also R&D projects require substantial more techniques than any other type of projects. Futhermore, R&D projects tend to implement relatively fewer techniques as the projects duration increases. This could be explained by: 1) the unfamiliarity of many R&D managers with the importance of project management techniques in tracking the duration of the project; 2) In most cases R&D projects are kept with the company and f_unded internally, which makes the duration a secondary factor. In addition, absence of contractual agreements usually make the use of project management techniques optional.

The results indicate a positive relationship between the number of project management techniques used and the level of complexity involved in the project. Projects with many activities usually imply more interrelationships (precedence relationships) and more multi-organizational involvement in the decision process. As such, additional project management techniques are required to support the management process.

Limitation of resources imposes additional constraints on projects. The results indicate a need for more techniques when such limitations are present. The relationship is strengthened even more for projects that are labor intensive; although the number of activities in a project has a minor dampening effect.

Projects with a well defined deadline (and possible contractual penalty clauses) call for more project management techniques very early in the life of the project, as can be seen from the interaction effect with the duration explanatory variable.

In general the model highlights the importance of three main project characteristics, project type, complexity, and resources limitation. Furthermore, the model displays a strong explanatory power with 91 percent of the variation in the dependent variable explained by the variation in the regressor values.

These results suggest possible future research on:

1. The development of project management models suggesting specific management methodologies and techniques for managing projects with different characteristics.
2. Research on more effective pedagogic approaches for training project managers.
3. Research on the identification of specific techniques commonly used to manage a particular project characteristic.

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