Project Performance as a Function of Subsystem Interdependence for Multi-Site Projects

by

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To Karen and Laura Emily

for their love, understanding

and support this past year.

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Abstract

Most studies of the interactions between groups on common new product development projects have been concerned with organizations that are physically in the same locale. As corporations continue to grow through normal expansion or acquisition, subdivision of skills, functions and missions is only natural. In some cases, this subdivision will also become geographic. As this growth continues, corporations will increasingly find the need to simultaneously utilize parts of these now diverse subdivisions for developing and producing new products. The resulting organizational structure and project/subsystem interdependence could greatly influence the ultimate performance of these "distributed" projects.

This study investigates the relationship between project/subsystem interdependence and project performance. The data for this investigation was obtained through surveying managers of projects that have been developed by multi-site organizations. The study concludes that interdependence as well as the number of projects supported by the subsystem and subsystem manager, are critical factors contributing to project performance.

Thesis Supervisor: Thomas J. Allen
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Contents

Figures

Tables

Chapter 1. Introduction

As corporations continue to grow through expansion and acquisition, subdivision of skills, functions and missions is only natural. In some cases, this subdivision will also become geographic. As this growth continues, corporations will increasingly find the need to simultaneously utilize parts of these now diverse subdivisions for developing and producing new products. The resulting organizational structure and project/subsystem interdependence could greatly influence the ultimate success of these "distributed" projects. This study examines the relationships between the interactions of subsystems and the primary project and their overall project performance in a complex organizational structure.

Background

Sayles and Chandler[1] pointed out in 1971 that the need for large multi-site organizations to handle new high technology projects, creates an interesting paradox. They suggest that with the trends toward large corporations and technologies that require collaboration of many

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[1] L. K. Sayles and M. K. Chandler, Managing Large Systems: Organizations for the Future, Harper and Row, NY, 1971.

organizations, it will become increasingly difficult to provide the highly innovative environment needed for effective project development. This free-wheeling environment could become stifled due to the "unbelievable (sic) precise integration and coordination necessary between the parts."[2] The discovery of design problems will often require a number of people in a variety of organizations be involved for quick resolution. Hence, the communication requirements in a large multi-site project are overwhelming compared to those of the traditional single location project.

Sayles and Chandler felt that the typical managerial tasks would have to change if companies were going to survive in this environment. No longer could traditional management, based on regularization, routine, and systematic control be used for controlling new large scale projects.

For simplification, this study has been done using one company. While this possibly limits the overall generality of some of the conclusions, this limitation allows investigation of an organizational issue without the problems of trying to equate the many parameters that vary

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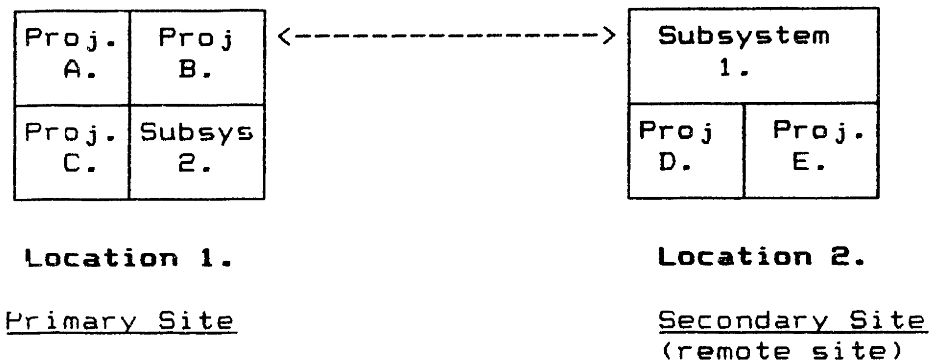
[2] ibid. p6.

greatly across companies (management levels, education levels, task/job boundaries, ...).

There are three basic organizational concepts that will be investigated in this paper. They are **project interdependence, project performance,** and **organizational structure** or complexity. In order to lay the groundwork for further analysis and discussion, an understanding is needed of these three concepts. For consistency, the term **primary project** will refer to that part of the project being performed by the primary site which has responsibility to the company for delivering the final product. The primary project may be part of a larger project that is being done at the same site. The term **subsystem** will refer to that part of the project under consideration that is not being developed by the primary site. The **secondary site** will deliver the subsystem to the primary site (Figure 1.1). For the purposes of this study, the secondary site will always be a remote site.

Figure 1.1 Project/Subsystem Structure



The definition of Primary and Secondary Sites is **relative.** In this example, Project B is primarily being developed in Location 1. This makes Location 1 the primary site. One part of Project B is also being developed at Location 2. This part is referred to as a subsystem. In this case, Location 2 is referred to as the secondary site.

Example 1.0

A better understanding of these relationships can best be demonstrated with an example. Consider a new release of a computer operating system which is usually made up of many independent pieces of software. A project in this study will concern itself with one of the pieces that is being developed jointly by the site which has the primary responsibility for the operating system (primary site and primary project) and another site (secondary site and subsystem) which is acting as a co-developer or subcontractor.

Project Interdependence

The term interdependence has been used in many different ways in the organizational theory literature. Sayer and Chandler refer to interdependence as the "system of inter-organizational exchanges or transactions".[3] They differentiate interdependence from "dependency" by suggesting that dependency is the degree to which a participant receives support from a parent organization. Support includes a variety of items such as resources and financing.

Robbins, in Organizational Theory[4], takes a broader view of interdependence and in essence merges Sayles and Chandler's views on interdependence and dependency. For this study, Robbins' definition of interdependence will be used. It will be further defined as the amount of interaction necessary between the primary project and remote site in order for each to complete its assigned tasks in an agreed upon contract. Interdependence can also be thought of as

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[3] ibid. p71.

[4] S. P. Robbins, Organizational Theory: Structure, Design and Applications, Prentice-Hall, Englewood Cliffs, NJ, 1987.

the degree to which a change in the primary project affects the work activities of the secondary site and vice versa.

Project Performance

For this study, project performance is a measure of the effectiveness of the two organizations (primary and secondary sites) in working together to produce a product for general use. Some of the specific items that can be included in this evaluation are: schedules, costs, resources, and technology transfer. Organizational effectiveness or performance has traditionally been defined as the degree to which an organization has achieved its goals. This traditional set of criteria has received much criticism since goal definition and ownership is very difficult to measure. In Example 1.0, the project performance measurement encompasses both the primary project and the subsystem under study. It does not attempt to evaluate the two pieces separately or, place an evaluation on the overall success of the many independent pieces. The primary reason for this limitation is so that the interaction and performance for a development project being done between sites can be investigated. If the performance of the entire project (the many independent pieces) was used, the relationship of performance with one specific subsystem would be impossible to ascertain. The method used in measuring project performance will be discussed in Chapter 2.

Organizational Structure[5]

Organizational Structure comprises three components: **formalization, centralization** and **complexity** (figure 1.2). Organizational formalization refers to the degree to which jobs within the organization are standardized. With a high degree of standardization, there is little employee discretion as to how the job is to be performed. Conversely, a low degree of formalization allows the employee to perform the job as he/she sees fit. This study will not concern itself too much with the formalization of the specific jobs. The degree of formalization varies by the type of job. The company surveyed goes to great lengths to make job descriptions for many of the standardized job categories fairly consistent across the various company sites. Hence formalization can be considered as constant.

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[5] Basis for this discussion is the textbook Organizational Theory: Structure, Design and Applications by S. P. Robbins, Prentice Hall, Englewood Cliffs, N.J., 2nd edition, 1987.

Figure 1.2 Organizational Structure

Formalization
- degree of task standardization within the organization

Centralization
- degree of concentration of decision making authority within the organization

Complexity
- Horizontal Differentiation
  differences between groups based on education, tasks, orientation
- Vertical (hierarchical) Differentiation
  depth of management structure
- Spatial Differentiation
  degree of geographic dispersion

Organizational structure is also affected by the degree of centralization found in a corporation. The term centralization, when used in this context refers to the degree to which decision making is concentrated at a single point within the corporation. Typically, low centralization (also referred to as decentralization), indicates that decisions are able to be made at relatively low levels within the organization, and typically they do not need the review and approval of many upper level managers. Centralization can also be described as the degree to which the formal authority to make discretionary choices is concentrated in an individual, unit, or level. Robbins points out that centralization is very difficult to measure. Where it is relatively easy to define, finding the real concentration level of decision making can be extremely difficult if not impossible. As with formalization, since this study is concerned with only one company, it will be assumed that the implementation of centralization is fairly consistent.

The third component of organizational structure is organizational complexity, itself comprised of three components. The first of these is **horizontal differentiation.** Horizontal differentiation deals with the degree of differentiation between departments, groups, etc., based on the orientations of the personnel, the nature of the tasks performed, and the education and training levels required. Since the projects with which this paper are concerned are new product development projects, and because they are within the same company, the horizontal differentiation between the groups, both in the same site, and between sites is small with respect to education and the nature of the tasks. Most of the organizations studied were composed of engineers, programmers, managers, and occasionally a technician. Most of the engineers, programmers and managers have bachelor's degrees while the technicians usually have two year degrees from technical colleges[6]. While the horizontal differentiation within the group may be small, the number of other projects and subsystems with which the groups in this study interact may vary widely. Several questions in the survey deal with this part of horizontal differentiation.

The second component of complexity is **vertical differentiation**. Vertical differentiation indicates the depth of the actual management structure (ie, how many levels of management there are between the top management and the operatives). Once again, as this study is concerned with only one company, the variance is very small both within and across sites. This company has specific guidelines regarding the span of control for all managers. Adherence to these guidelines is monitored quite extensively (computers now make this very easy). Hence, like horizontal differentiation, vertical differentiation should not be considered important in addressing

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[6] The data concerning the makeup of the jobs, department members, and education levels is not included in the survey to be discussed later. This data was collected through conversations with the department heads and some technical people.

organizational complexity. The survey includes a question to verify this assumption.

The third component of organizational complexity is **spatial differentiation.** Spatial differentiation refers to the degree to which the offices, plants and personnel are geographically dispersed. Of the projects studied for this paper, all involve one primary site and the development of a subsystem at a remote secondary site. While this condition is common to all, the actual physical distances between sites vary. Since the other components of organizational structure and complexity are held relatively constant, it seems fair to approximate the effect of organizational structure on these projects by the effect created by spatial differentiation.

<u>Company Background</u>

The company involved in this study has over thirty thousand employees. It develops products in high technology fields for worldwide sales and distribution. Recent gross sales revenues were greater than two billion dollars. The company's overall structure has a corporate level, then sectors, divisions, and sites. All of the projects selected involved having some part of the new product developed at a remote site. Hence the organizational structure is an important issue.

Chapter 2. Research Method

Having decided on the overall objectives of this study, there are five major items that must be accomplished. These are: define and establish the project criteria. develop the survey, identify the projects for the survey, administer the survey, and then analyze the results.

Project Criteria

Four basic criteria were used in selecting the projects. First, all of the projects had to be oriented toward **developing** new products. In essence, the product must be (or have been) in a R&D type of organization. The intent of this was to eliminate such organizations as manufacturing where it would be difficult to control for horizontal differentiation.

Secondly, a time frame constraint was established. All selected projects must have been completed within the past year or were scheduled for completion within the next six months. As it was desirable to collect as much first hand information as possible concerning the management of multi-site projects, the recent time frame would help to eliminate the problem of locating participants from long disbanded projects. Since the degree of a project's success has the tendency to become exaggerated as the time since completion increases, this too would be controlled by the imposed time constraints.

Each project must have some part or subsystem being developed at a remote site. This could involve any degree of project splitting or any distance. Finally, the project management must be willing to cooperate with the survey. There would be no forced or "volunteered" cooperation.

The Survey: Intent and Reality

While not labeled as such[7], the questions within the survey fall into five basic categories. These are: basic data, structural data, interdependence and performance data, basic communications, and "what's on your mind?". The first category, basic data, was designed to determine the project length (months), the number of people working in the primary and secondary sites on this project/subsystem, and the type of project that was involved. While none of these data were critical for the specific study, it was felt that they would be helpful in project characterization. If some anomalies did exist, a follow-up survey could be designed with some of these factors taken into consideration.

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[7] Appendix A is a representative copy of the survey used for this study. While the actual physical format varied somewhat from the appendix, the questions were the same.

The second category, structural data, was designed to determine the organizational macro-structure that was involved in the projects. One of the questions requested the locations involved with this project. From these data, the respective divisions, sectors (groups of divisions), and companies (if others were involved) could be determined. The names of other companies were not be collected, just the fact that another company was involved was recorded. This information allowed the calculation of two parameters mentioned previously: spatial and hierarchical differentiation. Knowing the locations of each of these sites allowed the calculation of the actual miles between them (rounded to the nearest 200 miles). From information provided in the company's annual report, an organizational distance number was calculated to measure hierarchical differentiation. Assuming that the hierarchical differentiation was similar at all sites, then the organizational distance number would represent the number of macro-levels of management that are involved before a common level is found for the two sites in question. A number 1 meant that the two sites were in the same division, 2 meant the same sector, 3 meant the same company, and 4 meant different companies.

Along with spatial and hierarchical separation, the survey attempted to determine the type of management structure that existed in both the primary and secondary sites. Specifically, the questions were designed to indicate if the managers and technical people were dedicated to this one project, or were divided in responsibility across several different projects. Dedication to a single project would indicate a project type of management structure, while divided responsibility would indicate some form of matrix management. Sayles and Chandler state that the "higher the degree of dependency [of a satellite project on the primary project], the more apt the satellite is to structure its organization to specifically address the sponsor"[8]. While possibly true in very large projects and subsystems, the validity of this statement is questionable in today's environment of using small pieces of organizations. In defense of Sayles and Chandler, most of their studies involved very large Department of Defense or NASA projects.

The next section of the survey gathered the data necessary to measure project interdependence and performance. It became obvious in the first two interviews that explaining

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[8] L. K. Sayles and M. K. Chandler, Managing Large Systems: Organizations for the Future, Harper and Row, NY, 1971, p75.

interdependence in few enough words to be read, yet enough to prevent widely different interpretations was going to be extremely difficult. It was solving this dilemma that necessitated an interview based study rather than a simple mailing. Another problem also surfaced. It was very difficult for the project managers to give one combined interdependence evaluation for both sites. In some cases, the managers indicated that the dependencies between sites were at extremes. If they were to average the two numbers, some valuable data might be lost. As such, the survey was designed to collect two interdependency evaluations. The managers were asked to evaluate the relative number of times a change in the subsystem resulted in a change in the primary project and likewise, evaluate the number of times a change in the primary project resulted in a change in the subsystem. After splitting the interdependency evaluation as described, the managers felt much more comfortable making the evaluation. Overall, there was very little disagreement between the managers or technical people involved with these evaluations.

Performance evaluations, while somewhat more easily substantiated with objective measures than interdependencies, were also causes of concern for the managers questioned. Their biggest concern was how to condense the criteria that compose performance, into one numerical evaluation. The response to this question was often determined by the managers in two ways. First, the manager gave an evaluation based on his "gut" reaction to the question. Then, he/she made an individual evaluation of each of the criteria mentioned in the survey (schedule, costs, product functions as expected). The manager averaged these individual evaluations to arrive at an overall project evaluation. In most cases, the two methods (gut reaction and individual evaluation) produced identical results. In all cases, the value recorded for the survey was that value the manager felt best represented the actual overall project performance, regardless of the method used.

The performance and interdependence section of the survey, while being the most important section for this study, is also the section most prone to error. These questions deal with feelings and evaluations by people of a variety of viewpoints and experiences. Their responses while accurate in themselves, are based on their own past experience. What is average for one person could be an extreme for someone else. In all cases, these responses were discussed with at least two people and a "group" consensus was used. While reducing some of the variance, it still leaves room for possible error. Obviously, this is one of the problems encountered when doing organizational research on small groups with small sample sizes.

The next section of the survey was designed to gather data regarding the types of practice used in establishing a remote subsystem. It is important to investigate where and how the subsystem requirements and specifications were developed and to see whether this has any direct influence on interdependency or performance. Along the same lines, the question of personnel assignments or transfers (seedings) was raised. Both of these factors may affect project interdependence. Transferring skills, while breaking down some of the spatial barriers, can create skills shortage hence making the one site even more dependent on the other. Likewise, a subsystem accepting specifications from a primary site, could have increased dependence on that site.

The final section of the survey was intended to allow the survey participants to express their feelings and thoughts on the topic of what it takes to successfully manage projects across geographically dispersed sites. These comments are valuable as they come from a group of managers who have experienced both success and failure in these types of project.

With the project criteria and survey definition completed, it was possible to approach the company for assistance in identifying projects. Approximately fifteen projects were desired so as to have some degree of statistical significance in the results.

Project Identification

Identifying the potential projects for study involved meeting with several of the company's executives. They were able to identify many potential projects that met the selection criteria. From this list, phone contacts were established and follow-up letters with sample surveys were sent to the project managers. The letter was intended to describe in detail the nature and purpose of the study and to solicit their assistance. For their cooperation, the managers were offered summary statistics of the survey and the satisfaction of having helped someone with a MIT thesis. Approximately fifty percent of the candidates agreed to participate in the study.

The Survey Process

The survey was developed to gather data on the relationship between project interdependence and performance in multi-site projects. Initially, the survey was to be sent to those project managers identified in the project identification process. The original plan called for doing the first two surveys in an interview fashion so as to be sure that the surveys were clear and the data returned would be meaningful and accurate. Then, the remainder of the surveys would be sent out to the managers who had volunteered their participation.

The initial two interviews showed some problems in interpreting some of the questions. The interviewer's assistance was needed for clarification and further definition of some of the terms used (project interdependence, performance, etc.). This resulted in the survey taking longer than originally anticipated. However, the dialogue and information gathered during the interview process was very helpful. As a result, the decision was made to interview all of the managers, either in person or by telephone. This change in process had two effects on the data collected. First, with the interviewer present, there were undoubtedly some interviewer biases generated. These result from the word choice, intonation, and gestures that any interviewer uses when conducting a session. The second effect, and most likely the more significant one, was the willingness of the respondents to "work" the questions. All of the participants showed extreme interest in answering all of the questions to the best of their ability. The quality of the responses was undoubtedly better than if the surveys had been mailed. One additional bonus generated by the personal interviews was the fact that the results were available immediately. There was no waiting for someone to fill out the forms or for the mailing process to return them.

Analysis

There were two forms of data collected from the surveys. First there was the direct responses to the questions on the survey. In addition however, there were the questions and responses that arose throughout the interview. Many of these comments were captured in the next to last two survey questions. The first set of data was analyzed using the SPSS/PC+ statistical analysis package available for personal computers from SPSS Inc.[9]. The results of this analysis along with the analysis of the other responses is presented in the next chapter.

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[9] SPSS Inc. 444 N. Michigan Avenue, Chicago, Illinois.

Chapter 3. Results and Analysis

General Overview

The survey was conducted over a two month interval with fifteen different new product development projects. The majority of the projects involved hardware or microcode design and development. The average duration of the projects was thirty seven months while the average number of people working on them was eighteen at the primary site and twenty-one at the secondary site. As mentioned in Chapter 1, this study examines the performance-interdependence relationship between primary and remote development organizations. The number of people involved with the projects (primary and subsystem) reflect the number of people in the respective sites who are directly involved with the joint development project. In all cases, the total number of people on any one large project was significantly greater (at least an order of magnitude) than the number of people involved with the one specific subsystem. Appendix B contains a summary showing the distributions of responses to the survey categories.

The company involved in this study is a high technology based company, hence the large distribution of projects in the hardware/logic design and microcode disciplines, while few in the software or more application oriented areas.

The "testing" project was a project specifically involved with the testing of a new product design. The testing was performed within the new product development organization. As such, this project fell within the criteria for selecting projects for this study.

Appendix F provides a summary of the statistics generated through correlating all of the variables identified and measured in this survey. Three categories of data have significant correlation with project performance: interdependence, the number of projects a remote site manager is responsible for, and the number of projects supported by the subsystem. Appendix G provides the first order (partial) correlations of these relationships with all other measured variables.

Performance and Interdependence

The primary purpose of this study is to determine if a correlation exists between project interdependence and project performance. For the reasons mentioned in the previous chapter, project interdependence was measured as the interdependence of the primary site with the secondary site and vice versa when one or the other required a design change. The correlation of these variables with performance is shown in Table 3.1.

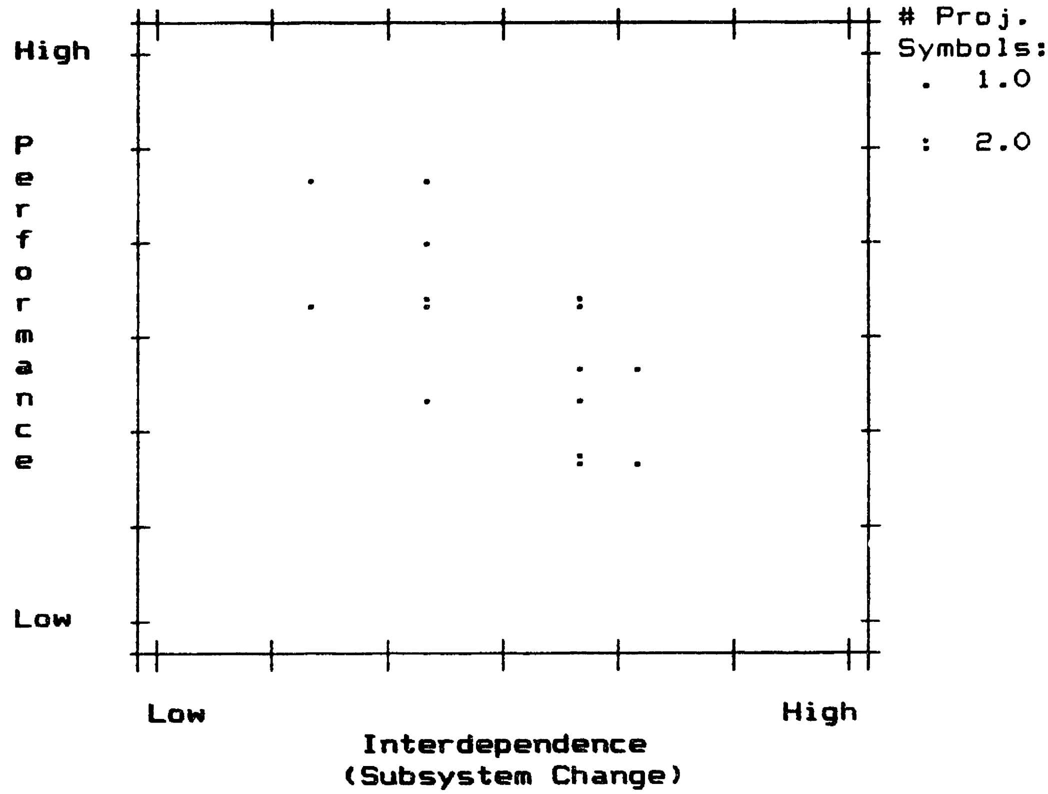
Table 3.1 Project Performance and Interdependence Correlations

	Performance
Interdependence (Subsys change effects on Proj.)	-.66*
Interdependence (Proj. change effects on Subsys)	-.04

1-tailed significance: * - .01

The results indicate that there is indeed (at least for this sample of projects) a significant negative correlation between project performance and the degree of interdependence of the primary site on secondary site changes (Figure 3.1).

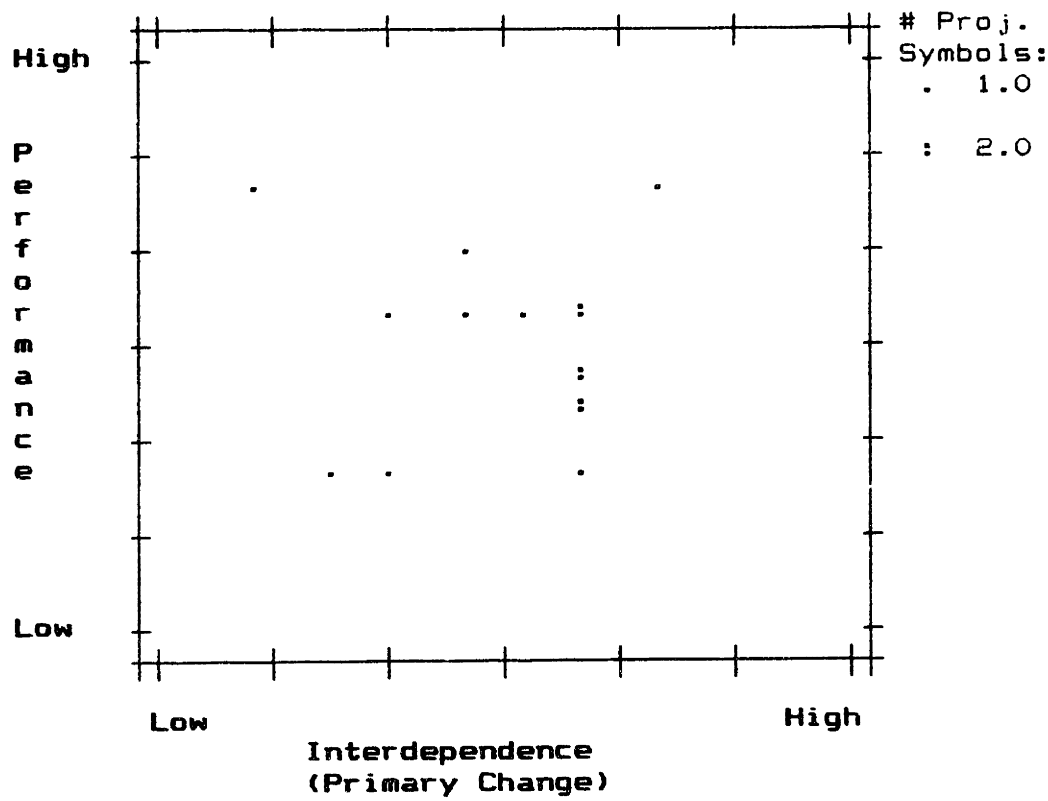
Figure 3.1 Project Performance and Interdependence of Primary Site on Secondary Site Changes.



This correlation indicates that as the degree of interdependence increases, project performance decreases or, low interdependency results in higher project performance when compared to high interdependency.

The correlation coefficient for performance with respect to the degree of interdependence of the secondary site on the primary site, for changes instituted by the primary project, is well below the level of statistical significance.

Figure 3.2 Project Performance and Interdependence of Secondary Site on Primary Site Changes.



Looking at the scatterplot (Figure 3.2) it appears that there would be some correlation if three outlying projects are removed. Examination of the three projects, however, shows no obvious statistical or organizational evidence for ignoring them. Comparing these three cases to the others, the only element that appears to distinguish them is the fact that these three projects were evaluated at the extremes for performance. This fact alone however, indicates nothing significantly different about them to cause them to be considered separately. Hence, there is no statistically significant correlation between project performance and interdependence for those cases when the primary project requires a change to the specifications.

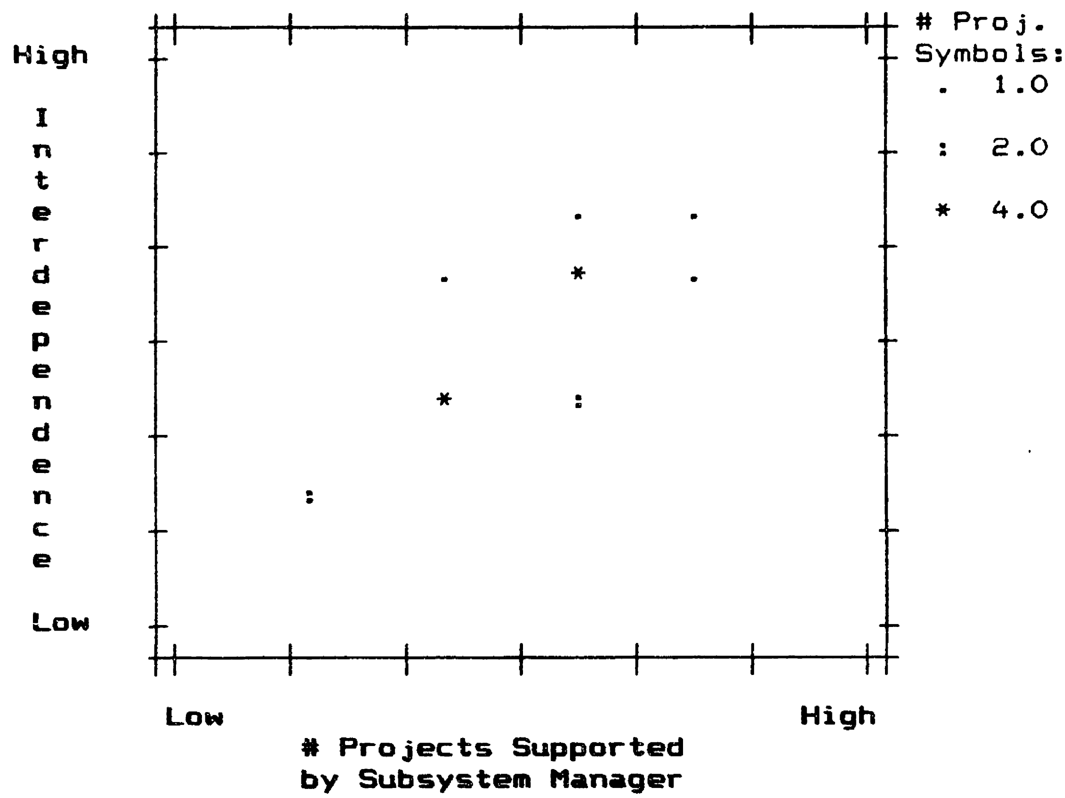
One possible explanation of this may be the source of project change. In this study, project performance is a measurement of the overall performance of the project. It would seem reasonable to expect that changes initiated by the primary project would have been screened so as to minimize the effect on overall project performance. If this is true, the correlation of performance and interdependence of the primary project and remote subsystem, for changes initiated by the primary project, would be negligible. Additional data is necessary to statistically substantiate this hypothesis.

First Order Effects

The project performance-interdependence relationship is affected significantly by the number of projects that a manager at the remote site is supporting. Appendix G shows that when controlling for the number of projects, the performance-interdependence relationship decreases sixty-two percent.

Statistically, the reason for this relationship is that the correlation between interdependence and the number of projects supported by subsystem managers (.78 with a .001 one-tailed significance). This indicates that there is a very strong positive relationship between the number of projects that a manager is supervising and the interdependency of his subsystem with the primary project (Figure 3.3).

Figure 3.3 Number of Projects Supported by Subsystem Managers and Interdependence.



Perhaps this is due to the reduced amount of time that the manager is able to devote to any one project, especially in the early stages of planning and development. The results of this study show that interdependence is variable across projects. As defined in Chapter 1, interdependence is the amount of interaction necessary between the primary project and the remote site in order for each to complete its assigned tasks in an agreed upon contract. Decisions or lack thereof by the managers could influence the "amount of interaction" that takes place. A manager supporting many projects may not be able to make all of the necessary (or best) decisions. For example, failure to adequately define a product interface that will be used by the primary project and the subsystem may cause a large degree of interdependence. Not having the well defined interface could have come from the manager's lack of attention to this one detail because of concentrating on "more important problems" that arose on another project. The specific factors influencing interdependence would make an interesting follow-on study. The data gathered in this survey provides little insight into this area.

Performance and Number of Projects Supported by Managers

Survey question three, "number of projects supported by managers", gathered data to determine the type of organizational structure (functional verses project) in which projects and subsystems were being developed. At both the primary and secondary sites, any manager may be responsible for the development of more than one project or subsystem. As the number of projects increases, the number of interfaces increase and thus the overall complexity of the manager's job. This increased complexity could influence overall project performance. Table 3.2 shows the correlation coefficients for performance and the number of projects supported by managers at the primary and remote sites.

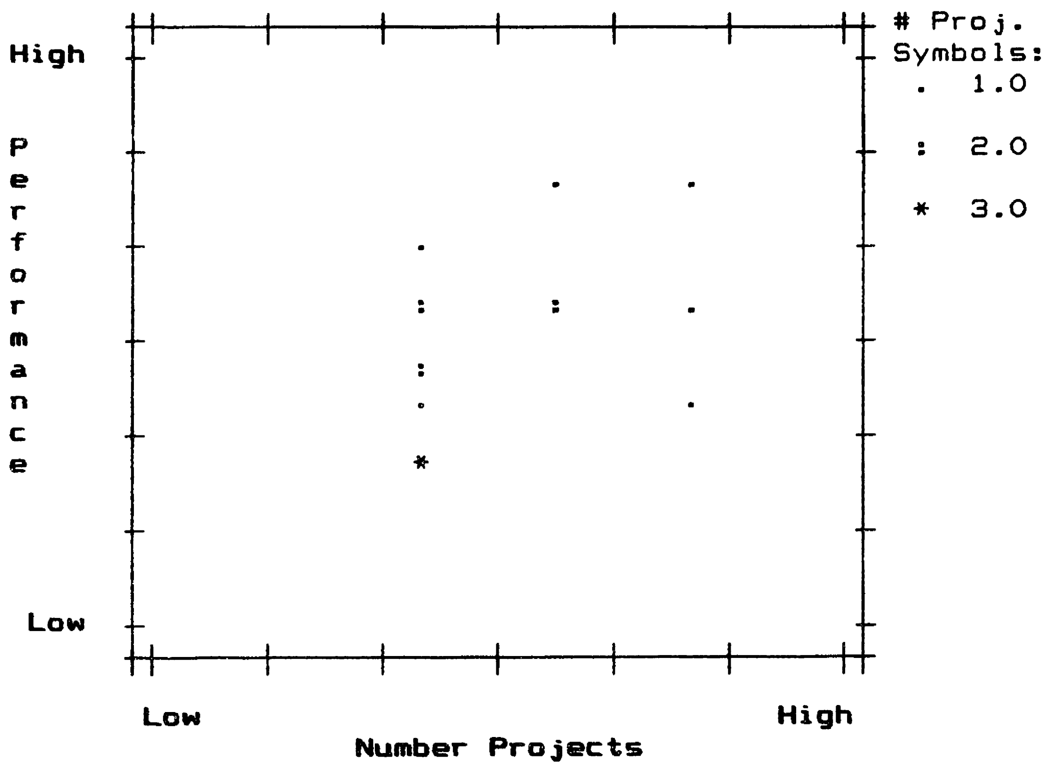
Table 3.2 Correlation of Project Performance and Number of Projects Supported by Primary and Subsystem Managers

	Performance
Number of Projects Supported by Primary Mgr	.41
Number of Projects Supported by Subsys Mgr	-.70*

1-tailed significance: * - .01

The low correlation (statistically insignificant) of performance with the number of projects supported by managers at the primary site is indicative of the large number of managers that were working on only one project (60%). For subsystem managers, there is a definite negative correlation indicating that overall project performance decreases as the number of projects the subsystem manager is supporting increases. This most likely represents the increased job complexity that these managers are experiencing. The scatterplots of these relationships are shown in Figures 3.4 and 3.5.

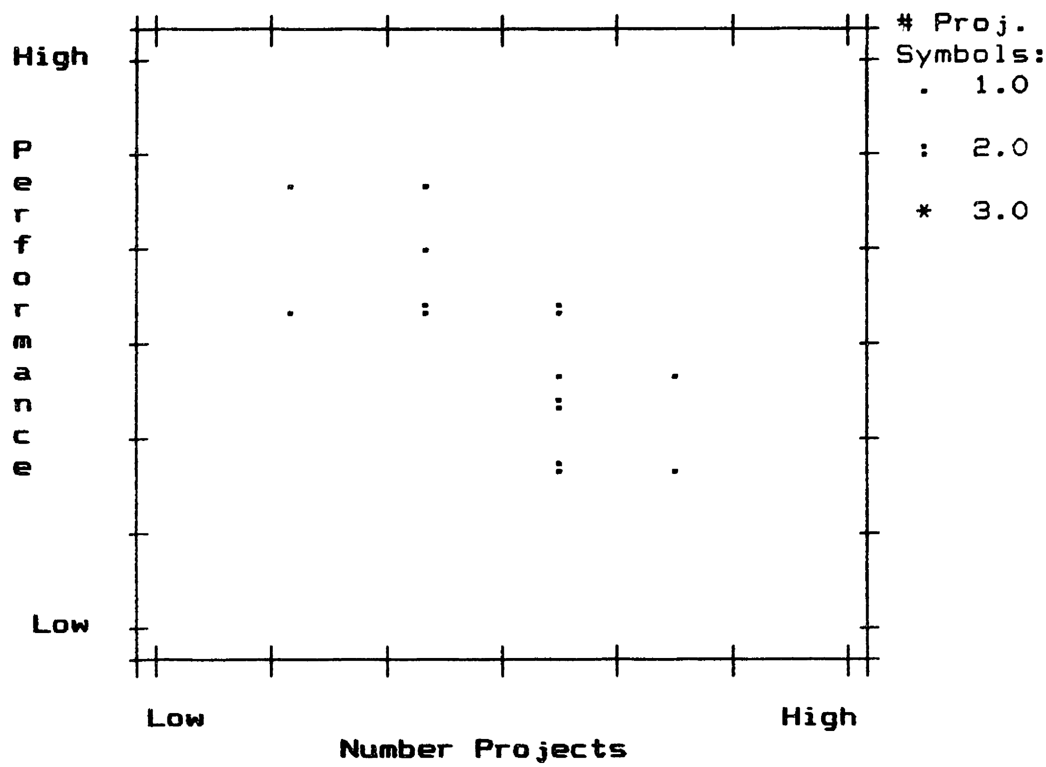
Figure 3.4 Project Performance and Number of Projects Supported by Managers at Primary Site



First Order Effects

The "project performance" and "number of projects supported by subsystem managers" relationship is affected significantly by interdependence. Appendix G shows that when controlling for interdependence, the performance-number of projects deceases forty-two percent. This is the same relationship discussed in the performance interdependence section.

Figure 3.5 Project Performance and Number of Projects Supported by Managers at Secondary Site



A significant negative correlation exists between the number of projects supported by managers at the primary site and the number of projects supported by managers at the secondary site (Table 3.3). Since primary sites are seldom organized functionally, the remote sites are more likely to be organized with a functional structure. This is contrary to what Sayles and Chandler found in their studies of large Department of Defense and NASA projects[10]. An explanation of this difference is not immediately obvious. Perhaps it is due to restrictions placed on the remote sites by the primary contractors. In this study, these remote groups offer a common service to any project located at any site. In most cases, these groups are supporting primary projects at many sites. Their organizational structure is functional by design.

Table 3.3 Correlation of Number of Projects Supported by Managers at Primary and Remote Sites

	Correlation
Correlation Between Number of Projects Supported by Managers at Primary and Remote Sites	-.61*

1-tailed significance: * - .01

Performance and Number of Projects Supported by Subsystems

Survey question nine gathered data measuring the number of projects that any specific subsystem was supporting. It is possible for a manager to be managing only one subsystem, but that subsystem could be used in many other projects.

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[10] L. K. Sayles and M. K. Chandler, Managing Large Systems: Organizations for the Future, Harper and Row, NY, 1971.

While the manager's number of internal interfaces are low (for the case when managing only one subsystem), the number of external interfaces may be large (when supporting many projects). This large number of projects increases the complexity of the manager's job and the subsystem design and hence, could affect the performance of any one project.

The degree of complexity is further increased by the numerous contradictory demands that may be placed on the subsystem by the different projects. Problems like priority of functions needed, costs, schedules, etc. will most likely be different among the projects. For example, where cost of the subsystem may be of utmost importance for some projects, delivered function may be more important for others. The subsystem manager will often be placed in the position of having to negotiate and manage these differences. Not only does this increase the complexity of the task for the manager, but often it results in subsystem designs that are not optimal for any specific project.

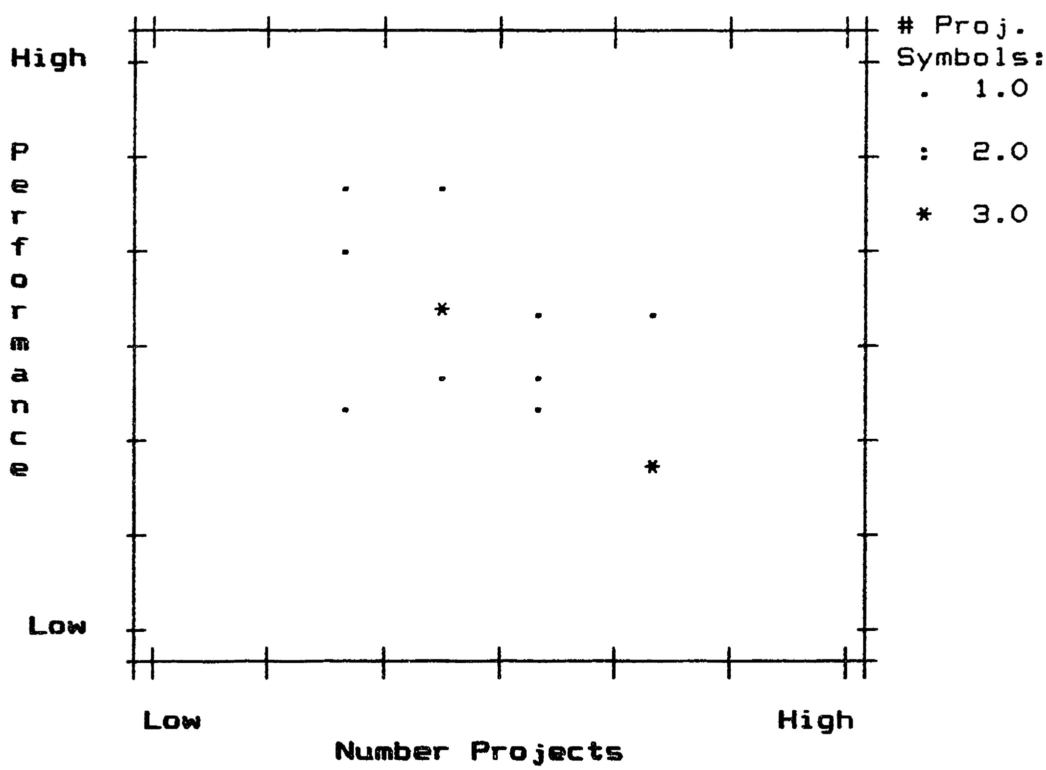
There is a definite negative correlation (Table 3.4) indicating that performance decreases as the number of projects supported by the subsystem increases (Figure 3.6).

Table 3.4 Project Performance and Number of Projects Supported by Subsystem

	Performance
Number or Projects Supported by Subsystem	-.63*

1-tailed significance: * - .01

Figure 3.6 Project Performance and Number of Projects Supported by Subsystem



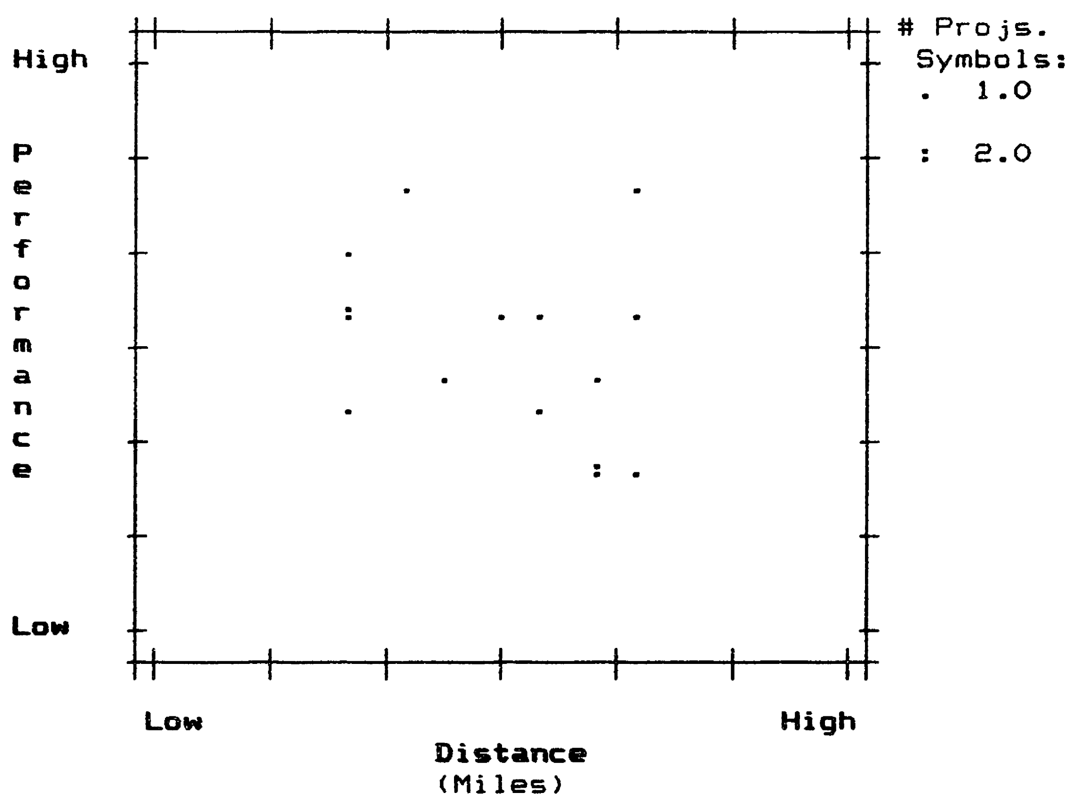
This most likely represents the increased complexity experienced by the managers and the non-optimal subsystem design. The subsystem managers are dealing with more organizations, more projects and hence more uncertainty. These positions would require much negotiation and compromising in order to satisfy the requirements from the many different interfaces. As the number of interfaces increases, these negotiation skills will become even more important for the success of multi-site projects.

The number of projects supported by a subsystem often indicates a degree of compromise on the subsystem design. Design compromise may affect project performance; a non-optimally designed subsystem may cost more or provide fewer functions than an equivalent subsystem designed exclusively for one project. Since cost and function are components of project performance, it follows that an increase in the number of projects supported by a subsystem adversely affects project performance.

Affects of Spatial Separation on Performance

Another topic of concern to this study is the question of whether there is any relationship between the performance of a project and the spatial separation of the primary and secondary sites. The correlation between performance and spatial separation is -0.31. While this is somewhat negative (high performance and small distances or, low performance with large distances), the overall significance of this figure is questionable. Figure 3.7 shows the scatterplot of the relationship. From this chart, there appears to be no significant correlation of project performance and distance separating the sites concerned, given that all of the projects were being performed at more than one site.

Figure 3.7 Project Performance and Distance (mi.) Between Primary and Secondary Sites.



These data do not allow the conclusion that distance isn't important. Another study would need to be performed which includes surveying the performance of projects that were done within the confines of one location. Such a comparison would allow further analysis and conclusions. As this was not done in this study, no conclusion can be reached. If there is anything reassuring that can be drawn from this analysis, it is that sites with 1200 miles separation have no more difficulty in coordinating projects than do those with only 200 miles separation.

Macro-Organizational Distances

The organizational distance between the primary project and the remote site (hierarchical differences in divisions, sectors, and companies) shows no statistically significant correlation with any of the other study categories. This indicates that like spatial separation, there is no significant difference in coordinating projects that are separated by organizational boundaries and distance, given that they are going to be separated. A more complete study including projects that are not organizationally separated would be necessary for more specific conclusions.

Requirements and Specifications

Two questions collected data on the origin of subsystem requirements and specifications. The correlation of these data with performance and interdependence shows very little statistical significance.

Transfers or Cross-training

The measured effect of the transfer or seeding of personnel on project performance and interdependence is statistically insignificant. Perhaps a larger sample would reveal different results, but for the data collected, personnel transfers had little effect on either project performance or interdependence.

Performance Model

Of the many variables measured, three have been shown to have a statistical primary (zero order) effect on project performance. These are interdependence (for changes made by the secondary site), the number of projects that the subsystem is supporting and, the number of projects supported by the subsystem manager. It would be useful to have a model that described project performance based on the various project characteristics measured in this study. While the model is not globally applicable, it will give some indication as to the relative importance of the sixteen catagories measured in this study on project performance.

The SPSS/PC+ stepwise multiple regression procedures were used to build this project performance model. The default criteria for adding or removing a variable from the model were modified to allow more variables to be entered (PIN = .3, POUT = .35). The final decision on whether the variable was retained or omitted from the model was the statistical significance of the variable's coefficient within the model. The coefficients for all variables selected must have at least a probability of .95 of not being zero. The results of the regression are shown in Table 3.5.

Table 3.5 Project Performance Model

Variable	B
# Proj. Supported by Subsystem	-1.26
Interdepen.(Sec. change)	-.39
Project Length (mos)	.03
Interdepen.(Prime change)	.39
Cross Training	-.64
Org. Distance	.66
# Projs Tech Person Resp. for at Prime	1.09
Subsystem Specifications	.55
Subsystem Requirements	.48
# Projects Mgr Resp for at Sec	-.46
Phys. Distance	.11
# Staff at Primary Site	.01
(Constant)	2.62

Notes:
For each individual variable, P(B=0) < .05
For model, P(all B = 0) = .0015
Variables listed in Beta Rank Order (High to Low)

Of the sixteen independent variables measured in this study, twelve are included in the model. The categories: project type, the number of projects supported by managers and technical people at the secondary site, and the number of persons at the secondary site, were not included in the model as the probability of their coefficients not being zero was less than 0.95. Appendices H and I contain the detailed results of this multiple regression.

Based on the variables' beta factors, the "number of projects supported by a subsystem" and "project interdependence" are the two most significant factors influencing project performance. Their signs indicate a negative relationship with performance as would be expected from earlier discussion and analysis. The coefficient for the variable "number of projects supported by remote site manager" also has the expected negative relationship with performance. While this variable had the largest correlation with performance, it ranks tenth in importance within the model. The coefficients for the development of the subsystem specifications and requirements imply that project performance increases the more the specifications and requirements are developed by the remote sites. This seems consistent with current management practice.

Some of the coefficients are questionable. The signs of the coefficients for physical and organizational distance are positive. This implies increased performance as the primary and secondary sites become further separated (hierarchically and physically). Interdependence (for primary changes) also has a positive coefficient. Both seem contrary to what is expected. The coefficient for cross training is negative. This implies that increased cross training reduces project performance; a non-intuitive suggestion. These questionable relationships involve variables that show little or no significant statistical relationship with project performance. In this multiple regression, these variables are taking on the characteristics of the projects studied. Interpretation of their relationship with project performance must be done cautiously.

"What Do You Really Think?"

The preceding part of this chapter summarizes and analyzes the results obtained from the first nine survey questions along with the overall project descriptions. The second part of the survey asked the project managers open ended questions about what they thought made a multi-site project run smoothly or, caused major problems. Summaries of their responses are included in Appendices B and C.

The responses to the first question ("What was the most important item that lead to the success of this project?") fell into two categories: communications and process. Several respondents indicated that the success of the project was due to the sharing and exposure to new ideas, contacts with other "cultures" (sites), the experience of working with other sites, having a larger experience base, transfer of skills, exposure to new tools and processes, and hard working people. While the items on this list are very difficult to quantify and measure, the managers felt these items were significant factors influencing a successful multi-site project. In general, the comments indicate that the ability to use a large group of people with diverse backgrounds (both in locations and experience) will help all sites involved through increased education and the communication and sharing of more ideas.

The second set of items that lead to the success of projects are in areas of process and project control. The managers felt that items such as one site with full responsibility and, having one specific solution in mind from the beginning, were important for a successful multi-site project. The difference in these two types of responses supports the paradox described by Sayles and Chandler[11]. It is indeed important to provide an environment where there is a free flow of information, ideas, and proposals, related to a specific project. Yet there is also the need for tight controls and, someone with authority to make decisions.

The importance of control and authority is further emphasized by the responses to the question, "What was the most troublesome item that affected this project?". Very few of the managers failed to reply to this question.

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[11] ibid.

Their responses primarily address problems of control, communications, and working with subsystems that were supporting other projects. Many of the managers expressed problems with having to compromise their project because of demands placed on a subsystem by other projects. The managers indicated that subsystems with many users, had difficult times establishing priorities. Problems such as who gets the first set of parts, the best response for problem resolution, etc. were common. One other set of responses indicate that there are problems with site cultures. Words and phrases describing organizations and tasks, that were common to many sites, actually had different meanings. For example, a testing organization in one site may actually perform the tests while in another site, they may "monitor" the developers performing the test. While the words used to describe the organization are the same, their function is very different depending on location. The failure to recognize and comprehend these differences was indicated by many managers as one of the most severe difficulties encountered.

As anticipated, other problems mentioned were: control of software and hardware levels across multiple sites; longer response times for fixing problems; too many coordinators, and too many managers. In general, the respondents felt that these problems were relatively easy to solve compared to those mentioned previously. As a result, all too often the critical problems went unresolved until a real crisis occurred.

All of the managers surveyed had recommendations for what it takes to have a successful multi-site project. Their responses are summarized in Appendix E. Most of the responses center around providing means for excellent control, prioritization, and communications. The managers felt that multi-site projects need to be more highly structured than if the same project was done at one site. The decision as to what part of the project should be done as a subsystem should be based on logical boundaries of the product, along with the skills and expertise that are available. There needs to be a formalized method of determining priorities, and in addition, a means recognized by all parties involved for resolving problems quickly. Accountability and ownership of the many parts must be clearly established from the onset. The communications between the various groups must be frequent and of high quality. Many of the managers recommended face to face meetings. In general, the managers felt that the key to making a multi-site project work was being able to communicate and compromise effectively and quickly.

The responses to the second part of the survey serve as a good summary for the first nine questions. While few managers mentioned interdependence specifically, they did bring up and discuss many of the factors discussed in Chapter 1 that comprise project/subsystem interdependence. The responses indicate that control, communications, and negotiation are all necessary for a successful multi-site project.

Chapter 4. Conclusions

As technologies become more complex and corporate resources more widely dispersed, the number of projects that span sites will continue to increase. Managers of multi-site projects should recognize a set of critical factors that influence project performance. This study demonstrates that project performance is affected by interdependence, the number of projects supported by the subsystem, and organizational structure. The results of the survey indicate that the higher the degree of interdependence, the lower the overall project performance. Likewise, the larger the number of projects supported by the subsystem or subsystem managers, the lower the project performance. Accordingly, project managers should attempt to conduct projects entirely at one location, or if that is impossible, select remote subsystems that are dedicated to their project. The increase in product cost that this decision may incur must be balanced with the decrease in project performance that may otherwise result. In all cases, the number of interfaces that the managers confront should be minimized.

The effects of spatial separation and organizational distance on project performance are insignificant for multi-site projects. Regardless of whether the secondary site is within two hundred miles or twelve hundred miles, within the same division or different companies, there is little affect on project performance. This does not suggest that spacial differentiation never affects project performance. Further research would need to be undertaken to compare the performance of single site projects with the performance of multi-site projects. This study concludes that once the decision is made to develop a project at multiple sites, the secondary sites should be chosen based on factors other than organizational or physical distances.

The managers who participated in the survey stated that there were advantages and difficulties associated with projects that spanned sites. They indicated that the educational advantages of sharing ideas, learning different development processes, and being exposed to other site cultures, partially compensated for the problems encountered. The problems most often experienced were prioritization of resources across projects, difficult communications, and controlling the development process. The managers recommended better initial planning, establishing controls and procedures for more effective and rapid problem resolution, and more frequent communications between all participants. Face to face dialogue was considered an absolute necessity for honest, effective communications. Careful planning must be performed in order to establish the right amount of controls and organizational structure to prevent over burdening the development process.

While this study was based on a small number of projects within one company, it strongly indicates that for multi-site projects, organizational complexity and project interdependence affect project performance. Managers should be aware of these factors when planning and organizing projects that span multiple locations.

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Appendix A. Project Interdependence Survey

Note: The wording of this survey is identical to the original used for the actual data collection. The format has been altered so that it is reproducible in this paper.

Project Interdependence Survey

Project: ______________________________ (name)

Subsystem: ____________________________ (name)

Locations: ____________/____________ (primary/secondary)

Type: ______________________________ (hardware, ...)

Please answer the following questions to the best of your ability. In all cases, project refers to the project identified above.

Please return the completed survey as soon as possible to:

Mark S. Harris
11 Lilac Court
Cambridge, MA 02141
Telephone 617-576-3925

Thanks again for your participation.

1. How long has your project been in existence?

_____________ months

2. How many people are working on your project full time

at this site? _____________ people

at remote site? _____________ people

3. Is the management team (include both sites) dedicated to this project or are they also working on other projects? Please check one box for each site.

Primary	Remote	
☐	☐	Dedicated to this project
☐	☐	working on one other project in addition to this project
☐	☐	Working on two other projects in addition to this project
☐	☐	Working on more than two other projects in addition to this project

4. Are the technical people dedicated to this project or are they also working on other projects? Please check one box for each site.

Primary	Remote	
☐	☐	Dedicated to this project
☐	☐	working on one other project in addition to this project
☐	☐	Working on two other projects in addition to this project
☐	☐	Working on more than two other projects in addition to this project

5. **Subsystem Interdependence** can be defined as the amount of interaction necessary between the main project and subsystems in order for each to complete its assigned tasks. It also can be thought of as the degree to which a change in the primary project affects the work activities of the various subprojects.

Please estimate the degree of interdependence between the main project and the remote subsystem development organization on the form below. For the line labeled "Primary Project Change", estimate the degree of impact that the majority of changes have had on the subsystem identified on page 1. A degree of "7" means that for every type of Primary Project change, the subsystem was required to make some type of appropriate change to its development plans. Conversely, a degree of "1" means that for every type of Primary Project Change, the subsystem required no changes. Then perform the same evaluation for changes made by the Subsystem: determining the degree of impact on the Primary Project.

Please evaluate the overall performance of this project to the best of your ability. Some factors to consider are:

Time to complete compared to other similar projects
Costs as projected
Product as expected

		Degree of Interdependence						
System		very high			moderate			very low
Primary Project Change		7	6	5	4	3	2	1
Subsystem Change		7	6	5	4	3	2	1
Performance		7	6	5	4	3	2	1

6. Where did the subsystem requirements for this project come from? Please check only one box.

- ☐ Prime project site.
- ☐ Developed completely by the subsystem organization.
- ☐ Jointly developed by prime site and the subsystem organizations.
- ☐ Other (please specify). ______________________

7. Where did the subsystem technical specifications for this project come from? Please check only one box.

- ☐ Prime project site.
- ☐ Developed completely by the subsystem organization.
- ☐ Jointly developed by prime site and the subsystem organizations.
- ☐ Other (please specify). ______________________

8. Did any personnel "seeding" occur between sites? Please check only one box.

- ☐ None
- ☐ 0 - 10% of the organizations came from remote primary sites
- ☐ 10 - 25% of the organization came from remote or primary sites
- ☐ greater than 25% of the organization came from remote or primary sites

9. How many different projects is the subsystem supporting (including this project)?

____

10. What was the most important item that led to the success of this project (person, process, ...)?

____

____

____

11. What was the most troublesome item that affected this project?

____

____

____

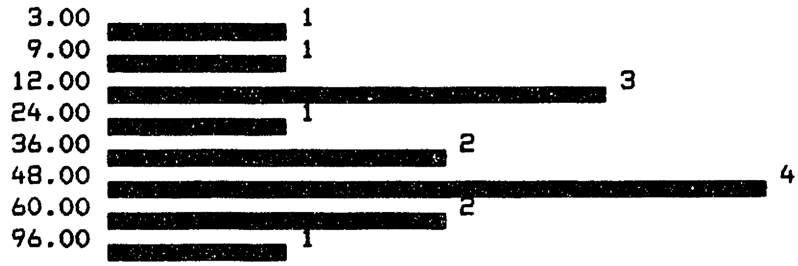
12. Would you like to receive a copy of the overall compiled statistics from this survey?

☐ Yes

☐ No

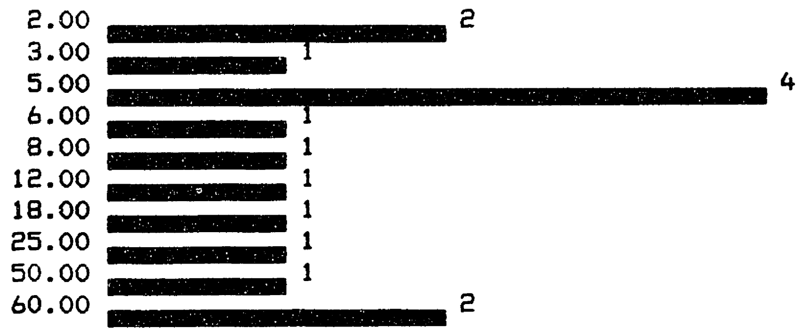
Appendix B. Survey Results

Project Length (months)



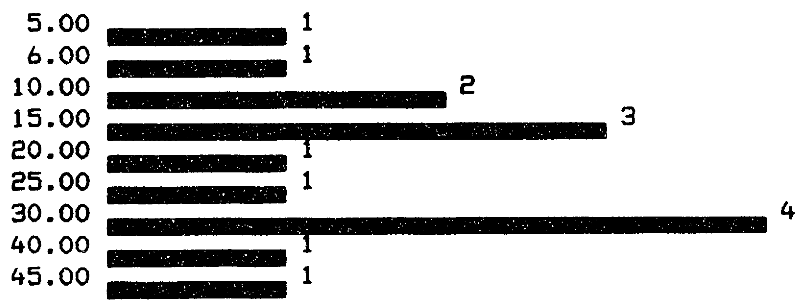
Mean	36.800	Std Dev	25.366
Minimum	3.000	Maximum	96.000

Total Number of Project Staff at Prime Site



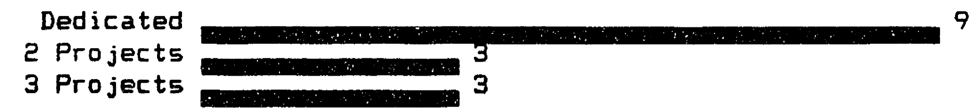
Mean	17.733	Std Dev	21.201
Minimum	2.000	Maximum	60.000

Total Number of Subsystem Staff at Secondary Site



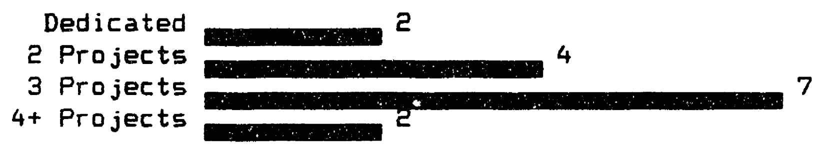
Mean	21.733	Std Dev	12.250
Minimum	5.000	Maximum	45.000

Number of Projects Manager Responsible for at Primary Site



Mean	1.600	Std Dev	.828
Minimum	1.000	Maximum	3.000

Number of Projects Manager Responsible for at Secondary Site

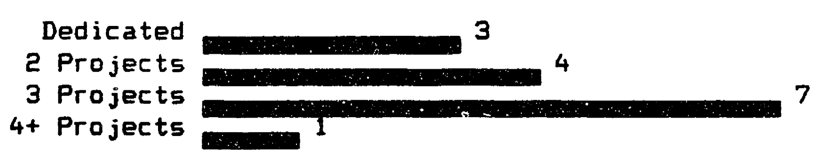


Mean	2.600	Std Dev	.910
Minimum	1.000	Maximum	4.000

Number of Projects Technical Person Responsible for at Primary Site

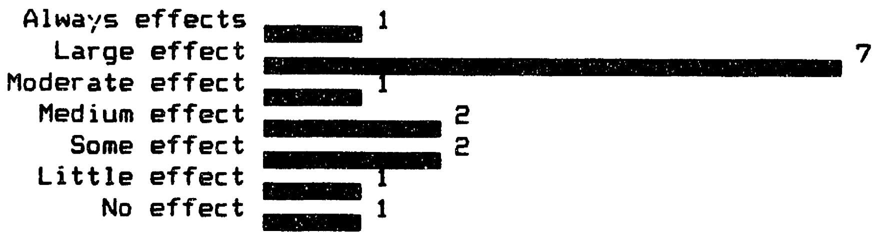
Mean	1.133	Std Dev	.516
Minimum	1.000	Maximum	3.000

Number of Projects Technical Person Responsible for at Secondary Site



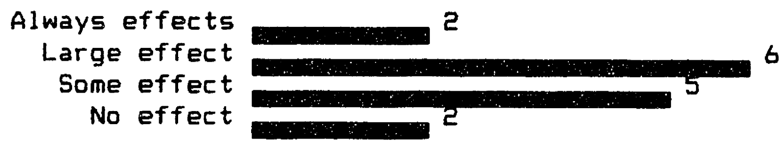
Mean	2.400	Std Dev	.910
Minimum	1.000	Maximum	4.000

Interdependence (How changes to Primary affect Subsystem)



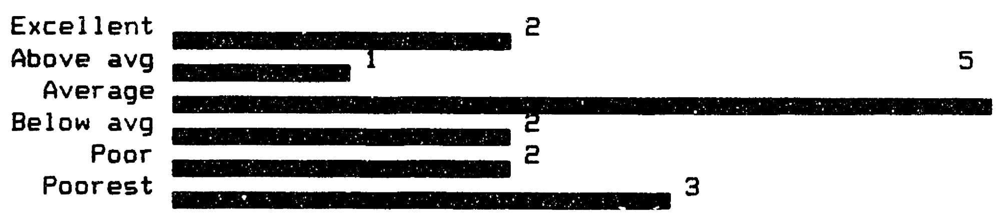
Mean	3.267	Std Dev	1.792
Minimum	1.000	Maximum	7.000

Interdependence (How changes to Subsystem affect Project)



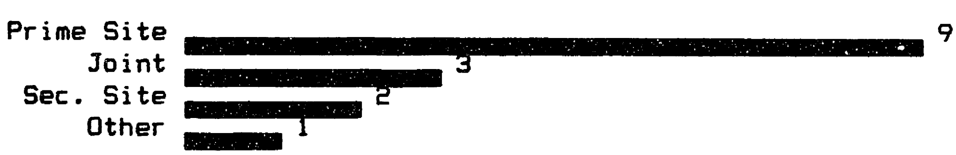
Mean	3.533	Std Dev	2.100
Minimum	1.000	Maximum	7.000

Project Performance



Mean	4.667	Std Dev	1.676
Minimum	2.000	Maximum	7.000

Subsystem Requirements Developed by:

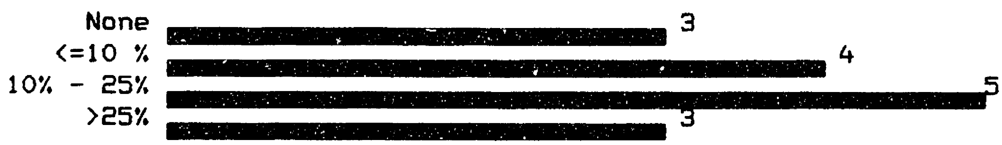


Mean	1.667	Std Dev	.976
Minimum	1.000	Maximum	4.000

Subsystem Specifications Developed by:

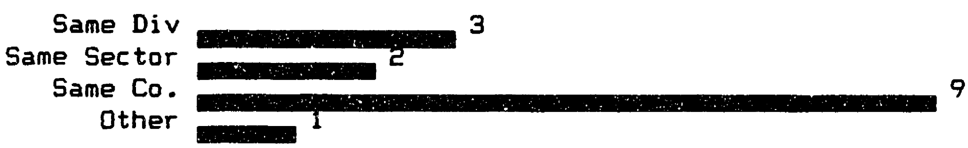
Mean	2.267	Std Dev	.884
Minimum	1.000	Maximum	4.000

Cross Seeding of Personnel:



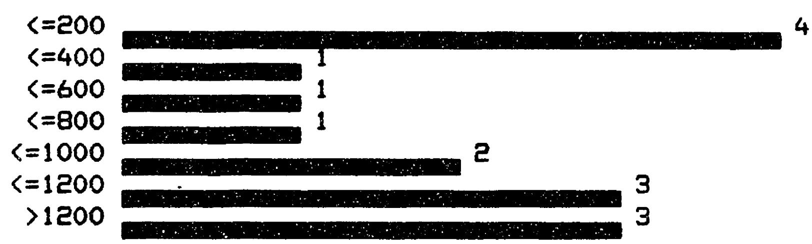
Mean	2.533	Std Dev	1.060
Minimum	1.000	Maximum	4.000

Organizational Distance



Mean	2.533	Std Dev	.915
Minimum	1.000	Maximum	4.000

Physical Distance (miles)



Mean	4.133	Std Dev	2.416
Minimum	1.000	Maximum	7.000

Project Type

Mean	2.467	Std Dev	1.187
Minimum	1.000	Maximum	5.000

Total number of projects supported by remote subsystem

Mean	2.533	Std Dev	1.125
Minimum	1.000	Maximum	4.000

Appendix C. Comments from Question 10 (Success Items).

The following comments were in response to survey question 10, "What was the most important item that led to the success of this project (person, process, ...)?".

Good People

Hard Working people

Allows distribution of skills

Experience of working with other sites is invaluable

Contacts with other cultures, points of views

Large experience base

Site given full responsibility

Very specific solution in mind from beginning

People able to focus on problem

Different people, new ideas and procedures help get out of ruts

Capability to learn - new tools,

Sharing and exposure to new ideas

Transfer of skills

Appendix D. Question 11 Comments (Troublesome Items)

The following comments were in response to survey question 11, "What was the most **troublesome** item that affected this project?".

Project having to support multiple masters.

Problems with additions from others.

Supporting multiple programs with various unknown priorities.

Project second in priority to one other. Not getting prime skills on my project.

Control of code for multiple sites

Ability to communicate

Testing philosophies vary

Lack of experience

No high level prioritization amongst many projects.

Attention to my needs was not top priority.

Managers didn't work well together - leading to technical people not working well together.

Defining responsibilities not done well

Control and reporting difficult (distance)

Coordination of code

Fixing user errors difficult due to distance

Second out the shoot. Not getting response as needed.

Communication time (compared to when someone is next door)

Too many coordinators

Maintaining concurrent libraries

Too much management direction

Too broad a scope

Solution was not optimum for anyone (all compromise)

Lack of common goals

Lack of good management direction

Appendix E. Comments for a Successful Multi-site Project

Most of the managers interviewed had some suggestions for how to make a multi-site project proceed smoothly and successfully. These comments are summarized below.

Need to do more front end planning.

Set up good procedures first.

Need periodic reviews.

Realize that the process will always be tougher than non-multi site project.

Need good communications:

- work together
- should be win-win situation
- needs to be face to face
- need compromise on both sides

Multi-site:

- needs to be more structured
- need experienced managers who know questions to ask and are able to read between the lines

Depends on product:

- some projects are easily split and others aren't
- strive for logical boundaries.
- don't force it.

Primary developer must drive.

Problem arises when there are several primary developers...

Must be a mechanism for prioritizing

Must be an escalation path

Need strong clear direction from high level management-
consistency

Need an arbitration board that will make decisions

Give one site full responsibility.

Close tracking of progress. Actual versus planned weekly

Experience in coordinating multi site activity helps

Must have accountability and ownership

Must have frequent meetings (face to face) - monthly.

Must have tracking mechanism that works

Appendix F. Pearson Correlations of Survey Results

Correlations:	1	2	3	4	5
1. Project Length (mos)	1.0000**	.2801	.4104	-.5550	.5810
2. Tot # Staff Prime Site on this Proj	.2801	1.0000**	-.2833	-.5151	.2495
3. Tot # Staff Sec. Site on this Proj	.4104	-.2833	1.0000**	-.4478	.3869
4. # Projs Mgr Resp. for at Prime Site	-.5550	-.5151	-.4478	1.0000**	-.6065*
5. # Projs Mgr Resp. for at Sec. Site	.5810	.2495	.3869	-.6065*	1.0000**
6. # Projs Tech. Pers Resp. for at Prime Site	-.3686	-.1661	-.3779	.1336	-.1823
7. # Projs Tech. Pers Resp. for at Sec. Site	.5605	.3723	.3113	-.7202*	.7241*
8. Interd.(Primary change affect on Secondary)	-.0940	-.2070	-.1206	-.0770	.1927
9. Interd.(Secondary change affect on Primary)	.3546	.0591	.3051	-.4190	.7773**
10. Project Performance	-.4200	-.0275	-.5380	.4117	-.7022*
11. Sub-Sys Requirements	.4270	.0265	.3147	-.1768	.5629
12. Sub-Sys Specifications	.2957	.1604	.5085	-.2343	.2309
13. Cross Training	-.1047	-.3110	.2647	.0163	.3109
14. Org. Distance	-.1396	-.2682	.1091	.1131	-.1543
15. Phys. Distance between Sites	.6030*	-.0899	.6480*	-.4355	.4157
16. Project Type	.0365	.5558	-.4034	.0581	-.4098
17. Number of Projects Supported by Subsystem	.8472**	.1351	.6224*	-.5978*	.5717

N of cases: 15 1-tailed Signif: * - .01 ** - .001

Correlations:	6	7	8	9	10
1. Project Length (mos)	-.3686	.5605	-.0940	.3546	-.4200
2. Tot # Staff Prime Site on this Proj	-.1661	.3723	-.2070	.0591	-.0275
3. Tot # Staff Sec. Site on this Proj	-.3779	.3113	-.1206	.3051	-.5380
4. # Projs Mgr Resp. for at Prime Site	.1336	-.7202*	-.0770	-.4190	.4117
5. # Projs Mgr Resp. for at Sec. Site	-.1823	.7241*	.1927	.7773**	-.7022*
6. # Projs Tech. Pers Resp. for at Prime Site	1.0000**	.1823	.3500	-.1932	.4401
7. # Projs Tech. Pers Resp. for at Sec. Site	.1823	1.0000**	.0701	.5680	-.3745
8. Interd.(Primary change affect on Secondary)	.3500	.0701	1.0000**	.3962	-.0396
9. Interd.(Secondary change affect on Primary)	-.1932	.5680	.3962	1.0000**	-.6562*
10. Project Performance	.4401	-.3745	-.0396	-.6562*	1.0000**
11. Sub-Sys Requirements	-.1890	.5629	-.2996	.3253	-.4512
12. Sub-Sys Specifications	-.3965	.3907	-.5835	.1206	-.1607
13. Cross Training	.1218	.1332	.1931	.3294	-.5494
14. Org. Distance	-.1612	-.1886	-.4297	.0842	.0621
15. Phys. Distance Between Sites	-.2443	.4612	-.2717	.3670	-.3116
16. Project Type	-.1087	-.3173	-.3739	-.6380*	.3470
17. Number of Projects Supported by Subsystem	-.3769	.6136*	-.3141	.3707	-.6311*

N of cases: 15 1-tailed Signif: * - .01 ** - .001

Correlations:	11	12	13	14	15
1. Project Length (mos)	.4270	.2957	-.1047	-.1396	.6030*
2. Tot # Staff Prime Site on this Proj	.0265	.1604	-.3110	-.2682	-.0899
3. Tot # Staff Sec. Site on this Proj	.3147	.5085	.2647	.1091	.6480*
4. # Projs Mgr Resp. for at Prime Site	-.1768	-.2343	.0163	.1131	-.4355
5. # Projs Mgr Resp. for at Sec. Site	.5629	.2309	.3109	-.1543	.4157
6. # Projs Tech. Pers Resp. for at Prime Site	-.1890	-.3965	.1218	-.1612	-.2443
7. # Projs Tech. Pers Resp. for at Sec. Site	.5629	.3907	.1332	-.1886	.4612
8. Interd.(Primary change affect on Secondary)	-.2996	-.5835	.1931	-.4297	-.2717
9. Interd.(Secondary change affect on Primary)	.3253	.1206	.3294	.0842	.3670
10. Project Performance	-.4512	-.1607	-.5494	.0621	-.3116
11. Sub-Sys Requirements	1.0000**	.5245	.3222	-.0267	.2625
12. Sub-Sys Specifications	.5245	1.0000**	.0661	.1648	.4505
13. Cross Training	.3222	.0661	1.0000**	.0540	-.1413
14. Org. Distance	-.0267	.1648	.0540	1.0000**	.3531
15. Phys. Distance Between Sites	.2625	.4505	-.1413	.3531	1.0000**
16. Project Type	-.2877	-.0590	-.4389	-.3111	-.3718
17. Number of Projects Supported by Subsystem	.5636	.4213	.0439	.0508	.7600**

N of cases: 15 1-tailed Signif: * - .01 ** - .001

Correlations:	16	17
1. Project Length (mos)	.0365	.8472**
2. Tot # Staff Prime Site on this Proj	.5558	.1351
3. Tot # Staff Sec. Site on this Proj	-.4034	.6224*
4. # Projs Mgr Resp. for at Prime Site	.0581	-.5978*
5. # Projs Mgr Resp. for at Sec. Site	-.4098	.5717
6. # Projs Tech. Pers Resp. for at Prime Site	-.1087	-.3769
7. # Projs Tech. Pers Resp. for at Sec. Site	-.3173	.6136*
8. Interd.(Primary change affect on Secondary)	-.3739	-.3141
9. Interd.(Secondary change affect on Primary)	-.6380*	.3707
10. Project Performance	.3470	-.6311*
11. Sub-Sys Requirements	-.2877	.5636
12. Sub-Sys Specifications	-.0590	.4213
13. Cross Training	-.4389	.0439
14. Org. Distance	-.3111	.0508
15. Phys. Distance Between Sites	-.3718	.7600**
16. Project Type	1.0000**	-.1461
17. Number of Projects Supported by Subsystem	-.1461	1.0000**

N of cases: 15 1-tailed Signif: * - .01 ** - .001

Appendix G. Partial Correlations

Performance and Interdependence (zero order correlation = -.6562)

Variable (N)	r Int-N	r Perf-N	Partial	%Chg
Project Length (mos)	0.3546	-0.4200	-0.5978	8.9%
Tot # Staff Prime Site on this Proj	0.0591	-0.0275	-0.6560	.0%
Tot # Staff Sec. Site on this Proj	0.3051	-0.5380	-0.6130	6.6%
# Projs Mgr Resp. for at Prime Site	-0.4190	0.4117	-0.5846	10.9%
# Projs Mgr Resp. for at Sec. Site	0.7773	-0.7022	-0.2464	62.4%
# Projs Tech. Pers Resp. for at Prime Site	-0.1932	0.4401	-0.6483	1.2%
# Projs Tech. Pers Resp. for at Sec. Site	0.5680	-0.3745	-0.5811	11.4%
Interd.(Primary change effect on Secondary)	0.3962	-0.0396	-0.6981	-6.4%
Sub-Sys Requirements	0.3253	-0.4512	-0.6037	8.0%
Sub-Sys Specifications	0.1206	-0.1607	-0.6499	1.0%
Cross Training	0.3294	-0.5494	-0.6024	8.2%
Org. Distance	0.0842	0.0621	-0.6651	-1.4%
Phys. Distance between Sites	0.3670	-0.3116	-0.6130	6.6%
Project Type	-0.6380	0.3470	-0.6021	8.2%
Number of Projects Supported by Subsystem	0.3707	-0.6311	-0.5861	10.7%

Notes:

r Int-N is the correlation between Interdependence and the variable listed.

r Perf-N is the correlation between Performance and the variable listed.

Partial is the partial correlation of Performance and Interdependence when controlling for the variable listed.

%Chg represents change from zero order correlation value.

Performance and Number of Projects Supported by
Remote Site Manager (zero order correlation = -.7022)

Variable (N)	r #Prj-N	r Perf-N	Partial	%Chg
Project Length (mos)	0.5810	-0.4200	-0.6203	11.7%
Tot # Staff Prime Site on this Proj	0.2495	-0.0275	-0.7183	-2.3%
Tot # Staff Sec. Site on this Proj	0.3869	-0.5380	-0.6356	9.5%
# Projs Mgr Resp. for at Prime Site	-0.6065	0.4117	-0.6245	11.1%
# Projs Tech. Pers Resp. for at Prime Site	-0.1823	0.4401	-0.7045	-0.3%
# Projs Tech. Pers Resp. for at Sec. Site	0.7241	-0.3745	-0.6740	4.0%
Interd.(Primary change effect on Secondary)	0.1927	-0.0396	-0.7084	-0.9%
Interd.(Secondary change effect on Primary)	0.7773	-0.6562	-0.4047	42.4%
Sub-Sys Requirements	0.5629	-0.4512	-0.6077	13.5%
Sub-Sys Specifications	0.2309	-0.1607	-0.6926	1.4%
Cross Training	0.3109	-0.5494	-0.6691	4.7%
Org. Distance	-0.1543	0.0621	-0.7024	.0%
Phys. Distance between Sites	0.4157	-0.3116	-0.6626	5.6%
Project Type	-0.4098	0.3470	-0.6546	6.8%
Number of Projects Supported by Subsystem	0.5717	-0.6311	-0.5364	23.6%

Notes:

r #Prj-N is the correlation between Number of Projects Supported by the Remote Site Manager and the variable listed.

r Perf-N is the correlation between Performance and the variable listed.

Partial is the partial correlation of Performance and the Number of Projects Supported by the Remote Site Manager when controlling for the variable listed.

%Chg represents change from zero order correlation value.

Performance and Number of Projects Supported by Subsystem (zero order correlation = -.6311)

Variable (N)	r #prj-N	r Perf-N	Partial	%Chg
Project Length (mos)	0.8472	-0.4200	-0.5709	9.5%
Tot # Staff Prime Site on this Proj	0.1351	-0.0275	-0.6334	-0.4%
Tot # Staff Sec. Site on this Proj	0.6224	-0.5380	-0.4490	28.9%
# Projs Mgr Resp. for at Prime Site	-0.5978	0.4117	-0.5270	16.5%
# Projs Mgr Resp. for at Sec. Site	0.5717	-0.7022	-0.3931	37.7%
# Projs Tech. Pers Resp. for at Prime Site	-0.3769	0.4401	-0.5593	11.4%
# Projs Tech. Pers Resp. for at Sec. Site	0.6136	-0.3745	-0.5481	13.1%
Interd.(Primary change effect on Secondary)	-0.3141	-0.0396	-0.6784	-7.5%
Interd.(Secondary change effect on Primary)	0.3707	-0.6562	-0.5534	12.3%
Sub-Sys Requirements	0.5636	-0.4512	-0.5111	19.0%
Sub-Sys Specifications	0.4213	-0.1607	-0.6294	0.3%
Cross Training	0.0439	-0.5494	-0.7271	-15.2%
Org. Distance	0.0508	0.0621	-0.6363	-0.8%
Phys. Distance between Sites	0.7600	-0.3116	-0.6384	-1.2%
Project Type	-0.1461	0.3470	-0.6256	0.9%

Notes:

r Int-N is the correlation between the Number of Projects Supported by the Subsystem and the variable listed.

r Perf-N is the correlation between Performance and the variable listed.

Partial is the partial correlation of Performance and the Number of Projects Supported by the Subsystem when controlling for the variable listed.

%Chg represents change from zero order correlation value.

Appendix H. Project Performance Model Parameters

The following command block was used with SPSS/PC+ to create the project performance model.

```
SET SCREEN=OFF /PRINTER=OFF /LISTING="STAT5.DAT" /PTRANSLATE=OFF.
* SET SCREEN=ON /PRINTER=OFF /LISTING=OFF /PTRANSLATE=OFF.
SET MORE=ON /ECHO=OFF /LENGTH=59 /WIDTH=79 /EJECT=ON.
SET BOXSTRING="-|┼└┌┘┐├┤┬┴" /HISTOGRAM="▄" /BLOCK="█".

**********************************************************************
*         COMMAND FILE FOR ANALYZING BASIC PROJECT DATA              *
*                                                                    *
*               WITH  MULTIPLE REGRESSIONS                           *
*                                                                    *
*         -  USES FILE (USE ALL.DAT).                                *
*                                                                    *
*         -  DATA OUTPUT TO FILE  "STAT5.DAT"                        *
*                                                                    *
**********************************************************************
GET FILE="ALL.DAT".
**********************************************************************
*   MULTIPLE REGRESSION ON BASIC PROJECT DATA
*        - 70%  IN/OUT LEVELS
**********************************************************************

REGRESSION VARS=ALL
          /STATISTICS=ALL
          /CRITERIA=POUT(.35)
          /CRITERIA=PIN(.30)
          /DEP=PERF
          /METHOD=STEPWISE.

**********************************************************************
*            RESET SYSTEM PARAMETERS
**********************************************************************

SET SCREEN=ON /LISTING="SPSS.LST" /MORE=ON /LENGTH=24 /WIDTH=79 /EJECT=OFF.

**********************************************************************
*     MULTIPLE REGRESSION STATS PLACED IN FILE                       *
*                                                                    *
*                         STAT5.DAT                                  *
*                                                                    *
*                         COMPLETED                                  *
**********************************************************************
```

Appendix I. Results of Regression for Performance Model

See Appendix H. for parameters used in regression. The first thirteen steps are not shown. The regression actually progressed for a fifteenth step, however the probability that the final variable was not zero was 0.11. A description of the variables used in this regression is included at the end of the listing.

**** MULTIPLE REGRESSION ****

Equation Number 1   Dependent Variable.. PERF   Project Performance

Beginning Block Number 1. Method: Stepwise

Variable(s) Entered on Step Number
14..   MI   Phys. Distance

Multiple R	.99988		
R Square	.99976	R Square Change	.00233
Adjusted R Square	.99830	F Change	19.21537
Standard Error	.06912	Signif F Change	.0483

Analysis of Variance

	DF	Sum of Squares	Mean Square
Regression	12	39.32378	3.27698
Residual	2	.00956	.00478

F =   685.84618   Signif F = .0015

Condition number bounds: 14.531,   940.448

------------------ Variables in the Equation ------------------

Variable	B	SE B	95% Confdnce	Intrvl B	Beta
CT	-.64483	.03028	-.77510	-.51455	-.40782
TECHP	1.09459	.05095	.87536	1.31383	.33723
PSP	-1.25996	.06257	-1.52919	-.99073	-.84600
SSS	.55139	.04273	.36753	.73526	.29071
MMTHS	.03034	1.85679E-03	.02236	.03833	.45923
OD	.66146	.04126	.48392	.83900	.36127
ISP	-.39244	.02421	-.49659	-.28830	-.49165
IPS	.38602	.03295	.24427	.52778	.41259
SSR	.44723	.04066	.27229	.62217	.26039
MGRSO	-.45836	.05430	-.69200	-.22471	-.24892
MPERSP	9.615695E-03	1.63393E-03	2.585377E-03	.01665	.12163
MI	.11049	.02520	2.037418E-03	.21894	.15927
(Constant)	2.62093	.28605	1.39015	3.85171	

—————————— Variables in the Equation ——————————

Variable	SE Beta	Correl	Part Cor	Partial	Tolerance	T	Sig T
CT	.01915	-.54938	-.23473	-.99780	.33128	-21.297	.0022
TECHP	.01570	.44012	.23677	.99784	.49296	21.482	.0022
PSP	.04201	-.63106	-.22193	-.99754	.06882	-20.136	.0025
SSS	.02253	-.16074	.14222	.99405	.23932	12.903	.0060
NMTHS	.02810	-.41999	.18012	.99628	.15384	16.343	.0037
OD	.02254	.06207	.17668	.99613	.23918	16.031	.0039
ISP	.03032	-.65616	-.17870	-.99622	.13210	-16.213	.0038
IPS	.03521	-.03964	.12914	.99279	.09797	11.717	.0072
SSR	.02367	-.45122	.12124	.99184	.21678	11.000	.0082
MGRSO	.02949	-.70223	-.09303	-.98625	.13969	-8.441	.0137
NPERSP	.02067	-.02747	.06486	.97232	.28440	5.885	.0277
MI	.03633	-.31158	.04831	.95170	.09202	4.384	.0483
(Constant)						9.163	.0117

—————————— Variables not in the Equation ——————————

Variable	Beta In	Partial	Tolerance	Min Toler	T	Sig T
NPERSO	-.03683	-.98550	.17391	.04961	-5.809	.1085
MGRSP	.08529	.93578	.02924	7.1666E-03	2.654	.2294
TECHO	-.02204	-.12656	8.0134E-03	8.0134E-03	-.128	.9192
PT	-.01149	-.22451	.09274	.06358	-.230	.8558

Summary table

Step	MultR	Rsq	F(Eqn)	SigF		Variable	BetaIn
1	.7022	.4931	12.648	.004	In:	MGRSO	-.7022
2	.7839	.6145	9.563	.003	In:	CT	-.3665
3	.8760	.7674	12.099	.001	In:	TECHP	.4052
4	.9065	.8218	11.530	.001	In:	PSP	-.3041
5	.9361	.8763	12.746	.001	In:	SSS	.2698
6	.9642	.9297	17.628	.000	In:	NMTHS	.4873
7	.9773	.9551	21.277	.000	In:	OD	.1763
8	.9860	.9722	26.230	.000	In:	ISP	-.2302
9	.9920	.9840	34.187	.001	In:	IPS	.2635
10	.9909	.9818	40.488	.000	Out:	MGRSO	
11	.9951	.9902	56.186	.000	In:	SSR	.1406
12	.9977	.9953	85.373	.000	In:	MGRSO	-.1635
13	.9987	.9974	105.553	.001	In:	NPERSP	.0711
14	.9999	.9998	685.846	.001	In:	MI	.1593

Variable	Description
NMTHS	Project Length (mos)
NPERSP	Tot # Staff Prime Site on this Proj
NPERSO	Tot # Staff Sec. Site on this Proj
MGRSP	# Projs Mgr Resp. for at Prime Site
MGRSO	# Projs Mgr Resp. for at Sec. Site
TECHP	# Projs Tech. Pers Resp. for at Prime Site
TECHO	# Projs Tech. Pers Resp. for at Sec. Site
IPS	Interd.(Primary change affect on Secondary)
ISP	Interd.(Secondary change affect on Primary)
PERF	Project Performance
SSR	Sub-Sys Requirements
SSS	Sub-Sys Specifications
CT	Cross Training
OD	Org. Distance
MI	Phys. Distance between Sites
PT	Project Type
PSP	Number of Projects Supported by Subsystem