Managing I/S Planning and Design:
A Control Theory Perspective

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ABSTRACT

The recent change in the business environment that has had the largest single impact on most organizations is the intensification of competition in the markets for products and services. For this reason, a critical management issue in today's business environment is the "time-to-market," that is, the length of time it takes an organization to convert a product concept into a viable product available in a specific market. Since most organizations are finding that their products' profitability lifetimes are decreasing, they must produce an ever-increasing number of new products and services in less time without sacrificing quality.

Perhaps nowhere have the effects of this trend been more apparent than in the field of information system design. As information technology has become an integral part of an organization's competitive strategy, the I/S function faces increased demands to better its ability to manage the time-to-market for I/S products and services.

Given that the time-to-market is a crucial concept in today's I/S environment, it is of prime importance for the I/S function to find ways to deliver high quality products quickly. Several researchers have noted that there are two trends in the current practice of I/S planning and design. First, much of the current practice in software design involves a team approach. That is, the design team includes individuals with a wide range of organizational roles. Since prespecifying information system processes or requirements in a competitive environment is a very complex process, individuals with a wide range of organizational roles who will be affected by and who will affect I/S products are invited to participate in the development processes. Second, organizations have increasingly adopted computerized design aids to reduce the rising cost of their development. Many organizations are already claiming the benefits of increasingly powerful computerized design aids. The impact of these tools on the productivity of I/S planning and design teams and ultimately on time-to-market is, however, yet to be proven.

These two key motivating factors -- a team approach to design and the use of computerized design aids -- may be pivotal concepts in the 90's for the management of I/S functions. *The first purpose* of this study was, therefore, to provide a line of research that would contribute to managing I/S planning and design teams effectively. We developed a model that assumes that the task of planning and design requires the effective cooperation of multiple experts or organizational roles. In particular, we developed a theoretical model which attempts to use existing theories and empirical evidence to explain how team members work together as a team. This model was tested using 41 I/S planning and design teams.

The second purpose of this study was to understand how computerized design aids can affect the performance of I/S planning and design teams. We believe that there are three major issues in studying the impacts of design aids on the performance of I/S planning and design teams. First, the relevant factors affecting team performance should be identified, which is the first purpose of this study. Second, a careful characterization of computerized design aids is needed if we are to have the evidence necessary to increase the effectiveness with which they are used. Third, we need to map the features of the effect of computerized design aids on performance factors in order to understand better how these aids affect the performance of I/S planning and design teams. We explored these issues with 38 I/S planning and design teams that use computerized design aids.

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CHAPTER ONE. INTRODUCTION

The recent change in the business environment that has had the largest single impact on most organizations is the intensification of competition in the markets for products and services. In many industries, profit margins have been reduced by the slowdown in market growth and the influx of lower-priced imported goods. Even in the newer, high-technology markets, many products and services have become obsolete so quickly that markets reach maturity within a year or two after product initiation.

For this reason, a critical management issue in today's business environment is the "time-to-market," that is, the length of time it takes an organization to convert a product concept into a viable product available in a specific market (Henderson and Cooprider, 1988). Since most organizations are finding that their products' profitability lifetimes are decreasing, they must produce an ever-increasing number of new products and services in less time without sacrificing quality.

Perhaps nowhere have the effects of this trend been more apparent than in the field of information system design. As information technology has become an integral part of an organization's competitive strategy, the I/S function has faced increased demands to better its ability to manage the time-to-market for I/S products and services. In fact, many have argued that the failure of the I/S function to reduce the time-to-market of its products has been a leading motivator for to decentralizing computing and has helped to stimulate the growth in end-user computing.

Given that the time-to-market is crucial in today's I/S environment, it is of prime importance for the I/S function to find ways to deliver high quality products quickly. Not surprisingly, there is a significant body of existing research reflecting a range of perspectives on this issue. There are two lines of research of greatest interest for the purposes of this thesis. Some researchers have asserted that players with different organizational roles should be involved in design teams in order to improve design validity. Others have focused on the use of computer-aided planning and design tools such as CASE (Computer Assisted Software Engineering) technology to improve the timing and costs of products and services delivered by the I/S function.

We believe that these two research focuses - the team approach to I/S planning and design and the use of computerized design aids - may provide key concepts in the 90's for the management of I/S functions. Much of the current practice in software design involves a team approach (Henderson, 1988; Kling, 1977), combining the efforts of individuals with a range of organizational roles. This practice is the result of the difficulty of prespecifying information system processes or requirements in a competitive environment . It is necessary that individuals who will be affected by and who will affect I/S products are invited to participate in the development processes. Another measure that is assuming increasing importance in the quest for efficient, effective, low-cost information systems has been the adoption of computerized design aids to reduce the rising cost of their development. Many organizations are already claiming the benefits of increasingly powerful computerized design aids. The impact of these design tools on the productivity of I/S planning and design teams and ultimately on time-to-market is, however, yet to be proven.

The first purpose of this study is, therefore, to provide a line of research that can be used in managing I/S planning and design teams more effectively. As such, we will not focus on theories of planning and design that concentrate on the behavior and performance of individual designers. Rather, we will develop a model that assumes that the tasks of planning and design require the effective cooperation of multiple experts or organizational roles. In particular, we want to develop a theoretical base that attempts to use existing theories and empirical evidence to explain how team members work together as a team.

The second purpose of this study is to understand how computerized design aids can affect the performance of I/S planning and design teams. We believe that there are three major issues in studying the impacts of design aids on the performance of I/S planning and design teams. First, the relevant factors affecting team performance should be identified, which is the first purpose of this study. Reference theories, such as behavioral science theories and control theories, could indicate which performance factors may be enhanced with information technology (IT), in particular, computerized design aids. Second, computerized design aids need to be studied in depth. As survey articles in the MIS literature have noted (Benbasat, 1984; Scott Morton, 1983), there has been little research on the nature and types of IT available on the market and actually in use. A careful examination of IT, in particular, computerized design aids, is needed if we are to have the evidence necessary to increase the effectiveness with which they are used. Third, we need to map the effects of computerized design aids on performance factors in order to understand better how computerized design aids affect the performance of I/S planning and design teams. We need models that can predict how certain features of a particular design aid can affect team performance through their impacts on intermediate factors. The development of such a model is the second major purpose of this study.

Thesis Overview

Given that recent trends in managing I/S planning and design are to use a team approach and to adopt computerized design aids, we will focus on these two issues throughout this study.

Chapter Two reviews the empirical literature on the impact of design aids. This review reveals that three areas, in particular, need to be addressed in research studies. First and most important, since most information systems are developed by a number of individuals, we need to understand how people with different roles work together first. Second, we need to develop and validate standard measures for computerized design aids which correspond to design behavior, particularly team behavior. Third, future research requires rigorous attention to measuring performance.

Chapters Three and Four have creatively extended control theories to provide a model to explain team performance. They discuss how computerized design aids can affect the performance of design teams and provide eight testable hypotheses that are theoretically grounded in the current literature and that extend the literature to its next logical step.

Chapter Five discusses the research design used in this study. First, threats to validity pertinent to testing our hypotheses in this study are reviewed and current methodological practice reported in I/S research is critiqued. Then, the research design, including the measures used to protect against these threats to validity, is described. Threats to validity in key informant analysis and counter measures used in the research design are focused on.

Chapter Six discusses the measurement model used in this study. The model shows how we tested the relationships among the measured variables and the theoretical variables we intended to study. Chapter Seven empirically tests our model of team process using 41 design teams and 290 participants. Chapter Eight empirically tests the relationship between the use of computerized design aids and performance. Throughout these two chapters we emphasize that understanding team process is the key to examining the impact of computerized design aids.

Chapter Nine reviews the total research effort and discusses managerial and methodological implications of the findings. Finally, possible research directions are explored.

CHAPTER TWO. REVIEW OF EMPIRICAL LITERATURE ON THE IMPACT OF DESIGN AIDS

Recent surveys of projects aimed at the development of information systems clearly indicate the following trends in managing information system (I/S) planning and design: (1) the use of a team approach and (2) the adoption of design aids, that is tools, techniques and practices developed specially for I/S planning and design. Jenkins *et al.* (1983) found that, of 72 project teams surveyed, 63 employed systems-development methodologies, and Beck and Perkins (1983) reported that 56 of 97 organizations surveyed used automated tools in I/S planning and design. Zmud (1983) noted that, since the early 1970s, a substantial effort has been directed toward improving the methodologies used for developing large software systems and for combining the efforts of individuals with diverse organizational roles. Necco *et al.* (1987) also reported that many different tools, techniques, and approaches have been used to develop computer-based information systems, and that a wide variety of roles have been involved in I/S planning and design.

While many design aids have been created that purport to improve the software development process, only a few empirical studies have focused on the impact of design aids on the performance of a design team (Card *et al.* 1987). These studies have sought to link the use of design aids to hypothesized consequences. Hypothesized consequences of the use of design aids in I/S planning and design include productivity, software quality, perceived value of design tools, management of design life-cycle strategy, and team strategy. The results of the studies, however, have been decidedly mixed. For example, some researchers have reported that the use of design aids increased the productivity of design teams (Necco, *et al.*, 1987; Semprevivo, 1980) and software quality (Card *et al.*, 1987; Lempp and Lauber, 1988; Necco *et al.*, 1987). In contrast, other researchers could not find a significant relationship between the use of design aids and the productivity of design teams (Card *et al.*, 1987; Lempp and Lauber, 1988) or between the use of design aids and software quality (Beck and Perkins, 1983; Lientz and Swanson, 1980).

Therefore, it is the purpose of this chapter to identify reasons for these inconsistent empirical results by reviewing the past literature. In Section 2.1, we will provide a framework for understanding the impact of design aids on the performance of a design team. This proposed framework identifies software development processes that can be affected by design aids. Using this framework, in Section 2.2, we will review the empirical literature on the impact of design aids on the performance of a design team. Section 2.3 will summarize and critique these studies of the impact of design aids on the performance of a design team.

2.1. A Framework for Understanding the Impact of Design Aids on the Performance of a Design Team

Figure 2.1 provides a framework for understanding the impact of design aids on the performance of a design team. It synthesizes several frameworks previously proposed for the I/S planning and design process (Card *et al.*, 1987; Cooprider and Henderson, 1988; Naumann and Palvia, 1982; Semprevivo, 1980; Welke and Konsynski, 1980). In general, our proposed framework considers the impact of design aids at three levels: individual resource utilization, cooperative team strategy, and organizational life-cycle management strategy. These three levels represent key design behaviors that can be affected by the use of design

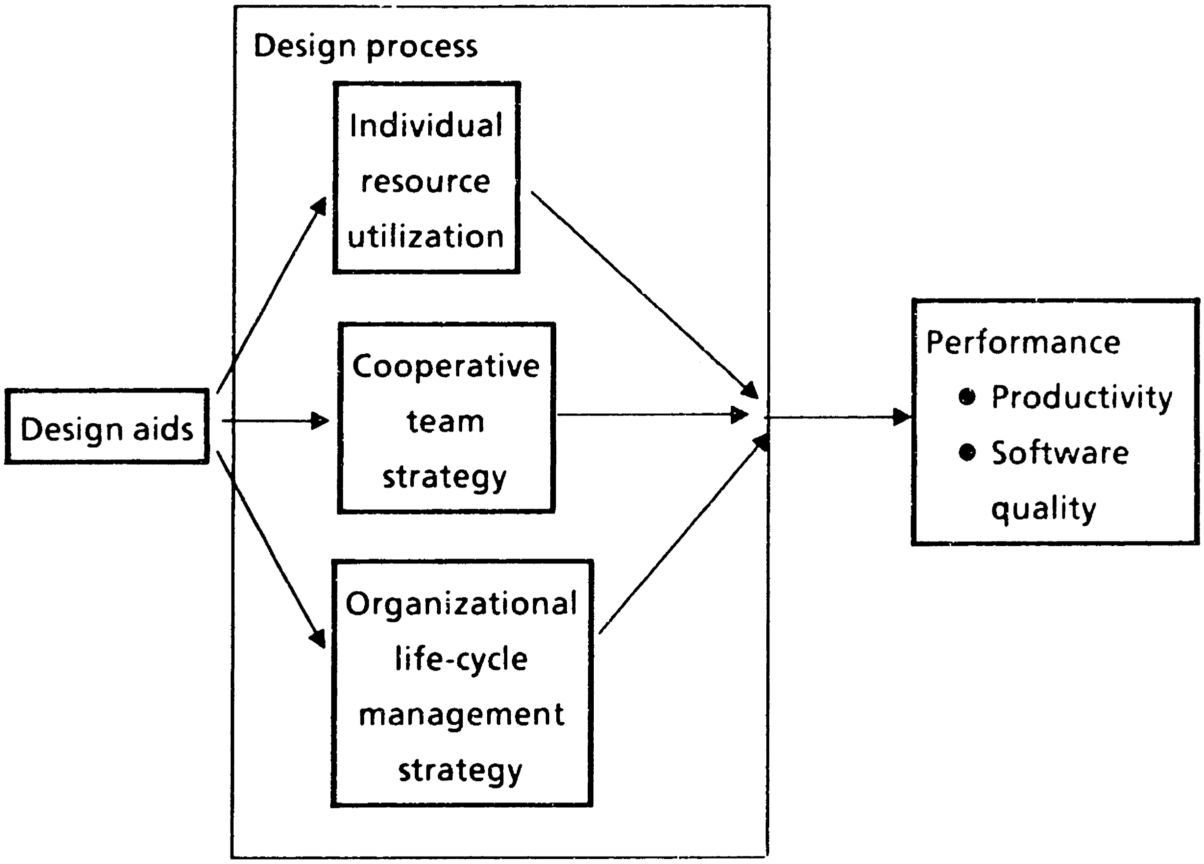

Figure 2.1. A framework for understanding the impact of design aids on the performance of a design team.

aids (Henderson and Cooprider, 1988). The elements of this framework will be discussed in detail below.

2.1.1. Design Aids

Ewers and Vessy (1981) defined a design aid as an application of design methodologies used for software development, maintenance, or analysis. These appiications, collectively, constitute a design methodology. Design methodology, in turn, can be seen as the logical discipline underlying I/S planning and design activities. Some researchers have used the term *software* *engineering* to capture the diversity of design methodologies. For example, Shemer (1987) claimed that software engineering is the practical application of scientific knowledge to the design and construction of computer programs. Beck and Perkins (1983) and Konsynski (1985) defined software engineering as the application of sound engineering principles to produce economical and reliable software that works efficiently on real machines.

A design aid can have many features because it may be based on a variety of approaches and methodologies that can be used in I/S development. This multiplicity of features poses a problem in interpreting the results of many empirical studies. These studies have used a level of aggregation of design aids for measurement that may not be relevant to the way in which the designers use them during the I/S planning and design phase. For example, consider a certain CASE system. As Case (1985) claimed, a CASE system is actually a macro-system characterized by various methods, procedures, and tools. As such, design teams may spend similar amounts of time using a CASE system, but utilize quite different subsets of functionality (Henderson and Cooprider, 1988).

Therefore, we propose that an adequate definition of a design aid must reflect functions that correspond to the designers' actual usage behavior. Although several models of design aids have been developed in terms of the features supported, the recent model of Henderson and Cooprider (1988) represents one of the first attempts to integrate diverse features commercially available into a small set of distinguishable dimensions. Their study lists 98 specific technology functions that planning and design technology experts have identified as important. These 98 functions have been categorized into three general technology dimensions: production, coordination, and infrastructure. The production dimension has a direct impact on the production efficiency of the individual system builder. The coordination dimension enables individuals on a team to work more effectively among themselves. The infrastructure dimension addresses the organization's flexibility in creating and managing a variety of design processes without a significant loss in the effectiveness of any given development team.

Unlike other models of design aids that focus only on the production dimension, Henderson and Cooprider's (1988) model includes coordination and infrastructure. The production dimension enables the individual system builder to build systems as rapidly as possible. However, this dimension will only marginally increase the performance of I/S development teams as long as it is used only to "do the same things faster." On the other hand, the coordination and infrastructure dimensions enable the design team to solve problems differently by providing the functionality of control and cooperative support. Coordination and infrastructure can also help in the establishment of an organizational infrastructure for inter-team coordination by providing support functions and technology standards for the entire organization.

2.1.2. Three Levels of Design Behavior

Several researchers have noted that a model of design processes can be analyzed at the individual, team, and organizational levels (Curtis *et al*, 1987; Henderson and Cooprider, 1988). In the following discussion we claim that design aids can have impacts on these three levels by affecting individual resource utilization, team strategy, and organizational life-cycle management strategy.

Individual Resource Utilization

This section briefly reviews the concepts related to the impact of design aids on the efficiency and effectiveness of individual resource utilization. The use of design aids can directly increase working efficiency and cause gains in productivity, and these productivity gains may be assessed as classic capital-labor substitutions. That is, a design aid can substitute for labor or greatly enhance the capacity of a single individual. The most commonly used metrics for assessing the impact of design aids at the individual level are source lines of code, number of persons, and person-hours-spent. Such measurements or criteria reflect how efficiently individual resources are allocated, and Cooprider and Henderson (1988) argued that these metrics can evaluate the efficiency of individual programmers in the design process. They also noted that resource utilization can be assessed by outcome measures as well. For example, "bugs" per thousand lines of code and run-time efficiency are typical measures of the outcome of individual resource utilization. Kabat *et al.* (1986) and Karimi (1987) claimed that software quality can be assessed by the consistency, completeness, and correctness of the modules produced by each designer.

While these impacts of design aids on individual resource utilization are the current theme of software tools, many have noted that the ultimate impact of design aids cannot be understood only at this level (Case, 1985; Necco *et al.*, 1987) for at least two reasons. First, much of the current software practice involves a team approach. That is, organizations increasingly are using teams composed of individuals whose roles may differ. Since it is very difficult to prespecify information processes or requirements in a competitive environment, individuals who will be affected by, as well as those who will affect, I/S products are invited to participate in the I/S planning and design processes. Second, large-scale software involves several designers and product teams working together. Therefore, a particularly important issue will be how an organization manages relationships among designers and product teams.

The next two levels of design behavior focus on the potential for design aids to impact team performance.

Cooperative Team Strategy

Prior research on I/S planning and design has shown the importance for team functioning of project management and of the interaction between users and designers. Team functioning is the second level in Figure 2.1. Project management reflects the need at the team level that policies, priorities, and standard operating procedures be enforced to meet the project schedule. The implicit objective of project management is to align the goals of each designer with organizational goals. Zmud (1980) claimed that in the development of large-scale applications software the managerial obstacles are greater than the technical obstacles. Case (1985) have also argued that I/S design projects would not be improved without rigid procedures to estimate, measure, and control the work of the designers.

Design teams commonly include members whose function is to simulate user interactions with the I/S in the real world. The interaction between designers and users has been extensively studied [see Ives and Olson (1984) for a review of these studies]. Kabat *et al.* (1986) argued that since design aids often provide structure for the designers' interactions with the users, the users can foresee the results of design processes in a more concrete way and can communicate their needs more satisfactorily. This, in turn, increases the possibility of meeting the users' requirements. In their recent survey, Necco *et al.* (1987) asked 97 organizations what they considered to be the most important factors in developing improved I/S design in the future. The factors that were considered most important are improved management support and improved user involvement.

Organizational Life-Cycle Management Strategy

The last level of design behavior in Figure 2.1 relates to organizational strategies for managing product-development processes. These processes include the design team's interactions with other interdependent groups or individuals to obtain resources, coordinate work, make decisions, and exchange inputs and outputs.

To some extent, all organizational units compete for limited organizational resources. I/S development requires the use of resources, such as time, cost, staff time, and hardware (Halloran *et al.*, 1978). Design aids can facilitate project teams' efforts to gain organizational resources. For example, by using the same data directory/dictionary, the amount of conventional computer programming required to develop several interrelated projects can be significantly reduced (Semprevivo, 1980). Evans (1982) claimed that by adopting a standard structured approach, much of the information or many procedures can be effectively shared among teams.

Design aids have another very important use from the perspective of organizational management: facilitating communication between stakeholders and the design team. Stakeholders are those who have an interest in a project team's outcome but who do not have a role on the design team. Stakeholders may include users of an information system. Kaiser and Bostrom (1982) found that the most significant reason for the failure of a project can be ascribed to the users assigned to the projects. This finding implies that user representatives on the project teams may not adequately represent the end users. Therefore, even though a design team includes users as official team members, it should still interact with stakeholders (including users) who may be affected by the design team or who can affect the design team activities.

Some design aids allow more concrete identification and validation of stakeholder requirements, and facilitate design processes by getting test portions of the systems to stakeholders more quickly (prototyping). Moreover, design aids can make efficient exchange of information possible in the other direction. Many stakeholders who are not design team members may not respond to designers without appropriate communication channels. For efficient information exchange, Berzins *et al.* (1986) claimed that a minimal automated software development environment should include an electronic mail facility or a tool for the display of design information.

2.1.3. Performance

Since most organizations find that the time a product remains profitable is decreasing, they must produce an increasing number of new products and services in less time without sacrificing quality. Perhaps nowhere has this trend been more apparent than in the design of information systems.[1] As information technology becomes an integral part of an organization's competitive strategy, the I/S function faces increased demands to improve its ability to manage the amount of time it takes to get I/S products and services from their inception to the market place (Henderson and Cooprider, 1988).

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1 An IBM study indicates that applications programs, on average, have a very short life (18 months). (Kendall, 1977)

Given that time-to-market is a pivotal concept in today's I/S environment, it is of prime importance to find ways of delivering high-quality products in a short period of time. Related to this time-to-market concept are productivity and software quality. Most researchers agree that these two measures are representative of team performance (Card *et al.*, 1987; Lempp and Lauber, 1988).

2.2. Review of Empirical Research

In this section, empirical research on the impact of computer-based design aids in I/S planning and design is reviewed and evaluated. However, we do not restrict ourselves to computerized design aids *per se*. Since computer-based design aids are the implementation of software engineering tools, we will also examine papers that have studied the impact of design aids that can be computerized[2]. For example, studies which examined the impact of using the decision table are included in our review, because a tool for the computerized decision table is commercially available.

2.2.1. Measures of Design Aids

In the papers reviewed, several kinds of independent variables were used to measure the impact of design aids in the I/S planning and design process. In Beck and Perkins (1983), Card *et al.* (1987), Guimaraes (1985, 1983), Jenkins *et al.* (1983), Lientz and Swanson (1980), Mahmood (1987), and Mantha (1987), this

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2 A more practical reason for this is that very few papers focused on computerized design aids.

variable was the use or non-use of either specific or general design aids. The availability of design aids was the variable used by Berzins *et al.* (1986), Lempp and Lauber (1988), Semprevivo (1980), and Sheonolikar (1981).

Generally, the independent variables were expressed either as single-item or multiple-item dichotomous scales (use and nonuse), based on the self-report of a project manager or designer; data were collected after the system was developed. Two studies used perceptual measures that focus on the frequency of usage of design aids (Lientz and Swanson, 1980; Necco *et al.*, 1987). Two studies used specific computer-based design aids (Lempp and Lauber, 1988; Semprevivo, 1980). Other studies used perceptual measures that focus on design methodology and design tools that might be used with or without a computer system, such as HIPO and data flow diagrams.

The measures of the impact of design aids used in previous studies, indicated in Table 2.1, are generally weak. The most common measure is the accumulated usage of design aids. For example, Beck and Perkins (1983) used the sum of the number of design aids employed in I/S planning and design. Berzins *et al.* (1986), Lempp and and Lauber (1988), Mahmood (1987), and Sheonolikar (1981) compared projects that used design aids with projects that did not. However, their design aids were capable of several functions, such as project management, project planning, project control, documentation support, quality control, and automatic coding. Therefore, because there is no information about the way in which the design aids were used, this level of aggregation does not provide sufficient discrimination to predict the actual performance of any given function. Also, without knowing how specific functions of design aids were used, even if they did contribute to productivity, their effect may be masked by other factors. If teams indicate a similar usage level of design aids but utilize quite different subsets of functions, the impact of any given function in a design aid could easily be obscured and the potential impact of the design aid could go unrecognized if other functions were used.

In summary, the review of the literature on the characterization or definition of design aids reveals three major shortcomings:

(1) It is difficult to generalize the research results beyond the narrow circumstances in which they were observed.

(2) Current measures are likely to miss much of what is important and relevant about the use of design aids.

(3) Finally, this definitional problem inhibits the long-term evolution of design aids from their current primitive level to a more sophisticated stage (Acly, 1988; Wasserman, 1982).

2.2.2 Design Behavior

The results of the impact of design aids on design behavior are summarized in Table 2.1 and are briefly discussed in the following section, which is organized according to the framework of design behavior levels suggested earlier. It should be noted that since the terms used in those studies are different from the constructs suggested in our framework, our summary is necessarily subjective in nature.

Individual Resource Utilization

Only one study quantitatively examined the relationship between the use of design aids and individual resource utilization. Lientz and Swanson (1980) did not find that productivity aids were significantly related to programmer

Study	Design aids Level of aggregation	Design behavior			Performance			Sample size
		Individual resource utilization	Team strategy	Org'al life-cycle	Productivity	Software quality	Rated by	
Beck & Perkins (1983)	Aggregated usage					-	Designer	63
Berzins *et al.* (1986)	Aggregated usage		+				Authors	?
Card *et al.* (1987)	Aggregated usage				N.S.	+	Hard data	22
Guimaraes (1985, 1983)	Aggregated usage					+	Hard data	43
Jenkins *et al.* (1983)	Aggregated usage						Designer	72
Lempp & Lauber (1988)	Aggregated usage		+	+	+	+	Designer	22
Lientz & Swanson (1980)	Use of functionality	N.S.				N.S.	Hard data & designer	487
Mahmood* (1987)	Aggregated usage		Mixed		Mixed		Designer & user	61
Mantha (1987)	Use of functionality					+	Hard data	20
Necco *et al.* (1987)	Use of functionality				+	+	Designer	97
Semprevivo (1980)	Aggregated usage	+	+				Author	1
Sheonolikar (1981)	Aggregated usage	+	+	+			Author	1

Table 2.1. Review of empirical literature on the impact of design aids.

Note:
* This study compared two alternative approaches.
\+ Significantly positive
\- Significantly negative
N.S. Not significant

effectiveness. However, two case studies found that design aids can increase the effectiveness of individual resource utilization.

Semprevivo (1980) described users' experiences with a Dictionary/Directory Facility (DDF) developed by the University's Administrative Systems group. The use of the DDF significantly reduced the amount of conventional computer programming required to develop a very contemporary and integrated on-line Financial and Accounting Management Information System. He noted that the amount of computer programming required to support on-line transactional processing was a fraction of what it would have been using conventional techniques.

Sheonolikar (1981) reported that adoption of the HIPO documentation technique simplified the programming assignment, even for a novice designer assigned to the task. The availability of the users' manual helped improve programmer productivity by enabling the designer to gain a concrete understanding of the system functions to be supported before actual coding.

In general, these case studies found a positive relationship between the use of design aids and individual resource utilization.

Team Strategy

Five studies looked at the relationship between the use of design aids and team strategy. These studies can be classified into two types. The first type of study focused on the impact on design aids on cooperative team strategy, particularly the interaction between designers and users. Guinan and Bostrom (1986) suggested that the largest single benefit of the new structured-design techniques may be the improvement in user and analyst communication via the development of a shared logical model of the system. The second type of study focused on the management control issues in dealing with participants during the design process. Case (1985) claimed that projects would not be successful and productivity would not be consistently improved without rigid procedures to estimate designer's work, measure progress, and control the work of the designers.

Mahmood (1987) compared two design principles: prototyping and standard design life-cycle (SDLC) approaches. He found that while the prototyping approach made it difficult to manage and control system development, it increased users' contributions by improving communication between users and designers during the development process. The prototyping approach resulted in more satisfied users. On the other hand, the SDLC approach allowed effective management control, but the main complaints about it were that it: (1) delayed the delivery of systems to users until the last stages of system development, (2) required specified systems outputs at the outset, and (3) created communication problems. Lempp and Lauber (1988) examined the effect of using the CASE environment in managing medium- to large-scale projects. According to them, the CASE environment improved quality because it provided better project management control.

Three case studies found that design aids can be effective both in management control and in the interface between user and designer. Semprevivo (1980) described the users' experience with a Dictionary/Directory Facility (DDF). DDF consists of several generalized COBOL processors, or programs, which utilize the dictionary/directory to determine how to process an end-user's transactions. Its use in systems development demonstrated that DDF has significant implications for the ways in which user, management, and systems personnel interact throughout the development life-cycle of the system.

Because of its low programming requirement, it can be used effectively much earlier in the system development life-cycle as a design aid. DDF provided a tangible frame of reference to be used in the conceptual design of systems. Since the users can actually see a demonstration of the full range of decision consequences, they can make more intelligent suggestions.

Sheonolikar (1981) described how the generation of Activity Description Charts and Hierarchy plus Input-Output documentation during system development affected the productivity of project personnel because : (a) they clearly understand their individual responsibilities, and (b) they know the relationship of their work to the overall project development goals. It was possible to formally present the system to the user before major programming was started, thus leaving room for modifications of system functions before major development work was started. Berzins *et al.* (1986) found that the use of abstractions and rigorous specifications reduced the need for inter-team communication and facilitated the successful implementation of complex modules.

Organizational Life-Cycle Management Strategy

Lempp and Lauber (1988) found that the introduction of a CASE environment has a tendency to make the style of working more structured and orderly. They also noted that the organized information capture resulting from adherence to the environment's discipline has tremendous value for later traceability. Sheonolikar (1981) reported that the availability of the users' manual and HIPO documentation enabled designers to facilitate the communication between designers and people in the organization who will be affected by the information systems. Even though these studies did not provide quantitative results, we can infer that design aids can facilitate inter-team cooperation by institutionalizing design work patterns. In addition, design aids can also help train designers in advanced techniques and enforce consistent usage of techniques throughout the organization.

Only two studies focused on the impact of design aids on organizational life-cycle management strategy. One of the reasons for this small number of studies is that most studies focused on the project teams which manage the entire life-cycle of the design process. However, if an organization used multiple cooperating design teams for a single project, managing inter-team relationships would be important. For example, the communication channels among design teams and the integration of outputs produced by the design teams would be an important focus of design aids.

2.2.3. The Impact of Design Aids on Design Team Performance

The measure most often used as the performance variable was the perceived software quality as reported by a single designer or project manager (Beck and Perkins, 1983; Lempp and Lauber, 1988; Necco *et al.*, 1987). None of the studies were designed to eliminate threats to validity and to assure reliability of the findings. Since any I/S will be used by many people, the designer may not be the best person to judge the success of a design aid. As a more objective measure, some studies used the maintenance cost of the I/S (Card *et al.*, 1987; Guimaraes, 1983, 1985; Lientz and Swanson, 1980), but maintenance cost may reflect the influence of factors other than quality and may also provide only a partial reflection of the technical completeness of the I/S produced.

Some of the studies focused on whether design aids were associated with higher productivity of a design team and used perceptual measures assessed by project managers or designers (Card *et al.*, 1987; Lempp and Lauber, 1988; Mahmood, 1987; Necco *et al.*, 1987).

Productivity

The four studies that investigated the relationship between the use of design aids and productivity of a design team seem to provide little justification for the use of design aids. As seen in Table 2.1, only Necco *et al.* (1987) and Lempp and Lauber (1988) provide quantitative data to support a positive relationship, which they noted as "moderate." Necco *et al.* (1987) conducted research on how organizations currently perform systems analysis and design. They found that respondents who included some type of automated aids in their procedures to develop computer-based information systems generally achieved higher ratings in terms of systems developed on time, systems developed within budget, programming time reduced, and testing time reduced.

In their survey of 22 major projects supported by one specific CASE environment (EPOS) in the last 5 years, Lempp and Lauber (1988) found an increase in expenditure during the first phases of the projects due to two factors: first, the additional work of inputting textual information into the database (previously done only sketchily), and second, the enforcement of a structured approach which includes more detailed analyses in the beginning. Ultimately, this was more than compensated for by a decrease in expenditure during the later phases, which resulted in a net savings of about 9% over the entire development period. One specific factor which heavily influenced productivity in projects was the extent to which the documentation was produced automatically by the CASE tools. Because the automatic code generation and code feedback features were not introduced, the savings in program coding and unit test were estimated in their survey to be relatively low. They noted that code generation support could substantially change the estimates for this activity.

On the other hand, Card *et al.* (1987) could not find any significant relationship between design aids and productivity. They cautioned that this does not indicate that software practitioners should not expect any dramatic increase in development productivity as a result of applying the design aids considered in their study. Even if the design aids do improve productivity, that effect may be masked by other factors. In their study, however, they could not find the intermediate factors.

Software Quality

Seven studies examined the relationship between design aids and software quality, and of these five (Card *et al.* 1987; Guimaraes, 1983, 1985; Lempp and Lauber, 1988; Mantha, 1987; Necco *et al.*,1987) reported a significant relationship. Card *et al.* (1987) found that limited use of the design aids considered in the analysis produced approximately a 30 % increase in software reliability operationalized by the number of code lines divided by the number of errors. Guimaraes (1983, 1985) reported that data from 43 companies indicated an inverse relationship (t = 1.91, 0.04 significant level) between the availability of a self-contained query language (SCQL) and the ratio of maintenance budget to development budget. His interpretation was that the availability of tools that are targeted for prototyping decreases the maintenance budget.

Based on project manager estimates, Lempp and Lauber's (1988) survey on the use of the EPOS CASE environment in medium-to large-scale projects showed that considerable improvement in software quality was achieved. Because the survey had a relatively small sample and was restricted to one specific CASE environment, the results are not, as they noted, generally applicable to all environments in every detail. The quality of the software was improved in that its structure and documentation made it possible to reuse it in new applications without having to reverse-engineer system representations that did not already exist.

The degrees of the completeness of system representation using different design aids were compared in a study conducted by Mantha (1978). In Mantha's (1987) experiment, data structure analysts and data flow analysts generated logical file specifications on one specific case. When these specifications were compared and evaluated for completeness, the data structure analysts produced a greater number of entity views and attributes than the data flow analysts did. Necco *et al.* (1987) found the use of automated design aids was related to high software quality in terms of meeting user requirements, being easy to maintain, being easy to modify, and having consistent and complete documentation.

Two studies did not report an overall positive relationship between design aids and software quality. Beck and Perkins (1983) observed a positive correlation between problem levels and the number of design aids used. Lientz and Swanson (1980) found that the overall level of maintenance remains the same, whether productivity aids were used in development or not. Their finding indicates that such design aids have an adverse or no effect on the software development process. However, Beck and Perkins (1983) claimed that the positive correlations between design aid use and problem levels may have occurred because the knowledge and use of software engineering methods is stimulated by the existence of problems with software development. That is, projects having difficulties are motivated to find out about and to use methods designed to remedy these problems. Similarly, Lientz and Swanson (1980) claimed that the use of design aids somewhat redirects resources away from corrective maintenance and towards adaptive and perfective maintenance.

As we can see, most of the studies found that the use of design aids generally increased the quality of software produced. However, there are two problems with this claim. First, these studies in general used designers to rate the success of their own design aids. Studies employing only designers as informants tend to share methodological problems. If software produced will be used by other people, designers may not be the best judges of the success of the systems produced. Second, the criteria for software quality were mainly related to technical superiority, particularly maintenance efforts. Even though these criteria are important ones, software quality should include other criteria as well, such as meeting user requirements.

2.3. Critique of Research on the Impact of Design Aids

As Table 2.1 demonstrates, evidence for relationships between the use of design aids and outcome variables is not strong for the following reasons. First, there have been very few empirical studies. More empirical evidence from a wide variety of organizations is needed if we are to have the evidence necessary to evaluate the effectiveness with which design aids are used. Second, most previous studies have been based on the expectation of direct relationships between undifferentiated measures of the use of design aids and a performance variable; they have ignored the process of design. Third, these studies typically used poor research designs and inadequate measures. The problems with previous research can be summarized as falling into one or more of the following: lack of an underlying theory of design behavior, inappropriate characterization of design aids, and inappropriate measurement of performance variables.

Lack of an Underlying Theory of Design Behavior

Several researchers have pointed out that at the heart of the difficulties in researching the impact of design aids is the lack of a generally accepted underlying model of the I/S planning and design process (Card *et al.*, 1987; Kemerer, 1989; Vessey and Weber, 1984). Much of the research reviewed here is based on the commonly accepted notion that the use of design aids contributed to improved performance of I/S design teams; however, these studies have not paid attention to the details of I/S design activities. Moreover, as Table 2.1. suggests, this commonly accepted notion was not strongly supported in the studies reviewed here.

Only a very few studies have based on an underlying theory their hypotheses concerning the relationships between the use of design aids and performance. Among these few are Beck and Perkins (1983), Card *et al.* (1987), and Lientz and Swanson (1980) who have pointed out that some mediating variables can affect the relationship between design aids and performance. Since none of the design aids they studied showed a significant direct effect on productivity, they tried to find intermediate variables that might be affected by design aids and that, in turn, might affect performance. They reported that their efforts were unsuccessful probably because software development is influenced by a large number of factors, including some that they did not measure.

Table 2.1 suggests that even though the studies did not provide strong support for the impact of design aids on performance, they yielded reasonable evidence of the impact of design aids on individual resource utilization, team strategy, and organizational life-cycle management. Nevertheless, they did not contain a general theory linking these impacts to overall performance measures. For example, earlier productivity studies (Bohem, 1981; McGarry, 1982; Walston and Felix, 1977) found personnel experience and capability to be extremely influential factors on productivity. Nevertheless, there is no theory that can explain how these variables get translated into productivity and quality outcomes. Design aids can increase a single individual's level of information processing capacity, but how this improved individual resource utilization can contribute to team performance is yet to be explored.

At the team level, as Curtis *et al.* (1987) suggested, a major role of the project manager is to educate other members of the project team about the software system they are responsible for designing, and to ensure that they come to share a common model of how the software system should operate. The crucial processes that should be modeled at this level are personnel selection, assignment, education, and communication. Although these processes are obvious, few models include a recognition of these factors.

At the level of the organizational management life-cycle, several teams occasionally work together to develop a single system. During this process, each team may compete with the others to define system requirements and to obtain organizational resources such as skilled designers, computer time, and funding. It is yet to be seen how future design aids can support these non-technical constraints in the I/S planning and design process.

The task of theory development for I/S planning and design processes can be somewhat simplified in that relevant theories from other fields can be adapted to explain various aspects of I/S planning and design. For example, small group behavior theories and organizational control theories suggest how individuals work together as a team. Theories on new product development are also relevant to design teams in that I/S design can be viewed as the development of a new product. Moreover, many studies in the MIS literature itself provide useful insights into the design processes, although their focus is scattered. Using these theories as a starting point, we can develop a more concrete model of how design aids can affect design behavior, and not wind up with a private or idiosyncratic theory.

Inappropriate Characterization of Design Aids

The characterization of design aids is central to studying the impact of design aids on the performance of a design team. The diverse capabilities of this technology and its pace of evolution are at the core of the I/S management problem, as Zmud (1983, 1980) suggested. However, our review of empirical papers revealed that they do not contain an adequate definition or characterization of design aids in terms that allow us to compare and contrast systems and generalize results across studies.

A design aid can be quite complex. It can consist of a general process for managing the software product over its life-cycle as well as infrastructures that support the project team. As such, each team using a given design aid may develop its own usage pattern. Therefore, an aggregation representing a design aid and based on a dummy variable (e.g., use versus non-use of a design aid) cannot provide sufficient evidence about performance change. Moreover, current design aids are not perfect and are in a state of evolution. Empirical evidence about functions that would be helpful but are as yet missing could suggest future directions for the next generation of design aids.

Kemerer (1989) has argued that the lack of well-accepted models of the software development process hinders the ability to evaluate new methodologies and technologies. This argument is consistent with the findings of organizational researchers such as Fry (1982), Fry and Slocum (1984), Slocum and Sims (1980) and others, that an appropriate characterization of technology should reflect the underlying process of an organization. According to this argument, we need to characterize design aids in terms that correspond to the underlying design behavior of I/S planning and design. Thus, the success of a characterization of design aids depends on its ability to predict how underlying design processes can change with the use of design aids.

Several efforts are now in progress to develop valid, generalizable measures of design aids. Researchers should investigate these measures before studying the impact of design aids. Among these, the Henderson and Cooprider (1988) model might provide an initial understanding of functions that correspond to design behavior. Their model is based on organizational theories of how individuals work together as a team. As suggested in Section 2.1, design behavior should be studied on the individual, team, and organizational levels. Henderson and Cooprider's three dimensions refine our view of these three levels by suggesting distinct and specific features of design aids for each dimension.

Inappropriate Measurement of Performance Variables

As Kemerer (1987, 1989) indicated, all studies of I/S design have had measurement problems, and most studies have had the weakness of having used only a single designer to assess the outcome measures. However, team-level outcome measures reported by a single individual can be confounded by bias in that such individuals may protect their teams. Henderson (1988) found that teams facing budget overruns often either do not report overtime hours or under-report them. Bagozzi and Phillips (1982), Huber and Power (1985), and Silk and Kalwani (1982) have pointed out other problems in obtaining assessments of team level performance from a single individual. The reliability and validity of performance measures can be increased if a design team's performance can be assessed by several stakeholders: people who can affect design activities and who can be affected by the resulting I/S design. In this situation, we need to have stakeholders assume the role of key informants who can provide information at the aggregate or organizational level by reporting on team or organizational properties rather than personal attitudes and behaviors (Seidler, 1974).

As our review suggests, the current measures for software quality are restricted to technical measures. Since most I/S products will be used by non I/S personnel, the degree of incorporation of user needs can be another dimension of software quality. Another possible measure can be derived from the work of Cooprider and Henderson (1988). They pointed out that, since the organizational environment is becoming increasingly turbulent, the length of time from inception to market is becoming more important. This time-to-market measure highlights the criticality of rapid response to environmental change while directly incorporating aspects of quality and maintainability. In order to have useful measures of performance, we need a more comprehensive view of how an I/S product can help an organization.

In conclusion, while the performance measures we suggest are still subjective, the use of multiple informants and wider organizational perspectives will provide adequate reliability and validity for future studies.

2.4. Chapter Two Summary

The impacts of design aids on the performance of design teams have not been strongly demonstrated, even though we can identify some benefits of using design aids. Of 12 studies included in Table 2.1, only two claimed to demonstrate a positive relationship between the use of design aids and productivity, and five studies reported a positive relationship between the use of design aids and the quality of software produced.

This review of existing studies has shown three problems which might account for inconsistent results: the lack of an underlying theory of design behavior, inappropriate characterization of design aids, and inappropriate measurement of performance variables. The question now arises of how to move forward.

Three steps need to be taken in the next stage of investigating the impact of design aids on the performance of a design team:

(1) Studying the impact of design aids requires strong theories on the nature of the development process. Since most information systems are developed by a number of individuals, and since there is an extensive literature about groups, including organizational control theory, small group literature, new product development studies, and communication science, this literature should form the backbone for future work. Using this literature to develop such a model will be the focus the of next chapter.

(2) We also need to develop and validate standard measures for design aids which correspond to design behavior. Since the Henderson and Cooprider (1988) model seems to provide sufficient characterization of

design aids, the following chapter will also review their model in depth.

(3) Future research requires rigorous attention to measuring performance. Although we cannot provide a panacea for this problem, we have suggested several ways to increase the reliability and validity of outcome measures. These will be discussed in more detail in Chapter Five.

CHAPTER THREE. A MODEL OF TEAM PROCESS: A CONTROL THEORY PERSPECTIVE

While the potential for design aids to improve I/S planning and design appears compelling, such improvement will not nappen automatically. The impact of design aids can occur only through their use by the design team. As such, there is a need to understand team process in I/S planning and design first. In this chapter a theoretical model of team process based on organizational control theories is proposed.

In Section 3.1. we provide a rationale for using control theories to provide a model of team process. In the following sections we articulate theoretical bases for the inclusion of specific variables into our model and for the relationship among those variables and the performance of the design team.

3.1. Control Theory

In developing a model of team process in our research, two issues are of importance concerning our focus. First, while there are many variables that can affect the performance of a design team, we are interested only in those variables that could be manipulated by the design team. Furthermore, since the purpose of design aids is to help the design team better perform I/S planning and design, we need to select from a large set of performance factors those variables that are affected by the use of design aids or by the design team. That is, we need to find a small set of variables that are interesting from the perspective of the change agent.

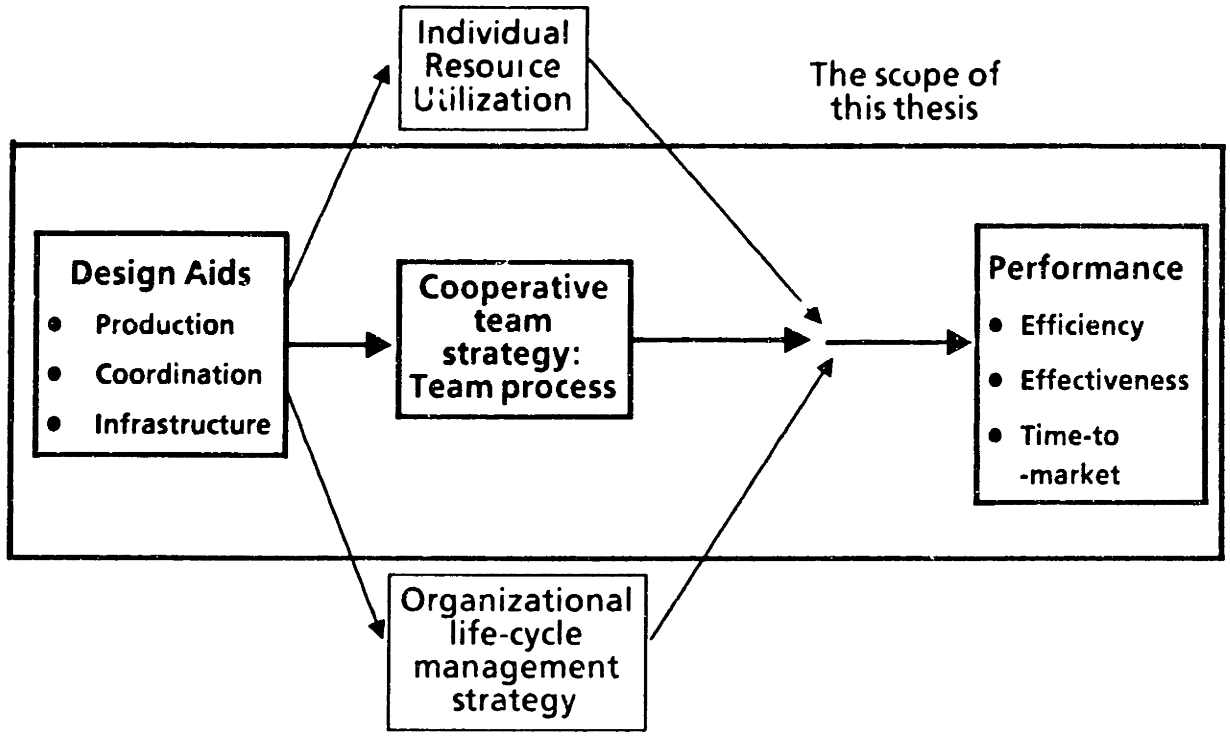

Figure 3.1. The scope of this thesis.

This dissertation does not focus on organizational life-cycle management strategy because most design teams manage the entire life cycle of the design process. If an organization did use multiple cooperating design teams for a single project, managing inter-team relationships would be important.

Individual resource utilization is not given major emphasis either. Although there has been considerable discussion of the possible impact of individual resource utilization on team performance (Collins and Guetzkow, 1964; Davis, 1969; Steiner, 1972), some researchers have made a convincing argument that individual resource utilization may account only for small amount of performance in an I/S planning and design team (Cooprider and Henderson,1988; Curtis *et al.*, 1987). Thus, our focus is on team strategy, particularly, on how team members work together as a team, as shown in Figure 2.1.

Second, complex human interactions and communication are intrinsic to the nature of I/S planning and design (Guinan and Bostrom, 1986). Because design teams are composed of a number of individuals, including the manager, designers, and users, understanding the underlying interactions among these individuals is the first step in developing a model of team process. Key to these interactions is the pattern of influence in a team. Salaway (1987) argued that these interactions occur at the intersection where user knowledge (business knowledge) and designer knowledge (I/S knowledge) meet. Each kind of knowledge must influence the other effectively in order to design information systems that can better meet user needs. In addition, designers and users bring different goals, skills, expectations, and motivations to the design process; the manager should influence both designers and users to work toward the team's goals instead of their own goals.

The above discussion fits quite well with our understanding of the philosophy of control systems. Flamholtz *et al.* (1985) defined control as *the organization's attempts to increase the probability that the employees will behave in ways that lead to the attainment of organizational goals.* Some students of organizational control believe that the sole aim of organizational control is to achieve particular organizational goals; they have suggested various methods of achieving such goals, methods we will call *control systems.*

Weber (1947) defined control as a process of creating and monitoring rules through hierarchical authority. In his view, control systems regulate patterns of interaction to restrict employees' behavior. Ouchi (1979) saw control as an evaluation process which is based on the monitoring and evaluation of behaviors or outputs. In the leadership literature, control has been defined as a leader's taking actions that induce a subordinate to adopt organizational goals (House and Dessler, 1974; Jermier and Berkes, 1979; Schriesheim *et al.*, 1976). Thompson (1967) and Reeves and Woodward (1970) defined control as a cybernetic process of testing, measuring, and providing feedback.

We believe that the *raison d'etre* of control systems is to increase performance by increasing the likelihood that people will internalize organizational goals and thus behave in ways that lead to the achievement of these goals. Therefore, from our point of view *control includes self-control as well as managerial control*. Our focus is on how design aids can be used as a part of a control system from the viewpoint of the organization as a whole. If design aids can make users knowledgeable enough to assume more responsibility for achieving organizational goals and if their performance improves at the same time, a traditional definition of control may view this as loosened control, but we see it as a form of control that is effective in so far as performance does not deteriorate.

This control perspective has been adopted by many studies in the MIS design literature. For example, Boland (1978), De Brabander and Thiers (1984), Henderson (1988), and others investigated different patterns of influence between designers and users in the design of information systems. They found that strong mutual influence of designers and users produces an environment that better matches the way design actually takes place. Keider (1984) and Schmitt and Kozar (1978) found that most projects that lacked basic management principles of such planning and control had failed.

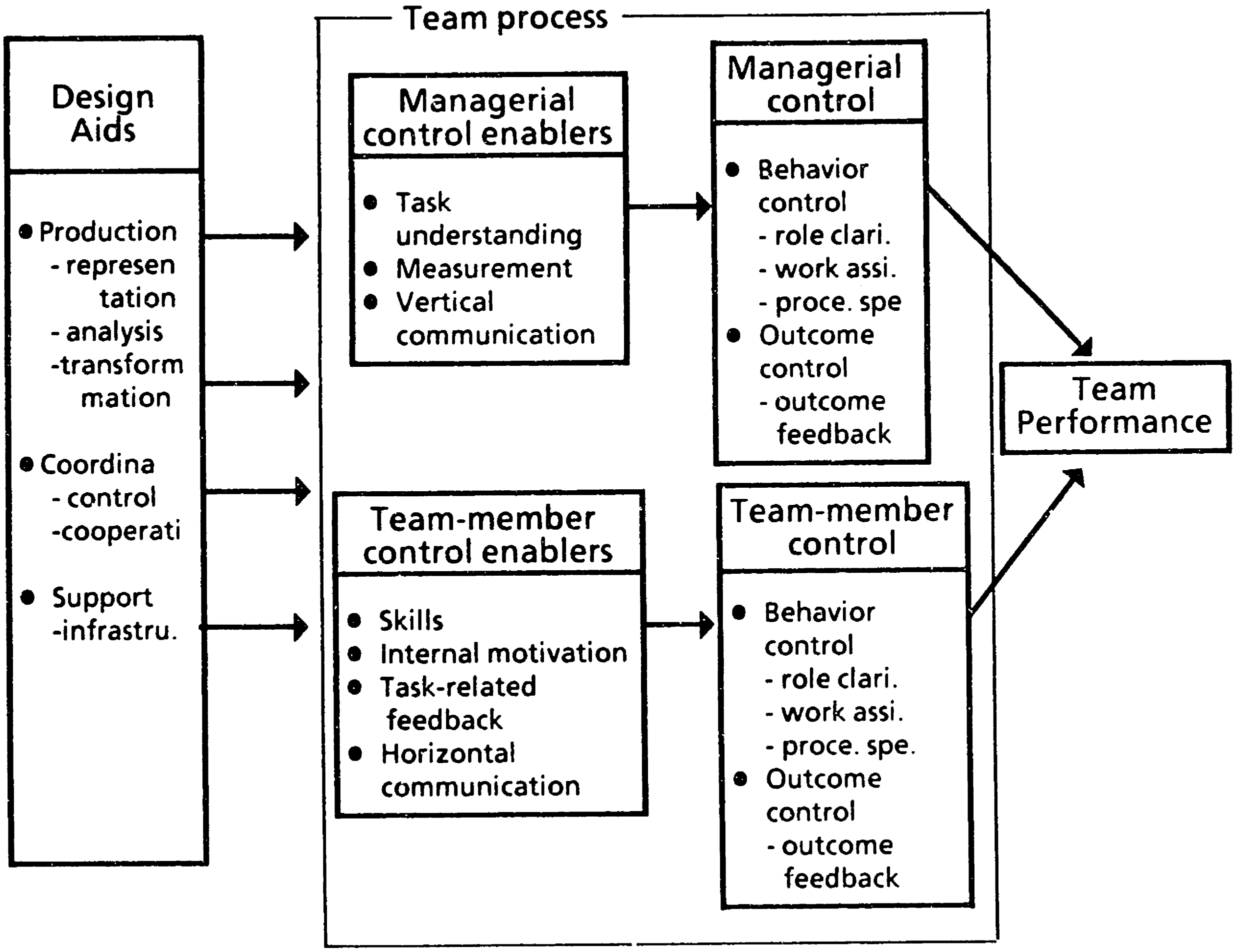

Figure 3.2. A model of the impact of design aids on the performance of a design team.

The control model to be developed in this thesis is presented in Figure 3.2. According to the model, managerial control and team-member control should explain a significant portion of the variation in team performance. Managerial control and team-member control, in turn, are functions of managerial control enablers and team-member control enablers, respectively. Design aids, represented by the use of specific functions, can influence team performance through the team process.

This model synthesizes two approaches to control that are contained in various theories of organization and behavior. The basic mechanisms of these two control approaches can be explained by analogy to a *principal-and-agent* relationship. In this relationship, a manager or leader (principal) contracts with employees (agents) to develop an information system. We conceptualize two ways in which design aids can affect this simple principal-and-agent relationship.

First, the upper path in Figure 3.2 shows how design aids can increase the principal's information-processing capacity, resulting in more effective managerial control. However, since the actual performer of the given task is still the agent, this impact of design aids on performance is either amplified or dampened by the principal's intervention activities. Second, as the lower path in Figure 3.2 suggests, design aids can also affect performance without the principal's intervention. This path reflects a direct effect of design aids on the agents' behavior.

The two paths illustrated in Figure 3.2 suggest that performance can be increased not only by reinforcing the managerial capability of the principal in some dimensions (managerial control) but also by decreasing the need for managerial control in other dimensions (team-member control). The remaining sections in this chapter describe in detail the elements of the team process outlined in Figure 3.2. The characterization of design aids is discussed in the next chapter.

3.2. Control and Performance

3.2.1. Managerial Control

Managerial control refers to the manager's attempts to influence employees to behave in accordance with the organizational goals. In our context, managerial control refers to the manager's attempts to influence team members to design information systems in accordance with organizational goals. The first thing a manager should do when he or she plans a project is define and document the work to be done (Katz and Lerman, 1985). Based on this work plan, team members are assigned to defining the functions of the system and to coding modules for a given function of a system. The manager establishes a closed loop in which the performance output of his group is fed back to him, compared with performance standards, and corrective control action is then directed into the system.

The perspectives of cybernetics and leadership study are essentially concerned with managerial control (Flamholtz *et al.*, 1985; Jermier and Berkes, 1979; Schriesheim, 1978). Flamholtz *et al.* (1985) claimed that the core control system, which is composed of planning, a measurement system, feedback, and reward, directly affects individual or group behavior. Both the Jermier and Berkes (1979) and the Schriesheim (1978) studies claimed that a leader's behavior can be viewed as a control mechanism which encourages employees to behave consistently with the goals of the organization and discourages them from doing otherwise.

Recent control theories (Eisenhardt, 1985; Ouchi, 1979,1977; Ouchi and Maguire, 1975; Peterson, 1984) claimed that managerial control can be established by either behavior-based control or outcome-based control.

According to this view, behavior-based control refers to the extent that the manager monitors and evaluates team members' behavior in order to assist them. In contrast, outcome-based control is the degree to which the manager provides evaluation of the outcome produced by the team members.

From the perspective of the employees, managerial behavior control consists of the actions (behavior) of a manager that are aimed at clearly defining the team members' roles and letting them know what is expected of them. These actions, collectively called the manager's instrumental behavior, refer to the extent to which a manager initiates activity in the work settings, and organizes and defines the way work is to be done. Leadership behavior studies emphasize that an effective leader (manager) provides some type of guidance and/or positive feelings for subordinates as they carry out their tasks (House and Dessler, 1974; Howell and Dorfman, 1981; House and Mitchell, 1974; Jermier and Berkes, 1979; Schriesheim, 1978).

Leadership behavior studies have also provided what we believe to be the most complete characterization of managerial behavior control These studies have identified three dimensions of managerial behavior control: (1) ***role clarification***: clarifying management expectations of subordinates in their work, (2) ***work assignment***: assigning subordinates to specific tasks, and (3) ***procedure specification***: enforcing rules, procedures, and work methods. In this thesis we have adopted these three dimensions to characterize the manager's *behavior control* in I/S planning and design projects. To characterize the manager's *outcome control*, we have adopted perspectives from communication and cybernetics theories (Campion and Lord, 1982; Flamholtz *et al.*, 1985; Sorensen and Franks, 1972). According to these theories, ***outcome feedback*** is the most relevant dimension of outcome-based control. A manager must provide feedback on interim design activities in order to achieve successful outcome control.

3.2.2. Team-Member Control

Recently several researchers have pointed out that managerial control accounts for only a small portion of the criterion variance, such as performance and job satisfaction, in most empirical studies of leadership. Two explanations have been provided for these findings (Howell and Dorfman, 1981; Kerr, 1977; Kerr and Jermier, 1978). First, as we have already said, managerial control is exercised through the manager's intervention process. Therefore, the actions or style of control of a given manager might be perceived variously by different employees. Second and more important, most empirical studies ignore team member's self-control, which may, in fact, be acting in such a way as to prevent or neutralize the manager's influence.

In this self-control process, which others call self-management or self-regulation, a person faced with response alternatives decides to choose what otherwise would be regarded as a low-probability response (Thoresen and Mahoney, 1974, pp. 12). Self-control is differentiated from freedom or *laissez faire* in that it is related to organizational effectiveness. While there has been little empirical and theoretical research on models specifically addressing self-control in organizations (Manz and Sims, 1980; Mills, 1983; Slocum and Sims, 1980; Van de Ven *et al.*, 1976), this literature is consistent in concluding that, as tasks become more complex, a change from managerial control to self-regulated control is desirable.

Unlike managerial control which is exercised through the manager's intervention process, team-member control refers to self-control or self-management by team members. A review of the literature shows that there are two schools of self-control. The first school of researchers, such as Slocum and Sims (1980) and Van de Ven *et al.* (1976), have observed that self-control is likely to be implemented when the organization cannot adequately measure the behavioral performance or standardize the transformation procedures. In other words, self-control is resorted to when the management does not have any other choice but self-control. On the contrary, the second school of researchers, such as Manz and Sims (1980) and Mills (1983), has advocated the view that self-control can be implemented by the team members' own will and that managerial control and team-member control can be operative at the same time. By providing more accurate and timely information to the design team, design aids can improve central performance monitoring by the manager and at the same time can increase the ability of team members, resulting in a delegation of decision-making authority. The position of the second school seemed more reasonable to us, and we adopted its perspectives in constructing our hypotheses.

Since the roles of group members can be classified as either a designer role or a user role, team-member control refers to both self-control by the designer and self-control by the domain representative. In team-member control, role clarification, work assignment, procedure specification, and outcome feedback are done by the individuals filling the roles of designers and domain representatives.

3.2.3. Managerial Control and Team-Member Control as Predictors of Team Performance

Mantei (1981) claimed that the two predominant control structures in I/S planning and design are the chief programmer team proposed by Mills (1971) and the egoless programming team proposed by Weinberg (1971). In a chief programmer team, the decision-making authority belongs to the chief programmer; in Weinberg' structure control is diffused throughout the project membership. Communications are centralized in the chief programmer design team, but are decentralized in Weinberg's team. That is, while a chief programmer team is characterized by strong managerial control, Weinberg's team is characterized by strong team-member control.

March and Simon (1958) proposed that task predictability largely determines what type of team structure is appropriate. When tasks are routinized and predictable, hierarchical control is effective because coordination and control by plan and schedule is possible; when tasks become variable and work sequencing is difficult to predict, coordination by feedback is necessary and a decentralized team is more effective. Bavelas (1950) and Leavitt (1951), in their experiments on centralized and decentralized problem-solving behavior, found that decentralized groups take more time and generate twice as many communications as centralized groups. These findings suggest that in order to finish a project on time a chief programmer team structure should be employed. On the other hand, these findings also suggest that, if a project is difficult, a decentralized team structure might be more effective.

The position we take in this thesis is that neither the purely hierarchical approach nor the purely decentralized approach is appropriate in most real software development practices. First, as Yourdon (1976) pointed out, the effective chief programmer is a rare individual; most so-called chief programmer teams are headed by someone who is unlikely to adequately handle the communication and decision-making complexity. Second, although the decentralized group is lauded for its open communication channels, the design teams often fail to finish their tasks on time.

In this section we propose that a third design team structure is more likely to be effective in I/S planning and design. This team structure is characterized by both strong managerial control and strong team-member control. The reason we believe that this new approach may be more effective is that it may remedy the disadvantages of either approach of the chief programmer team or the Weinberg team. Strong team-member control is necessary in modern software development practice because tasks in I/S planning and design are difficult in nature; strong managerial control is necessary because competitive market forces make it imperative to produce products as rapidly as possible.

We believe that both managerial control and team-member control can be increased at the same time. Past studies of small group behavior in general assume a zero-sum view of control in design teams (Cartwright and Zander, 1968; McGrath, 1984). Given the zero-sum assumption, an increase in the control exercised by team members must be accompanied by a reduction in the control exercised by the manager. With this assumption, the past studies have indicated which design team structure is more effective in terms of task contingency. This perspective suggests that a Weinberg group would function well in difficult I/S development projects which do not have time constraints. In a software project with a tight deadline, a group decision-making structure might cause the project to fail. The literature shows two major patterns of weakness in relation to these assumptions. Although a great deal has been learned about the potential influence of leader behavior, leader behavior alone accounts for only a small portion of performance variance in most empirical studies (Kerr, 1977). In addition, past control research, which focused on bivariate relationships, has not produced consistent research findings. In order to design an I/S product which is difficult to develop, we claim that both strong managerial control and strong team-member control should be exercised in the design team.

This position runs contrary to the zero-sum view of control, in that we maintain that strong managerial control can be achieved without the expense of team-member control. Tannenbaum (1968) claimed that both the manager and the employee can increase their influence together without a negative impact upon one another. He also reported that in his comparative analysis of several different organizations, performance was correlated with the sum of the managers' control and the subordinates' control. Similarly, Bartolke et al. (1982), Clegg (1981), and Hofstede (1967) provided arguments consistent with the hypothesis that strong managerial control and strong team-member control can exist at the same time. Conceptually many scholars recognize this fact, but research has tended to focus on either a bivariate relationship between managerial control and performance or between team-member control and performance. Empirical studies have also tended to emphasize that only one form of control is desirable at a time depending on the contingency of tasks.

Given that a design team can have both strong managerial control and strong team-member control, we hypothesize that this strong managerial control and strong team-member control will lead to performance increases. Tannenbaum (1968) claimed that a high degree of control by the manager is necessary for the efficient administration of an organization and, at the same time, a high degree of team-member control is also necessary to foster identification, motivation, and loyalty. Lickert (1961) has also suggested the importance of a high level of mutual influence within teams as the basis for effective coordination of organizational activity as well as for the integration of the goals of individual members and of the organization. These conditions, leading to effective performance, entail significant control exercised by persons at all levels, the manager as well as all of the team members.

On the basis of this discussion in this section, we propose the following hypothesis:

H1: Managerial control and team-member control have significant effects on the performance of design teams.

3.3. Managerial Control Enablers

In organizational control and leadership behavior studies there is a strong research tradition that has focused on the relationship among the determinants of control strategy, the control strategy employed, and performance. As we have mentioned previously recent organizational control studies (Eisenhardt, 1985; Ouchi, 1979, 1977; Ouchi and Maguire, 1975) have suggested that there are two underlying control strategies: behavior control and outcome control. While behavior control refers to the cybernetic process of monitoring employee behavior, outcome control refers to control through monitoring and evaluating performance. Ouchi and Maguire (1975) reported that as managers understood the means-ends relationship better, they used more behavior control. Eisenhardt (1985) also reported that as the managers understood the employee's job better and the cost of behavior measurement was reduced, they exercised more behavior control.

Peterson (1984) and Randolph (1981) claimed that the control strategy employed depends on a small set of organizational control enablers. For example, if the manager can clearly specify and accurately measure the outcomes of an employee's work, then the manager has a concrete way of evaluating the effectiveness of that employee's work.

These studies collectively contribute to the understanding of the relationship between managerial control enablers and the control strategy that can be employed by the manager. However, there are two limitations in this type of research. First, as Ouchi and Maguire (1975) found, behavior and outcome controls are not substitutes. The use of outcome control by the manager does not suggest either less or more behavior control. Both behavior and outcome controls can be operative in one organization, and therefore the relationship between the use of outcome and/or behavior controls and performance must be explored further. Second, the operationalizations of behavior and outcome controls are not sophisticated enough to reflect fully the managerial control behavior. For example, in Eisenhardt's (1985) work, behavior control was operationalized by those pay plans in which pay is either salary or an hourly rate, and outcome control by commissions for the sales persons.

In summary, even though organizational control studies identify important relationships between control enablers and the control strategy employed, their definitions or operationalizations are not appropriate for our purpose. In this study we will operationalize behavior control using the manager's task-related ***instrumental control*** and outcome control using the manager's task-related ***feedback control*** in order to better emphasize the theoretical and operational distinctions between them in two respects. First, although we have derived the underlying relationships between managerial control enablers and managerial control from traditional organizational control studies, such as Eisenhardt (1985), Ouchi (1979, 1977), Ouchi and Maguire (1975), Peterson (1984), and others, we differ with Ouchi and Eisenhardt in that we believe that design team managers can exert both behavioral and outcome control at the same time. Second, traditional control studies operationalized outcome control by focusing only on the final outcome, but we believe that it is important to operationalize the outcome of interim design activities during the I/S planning and design process, because the manager cannot see the tangible product until it is developed in its final form.

The enablers that are believed most relevant to effective managerial behavior-based control and outcome-based control can be grouped into three classes: the manager's understanding of the employees' job, the availability of measurement, and the ease of vertical communication. Eisenhardt (1985), Ouchi (1979,1977), and Ouchi and Maguire (1975) claimed that as the manager understands the means-ends relationship better and the cost of behavior measurement is reduced, he will exercise more effective instrumental control. Hage (1974) and Randolph (1981) claimed that effective communication channels are needed between the manager and the employee in order for them to clarify what is expected from each other.

Task Understanding: This control enabler reflects the fact that a manager needs to understand the means-ends relationships associated with the tasks the project team must perform. Design aids can provide the manager with opportunities for detailed analysis, the ability to consider alternative courses of action, and a comprehensive view of the tasks.

The Availability of Measurement: Measurement, the assignment of numbers to objects according to rules (Flamholtz *et al.*, 1985), is an important control enabler in that it can influence work behavior by the information it produces as well as by the act or process of measurement itself. Measuring progress in I/S planning and design usually consists of checking off completed outputs for a particular aspect of the software model at a particular time during a project (Katz and Lerman, 1985). However, since the manager does not see the I/S product until it is finished, it is not easy to see the construction and progress of a software project. Design aids can bring concreteness to I/S planning and design by structuring activities around structured design principles. This in turn enables the project manager to define and measure how much of a project has been completed.

Ease of Vertical Communication: In order to ensure effectiveness of control, the importance of effective communication as a control enabler throughout all phases of the project cannot be overstated. By making sure that individuals responsible for different parts of the system communicate with the manager regularly, there are likely to be far fewer surprises when the parts are brought together. The larger the project, the more important this element of communication becomes. Design aids, especially with telecommunication, can increase both the diversity and frequency of use of individual networks, leading to effective vertical communication. Recent studies of computer-based message systems or electronic mail systems (Crawford, 1982; Hiltz and Turoff, 1981; Montgomerry and Benbasat, 1983) all reported that these systems improved communication by reducing the dysfunctional features of meetings, conversations, written mail, and telephone calls.

Based on the above discussion, we propose the following two hypotheses:

H2: The manager's task understanding, the availability of measurement, and the ease of vertical communication have significant effects on the manager's behavior-based control.

H3: The manager's task understanding, the availability of measurement, and the ease of vertical communication have significant effects on the manager's outcome-based control.

The above two hypotheses (the two relationships between managerial control enablers and managerial control) were derived from the literature on organizational control, leadership behavior, and communication science. However, MIS literature has also noted these relationships. Keider (1984) asked 100 MIS professionals which single factor caused the most failures in projects in which they had participated. He found that although some projects fail because of technology or design problems, the three most often cited causes of failure are within the control of the project manager. They are (1) the lack of a project plan, (2) an inadequate definition of the project scope, and (3) a lack of communication. According to him, these three problems can occur if the manager cannot understand the team members' responsibilities and skills, and if he lacks an adequate standard against which to measure project progress.

Beath (1986) also emphasized the importance of the manager's understanding of the project. She argued that for fairly simple projects the manager needs to establish a market-like governance structure between the project team and users. In a more complex project, the manager needs to establish a matrix structure. After studying managerial control in four project teams, she concluded that I/S project managers need to master a variety of governance techniques, which can be matched to a variety of project characteristics.

A study by Schmitt and Kozar (1978) of the unsuccessful development of an information system is also consistent with our hypotheses. Organizational deficiencies in the area of project planning and control were highlighted in their analysis. Particularly, infrequent communication between the project manager and team members and a lack of measurement of project progress during the design process resulted in weak managerial control, such as giving vague objectives and criteria for successful systems, and a lack of formalized project control. In other words, the managerial control enablers were inadequate.

3.4. Team-Member Control Enablers

Variables that affect the impact design aids have on team-member control can be derived from the literature on self-control. Mills (1983), Slocum and Sims (1980), and Van de Ven *et al.* (1976) claimed that there are two antecedents of effective self-control. First, the individual should be familiar with transformation processes (***skill***). Second, the individual must be committed (***internal motivation***). Cummings (1978) showed how these conditions are related to those required for psychologically motivating work. He argued that team members can be self-regulating only if they have sufficient skills to understand the tasks they are performing and only if they are motivated enough to control task-related behaviors (motivation).

Thompson (1965) reported that as ***task-related feedback*** increased, employees' job-related motivation increased. Cherns (1976) emphasized the nature of an organizational task that can provide feedback and that can bring needed information directly to the level where it can be most directly acted upon.

Lastly, studies of communication (Allen, 1970; Allen *et al.* 1979; Ebadi and Utterback, 1984; Hage, 1974; Katz and Tushman, 1979) emphasized the need for ***horizontal communication*** in self-control. Thompson (1967) and Mills (1983) observed that increased peer or horizontal communication is likely to occur in self-managed situations because supervision has shifted to the realm of the experts who in some areas are more task-competent than the formal manager. Collegial interaction or horizontal communication is a process of interaction in an informal network in which expert advice is exchanged. Foster and Flynn's (1984) case study of General Motors' divisions reported that the implementation of information systems increased the number of horizontal communications, which caused a network to develop among task-related experts where previous communication had been largely hierarchical in nature.

Skill: The need for information support in carrying out complicated job tasks has been noted in many studies of limitations on human cognition (Slovic, 1976; Tversky and Khaneman, 1974). These studies noted that computerized analytical tools can augment the capabilities of the human mind. Many empirical findings reported that interactive computer support made group decision-making more effective by providing analytical decision support tools and by increasing the number of sources of information (Adelman, 1984; Kull, 1982). Semprevivo (1983) and Sheonolikar (1981) examined the impact on designers of using design aids. They reported that design aids significantly reduced the amount of conventional programming. The availability of design aids enhances team members' information processing capabilities and enables them to better understand the tasks assigned to them. Furthermore, design aids can also help train designers in advanced techniques and can help enforce usage of these techniques throughout design activities.

Internal Motivation: Curry *et al.* (1986) reported that people who were satisfied with their jobs were more likely to remain in the organization as well as to expend considerable effort for organizational performance. Thompson (1965) argued that internal commitment and a sense of intrinsic rewards are important for carrying out tasks effectively. Design aids can affect motivation by creating challenges and making tasks meaningful. For example, Malone (1982) discussed a number of ways to include motivational factors such as challenge, fantasy, and curiosity in a computer system so that a child could learn effectively. Berzins *et al.* (1986) and Sheonolikar (1981) reported that design teams had their jobs restructured so that they no longer performed isolated codings in a process they did not understand. Since design aids could improve their perception of the bigger picture, designers were motivated to handle on their own all the steps required in developing information systems, resulting in better overall performance.

Task-Related Feedback: Lawrence and Lorsch (1967) noted that the relatively greater uncertainty facing research development results, in part, from the longer time span needed for definitive feedback. This is a typical feature of I/S planning and design. Since design involves translating abstract concepts of an application to a tangible set of programs (Elam, 1987), the absence of feedback information is striking during the early stages of the project and often other stages as well. Design aids can reduce the span of task-related feedback by making goals explicit and then providing feedback on performance in relation to these goals.

Horizontal Communication: Churchman and Schainblatt (1965) and Gruber and Niles (1975) have stressed the importance of effective communication among parties with different competencies. Horizontal communication can be increased by increasing connectedness among experts and by sharing the logical model of the system. Galbraith (1977) and Tushman and Nadler (1978) noted that having the correct level of connectedness is vital to an organization's effectiveness. Design aids supported by telecommunications capabilities can facilitate the build-up of communication networks among experts. Studies of telecommunication (Crawford, 1982; Hiltz and Turoff, 1981; Montgomery and Benbasat, 1983) have indicated that communication facilities can increase the extent of connectedness by increasing both the frequency of communication and the diversity of an individual's communication sources. Guinan and Bostrom (1986) suggested that the largest single benefit of the new, structured design techniques may be the improvement in user and analyst communication via the development of a shared logical model of the system. Because they can see more concrete results of a design, team members can make more intelligent suggestions.

We believe that these enablers can increase team-member control. Team-member control is represented here as the influence of team members in task-related behavior. Traditionally, team-member control (self-control) has been considered in the context of the relationship between the manager and a single team member, and team-member control was operationalized by how much influence the team member has on the manager's task-related behavior or self task-related behavior. We can extend this notion by adding multiple team members to this simple relationship between a single team member and the manager so that the relationship becomes that between a single team member and the other team members including the manager. In addition to upward influence and self-control, the team member can influence other team members (horizontal influence).

This issue of the influence among team members appeared throughout the research in MIS studies. For example, many studies focused on user involvement in the I/S planning and design process. Boland (1978), Henderson (1988), and Robey and Farrow (1982) claimed that the pattern of influence between designers and users is important. They further argued that a high level of mutual influence by team members (designers and users) will lead to improved design products. De Brabander and Thiers (1984) also claimed that designers and users should have balanced power between them to develop a successful system.

Like managerial control, team-member control can be represented by two types of control : behavior-based control and outcome-based control. Behavior-based control is (1) the degree to which a team member helps others to carry out their work by providing assistance in areas such as role clarification, work assignment, and procedure specification and (2) the extent of the influence he has on his own task-related behavior. On the other hand, outcome-based control is the degree to which the team member supplies feedback on performance to other team members.

Based on the above discussion we propose the following two hypotheses:

H4: ***The team member's skills, internal motivation, task-related feedback, and the ease of horizontal communication have significant effects on the team-member's behavior control.***

H5: ***The team member's skills, internal motivation, task-related feedback, and the ease of horizontal communication have significant effects on the team-member's outcome control.***

In the MIS design literature, team-member control enablers have been studied in depth. For example, Alavi (1984) emphasized that for a prototyping effort to be successful three aspects of a designers' skill and knowledge are especially important: (1) experience in working with the software tools typically used in the development of the prototypes, (2) interpersonal communication skills, and (3) experience in the functional area for which the system is being designed. She also stressed the need for knowledgeable and motivated users throughout the prototyping process. White and Leifer (1986) asked 68 design teams to list five factors that they thought led to task system success. They reported that team members' skills and abilities, including both technical skills and communication skills, were most important.

De Brabander and Thiers (1984), Hirschheim (1985), Olson and Ives (1982), Salaway (1987), and others, have pointed out instances of ineffective communication between designers and users and provided ways of increasing communication effectiveness. De Brabander and Thiers and Hirschheim used third parties or consultants to stimulate the communication between designers and users. Olson and Ives examined the relationship between the use of several chargeback systems and user involvement. Although they did not find a positive relationship, they reported that most organizations adopted a chargeback policy to increase user involvement in system design and implementation. Salaway claimed that traditional user/analyst interactions display primarily error-prone characteristics. Therefore, she proposed an alternative organizational learning interaction methodology based on Argyris and Schon's (1974) organizational learning theory. In an experiment she found that the new interaction methodology successfully generated more valid information with increased detection of error.

3.5. Control Enablers and Performance

In hypothesis H1, we claimed that managerial control and team-member control have significant effects on the performance of design teams; in hypothesis H2 through H5 we claim that managerial control enablers and team-member control enablers have significant effects on managerial control and team-member control. The general premise of several leadership behavior studies is that leader behavior is amenable to change with managerial control enablers, such as the manager's task understanding, the availability of measurement, and the ease of vertical communication. As House and Mitchell (1974) pointed out, different leadership styles can be shown by the same leader in various situations. Thus, if the enablers of managerial control change, the managerial control will be changed accordingly. Suppose that the level of managerial control enablers is high, but that managerial control is not high; in this case there might be little or no relationship between managerial control enablers and team performance. Stated differently, managerial control plays a role of mediation between the managerial control enablers and team performance (Venkatraman, 1988).

Venkatraman claimed that the mediation variables (managerial control) account for a significant proportion of the relation between the predictor (managerial control enablers) and the criterion (team performance). In our context, the manager can exercise strong managerial control, depending upon the managerial control enablers. We derived the relationship between the managerial control enablers and managerial control from the literature on organizational control-related studies. Thus we believe that managerial control enablers can affect managerial control directly but not team performance. The effect of managerial control enablers on team performance is indirect. This will be the same in the case of team-member control enablers.

Therefore, we propose:

H6: Managerial control enablers have a significant effect on the performance of design teams. The impact of managerial control enablers on team performance will be significant through managerial control.

H7: Team-member control enablers have a significant effect on the performance of design teams. The impact of team-member control enablers on team performance will be significant through team-member control.

Hypotheses H6 and H7 refer to the validity of our model presented in Figure 3.2.

3.6. Chapter Three Summary

This chapter has synthesized a number of control theories to provide a model of the team process in I/S planning and design. A central feature of the model is that managerial control and team-member control can explain a significant portion of the variation in team performance. Managerial control and team-member control, in turn, are functions of managerial control enablers and team-member control enablers, respectively, which are defined below.

The enablers of managerial control believed most relevant to effective managerial control are derived from the leadership literature and organizational control literature. They are the manager's task understanding, the availability of measurement, and the ease of vertical communication. Skill, internal motivation, task-related feedback, and horizontal communication were proposed as enablers of team-member control based on the literature on self-control and communication.

Assuming these relationships, we proposed seven testable hypotheses that are theoretically grounded in the present literature and that extend the literature to its next logical step. In Chapter Six we explain how these hypotheses will be tested, and which variables will be included and how they will be operationalized in detail. In Chapter Four we discuss the theoretical background and empirical evidence for the relationships between design aids and design behavior. Then, in light of our model for the team process we describe the implications of those relationships for computer-aided support of team performance.

CHAPTER FOUR. THE IMPACT OF COMPUTERIZED DESIGN AIDS ON THE PERFORMANCE OF I/S PLANNING AND DESIGN TEAM

In Chapter Three we proposed a model of team process. According to this model, managerial control and team-member control explain a significant portion of the variation in team performance. Managerial control and team-member control, in turn, are functions of managerial control enablers and team-member control enablers, respectively. In this chapter we propose that design aids can affect performance through the team process, which is affected by management control and team-member control.

In Section 4.1 we review Henderson and Cooprider's (1988) model of design aids in which design aids are represented by the use of specific functions. In section 4.2 we review the literature pertaining to the impact of design aids and hypothesize that design aids do not have a direct effect on team performance. Instead design aids affect team performance only indirectly through managerial control and team-member control.

4.1. A Functional Characterization of Computer-Based Design Aids

A broad definition of computer-based design aids may include all computer technology used to support I/S planning and design activities. This definition includes operating-system-level support and database system support with automated code generation and automated project management tools. This definition, however, offers does not help to clarify distinctions among different computer-based design aids.

We believe that an appropriate characterization of design aids should include the following three aspects. First, it should provide a common basis for measurement of different technologies. The characterization must have sufficient capacity for making measurements or distinctions, so that it is possible to compare different technologies and to make generalizations about research results that go beyond the narrow circumstances in which they are observed. Second, the characterization should include all the characteristics of the current existing tools as well as the functions we believe design aids will have in the future. It has been observed the capabilities of computer-based design aids are quite primitive now and should be seen as the early stages of a far more significant long-term evolution (Acly 1988; Wasserman, 1982). Third and most important, our characterization should correspond to actual designer behavior. As Case (1985) suggested, a current design aid is composed of several distinguishable features. Hence, merely indicating the availability of a specific design aid, as some research has done, does not shed light on which feature is used for which purpose. As Henderson and Cooprider (1988) and Osterweil (1981) claimed, an appropriate characterization should be based on the basic nature of the design process.

These aspects were fruitfully examined by Henderson and Cooprider (1988). While there are a number of competing models of computer-based design aids, Henderson and Cooprider's model can be operationalized with relative ease and offers a starting point for understanding explicitly how design aids are used by designers in I/S planning and design. The Henderson and Cooprider model is based not on technology features (e.g., PC-based or networked, having an embedded design language or structure code compiler), but instead of technology usage behavior. That is, Henderson and Cooprider's model characterizes design aids in behaviorally- and organizationally-motivated terms.

Reviews of the organizational literature on technology (Fry, 1982; Fry and Slocum, 1984; Slocum and Sims, 1980; Withey *et al.*, 1983) reveal a diversity of approaches to its measurement. As Henderson and Cooprider (1988) claimed, these approaches can be classified into three dimensions: production, coordination, and infrastructure technology. Production is related to the actions used to transform inputs into outputs (Perrow, 1967). In that context, technology is a production variable, describing the way inputs are converted into desired outputs. A second dimension used to measure technology is coordination. Thompson (1967) argued that coordination is needed when interdependence occurs. Interdependence requires that the performance of one or more discrete operations has consequences for the completion of others. Different types of interdependence create different coordination structures among the participants involved (Galbraith, 1977; McCann and Galbraith, 1981; Thompson, 1967). Since a design team consists of a number of agents whose goals and skills are different, coordination technology may emerge as being important. A third dimension of technology is infrastructure which can be viewed as the organizational support technology. Design teams may interact with other teams and individuals to obtain resources, coordinate work, make decisions, and exchange inputs and outputs. In this regard, infrastructure technology is concerned with a team's interaction with persons or units that are outside the design team. The difference between coordination technology and infrastructure technology is that the former concerns coordination within the design team and the latter is concerned with organization-wide interaction across the design team boundary.

Taken together, technology can be conceptualized as production technology, coordination technology, and infrastructure technology. In the following sections we use the concept of bounded rationality to characterize design aids and to provide a link between organizational theories and design aids. Bounded rationality refers to human behavior that is intended to be rational, but which has limited success in attaining this goal (Simon, 1976). Although Simon proposed bounded rationality at the individual level, we can extend it to the group and organizational levels. The major premise of the following discussion is that design aids can affect the efficiency and effectiveness of the design team by reducing the limitations that bounded rationality places on the team.

4.1.1. Production Technology

At the individual level, bounded rationality involves neurophysiological limits on the computation capacities of an individual. The information-processing view of organizations (e.g., Cyert and March, 1963; Galbraith, 1977; March and Simon, 1958; Tushman and Nadler, 1978) has asserted that human limitations on information processing interact with environmental factors, such as environmental complexity and uncertainty, to produce bounded rationality. Treacy (1981) claimed that human beings are not good problem solvers because they try to maximize only one or two of the most important dimensions of an outcome, and are satisfied with merely adequate results in all other dimensions. In other words, human beings are not good at digesting information beyond a certain level of complexity, and this capacity may not be sufficient for the task.

The need for information support in carrying out complicated job tasks has been noted in many studies of the limitations on human cognition. These studies indicated that computerized analytical tools can augment the capabilities of the human mind, and thereby expand the limitations of bounded rationality. Many empirical studies have also reported that interactive computer support helps make decision-making more effective by providing analytical decision support tools and by increasing the number of sources of information that can be considered (Adelman, 1984; Kull, 1982).

Early studies of decision support systems (Keen and Scott Morton, 1978) found that a computer system can increase the efficiency and effectiveness of decision making by automating and supporting specific activities. This is the case with I/S planning and design activities. Henderson and Cooprider (1988) identified three dimensions related to production technology: (1) analysis, (2) representation, and (3) transformation. The first two reflect the use of technology to develop and analyze plans or designs. The third reflects a pure efficiency gain by using automation instead of completely manual human planning and design activities.

Analysis Dimension: The analysis dimension enables the user to explore, simulate, or evaluate representations or models of objects, relationships, or processes (Henderson and Cooprider, 1988). This dimension reflects the need to compare, simulate, evaluate, ask "what if" questions with respect to a criterion, and to choose or optimize. Analysis in this context is similar to the functional building block of decision support systems (Keen and Scott Morton, 1978; Sprague and Carlson, 1982; Treacy, 1981).

With the widespread use of AI concepts in the development of design aids, we note that embedded intelligence is often included in design tools. These tools let designers easily apply tests for consistency, completeness, and conformance to standard.

Representation Dimension: Henderson and Cooprider (1988) defined the representation dimension as a dimension that enables the individual to define, describe or change a definition or description of an object, relationship or process. Any activity in the design of an I/S takes place in the context of some conceptualization of the information that will be used in the activity. The conceptualization may be a chart, a picture, a few numbers, an equation, and so on. Even though the early conceptualization may be mental, this conceptualization should be represented physically.

Representation tools provide a context in which designers can interpret results of decision-making processes and use the results as inputs for the next stage of the design process. These tools can also help the user construct several types of models (e.g., data, process, functions) to represent different types of design information. They can also be helpful in choosing a first-cut model from among stored generic models, making it unnecessary to start from scratch. For example, the user can sketch or outline a model, then search a library of models for one that matches its general form.

Transformation Dimension: Transformation dimensions are those that execute significant planning or design tasks, thereby replacing or substituting for a human designer/planner (Henderson and Cooprider, 1988). The bulk of the current transformation technology focuses only on activities late in the design life cycle, e.g., code generation. Thus, we anticipate that new types of features will emerge for this dimension in the future. These features will enable systems designers to document and model an information system from its initial user requirements through design and implementation.

4.1.2. Coordination Technology

Williamson (1975) asserts that constraints on human information processing are a major reason for the very existence of groups. However, he also notes that groups can be limited by bounded rationality in both decision-making and communication. First, since the group is composed of several actors with different goals, each actor will strive to achieve his personal goals rather than organizational goals (opportunitism). Second, a number of actors need to communicate during the group process. However, when individuals are inarticulate about their knowledge or feelings, a group's communication is thereby constricted, which limits their ability to achieve rationality.

The modern business environment and the amount of work required usually make it difficult for one person to design an I/S in a timely way. An individual actor must, then, depend on others in order to complement his neurophysiological limits, which place constraints on the amount of knowledge of which he is capable and the time it takes to process information. When a number of actors work together, they have to perform tasks to organize themselves that a single person working alone would not have to do. Coordination technology helps people coordinate information processing tasks that are necessary when more than one actor is involved (Malone, 1988).

Henderson and Cooprider (1988) characterized two coordination technology dimensions based on goal consistency among actors involved in the I/S design. First, if multiple actors do not share the same goals, they might behave differently since each is pursuing his own goals. The control dimension is concerned with helping team members with different goals focus on organizational goals. Second, even if goals are shared among actors, groups can be ineffective because group interactions are not well coordinated. The cooperative dimension provides functions for group interactions among multiple actors with shared goals.

Control Dimension: The objective of control is to enable the group to plan for and enforce rules, policies, or priorities that will govern or restrict the activities of team members during the planning and design process (Henderson and Cooprider, 1988). The control dimension reflects the role that a manager/employee or principal/agent relationship plays in the planning or design process. In our context, a project leader may contract with individual designers to develop an information system. In order for the project manager to ensure that individuals do, in fact, carry out the contract in the intended way, information is required both to ensure effective execution of tasks and to monitor the contract. That is, the project manager must be able to communicate project goals (even the means to achieve goals) and to ensure that the resources of the teams are allocated in a manner that best achieves the goals.

Of course, the need to control the activities of a group has long been recognized by the developers of computer-aided design technology. Most current design aids include many features which span several areas of project management, such as a database on project control information (e.g., actual vs. planned progress) and a record of design changes made, including who made them and when. In addition, more intelligent tools include security systems, such as freezing a portion of the design to protect it from changes and specifying who can review various parts of the design work.

Cooperative dimension: An alternative mode of coordination assumes that the participants are of equal power or influence. In this mode, the interaction among individuals is based on shared goals and a perception of mutual gain from a given interaction. Thus, cooperative behavior is not enforced by a set of rules or a contract. Rather, such interaction reflects a sense of peer involvement where exchange is often voluntary.

The cooperative dimension technology enables the individual to exchange information with other individuals for the purpose of influencing and affecting the concept, process, or product of the planning/design team (Henderson and Cooprider, 1988). This dimension reflects the roles of design aids as communication channels and as facilitation aids. Berzins *et al.* (1986) and Reifer and Montgomery (1980) identify communication as an important aspect of computer-aided design technology. Current design tools include more than the general functions of electronic mail, and may have such abilities as being able to attach a note to a diagram or to embed rules that filter and interpret messages in order to determine a given team member's potential interest. Cooperative dimension technology may also help facilitate group interactions, such as electronic brainstorming and group voting.

4.1.3. Infrastructure Technology

Simon (1976) notes that one can reduce the limitations of bounded rationality not only by increasing individual computational power, but also by institutionalizing organization-wide aids to individuals, which Henderson and Cooprider (1988) called infrastructure. As such, infrastructure technology can be defined as organization-wide mechanisms through which an organization can provide "institutionalized help" to individuals and groups to ease the burden of demands for information processing that exceed their capacity. March and Simon (1958) argue that by establishing organization infrastructures, which they call standard operating procedures, the burdens of information processing can be reduced because search procedures are automated to some extent in the standard operating procedures.

Many organizations find that design aids can provide an organization-wide infrastructure for the development of complex software. Usually, complex software is built module by module by several designers. If the designers do not proceed carefully, the idiosyncrasies of an undisciplined team of programmers attacking a large, complex problem piecemeal can lead to expensive failures. Design aid tools help the design team manage the complexities of development by providing structures in the development of I/S. Design aids also help train designers in advanced techniques and enforce their consistent usage throughout the organization.

However, because enforcement of an organization-wide infrastructure comes primarily from limiting what designers can do with the design aids, some argue that an inflexible infrastructure can stand in the way of designing effective systems. Therefore, the ultimate power of infrastructure technology lies in the ability of the designer to widen as much as possible the range of solutions that can be handled by infrastructure technology. Infrastructure technology can aid in establishing institutionalized infrastructure in two ways: standardizing design processes and supporting design processes (Henderson and Cooprider, 1988).

The major purpose of the standardization of design processes is to provide portability of skills, knowledge, and methods across organizations (Henderson and Cooprider, 1988). Portable skills, knowledge, and methods can be promoted through standardized interfaces between various activities in the design life-cycle. For example, by adopting structured diagrams, like data flow diagrams or entity relationships diagrams, the design team can develop an I/S incrementally on a module basis. The information requirement stage can also take the form of standardized formal system development, which in turn can provide a basis for automating code generation and document production.

Standardization can be viewed as a part of the control system in the organization. Organizations attempt to control employees by creating standard operating procedures. Standardization can decrease the need for information processing and increase the predictability of individuals' actions. This can provide the side-effect of better communication among analysts, developers, and managers with well-defined steps for making progress visible throughout the development activity. Even though today's design aids lack an adequate way to combine data flow diagrams, process descriptions, and functional requirements, future design aids should contain these features and capabilities.

The support dimension of the infrastructure helps individual users to understand and use design aids effectively (Henderson and Cooprider, 1988). Support functions can range from providing information requiring little understanding of the application domain or design process (e.g., an on-line help function to describe the parameters of a function), to proactive functions that use domain knowledge or past user behavior patterns to diagnose or recommend appropriate action (e.g., the ability to explain why a particular dimension should be used). Design aids help train junior analysts in advance techniques, because the support dimension provides a vehicle through which the organization can teach junior members about organizational procedures. The support dimension also provides help mechanisms which eliminate many errors arising from inconsistent and incomplete specifications.

Many characteristics of user friendly systems incorporate these types of support dimension, such as templates/work examples which are stored for use in tutorials or exercises, quick reference aids for basic commands and functions, and on-line help for specific commands or features. More advanced design aids come with intelligent tools, such as context-specific on-line help, and backtrack or reverse engineering tools which will undo the most recent series of commands.

4.2. The Impact of Design Aids on the Performance of an I/S Planning and Design Team

The impact of design aids on managerial control: Design aids can affect managerial control. Case (1985) noted that some early design aids were developed which integrated the management procedures. Examples of such procedures include computerized on-line performance measurement, which can make goals and expectations very clear and can also help tighten the linkage between team member behavior and organizational goals. Also, Henderson and Cooprider (1988) showed that design aids with communication abilities can improve the communication between the project manager and team members. This improved communication can also provide a channel through which the manager can remind team members of one or more aspects of expected performance. Design aids can bring concreteness to I/S planning and design by structuring activities around structured design principles. This in turn enables the project manager to define and measure how much of a project has been completed.

The impact of design aids on team-member control: Although there are few studies which looked at the impact of design aids on team-member control, we can use several studies which looked at the impact of information technology to provide support for the claim that design aids can affect team-member control enablers.

Lee and Robertson (1987) and Pfeffer and Leblebici (1977) found that IT (Information Technology) could allow the manager to delegate much decision-making authority, because IT could improve central performance monitoring and thus allow team members to exercise decision-making authority. This can be interpreted as the manager's willingness to delegate operational responsibility to team members. Alternatively, we argue that team members will want to take more responsibility when they are better informed about the results of their actions. This argument is supported by research such as Matteis' (1979) and Zuboff's (1983) case studies on the impact of IT. They reported that because IT increased the team members' level of knowledge and made tasks more interesting and meaningful, team members were motivated to assume responsibility on their own.

The use of design aids can have the same effect as IT. Hypothetically, design aids can improve team-member control by providing more data for decision making, by providing speedy, reliable, and consistent data and immediate feedback on the consequence of team actions, and by encouraging the development of analytical, problem-solving skills. That is, team members can take more responsibility because they are better informed about the results of their actions and because they can work more efficiently and effectively. Design aids can also make the task more intrinsically motivating by increasing the autonomy of the team. By providing common languages and effective communication channels, design aids can improve collegial interaction.

A key concept for the next hypothesis is drawn from Zuboff's (1985) work: a distinction between "automating" and "informating" applications of information technology. The traditional use of design aid is automation - the replacement of human design activity and effort with computer-controlled design activity. But in order to automate a design process, its every detail must be made explicit in order to be translated into computer codes. This creates the potential for "informating." As design aids are applied in I/S planning and design, they generate new streams of data, thus, rendering transparent activities that had been either partially or completely opaque. That is, the use of design aids can convert the current state of the design process into information that can be monitored by the I/S planning and design team.

This constant stream of data drawn from ongoing operations provides an invaluable resource for understanding and further improving a given design process. It is this "informating" capability which is of great potential value to I/S planning and design teams. Since I/S planning and design is a complicated process of human interaction, complete automating of the whole design process is almost impossible. Nor can design be performed only by designers because designers need to understand user requirements. The data from ongoing operations can be supplied to the users, which results in effective communication. Because of the predominance of the support functions of design aids, we would predict that team process would be more important in predicting team performance than the use of design aids; that is, informating is more important than automating. Therefore, we believe that while technology may have a powerful direct effect on the team process, the team process can limit or enhance that effect to some degree. Thus, we propose:

H8: Design aids have a significant effect on the performance of design teams. The impact of design aids on team performance will be significant through managerial control and team-member control.

4.3. Chapter Four Summary

In this chapter a characterization of design aids was proposed based on the recent work by Henderson and Cooprider (1988). As we claimed in Chapter Two, since a proper characterization should correspond to design behavior, we used the concept of bounded rationality to provide a link between design behavior and design aids.

An integrative model of team process, which drew upon the existing literature on organizational control, was presented in Chapter Three. This model suggests that managerial control and team-member control produce variations in the performance of I/S planning and design teams. In this chapter design aids were theorized to affect team performance by affecting managerial control and team-member control.

CHAPTER FIVE. RESEARCH DESIGN AND THREATS TO VALIDITY

This chapter discusses the research design employed for this study. First, threats to validity pertinent to hypothesis testing are reviewed and current methodological practice reported in I/S research literature is critiqued. Subsequently, two issues are addressed: (a) the measurement scheme and its validity; and (b) threats to validity in key informant analysis.

5.1. Threats to Validity in Theory Testing

To test a theory, we need to measure each theoretical construct and analyze the relationships between the measured constructs. This process requires two steps: (1) developing valid measures of the theoretical constructs and (2) testing the relationships between theoretical constructs. In MIS literature in particular and in organizational research in general, much attention is paid to a statistical analysis of the relationships between measured variables, but the assessment of measure validity is implicitly carried out (Goodhue, 1988). This practice assumes that the measures are valid and adequately reflect theoretical constructs. However, as Bagozzi and Phillips (1982) noted, a lack of correspondence between the operational measures and the theoretical concepts they are intended to measure will probably result in the rejection of a hypothesis as either weak or absent. The opposite can also happen, since the measures are not measuring what they are intended to measure, resulting in the support for an "incorrect theory."

Therefore, in developing measures and testing theories correspondence between theoretical constructs and their measures should be formally ascertained. Bagozzi (1980) noted that this process be viewed in terms of six criteria:

1. Theoretical meaningfulness of concepts,
2. Observational meaningfulness of concepts,
3. Internal consistency of operationalizations,
4. Convergent validity,
5. Discriminant validity, and
6. Nomological validity.

The first two criteria of validity involve semantic issues, not statistical tests, and refer to the internal consistency of the language used to represent a construct and the conceptual relationships between a theoretical construct and its operationalization. "The theoretical meaningfulness of a concept refers to the nature and internal consistency of the language used to represent the concept" (Bagozzi, 1980, pp. 117). To achieve "meaningfulness", theoretical constructs must capture the characteristics and quality of the language used to represent the theoretical concepts. Since our theory has been derived from earlier research on organizational control and self-control, our constructs are consistent with prior theories.

The "observational meaningfulness of concepts refers to the relationship between theoretical constructs (which are unobservable) and their operationalizations (which, of course, are observable) (Bagozzi, 1980, pp. 121). To achieve this second criterion, measures must be clear, specific, unambiguous and related to theoretical constructs. In attitudinal research, theoretical constructs cannot be directly measured. Operational indicators (which are observable) can be used as long as one can demonstrate the link to theoretical constructs. This study used measures that have already been validated in previous studies, where feasible. In other cases, systematic pilot-test of the measures to the newly-proposed constructs was carried out.

The internal consistency of operationalizations refers to the degree of homogeneity of indicators purporting to measure the same theoretical construct. Evaluation of internal consistency requires more than one observational indicator (observational variable) for each theoretical construct. The most commonly used summary statistic of internal consistency is the Cronbach alpha coefficient (Cronbach, 1951), which is computed across a set of measures of a single theoretical construct. Acceptable limits for the range of reliability scores can vary according to the problems of measurement. For attitudinal measurement, a Cronbach alpha coefficient above 0.6 is generally considered acceptable (Nunnally, 1967). When the minimal level of internal consistency is not achieved, the implication is that these variables could be measuring more than one construct.

Convergent validity refers to the degree to which two or more measures of the same theoretical construct are in agreement. Discriminant validity refers to the degree to which one theoretical construct differs from another. Campbell and Fiske (1959) proposed a multitrait-multimethod matrix to assess convergent and discriminant validity of data gathered on multiple traits (theoretical constructs) using maximally dissimilar methods, such as self-report and unobtrusive observation. The criterion for convergent validity is that the correlation between measures of the theoretical construct should be different from zero and significantly large to encourage further investigation. The criterion for discriminant validity is that a measure should correlate with all measures of the same theoretical construct more highly than it does with any measure of another theoretical construct.

To assure that convergent validity and discriminant validity have been achieved in an empirical study, more than one theoretical construct and more than one method must be used. Unfortunately, in many areas of MIS research, multiple methods of measuring a theoretical construct have not been used. Most studies, however, do include more than one theoretical construct. The inherent assumption is that the method employed is a valid one. This assumption, however, might not hold true in many cases. For example, Silk and Kalwani (1982) and Patchen (1963) found that most often self-report tends to overestimate his influence in decision-making. In addition, when only a self-report is used, we cannot test whether there is a systematic method bias (self-report bias).

The final component of construct validity is nomological validity which refers to the degree to which predictions from a formal theoretical network containing the concept under scrutiny are confirmed (Campbell, 1960). Nomological validity can be interpreted as whether one's own theory, once it has been found semantically and empirically valid, is consistent with a wider body of theory and whether it contributes to that theory. Assessment of nomological validity takes place with reference to related research.

While Bagozzi's criteria were originally developed in order to ascertain the correspondence between theoretical constructs and observational constructs, these criteria can be used in research design. The theoretical meaningfulness of constructs and observational meaningfulness can guide theory generation and the development of the measures to be used. After empirical research is undertaken, the internal consistency of operationalizations, convergent validity,

Bagozzi's six criteria	How each criterion addressed in this study
Theoretical meaningfulness of concepts	Built on the emerging discipline of organizational control theory.
Observational meaningfulness of concepts	Used previously validated measures with new measures that are pilot tested.
Internal consistency of operationalizations	Employed multi-item scales and tested with Cronbach's Alpha.
Convergent validity	Employed multi-methods and tested with MTMM (Campbell and Fiske, 1959).
Discriminant validity	Employed multi-methods and tested with MTMM (Campbell and Fiske, 1959).
Nomological validity	The result of the study are should be consistent with a larger body of theory and contribute to the reference field.

Table 5.1. Bagozzi's criteria and how these are addressed in the study.

discriminant validity, and nomological validity criteria should be ascertained before the relationships among theoretical constructs using measured constructs are analyzed.

5.1.1. Key Informant Analysis

This study adopted a key informant method. In this section we discuss why key informant analysis was necessary. This section is followed by a discussion of threats to the validity of the multiple key informants' method, which may arise from disagreements among key informants.

Some of the paradigms for studying I/S planning and design teams are distinguished from previous frameworks in that they attempt to explain and predict the behavior of design teams or organizational subunits rather than that of individuals. However, these paradigms are not often reflected in empirical research in our field, which continues to focus on a single individual within design team rather than on a design team collectively. Our plane of observation, therefore, should not be that of individuals, but that of the teams. Measurement of team collectivity and other organizational characteristics requires research methods different from those used to measure the characteristics of individuals (Seidler, 1974).

As Phillips and Bagozzi (1981) have noted, the measurement of team-level properties has often entailed the use of a key informant method. The key informant method is a technique for collecting information on a social setting by interviewing (or surveying) a selected number of participants. In this case the key informant assumes the role of reporting on the patterns of behavior of a team after summarizing either observed or expected organizational relationships. Although the use of key informants has traditionally been associated with qualitative methodology (Lofland, 1971), Seidler (1974), Silk and Kalwani (1982), Phillips and Bagozzi (1981) have used key informant methodology in conjunction with procedures for collecting survey data to obtain quantifiable measures on organizational characteristics.

In these situations, survey respondents assuming the role of key informants provide information at the aggregate or collective unit of analysis (e.g., team or organizational properties), rather than reporting personal feelings, opinions, and behaviors (Campbell, 1955). We can envision four types of key informant analysis, depending upon number of informants and and number of indicators, as shown in Figure 5.1.

	Single indicator	Multiple indicators
Single informant	No formal test possible Cell 1	Cell 2 Reliability
Multiple informants	Cell 3 Convergent and discriminant validity	Cell 4 Reliability, convergent and discriminant validity

Figure 5.1. Key informant analysis: trade-off among number of informants vs. number of indicators.

Cell 1 (a single indicator and a single key informant): In studying the relationship between user involvement and success of I/S planning and design, Hirschheim (1985) and Robey and Farrow (1982) used a single indicator and a single informant to assess the extent of user involvement. In this case we cannot test internal consistency of observation, convergent validity and discriminant validity. As a matter of fact, in this case, using a cell 1 type of key informant analysis prohibits formal tests for construct validity. Studies that used single item indicators to operationalize theoretical constructs assume that the single indicator measures the theoretical construct perfectly and without error - which is a weak assumption (Joreskog and Sorbom, 1978). However, this assumption is unlikely to be justified (Bagozzi and Phillips, 1982). In most cases any single indicator will be biased, and the use of multiple indicators is a useful means of reducing the biasing effect of any indicator (Campbell and Fiske, 1959).

Cell 2 (multiple indicators and a single key informant): In studying the system acceptance by the users Baronas and Louis (1988) asked multiple questions (indicators) to measure theoretical constructs from a single key informant in each project. In this case we can test internal consistency of the operationalizations, but, since there is only one single key informant, we cannot test convergent and discriminant validity. As Seidler (1974), Silk and Kalwani (1982), and Phillips and Bagozzi (1981) have noted, there are many other problems in using a single key informant. First, selection of a single key informant is difficult, because he or she must be able to aggregate team-level properties. Second, there might be an informant bias, such as position bias. In fact this type of informant bias can be expected in the multiple key informants' approach, but at least we can test this bias if we employ the multiple key informants' approach.

Cell 3 (a single indicator and multiple key informants): To measure the degree of user involvement, Henderson (1988) used three types of key informants: project managers, designers, and users. He demonstrated convergent validity and discriminant validity of key informant data from project managers and designers. But, if we follow the Bagozzi's (1980) precise definition, Henderson was not able to test the internal consistency of the operationalizations because he used only a single indicator. However, he used a Cronbach alpha test to measure the internal consistency of the responses among informants, which might be viewed as one type of internal consistency of the operationalizations.

Cell 4 (multiple indicators and multiple key informants): This cell 4 approach enables one to assess the extent to which variation in measurements is due to methodological factors and to test the internal consistency of the operationalizations. We can test the internal consistency of the operationalizations with either Cronbach alpha or the structural equation approach (Joreskog and Sorbom, 1978). Bagozzi and Phillips (1982) suggested that, even though a set of measures achieves internal consistency, this is not strong evidence for the validity of one's measures. Informants' responses to a set of items may achieve internal consistency because they are converging on a methods' factor (e.g., position bias or knowledge deficiency). Since different key informants are used to measure the theoretical constructs in the cell 4, it is now possible to test for convergent and discriminant validity.

In this case, the different informants constitute the different "methods". More specifically, convergent validity for cell 4 refers to the degree of agreement between reports on the same theoretical construct measured by multiple indicators provided by the different informants. Discriminant validity is the extent to whether a particular theoretical construct measured by multiple indicators (items) differs from other concepts when measured by different methods.

This study adopted the Cell 4 approach, as it is the most rigorous for studying I/S planning and design and as we could test all Bagozzi's (1980) criteria for construct validity. Such an approach would be time consuming and expensive and would require extensive pre-survey contact with each design team, but the gains in terms of reliability and validity might well offset the costs as Phillips (1981) has noted.

5.1.2. Threats to Key Informant Analysis Within Cell 4

Unlike the respondent method which requires the respondent to report about himself or herself, the collection of data on team properties from individual informants may introduce considerable measurement errors because questions which require a person to aggregate data on many events, persons, or tasks may place unrealistic demands on survey respondents (Silk and Kalwani, 1980; Phillips and Bagozzi, 1981). In addition, factors related to motivational attitude can also increase measurement problems. Based on the literature on key informant analysis, we can identify several threats to validity with multiple key informants analysis, which is summarized in Table 5.2.

Motivational barrier: Huber and Power (1985) claimed that informants may believe that divulging specific information could have an adverse impact on their careers. To some extent, this form of bias is related to Seidler's (1974) concept of vested interest. In analyzing key informants' data on a study of authority conflict in Catholic dioceses in America, Seidler found that the closer the informants to the center of authority, the greater their tendency to protect the top leadership.

Huber and Power (1985) suggested removing as many "disincentives" to responding motivationally as possible. In the study we employed several disincentives. First, when we administered the questionnaires, we promised the confidentiality of data by explicitly promising that that the individual result (project information) would not be disclosed to any company person in any case and made respondents send questionnaires directly to us. This was necessary to ascertain that they would respond to us frankly without fearing that a company person would see their responses. Second, in our research design we tried to avoid self-reports because self-reports can inflate the respondents' role in I/S

Specific concern	Literature support	How addressed in this study
Motivational barrier	- Vested interests (Seidler, 1974) - Self report vs nonself report (Silk and Kalwani, 1981) - Position bias (Huber and Power, 1985)	No self-report and strict confidentiality
Perceptual and cognitive limitations	- Specific vs general question (Silk and Kalwani, 1981) - Inadvertent errors (Huber and Power, 1985)	Task-anchored questions and pilot-tested.
Lack of information	- Difficulty of observation (Seidler, 1974) - Lack of information about the event of interest (Huber and Power, 1985)	Chose only informants who are involved in the project

Table 5.2. Threats to validity in multiple key informants analysis and how they are addressed in this study.

planning and design process, as Kane and Lawler (1978) and Silk and Kalwani (1981) found. Third, since we recognized that the team members' emotional involvement with performance variables may decrease the accuracy of their responses, we asked stakeholders, who are not formal members of the I/S planning and design team, but who are affected by the output of the team or who can affect the performance of the team, to assess the performance.

Perceptual and cognitive limitations: The second reason for biased or inaccurate reports is the perceptual and cognitive limitations of people as information processors (Huber and Power, 1985). Since informants are asked to provide the researcher with team-level properties, this can increase the burdens of their information processing activity.

Huber and Power (1985) suggested using questions that are pretested, and structured and that impart an image of being rich in information content without being complex. In our study we tried not to invent new questions for this study, but we attempted to use previous questions which had been tested as valid ones. We also pilot tested these questions, before we undertook major research effort.

Patchen (1963) and Silk and Kalwani (1982) found that reports of influence in specific areas showed better reliability (between-informant agreement) than a global influence measure. Therefore, in addition to using already-validated questions as much as possible, we tried to rephrase our questions to be specific in their task-related activities, since framing questions will affect the informant's responses, as Huber and Power (1985) claimed. We anchored each question so that it was project specific. For example, to emphasize that we are asking the designers' skill for the specific project, we placed the name of the specific project on each page and especially when questions were sensitive to respondents' feelings, we placed the name of the project in each question.

Lack of information: A third source of data inaccuracy is an informant's lack of information or knowledge. Huber and Power (1985), Seidler (1974), and Phillips (1981) claimed that researchers should select those whose positions give them access to the needed information. In many studies informants were chosen because of their proximity to researchers.

To some extent lack of information is controlled for in this study, because all three types of informants for team process have been involved in their projects as official members of the design team. However, performance variables are assessed by non-team members. We educated our contact persons only to choose stakeholders who might affect or who may be affected by the I/S planning and design team. In addition, we originally asked that there should be at least four stakeholder informants. We included in the questionnaire demographic variables which can be used to measure how familiar each stakeholder is with the team whose performance they are to assess. After collecting data for an empirical analysis, this class of criteria should be validated before we analyze the relationships between theoretical constructs because, after all, theoretical constructs are assessed only by observational variables.

5.2. Research Design

This section describes the design and data collection of a field survey to test the theory of the impact of computerized design aids on the performance of design teams. Our principal instrument was multiple types of questionnaires administered to 432 individuals both inside and outside the design teams.

The total study was conducted in two phases: Phase One for the development of the measures and Phase Two for testing the proposed theory. The purpose of Phase One was to validate questions and to reduce their number in the questionnaires, since there are many theoretical constructs in our theory. In Phase Two we used measures evaluated in Phase One to test our theory.

Phase One

The purpose of Phase One was to validate the questions which would be used in Phase Two and to reduce the number of questions in Phase Two. We studied the existing instruments which are summarized in Table 5.3. Based on the existing instruments and their measurement properties, we selected approximately 5 indicators for each theoretical construct. In cases where we could not find reliable measures (e.g., task-related feedback construct) and where only a single indicator was used (e.g., task understanding construct) we generated new indicators. Since it was difficult to find design teams who use the

Construct	Scales/Measures	Sources	# of items	Reliab -ility
Managerial	Task understanding	Ouchi (1977)	1	n.a.
Control	Measurement	Ouchi (1977)	1	n.a.
Enablers	Vertical communication			
Managerial	Role clarification	Ohio State Leadership	5	.81
Control	Work assignment	Ohio State Leadership	6	.72
	Procedure specification	Ohio State Leadership	5	.60
	Outcome control	Ouchi (1977)	1	n.a.
Team member	Skill	Kerr & Jermier (1978)	3	.85
Control	Internal motivation	Kerr & Jermier (1978)	3	.85
Enablers	Task-related feedback	Kerr & Jermier (1978)	3	.40
	Horizontal communication			
Team member	Behavior control	Glick *et al.* (1986)	7	n.a.
Control	Outcome control	Kerr & Jermier (1978)	6	.78
Performance	Efficiency	Henderson (1988)	3	.90
	Effectiveness	Henderson (1988)	2	.89

Table 5.3: A summary of existing questionnaire for team process.

computerized design aids and who could spend a fair amount of time to pilot test the power of the design-aid usage questionnaire, we only pilot-tested team-process measures, which are control enablers and control variables. Performance measures were not tested because we adopted Henderson's (1988) measures in this study.

We asked 40 individuals to fill out the questionnaire. Based on the results, we eliminated duplicated questions and invalid questions. Because some of the original questionnaires contained similar wording to increase reliability, we eliminated tautological questions, which might decrease reliability of our items.

We kept at least two or three indicators for each construct. This step was required because we asked all our key informants the same questions. For example, all our informants were asked manager's task-understanding questions.

Phase Two

Phase Two tests the theory concerning the impact of computerized design aids on the performance of design teams with 432 individuals in 48 design teams in 10 organizations. Four roles were surveyed in this study: the project manager, the designers, the domain representatives, and the stakeholders. Our definitions of theses roles are as following:

Project manager:	The person who manages the focal project.
Designers:	Professionals whose expertise and duties are primarily in the area of IS technology, system development, programming, etc. for the focal project.
Domain representatives[1]:	Professionals whose primary expertise and and duties are in the function/activity/business of the customer/user. They should be team members of the focal project and often are customer representatives or users.
Stakeholders:	Professionals who are not formal members of the focal project but are affected by the output of the team or can affect the performance of the team. examples are senior executives and

1 In I/S planning and design literature, the term, users, refers to this role. However, strictly speaking, users are persons who use the system. But in many cases they might not use the system. Therefore, we used the term, domain representatives, to refer to the users, because the users on the design team is expected to provide domain knowledge. In our questionnaire, the above definition was given twice to avoid confusion.

client personnel who are not formal members of the focal project.

We used four types of instruments: a team process questionnaire for designers and domain representatives, a team process questionnaire for the project manager, a stakeholder questionnaire, and a design-aid usage questionnaire. The first two types of questionnaires cover the design process. That is, we surveyed control and control enablers with questions on the I/S planning and design process. We did not anchor our questions to the individual, but to the role. The team process questionnaire for project manager and the team process questionnaire for designers and domain representatives are basically the same questionnaires except for the wording. Even though we asked about the nature of all of the role's (described on the previous page) in our questionnaires, the project manager role's is filled by only one person. There is more than one designer and more than one domain representative, but only one project manager in an I/S planning and design team. Therefore, in cases where self-assessment was required from the project manager, we changed the wording. For example, in the team process questionnaire for the designers and domain representatives, we asked "how much influence the project manager for a specific project has in specifying work procedures," but in the team process questionnaire for the project manager we asked, "how much influence do I, as the project manager for a specific project, have in specifying work procedures?"

In the stakeholder questionnaire, we surveyed performance measures, since they can provide a more objective assessment of I/S planning and design teams. In the design-aid usage questionnaires we asked about the extent of usage of a specific feature of computerized design aids. Our definition of computerized design aids included not only CASE technology, but also telecommunication technology such as E-mail.

Selection of Sites: We sent our proposal of this study to twenty-five sponsors of MIT's *Center for Information Systems Research* (CISR). After several contacts, 10 companies agreed to participate in this study. In addition, other companies were also included in the study through personal contacts. Table 5.4 shows the range

Company	Type	Number of I/S planning and design teams who participated
A	Accounting	10
B	Insurance	4
C	Insurance	2
D	Software	1
E	Heavy manufacturing	1
F	Computer manufacturing	12
G	Light manufacturing	3
H	Insurance	4
I	Banking	5
J	Telecommunication	6

Table 5.4. Organizations Participating in the study.

of industries represented. While it would have been ideal from the point of view of generalizability to choose companies, groups, and individuals randomly, it was not possible in practice for the following reasons. First, only a relatively small number of design teams are using computerized design aids. Second, we needed a major commitment from design team members to finish our questionnaires. For example, it would take design team members at least half an hour to fill out each questionnaire. Furthermore, to be included in our data analysis, at least one project manager and one designer should complete two different questionnaires, and, one domain representative and two stakeholders would have to complete a questionnaire.

Selection of Design Teams: For each company, we tried to choose at least five design teams to cover both high-performance teams and low-performance teams. However, since the commitment of filling out the questionnaires took about one hour, several design teams did not participate. In some cases only one design team in one company participated in the study as shown in Table 5.4. In choosing design teams who would participate in the study, we limited group inclusion to a project team which has finished more than half the tasks of a project. This exclusion criterion was aimed at ensuring that the team has had a chance to work together for a significant period of time. The project must also have been composed of 5 to 10 people to control for the complexity of I/S planning and design.

Selection of Respondents and Informants: Even though we could not control for who would participate in the study in each design team, selection bias of individuals was controlled to some extent. We urged each design team to provide one project manager, two designers, and two domain representatives, and four stakeholders. Since our design teams are mainly composed of 5 to 10 people, this meant that practically all the individuals involved in the I/S planning and design agreed to respond to us.

Questionnaire Administration: The process that we have followed with most of the companies was for us to send the questionnaires directly to the project managers and to follow them up directly as appropriate. If this approach was not satisfactory with the company, then we sent a packet of questionnaires through our contact person in the company. The reason for our trying to use the first alternative as much as possible was to avoid bias that may result from the fact that the company contact person was distributing the questionnaires. Except for two companies, all the companies followed the first process.

Altogether about 432 individuals in 48 I/S planning design teams In 10 companies were asked to participate in the study. Among these, 310 usable replies were received, or about 72 % of the total number of questionnaires sent out. The response rate ranged from 100 % in some teams to about 44 % in the worst teams. The breakdown of response rate by role is shown in Table 5.5.

	Response rate	# of people
Project manager	48/48 (100%)	1
Designer	79/96 (82%)	2
Domain representative	57/96 (59%)	2
Stakeholder	126/192 (66%)	2-4

Table 5.5. Response rate.

Since each team has only one project manager, the response rate for the project manager was 100%. (However, this statistic is misleading, because we eliminated a number of design teams who originally promised to participate, but later did not participate when calculating the respond rate). The reason for difference among the rates of responses for the designers, domain representatives, and stakeholders is that designers can be controlled by the project manager, but the domain representatives and stakeholders might not directly report to the project manager, who was asked to distribute the questionnaires. In addition, the follow-ups were undertaken by the project managers only.

Of the 48 teams to whom a set of questionnaires were sent, 41 returned what we considered to be a full set, which consisted of questionnaires filled out by at least the following: one project manager, one designer, one domain representative and two stakeholders. Therefore, data analysis was conducted with the data from these 41 teams.

5.3. Chapter Five Summary

This chapter has identified the threats to validity, particularly the threats to validity of the multiple key informants' method. We categorized various threats to validity into two classes. The first category is related to finding the source of inaccuracy so that we could take precautions before we implemented empirical research. Huber and Power's (1985) list of three sources of errors are examples of this category. Also Bagozzi's (1980) first two criteria can be helpful in designing research. Based on the literature pertaining to key informant analysis, we took extreme caution to preserve the validity of this study. The second category is related to ascertaining the validity of the methods used in empirical analysis. After collecting data for an empirical analysis, this class of criteria was validated first before we analyzed the relationship between theoretical constructs because, after all, theoretical constructs are assessed only by observational variables. In the next chapter we will discuss the second category in detail.

CHAPTER SIX. MEASUREMENT MODEL

This chapter discusses the measurement model used in this study. The model shows how we tested the relationships between the measured variables and the theoretical constructs we intended to study. In the first section of this chapter we describe the procedures for testing for internal consistency and two forms of validity, and in the following sections we show how we were able to evaluate construct validity. However, since design-aid-usage questions are a different kind of measure from the others used in the study (design-aid-usage questions have a different relationship with the theoretical construct they are intended to measure), we will discuss a measurement model for design-aid-usage in Chapter Eight.

6.1. Procedures for Evaluating the Measures

Assessment of construct validity when the multiple key informants' method is used entails two steps. First, since there are multiple indicators, we need to assess the internal consistency of the operationalizations[1]. That is, informants' responses to indicators (questions) that have been used to measure the same theoretical construct must covary significantly with one another. Second, if this criterion is met, it is appropriate to test whether there is a consensus among the different key informants' responses intended to measure the same theoretical

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1. Many researchers (e.g., Phillips and Bagozzi, 1981; Silk and Kalwani, 1981) used the term "reliability" to refer to the internal consistency of operationalizations and "validity" to refer to convergent validity and discriminant validity. In order to be consistent with Bagozzi's (1980) criteria, we use "internal consistency," instead of reliability throughout this chapter.

construct. It is also appropriate to determine whether there is a disagreement between the different key informants' responses intended to measure different theoretical constructs.

6.1.1. Procedures for Evaluating the Internal Consistency of Operationalizations

Since multiple indicators (questions) were used to measure each theoretical construct, it is necessary to assess the internal consistency of the indicators (questions or operationalizations). This entails two sets of empirical procedures. First, it is necessary to determine the degree of consistency of the survey items designed to measure the same theoretical construct (Bagozzi, 1980; Phillips and Bagozzi, 1981). Second, the set of survey items intended to measure a theoretical construct should not correlate highly with other survey items intended to measure other theoretical constructs.

The internal consistency of survey items has been tested using the Cronbach alpha coefficient. The Cronbach alpha coefficient has a limited underlying assumption. As Bagozzi (1980) noted, it assumes equal units of measurement among the indicators, which may not be justified in situations where some items are better indicators than others.

Alternatively, we can give unequal weight to multiple indicators by using Joreskog's analysis-of-covariance structures methodology (Phillips and Bagozzi, 1981; Joreskog, 1974; Werts, *et al.*, 1974). In addition, Joreskog's analysis can model measurement error explicitly. However, to use this analysis, sample size should be more than one hundred. In this study, even though the number of respondents was 310, the sample size for the final analysis is 41 because our unit of analysis is the team. Therefore, we cannot use Joreskog's analysis.

If there were no internal consistency among indicators, we could not use them together to measure a given theoretical construct. If the informants' reports are internally consistent, then it is appropriate to test whether sets of survey items are measuring only the theoretical construct they were intended to measure.[2] That is, the survey item should correlate more highly with a survey item measuring the same theoretical construct than another item which is intended to measure a different theoretical construct. If this is the case, it would be necessary to check the theoretical constructs to be certain that they are, indeed, different and that all survey items are measuring the same theoretical construct.

There are two procedures for testing the second criterion of the internal consistency of the operationalizations, that is, for checking that the sets of survey items measuring different theoretical constructs must not correlate with one another. First, factor analysis can be used. In this case, factor analysis confirms that different sets of survey items should correspond to different theoretical constructs. Second, a revised multitrait-multimethod (MTMM) correlation can be used. The original multitrait-multimethod approach assumes that maximally different methods are employed [see Phillips and Bagozzi (1981) and Goodhue (1988) for how they used this approach]. However, since we are

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2. Phillips and Bagozzi (1981) used the term, discriminant validity at the monomethod level of analysis, to refer to this criteria. They also used the term, convergent validity at the monomethod level of analysis to refer to the first criteria of the internal consistency of the operationalizations. In this study we avoided using these terms, in that convergent and discriminant validity tests require the maximally different methods (See Campbell and Fiske, 1959).

concerned with only the internal consistency of operationalizations, we are not restricted to this assumption. We can build this revised MTMM matrix by viewing each indicator as a different, but not necessarily a maximally different method. Once this matrix is constructed, then we can test the internal consistency of the operationalizations in two steps. First, we can examine whether the correlations among survey items addressing the same theoretical construct are significantly large. In fact, this is a test of the first criterion of internal consistency of the operationalizations. Second, for each survey item we can count the number of times it correlates more highly with other survey items addressing another theoretical construct than with survey items addressing its own theoretical construct. If the number of violations is small enough, the second criteria for internal consistency is satisfied.

6.1.2. Procedures for Evaluating the Convergent Validity and Discriminant Validity

Bagozzi and Phillips claimed that

> "Even if a set of measures achieves *internal consistency of operationalization*, this is not strong evidence for the validity of one's measures or concepts. Informants' responses to a set of items may achieve unidimensionality and internal consistency because they are converging on a methods factor (e.g., position bias, knowledge deficiency, vested interest bias, etc.) rather than the theoretical factor of interest." (italics are ours.) (Phillips and Bagozzi, 1981, pp. 9)

In this subsection we discuss the procedures for evaluating the extent to which variation in measurements is due to genuine differences among theoretical constructs rather than methods factors. This may be assessed by constructing a multitrait-multimethod matrix of correlations (Campbell and Fiske, 1959). This matrix requires that more than one theoretical construct is measured and requires that each theoretical construct should be measured using different methods. The more dissimilar the methods, the more rigorous the procedures (Campbell and Fiske, 1959). Since multiple key informants were used to measure the theoretical constructs in this study, we can view different types of key **informants** as different methods.

Thus, convergent validity is assessed by the degree to which multiple attempts to measure the same theoretical construct through different types of key **informants** are in agreement. If convergent validity is achieved, we can test discriminant validity. This entails examining whether a particular theoretical construct differs from other concepts when measured by different **informants**.

6.2. Measurement Model for Control Enablers

Our theory of the impact of computerized design aids on performance is composed of four factors: design-aid usage, control enablers, control, and performance. Since control enablers and control variables are measured by multiple key informants, we can test construct validity using the procedures described in Section 6.1. The measures for control enablers are discussed in this section. Since our I/S planning and design teams are composed of the project manager, the designers, and the domain representatives, control enablers for these three types of roles are discussed separately.

6.2.1. Managerial Control Enablers

In Chapter Three we identified three dimensions of managerial control enablers. They are the task understanding of the manager (TUND), the availability of measurement (MEAS), and the ease of vertical communication (VCOM). These were assessed by asking informants to respond to multiple items using seven point Lickert-type scales. These items, contained in Appendix 1, are denoted as TUND1, TUND2, TUND3, MEAS1, MEAS2, VCOM1, and VCOM2. The means and standard deviations of the item scores are also shown in Appendix 1. Since these items measure the project managers control enablers, we can avoid self-report bias by using only the responses from designers and domain representatives. Thus, we can see that two methods were used to assess managerial control enablers.

Internal Consistency of Operationalizations

In our context, testing this criterion involves assessing whether the individual survey items are valid and whether they are measuring only what they are intended to measure and nothing else. We can test this using all of the 136 responses from designers and domain representatives, because we are only concerned with the validity of measures used in the questionnaire.

Reliability: The Cronbach alpha coefficients for TUND, MEAS, and VCOM were 0.809, 0.656, and 0.846, respectively. Our items were based on Ouchi's work (1977), but since Ouchi (1977) used only single indicators to measure TUND and MEAS, we cannot test whether our survey items were as reliable as his. However, Eisenhardt measured TUND and MEAS using multiple indicators. In her case the Cronbach alpha was 0.72 and 0.82. We cannot compare our coefficients to hers, since her measures were targeted to department store managers. For example, she asked the survey respondents about the selling space square footage of the store, the total number of store employees, and the number of salespeople per store supervisor to assess the ease of measurements. None of her indicators can be applied to task-related measurement in the I/S planning and design context.

Correlation Matrix[3]: The matrix of zero-order correlation is provided in Table 6.1. Scanning this correlation matrix shows that the smallest correlation within a

	TUND			MEAS		VCOM	
	TUND1	TUND2	TUND3	MEAS1	MEAS2	VCOM1	VCOM2
TUND1	1.000						
TUND2	**0.520**	1.000					
TUND3	**0.611**	0.633	1.000				
MEAS1	-.015	0.007	0.107	1.000			
MEAS2	0.294	0.232	0.327	**0.493**	1.000		
VCOM1	0.319	0.169	0.336	0.161	0.397	1.000	
VCOM2	0.321	0.207	0.303	0.093	0.314	**0.734**	1.000

Table 6.1. The zero-order correlation between item measures for project manager control enablers.

theoretical construct was 0.493 ($p<0.001$), which is significantly different from zero. In all cases, each item correlated more highly with items measuring its own theoretical construct than with items measuring another theoretical construct.

Factor Analysis: The matrix in Table 6.1. was factor analyzed using a varimax rotation and these results are shown in Table 6.2. Three factors resulted, from a scree test, and these are consistent with our three theoretical constructs and account for 78.8 % of the variance.

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3. Although we used the term "a revised MTMM" to describe how we would check the correlation matrix in Section 6.1, in the data analysis sections we did not use this term so that the MTMM in the study can refer to the original MTMM matrix developed by Campbell and Fiske (1959).

Item	Factor 1	Factor 2	Factor 3
TUND1	**.793**	.248	.011
TUND2	**.863**	.011	.038
TUND3	**.847**	.182	.151
MEAS1	-.059	.002	**.916**
MEAS2	.261	.285	**.769**
VCOM1	.154	**.899**	.176
VCOM2	.165	**.910**	.062

Table 6.2. Results of factor analysis of items for project manager control enablers.

From the above discussion, we can conclude that the items used in our questionnaire displayed good internal consistency of the operationalizations.

Convergent and Discriminant Validity

Since the individual items in the questionnaire showed good consistency of the operationalizations, we averaged them to produce a score for each dimension of managerial control enablers[4]. Also, this average was calculated for each type of key informant: designer and domain representative. In cases where more than two persons with the same role in the I/S planning and design team responded, we also used the average value of the scores. Table 6.3 is the MTMM matrix for managerial control enablers, where TUND, MEAS, and VCOM

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4. We can give more weight to the better items by using analysis of covariance structure. However, this requires a sample size larger than 100. Our sample size at this level of analysis is more than 100. However, since these individual questions are to be aggregated to the team level, and the sample size for team-level analysis is only 41, we cannot use Joreskog's analysis in the study.

are viewed as traits, and the designer informant and the domain representative informant as different methods. In our notation each trait is preceded by D or U, where D stands for a designer informant, and U stands for a domain representative informant. For example, DTUND is a manager's task understanding assessed by the designer informant and UTUND is the same task understanding as perceived by the domain representative informant.

Convergent validity among key informants showed a desirable property. The minimum correlation was 0.506 between the designer response and the domain representative response on the MEAS, which is not surprising because the reliability of the MEAS was the lowest. However, 0.506 is significantly different from zero ($p<0.001$).

Discriminant validity can be tested by counting for each theoretical construct the number of times that an informant's response addressing the same theoretical constructs correlates more highly with a measure of another construct than with the response on the same theoretical construct from other informants. None of the comparisons violated the discriminant validity test. However, we can find systematic bias based on the type of key informant analysis in the MTMM matrix. For example, the correlations among DTUND, DMEAS, and DVCOM (i.e., between designers) are significant and the correlations between UTUND and UVCOM and the correlation between UMEAS and UVCOM are significant (i.e., between domain representatives). This leads us to believe there are method factors operating in this data. However, since the data passed the minimal requirement of discriminant analysis, we can aggregate responses from different key informants to assess the scores for the managerial control enabler variables.

	TUND		MEAS		VCOM	
	DTUND	UTUND	DMEAS	UMEAS	DVCOM	UVCOM
DTUND	1.000					
UTUND	**0.694**	1.000				
DMEAS	0.239	0.117	1.000			
UMEAS	0.063	0.090	**0.506**	1.000		
DVCOM	0.276	0.293	0.294	0.279	1.000	
UVCOM	0.175	0.411	0.134	0.318	**0.549**	1.000

Table 6.3. The MTMM matrix for project manager control enablers.

	TUND			MEAS			VCOM		
	DTUND	UTUND	MTUND	DMEAS	UMEAS	MMEAS	DVCOM	UVCOM	MVCOM
DTUND	1.000								
UTUND	0.694	1.000							
MTUND	0.186	0.255	1.000						
DMEAS	0.239	0.117	0.058	1.000					
UTUND	0.063	0.090	0.133	0.506	1.000				
MMEAS	0.241	0.165	**0.546**	0.207	0.214	1.000			
DVCOM	0.276	0.293	-.154	0.294	0.279	0.038	1.000		
UVCOM	0.175	0.411	-.045	0.134	0.318	0.124	0.549	1.000	
MVCOM	0.043	0.046	**0.419**	0.230	0.342	**0.332**	0.348	0.026	1.000

Table 6.4. The MTMM matrix for project manager control enablers (including self-report by the project manager).

In order to test the bias of self-report, we asked the project manager the same questions measuring managerial control enabler variables (they are indicated by MTUND, MMEAS, and MVCOM in the MTMM matrix in Table 6.4).

Not surprisingly, the correlations between the MTUND, MMEAS, and MVCOM ranged from 0.3320 to 0.5456. Thus, there was a strong method (informant) bias in self-report. We also checked the difference between the manager's responses on managerial control enablers, and the designer's responses and the domain representative's responses. The managers consistently rated their assessment of control enablers higher than other informants. In other words, project managers believe that they understand the task well, that they have objective measures for assessing their team members, and that they talk to their team members often. To reduce the self-report bias, managers' responses were not included in the analysis.

6.2.2. Designer Control Enablers

The roles of team members on I/S planning and design teams can be divided into the designer role and the domain representative role. Since each role is thought to be associated with a different set of expectations, motivation, and skill (Henderson, 1988), we need to separate team-member control enablers. For example, designer skill refers to computer-related skills, but domain representative skill refers to business skills. Note that theoretical constructs for each role are the same, but the operationalizations of these constructs are different. In this subsection, we will discuss the designer control enablers, while in the next subsection we will discuss domain representative control enablers.

Designer control enablers are skill (SKD), internal motivation (MOD), task-related feedback (TFD) and the ease of horizontal communication (COD). These were assessed by asking informants to respond to multiple items using seven point Lickert-type scales. These items are shown in Appendix 2 and are denoted as SKD1, SKD2, SKD3, MOD1, MOD2, TFD1, TFD2, COD1, and COD2. The means and standard deviations of the item scores are also shown in Appendix 2. Since these items measure the designer control enablers, we can avoid self-report bias by using the responses only from the project managers and domain representatives. Thus, there were two methods to assess designer control enablers.

Internal Consistency of Operationalizations

Since this test involves validating questions used in the questionnaire, we can use all the responses from the project managers and domain representatives. In total, the number of usable responses was 105, which is fewer than the number of responses we used for managerial control enablers. We had smaller responses from the domain representatives than from designers.

Reliability: The Cronbach alpha coefficients for SKD, MOD, TFD, and COD were 0.789, 0.746, 0.526, and 0.631, respectively. All scales showed good reliability. However, the reliability for TFD was lower than for other scales. Previous empirical studies (Kerr and Jermier, 1978; Kerr, 1977) found that the reliability for task feedback questions was around 0.40. This was confirmed in our pilot test, as well. Therefore, we generated new questions for this scale. Our questions showed better reliability, but still need to be improved.

Correlation Matrix: The matrix of zero-order correlation is provided in Table 6.5. Scanning this correlation matrix shows that the smallest correlation for measures of a given theoretical construct was 0.357 ($p<0.001$) between TFD1 and TFD2, which is not surprising because the reliability for TFD was the smallest. However, 0.357 is significantly different from zero. In all cases each item correlated more

	SKD			MOD		TFD		COD	
	SKD1	SKD2	SKD3	MOD1	MOD2	TFD1	TFD2	COD1	COD2
SKD1	1.000								
SKD2	**0.542**	1.000							
SKD3	**0.533**	**0.595**	1.000						
MOD1	0.241	0.321	0.311	1.000					
MOD2	0.203	0.314	0.335	**0.614**	1.000				
TFD1	0.073	0.156	-.021	0.167	0.044	1.000			
TFD2	0.155	0.294	0.145	0.289	0.086	**0.357**	1.000		
COD1	0.247	0.305	0.248	0.393	0.351	0.172	0.296	1.000	
COD2	0.190	0.330	0.183	0.249	0.140	0.127	0.193	**0.462**	1.000

Table 6.5. The zero-order correlation between item measures for designer control enablers.

significantly with items measuring its own theoretical construct than with items measuring another theoretical construct.

Factor Analysis: The matrix in Table 6.5. was factor analyzed using a varimax rotation, and results are shown in Table 6.6. Based on a scree test, four factors were resulted. These four factors are consistent with our four theoretical constructs and account for 74.3 % of the variance.

Convergent and Discriminant Validity

Since the individual items classified as designer control enablers in our questionnaire showed good internal consistency of the operationalizations, we averaged them for a score for each dimension of the designer control enablers. Also, this average was calculated for each type of key informant: project

Item	Factor 1	Factor 2	Factor 3	Factor 4
SKD1	**.827**	.048	.088	.066
SKD2	**.788**	.154	.218	.197
SKD3	**.825**	.240	.059	-.056
MOD1	.165	**.824**	.181	.209
MOD2	.180	**.893**	.076	-.043
TFD1	-.019	.034	.029	**.848**
TFD2	.163	.097	.168	**.765**
COD1	.135	.355	**.719**	.174
COD2	.150	.004	**.900**	.062

Table 6.6. Results of factor analysis of items for designer control enablers.

manager and domain representative. In cases where more than two persons with the same role in the I/S planning and design team responded, we used an average value for the scores. Table 6.7 is the MTMM for designer control enablers, where SKD, MOD, TFD, and COD are viewed as traits, and each project manager informant and each domain representative informant can be viewed as different methods. In our notation each trait is preceded by M or U, where M stands for a project manager informant, U stands for a domain representative informant.

Convergent validity among key informants was satisfactory. The minimum correlation was 0.449 between project manager response and domain representative response on MOD, which is significantly different from zero ($p<0.001$).

Table 6.6 shows that there were significant correlations between UCOD and USKD, between UMOD and MCOD, and between UMOD and UCOD. These can

	SKD		MOD		TFD		COD	
	MSKD	USKD	MMOD	UMOD	MTFD	UTFD	MCOD	UCOD
MSKD	1.000							
USKD	0.481	1.000						
MMOD	0.225	0.269	1.000					
UMOD	0.177	0.440	0.449	1.000				
MTFD	0.214	0.159	0.249	0.188	1.000			
UTFD	0.153	0.295	0.060	0.309	0.453	1.000		
MCOD	0.305	0.326	0.312	**0.603**	0.140	0.178	1.000	
UCOD	0.321	**0.540**	0.281	**0.490**	0.295	0.419	0.625	1.000

Table 6.7. The MTMM matrix for designer control enablers.

be interpreted as follows. First, there might be a method's factor bias, which can explain high correlations between UCOD and USKD, and between UMOD and UCOD, but not a high correlation between UMOD and MCOD. In addition, the correlation between other variables, such as USKD and UTFD is relatively small compared to these exceptions. If method bias (that is, the domain representatives' bias in this case) is operating on the data, we should have a consistently high correlation among all the domain representatives' responses for all the theoretical constructs. Another reason for the high correlations, which we believe is the more probable one, is that these variables are correlated with other variables in a way that is valid reflection of reality. For example, suppose domain representatives find that the more skilled designers talk to other team members. In this case, the domain representative's responses concerning designer's skill and the frequency of communication will covary. Since the more self-motivated designers have a tendency to talk to other team members to increase the effectiveness of the design team, the manager's assessment of motivation and the domain representative's assessment of motivation might covary with the theoretical construct, the frequency of communication.

Even though there may be collinearity among the theoretical constructs measured by items for designer control enablers, since less than 10 % (3 out of 48) of the comparisons violated the discriminant test, we have reason to believe that the measures of all theoretical constructs displayed good convergent and discriminant validity. Thus, we can aggregate responses from different key informants to assess the designer control enabler variables based on our tests and theory.

6.2.3. Domain Representative Control Enablers

The dimensions of domain representative control enablers are the same as those of designer control enablers. But different types of questions must be asked for each category. For example, domain representatives are expected to have business skills, rather than computer-related skills. A domain representative's motivation and task feedback might be quite different from those of a designer. Communication, which can affect a domain representative's control, can be different as well, since he is supposed to talk to team members as well as in his department to build an agreed-upon information system. The questions are shown in Appendix 3 and are denoted as SKU1, SKU2, SKU3, MOU1, MOU2, TFU1, TFU2, COU1, COU2, and COU3. The means and standard deviations of the item scores are also shown in Appendix 3. Since these items measure the domain representative control enablers, we can avoid self-report bias by using the responses only from the project managers and designers.

Internal Consistency of the Operationalizations

Since some of the questions in the category of designer control enablers differ from the questions in the category of domain representative control enablers, we need to test the internal consistency of the operationalizations again. The total number of responses from the project manager and the designers was 127.

Reliability: The Cronbach alpha coefficients for SKU, MOU, TFU, and COU were 0.700, 0.751, 0.615, and 0.744, respectively. All scales showed good reliability. Again, the lowest reliability was found for TFU. However, this was much better than the reliability value of the task-related feedback for designer control enablers.

Correlation Matrix: The matrix of zero-order correlation is provided in Table 6.8.

	SKU			MOU		TFU		COU		
	SKU1	SKU2	SKU3	MOU1	MOU2	TFU1	TFU2	COU1	COU2	COU3
SKU1	1.000									
SKU2	0.487	1.000								
SKU3	0.435	0.394	1.000							
MOU1	**0.475**	**0.434**	0.358	1.000						
MOU2	0.283	0.205	0.287	0.612	1.000					
TFU1	0.138	0.241	0.112	0.310	0.202	1.000				
TFU2	0.237	0.316	0.207	0.409	0.261	0.444	1.000			
COU1	0.314	0.391	0.219	**0.474**	0.325	0.338	0.367	1.000		
COU2	0.303	0.310	0.193	0.310	0.201	0.151	0.225	0.424	1.000	
COU3	0.294	0.265	0.256	**0.429**	0.344	0.235	0.288	0.559	0.542	1.000

Table 6.8. The zero-order correlation between item measures for domain representative control enablers.

Scanning this correlation matrix shows that the smallest correlation within a theoretical construct was 0.394 ($p<0.001$) between SKU2 and SKU3, which is significantly different from zero. There were four violations out of 84 where an item correlated more highly with a measure of another theoretical construct than with other items that measure the same theoretical construct.

Factor Analysis: The matrix in Table 6.8 was factor analyzed using a varimax rotation and these results are shown in Table 6.9. Based on a scree test, four

Item	Factor 1	Factor 2	Factor 3	Factor 4
SKU1	.204	**.770**	.048	.181
SKU2	.224	**.745**	.300	-.039
SKU3	.043	**.742**	-.000	.242
MOU1	.262	.386	.293	**.676**
MOU2	.144	.126	.101	**.910**
TFU1	.100	.023	**.853**	.085
TFU2	.149	.186	**.758**	.162
COU1	**.652**	.177	.368	.218
COU2	**.839**	.198	.024	-.012
COU3	**.804**	.103	.123	.276

Table 6.9. Results of factor analysis of items for designer control enablers.

factors were resulted. These four factors are consistent with our four theoretical constructs and account for 71.4 % of the variance.

Based on the above tests, we can conclude that all questionnaire items used to measure domain representative control enablers displayed good internal consistency of operationalizations.

Convergent and Discriminant Validity

Since the individual items for designer control enablers in our questionnaire showed good internal consistency of the operationalizations, we averaged them to obtain a score for each dimension of the domain representative control enablers. Also, this average was calculated for each type of key informant: project manager and designer informant. In cases in which more than two persons responded who had the same role in the I/S planning and design teams, we also used the average value of their scores. Table 6.10 is the MTMM for the domain representative control enablers, where SKU, MOU, TFU, and COU are viewed as traits, and project manager informant and designer informant as different methods.

	SKU		MOU		TFU		COU	
	MSKU	DSKU	MMOU	DMOU	MTFU	DTFU	MCOU	DCOU
MSKU	1.000							
DSKU	0.182	1.000						
MMOU	0.287	0.400	1.000					
DMOU	-.033	0.665	0.280	1.000				
MTFU	0.233	-.044	0.337	-.098	1.000			
DTFU	0.105	0.463	0.534	0.329	0.255	1.000		
MCOU	0.557	0.058	0.322	-.084	0.375	0.232	1.000	
DCOU	0.098	0.409	0.356	0.547	-.001	0.454	0.260	1.000

Table 6.10. The MTMM matrix for domain representative control enablers.

Convergent validity among key informants was not achieved. In the case of SKU, the correlation between MSKU and DSKU is 0.188 ($p<0.106$), which is not significant. The reason for this low correlations can be explained by noting that designers have a tendency to blame domain representatives for project failure. For example Keider (1984) found that designers believe that users (in our case, domain representatives) do not have an adequate understanding of the business. Even though the correlations in the validity diagonals showed desirable properties, the correlations were not strong compared to those for designer control enablers and project manager control enablers.

Discriminant validity was tested by counting for each item the number of times that it correlated more highly with a measure of another theoretical construct than with the correlations among different informants for the same theoretical construct. More than 50 % of the comparisons (29 out of 48) failed to show the discriminant validity. Therefore, we can conclude that the items in our questionnaire in the domain representative control enabler category showed good internal consistency of the operationalizations, but we did not have good convergent validity and discriminant validity due to methods bias. This is a frustrating result in that we cannot use the average of the responses of these two informants' (project managers and designers) for measuring domain representative control enablers. Upon examining the means and standard deviation, we found that compared to the project manager, designers consistently underreported the domain representatives' skill, motivation, task feedback, and communication. On the other hand, this result is consistent with previous findings. De Brabander and Thiers (1984), Keider (1984), Necco *et al.* (1987), and others have reported that, when asked about why a project failed, most designers blamed the lack of skills, motivation of, and communication from the domain representatives.

Thus, we believe that the managers' responses are more objective than those of the designers. For further analysis, we will use only the project manager's assessment for the domain representative control enablers.

6.3. Measurement Model for Control

In this section we test the validity of the measures for control variables. Wrong (1968) emphasized that there is a distinct difference between the capacity to control and the actual practice of control. This distinction poses a dilemma for testing because we believe the following scenario is likely.

The team members use computerized design aids which increase their skills. These increases in skill enable them to become self-managed in the accomplishment of their tasks. Because more of their time is self-managed, they may interpret the decrease in direct managerial control or interference with their work as reflecting an increase in self-control and a relative decrease in the managerial control of their work. On the other hand, the manager of the I/S planning and design team with the computerized design aids may experience an increase in his managerial control because he is able to intervene if something exceptional occurs. He does not have to exercise managerial control beyond monitoring, but, if necessary, he can do so.

In the above case if we ask a team member about the extent of managerial control, he may say managerial control is decreased because his task is self-managed. On the other hand, if we ask the same question of the project manager, he may say that his managerial control is increased because he can monitor his team members better. In this situation, while the team members' assessments can measure the extent of the actual practice of managerial control, the manager's self-assessment of his own managerial control can measure the capacity to control.

Thus, for the analysis of managerial control and team members' control we included self-report by both team members and the project manager to assess this distinction and to test which is more closely related to performance variables - the manager or the team members' view of control.

6.3.1. Managerial Control

In Chapter Three we identified two different types of managerial control: behavior-based control and outcome-based control (OUTP). Behavior control was broken down into three categories, based on the leadership behavior theory (Jermier and Berkes, 1979; Kerr, 1977; Kerr and Jermier, 1978; Schriesheim, 1978; Schriesheim *et al.*, 1976). They are role clarification (ROLE), work assignment (ASSI), and procedure specification (PROC). These were assessed by asking informants to respond to multiple items using seven point Lickert-type scales. These items are included in Appendix 4 and are denoted by the acronyms OUTP1, OUTP2, ROLE1, ROLE2, ASSI1, ASSI2, PROC1, PROC2. The means and standard deviations of the item scores are also shown in Appendix 4.

Internal Consistency of Operationalizations

To test the internal consistency of the operationalizations (the items used in the questionnaire), all 184 responses from the project managers, designers and domain representatives were tested using the Cronbach alpha coefficients, the correlation matrix, and factor analysis.

Reliability: The Cronbach alpha coefficients for OUTP, ROLE, ASSI, and PROC were 0.858, 0.786, 0.696, and 0.534, respectively. Our items were based on the Ohio State Leadership Questionnaire and our reliability coefficients were similar to those of Ohio State Leadership Questionnaire (Schriesheim, 1978). Even though the reliability for procedure specification was low, the minimum level was achieved.

Correlation: The zero-order correlations between items measuring managerial control is given in Table 6.11. Scanning this correlation matrix shows that the

	OUTP		ROLE		ASSI		PROC	
	OUTP1	OUTP2	ROLE1	ROLE2	ASSI1	ASSI2	PROC1	PROC2
OUTP1	1.000							
OUTP2	0.751	1.000						
ROLE1	**0.680**	**0.583**	1.000					
ROLE2	**0.711**	**0.754**	**0.650**	1.000				
ASSI1	0.417	0.375	0.370	0.314	1.000			
ASSI2	0.337	0.228	0.199	0.174	**0.538**	1.000		
PROC1	**0.409**	0.304	0.355	0.330	**0.484**	**0.367**	1.000	
PROC2	0.087	0.151	0.043	0.155	**0.302**	0.135	**0.365**	1.000

Table 6.11. The zero-order correlation between item measures for managerial control.

smallest correlation within a theoretical construct was 0.365 ($p<0.001$) between PROC1 and PROC2, which is not surprising because the reliability for PROC was the smallest. However, 0.365 is significantly different from zero. With only seven exceptions (seven out of 48), items correlated more highly with other measures of the theoretical construct they were designed to measure than with items designed to measure another theoretical construct. For OUTP, one violation occurred because of the high correlation between OUTP2 and ROLE2. For ROLE, three violations occurred because of the high correlations between ROLE1 and OUTP1, between ROLE2 and OUTP1, and between ROLE2 and OUTP2. For PROC, three violations occurred because of the high correlations between PROC1 and OUTP1, between PROC1 and ASSI1, and between PROC1 and ASSI2. All violations except one were due to the high correlations between OUTP and ROLE, and between ASSI and PROC.

Therefore, we suspect that there are only two dimensions of managerial control. Ideally, since we used three categories of behavior-based control, we would expect role clarification (ROLE), work assignment (ASSI), and procedure specification items to be grouped together, and differ significantly from items for outcome control. However, the data suggested that the outcome control and role clarification items were grouped together, and work assignment and procedure specification items were grouped together. Thus, we need to explain why OUTP and ROLE covary. One plausible reason can be found by looking at the contents of the questions we used to measure ROLE. We used two questions: in one, the project manager "explains the level of performance that is expected of our project team members' work" and in the other, the project manager "lets our project team members know what is considered good performance". In the leadership behavior theory (Schriesheim, 1978), role clarification was theorized to be one part of the manager's behavior-based control, and was operationalized using the above questions in the previous empirical analysis. However, when we closely examined the questions, we concluded that as we asked about it, role clarification is <u>not</u> part of behavior-based control. Role clarification is more closely related to what should be expected from team members, that is, more closely related to manager's making sure that desired outcome is understood by the team members.[5]

Based on the above discussion, we believed that (1) role clarification should be viewed as part of outcome-based control and (2) behavior-based control has two components: work assignment and procedure specification. The following factor analysis confirmed this argument.

Factor Analysis: The matrix in Table 6.11 was factor analyzed using a varimax rotation and these results are shown in Table 6.12. Based on a scree test, two factors were resulted. These factors are consistent with the above argument and account for 65.5 % of the variance.

Based on the empirical result and the theoretical argument, we can include role clarification as part of outcome-based control. Therefore, for further analysis we averaged items measuring role clarification and outcome control as parts of outcome-based control , and item scores for work assignment and procedures specification as parts of behavior-based control. They are denoted as OUTPM and BEHAM, respectively.

Convergent and Discriminant Validity

Since there were three types of informants, we can view them three methods. Table 6.13 is the MTMM for managerial control, where OUTPM and BEHAM are

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5. One can argue that role clarification is part of input based control (see Peterson,1984).

Item	Factor 1	Factor 2
ROLE1	**.820**	.121
ROLE2	**.878**	.121
OUTP1	**.869**	.242
OUTP2	**.862**	.165
ASSI1	.302	**.761**
ASSI2	.148	**.695**
PROC1	.285	**.714**
PROC2	-.046	**.640**

Table 6.12. Results of factor analysis of items for managerial control.

viewed as traits, and the project manager informant, designer informant, and domain representative informant as different methods.

	OUTPM			BEHAM		
	DOUTPM	UOUTPM	MOUTPM	DBEHAM	UBEHAM	MBEHAM
DOUTPM	1.000					
UOUTPM	0.567	1.000				
MOUTPM	**0.144**	**0.144**	1.000			
DBEHAM	0.330	0.154	-.029	1.000		
UBEHAM	0.036	0.296	0.144	0.437	1.000	
MBEHAM	0.083	0.026	0.227	0.320	0.350	1.000

Table 6.13. The MTMM matrix for managerial control.

Convergent validity was not achieved in the OUTPM variable. The smallest correlation was 0.144 ($p>0.10$). There was no consensus between designer informants and manager informants, and between domain representative informants and manager informants. However, there was a strong correlation between the responses by the domain representative and the responses by the designer informants. Convergent validity for BEHAM is strong, since the smallest correlation between the responses from informants was 0.320 ($p<0.01$), which is significantly different from zero. The strongest correlation can be found again between the responses by the designer informants and the domain representative informants.

There are two possible reasons why we did not achieve convergent validity. First, since the weakest correlations were due to the manager informants, there might be self-report method bias. However, this does not explain why convergent validity was achieved for the BEHAM variable. Second and more probably, this can be explained by Ouchi's (1977) argument. Ouchi found that there are differences between a manager's perception of his managerial control and the team members' perceptions of managerial control. He used the terms "managerial control given" and "managerial control received" to refer to them respectively.

Many researchers have assumed control is realized only in dyadic relationships between social actors. Wrong (1968), however, asserted that managerial control need not be exercised to exist. Even though control is usually defined as the capacity to influence others, he emphasized that there is a distinct difference between the capacity to control and the actual practice of control. This distinction was noted by Cobb (1984) and Provan *et al.* (1980), as well. In this study this distinction was shown in the case of a manager's outcome-based control. Since designers and domain representatives are members of the I/S planning and design team and subordinates of the project manager, their perceptions of managerial control can be viewed as managerial control received.

The project managers' perception of his managerial control can be viewed as managerial control given.

This second reason can explain why we have achieved convergent validity for BEHAM. Since behavior control involves manager's behavioral interaction with team members, this can be felt strongly by the team members. In addition, unlike outcome based control, behavior control is directed at the team members (e.g., how the job should be done and which work should be done). Outcome-based control might not be perceived by the team members if they are performing well from the perspective of the project manager. In this case the project manager might closely monitor the outcomes of his team members and may claim that he is exercising strong outcome-based control, but his team members may not see strong managerial control.

From the above discussion, for the purpose of outcome-based control, we can separate managerial control given (managerial control perceived by the manager) from managerial control received (managerial control perceived by the team members). In the case of behavior based control, although convergent validity was achieved, we can also apply the above argument to behavior control in that strongest correlation was also found between responses by designer and domain representative informants.

Discriminant validity would be achieved if we separated managerial control received from managerial control given. Since managerial control received is assessed by two categories of key informants, the designer informants and the domain representative informants, we can test discriminant validity by counting the number of violations. No violations occurred in this case. However, managerial control given can not be tested, because we have only one informant, the project manager.

Since the assessment of designers and domain representatives of managerial control was in agreement, we can average their responses to measure the extent of managerial behavior-based control received and the manager's outcome-based control received. This average will be used for further analysis. Manager's self reports will be used to assess the managerial control given.

6.3.2. Team-Member Control

While there has been little empirical and theoretical research on models specifically addressing team-member control, the existing literature (Manz and Sims, 1980; Mills, 1983, Slocum and Sims, 1980; Van de Ven *et al.*, 1976; Tannenbaum, 1968) did not differentiate team members' control depending by the the types (in our case, the roles) of team members. However, in this study team-member control was divided into two types: designer control and domain representative control. The rationale for differentiating these two types of roles is that their tasks are quite different. Designers are expected to build an information system, domain representatives, on the other hand, are expected to supply relevant business knowledge. Therefore, in our study we used separate items to measure designer control and to measure domain representative control. For each role, the role's control is measured by two dimensions, giving four variables: designer outcome control (OUTPD), designer behavior control (BEHAD), domain representative outcome control (OUTPU), and domain representative behavior control (BEHAU). The items used to measure them are shown in Appendix 5 with their means and standard deviations.

	OUTPD		OUTPU		BEHAD		BEHAU	
	OUTPD1	OUTPD2	OUTPU1	OUTPU2	BEHAD1	BEHAD2	BEHAU1	BEHAU2
OUTPD1	**1.000**							
OUTPD2	**0.659****	**1.000**						
OUTPU1	**0.456****	**0.277****	**1.000**					
OUTPU2	**0.361****	**0.514****	**0.665****	**1.000**				
BEHAD1	0.107	0.076	0.065	0.103	**1.000**			
BEHAD2	0.157*	0.178*	0.057	0.106	**0.445****	1.000		
BEHAU1	0.014	-.042	0.139	0.084	**0.445****	**0.289****	1.000	
BEHAU2	0.046	-.011	0.183*	0.108	**0.260****	**0.475****	**0.5482****	1.000

Table 6.14. The zero-order correlation between item measures for managerial control.

(**: $p<0.01$ and *: $p<0.05$)

Internal Consistency of the Operationalizations

Since most of the empirical literature does not differentiate the type of team members, we need to test whether our differentiation is justified. This can be tested by examining the correlations between designer control and domain representative control at the item level; that is, whether items intended to measure domain representative control are significantly different from items intended to measure designer control. Table 6.14 shows the zero order correlations between items used in the questionnaire.

Scanning this matrix shows that all the correlations between the items for measuring designer outcome control and domain representative outcome control are significant ($p<0.001$). In addition, all the correlations between the items for measuring designer behavior control and domain representative behavior control are significant ($p<0.001$). On the other hand, the items measuring behavior-based control of any role was not correlated with items measuring outcome-based control at the $p = 0.01$ level.

Therefore, we can conclude that items used in the questionnaire can differentiate the theoretical constructs, outcome-based control and behavior-based control - but that there is no difference between designer control and domain representative control. To further clarify our argument we performed a factor analysis.

Factor analysis: The matrix in Table 6.14 was factor analyzed using varimax

Item	Factor 1	Factor 2
OUTPD1	.793	.035
OUTPD2	.797	-.021
OUTPU1	.738	.129
OUTPU2	.801	.092
BEHAD1	.068	.696
BEHAD2	.133	.710
BEHAU1	-.019	.786
BEHAU2	.038	.782

Table 6.15. Results of factor analysis of items for team member control.

rotation and the results are shown in Table 6.15. Based on a scree test, two factors resulted. These two factors can account for 59 % of the variation. They can be labelled as behavior control and outcome control, as are consistent with the above argument.

Reliability: Since we could find only two dimensions of team-member control, we averaged designer outcome-based control and domain representative outcome control (denoted by OUTPT), and designer behavior control and domain representative behavior control (denoted by BEHAT). The Cronbach alphas for BEHAT and OUTPT were 0.7440 and 0.7934, respectively. Because we aggregated several items which were not intended to measure the same theoretical construct, item analyses were performed by examining corrected item-total correlations, which were calculated by removing the item from the rest of items in the scale prior to computing the correlation. Reliability could not be increased by removing any single item. This reinforced our practice of aggregating the items. In sum, if we aggregate designer and domain representative control items, the items for team-member outcome control and the items for team-member behavior control showed good internal consistency of the operationalizations.

From the above analysis, we identified two dimensions of domain representative control and designer control: behavior control and outcome control. However, the data could not differentiate designer control from domain representative control. Since designers and domain representatives work as a team, we can use the terms, team-member behavior control and team-member outcome control.

Convergent and Discriminant Validity

Since items for team member outcome control and behavior control showed desirable internal consistency of operationalizations, we averaged them to have a score for each dimension of team-member control. This average was also calculated for each type of key informant: designer, domain representative, and project manager. In cases where more than two persons with the same role in the I/S planning and design teams responded we also used the average values of the scores. Table 6.16 is the MTMM matrix for team-member control, where OUTPT and BEHAT are viewed as traits, and the designer informant, the domain representative informant, and the manager informant as different methods.

	OUTPT			BEHAT		
	DOUTPT	UOUTPT	MOUTPT	DBEHAT	UBEHAT	MBEHAT
DOUTPT	1.000					
UOUTPT	**0.713**	1.000				
MOUTPT	0.149	0.046	1.000			
DBEHAT	0.044	0.044	0.056	1.000		
UBEHAT	0.116	0.359	-.087	**0.570**	1.000	
MBEHAT	-.170	-.084	-.026	0.104	-.085	1.000

Table 6.16. The MTMM matrix for team member control.

Neither convergent validity nor discriminant validity was achieved because of the manager informants' responses. If we eliminate the manager informants' responses, both convergent validity and discriminant validity would be achieved. Since designers and domain representatives work as a team, there should be strong interactions between these members. Designers are expected to build a system with help from the domain representatives and domain representatives are expected to work with designers on the system development and to evaluate the information with help from designers. However, project managers are more concerned with managing their design teams. Probably, designers and domain representatives have more opportunity to work together than with the project manager. Therefore, designer and domain representatives are more accurate sources of information.

However, since we cannot test the above argument with survey data (although this idea was confirmed with interviews), we will use separate scales to assess team-member control: (1) team-member outcome control perceived by the team members, (2) team-member behavior control perceived by the team members, (3) team-member outcome control perceived by the manager, and (4) team-member behavior control perceived by the manager. If the above argument is correct, then the first two scales should be more highly related to performance variables, which will be examined in the next chapter.

6.4. Chapter Six Summary

This chapter discussed a measurement model for control enablers and control variables. Since we used multiple indicators and multiple key informants, we tested the internal consistency of the operationalizations, convergent validity and discriminant validity.

Items used to measure control variables and control enablers variables showed good internal consistency of the operationalizations, validating items used in the questionnaires. However, we found that role clarification was not part of behavior control but that of outcome control.

Different informants' assessments of control variables and control enablers except for domain representative control enablers were in agreement and they can differentiate dimensions of theoretical constructs. However, managerial control variables can be differentiated depending upon who is giving or receiving control. In the case of domain representative control enablers, we will use the responses from the project manager, since the designer informants consistently underreported domain representative control enablers, which is consistent with the previous research findings.

In sum almost all of our data passed various strict criteria for the construct validity we identified. For further analysis we will use the measurement model developed in this chapter since the items are measuring what they are intended to measure and different key informants are in agreement for each theoretical construct.

CHAPTER SEVEN. AN EMPIRICAL TEST OF THE TEAM PROCESS MODEL

This chapter discusses how our team process model was tested empirically. After investigating the team process in this chapter, we will discuss the the impact of computerized design tools on I/S planning and design teams in the next chapter.

As discussed in Chapter Two, the team behavior of the design teams must be understood, before investigating the impact of computerized design aids on performance. This is especially critical, considering that I/S planning and design teams can achieve a high level of performance, even without computerized design tools. We, therefore, need to understand the interaction of a number of intermediate or process variables and their effects on performance before we can evaluate the impact of computerized design aids on performance.

Section 7.1 discusses the instruments we used to assess the performance of our I/S planning and design teams. In Section 7.2 relationships among a set of control variables and a set of performances variables are tested. In Section 7.3 we test the relationships among the managerial control enablers and the managerial control variables, and in Section 7.4 the relationships among the team-member control enablers and the team-member control variables. Sections 7.5 and 7.6 tie control enablers, control variables, and performance together with the hypothesis that the control enablers affect the performance of a design team through the control variables we have tested.

7.1. Developing Measures of Performance

In our questionnaire, we used subjective measures to assess performance because, as many studies have indicated, there are substantial problems involved in using objective measures for this task (Kemerer, 1989; Henderson, 1988). In our study we could not find accounting measures that could be used consistently across the entire set of design teams.

The performance of the design teams, in terms of their efficiency (EFFI), effectiveness (EFFE), and time-to-market (TIME) was assessed by non-team stakeholders who are defined as individuals who are not formal members of the project but are affected by the output of the team or can affect its performance. Examples include senior executives and client personnel not formally on the project. The number of stakeholders who filled out the performance questionnaire per team ranged from two to five with an average of 2.6.

Appendix 6 shows the questionnaire measures used for each dimension. Except for one item these measures for EFFI and EFFE were the same as those developed and validated by Henderson (1988). For TIME, we generated two measures. Instead of Henderson's item for measuring efficiency, which was "the team's adherence to budgets and schedules," we used two separate items: "the team's adherence to budgets" and "the team's adherence to schedules." However, there were several instances in which the question concerning the team's adherence to budgets was not answered. Several follow-up interviews suggested that stakeholders might have not known about the budgets. Additional reason why stakeholders may not have answered the budget question is that the concept of a budget for most stakeholders was a specific dollar amount of money, and for some I/S design projects no formal budgets had been planned. Therefore, we dropped the budget item in favor of consistency.

Cronbach Alphas of 0.750 0.723, and 0.736, respectively, suggest an adequate level of reliability. However, these values are quite low compared to those obtained by Henderson (1988). One reason for this difference may be that in our study we surveyed more organizations than Henderson did.

Therefore, before further analysis, we must be sure that our 41 teams represent independent sample points, in other words, that the variance in the dimensions of performance arises from genuine differences among the design teams themselves and is not being affected by the organizations in which the I/S planning and design teams were situated. To evaluate this source of bias, we ran three ANOVAs to test the hypothesis that the performance variables could be explained by the company variable, that is, to determine whether significant differences existed among the companies. The multivariate *F*s were 1.075, 1.881, 1.581 for efficiency, effectiveness, and time-to-market, indicating that there were no significant differences among the companies ($P>0.10$). Since the variations in performance variables among the companies were not greater than the within-company variations, we had partial support for the general notion that performance variables were different for different I/S planning and design teams within the same organization. In the following analysis, therefore, all design teams are treated as individual sample points.

Although we could not provide a certain explanation for the differences between the reliability coefficients of our study and those of Henderson's (1988), we felt we could use these measures to assess performance of I/S planning and design teams, since the minimum required reliability coefficients were achieved.

7.2. Performance and Control

The underlying theme for our team process model is that control is positively related to I/S planning and design teams. As discussed in Chapter Three, this view is widely advocated in organizational control literature and has strong empirical evidence to support it [see Tannenbaum (1968) for a review]. However, this view has not been tested in the I/S planning and design literature.

The purpose of the correlation matrix in Table 7.1 is to test hypothesis, H1, that managerial control and team-member control have significant effects on the performance of the design teams. The performance of the design teams has been measured in three dimensions: efficiency (EFFI), effectiveness (EFFE), and time-to-market (TIME).

The control variables we measured are managerial behavior control (BEHAM), managerial outcome control (OUTPM), team member behavior control (BEHAT) and team-member outcome control (OUTPT). Each control variable has been assessed by team members (designers and domain representatives) and the project manager. As discussed in Chapter Seven, the responses from the designers and domain representatives of each team covary, so we averaged their responses for further analysis.

In our notation each control variable is preceded by DU or M, where DU indicates that the designer and the domain representative assessed the variable, and M indicates that the project manager assessed the variable. For example, DUBEHAM is managerial behavior control assessed by the team members (the designers and domain representatives), and MBEHAM is managerial control as assessed by the project manager.

		EFFI	EFFE	TIME
Manager's assessment	Managerial behavior control (MBEHAM)	.239	.170	.046
	Managerial outcome control (MOUTPM)	-.059	-.055	.074
	Team-member behavior control (MBEHAT)	-.096	.099	-.196
	Team-member outcome control (MOUTPT)	-.012	-.161	.079
Team-members' assessment	Managerial behavior control (DUBEHAM)	.618**	.432**	.263*
	Managerial outcome control (DUOUTPM)	.243*	.199	.150
	Team-member behavior control (DUBEHAT)	.186	.330*	.125
	Team-member outcome control (DUOUTPT)	.385**	.485**	.303*

Table 7.1. The zero-order correlation between performance variables and control variables.

(**: $p<0.01$ and *: $p<0.05$)

As shown in Table 7.1, both DUBEHAM and DUOUTPT were closely related to all performance variables. In addition, DUBEHAT was related to EFFE ($p<0.05$) and DUOUTPM was related to EFFI ($p<0.05$). The managers' assessment of the control variables was not strongly related to any performance variables. In the case of managerial control, a manager's assessment of his own control (MBEHAM and MOUTPM) can be interpreted in two ways. First, these measures are self-reports, so position bias may be operating: the natural conclusion is that a manager's own self-report overestimates how much influence he is exercising.

Second, the two measures of managerial control may actually measure different things: managerial control as assessed by the project manager may refer to control given by the project manager and managerial control as assessed by team members can be viewed as control received, as Ouchi (1977) has claimed.

To assess the first argument, we ran two paired t-tests. The results are shown in Table 7.2. There was a significant difference between self-reports by the project managers and non-self-reports by team members. Thus, we cannot reject the hypothesis that there is a significant self-report bias.

Variable	Number of cases	Mean	Standard deviation	T-value
MBEHAM	41	5.012	0.816	4.12**
DUBEHAM		4.445	0.817	
MOUTPM	41	5.024	1.015	4.01**
DUOUTPM		4.191	1.021	

Table 7.2. The results of paired t-tests of MBEHAM and DUBEHAM, and MOUTPM and DUOUTPM.

(**: $p<0.01$ and *: $p<0.05$)

In Chapter Six we argued that, based on the measurement model, the second interpretation was at least as plausible as the first for our study. If we adopt this view, managerial control received is more significantly correlated with performance variables. In the case of the I/S planning and design teams, managerial control received may be more important than managerial control given. Since I/S planning and design entails complex tasks which require much interaction among individuals with different roles (Guinan and Bostrom, 1986), team members may need explicit guidelines from the manager. Thus, managerial control should have a manifest impact on team members' perception.

When the manager's behavior-based control and outcome-based control were compared, the behavior-based control was more significantly related to all the performance variables. The I/S planning and design team members have consistent goals (at least superficially): they are supposed to develop an information system. Therefore, one can argue that all project members share the same general objective, although they may differ on the details of the final outcome they should achieve. On the other hand, the nature of the team process for team members is a complicated pattern of interaction and far from uniform. The designers and the domain representatives have different skills, role perceptions, and mental schemas which must be combined through their protocols of interaction into a final outcome (Boland, 1978). Thus, the important role of managing this interaction is to help give direction to the process, which cannot be done using only outcome-based control. Instead of focusing solely on the final outcome the team members should achieve (which we assume they all share in common anyway), the project manager should be explicitly involved in assigning team members to specific tasks and helping them execute these tasks.

The relationships among performance and the team members' control variables were the opposite of those for the manager's control variables. Among team members' control variables, outcome-based control was more strongly related than behavior-based control to all of the performance variables. Moreover, the manager's assessment of the team-member's control was not correlated with any performance variables. In Chapter Six, we claimed that team members can better assess their own control[1] than can the project manager because they are working together as a team.

Team-member behavior control refers to self-control in executing a team member's own tasks, whereas team-member outcome control can be viewed as collegial control, such as providing feedback on performance. The I/S planning and design team members should interact with each other to produce a team product, which will be partly based on the business knowledge provided by the domain representatives and the system knowledge provided by the designers. Therefore, a team member should primarily work not by himself, but as part of a team. Since team-member behavior control was assessed in this study as self-control, and team-member outcome control was assessed as collegial control , it is reasonable that team-member outcome control explained more significant variation in performance variables.

Table 7.3. shows the results of the regression analysis. Each performance variable was regressed on the control variables assessed by the team members. Behavioral control by the manager and outcome control by the team members explained the significant variations in the performance variables (EFFI and EFFE). (Time-to-market showed no significant differences related to the control variables.) We have already explained how (1) managerial control affects performance variables through the team members' behavior and how (2) outcome control by the team members can affect performance variables

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1 We assessed team-member control separately for both designers and domain representatives, and found that self-report and non-self-report measures were in agreement in this study (for the measurement model see Chapter Six). Thus, we can exclude the possibility of self-bias in the aggregated measures, which include both self-report and non-self-report measures of the team-member control variables.

	EFFI	EFFE	TIME
R-square	.441	.384	.128
Adj. R-square	.378	.315	.032
Manager's behavior control	.539**	.309*	.183
Manager's outcome control	.076	-.016	.018
Team members' behavior control	.116	.247	.072
Team members' outcome control	.169	.353*	.227

Table 7.3. The results of regression analysis of performance variables on control variables.

(**: $p<0.01$ and *: $p<0.05$)

through its impact on team members' behavior. In sum, our data gave strong support for H1 and for the claim that I/S planning and design tasks are complicated and primarily require collective, not individual work to be efficient and effective. DUBEHAM and DUOUTPT together explain 44% and 38 % of variations in the efficiency and effectiveness of the I/S planning and design teams.

There are two interpretations of our findings concerning the TIME variable that seem likely. First, as discussed in Section 7.1, our subjective measures for TIME may not be very good. We used only two items which had not been pretested by other studies. Second, TIME might be better explained by other theoretical variables. We will discuss this in more detail in the next chapter when we examine the effects of computerized design aids.

Our findings can be compared to those of past empirical work described in the organizational control literature. Tannenbaum and his colleagues (1968) tested the hypothesis that a large amount of control, exercised both by leaders (in our case the project manager) and by team-members (the designers and the domain representatives), is related to organizational effectiveness. A strict comparison between their studies and ours is difficult, since the items they used are different from ours. They measured the leader's control by asking survey respondents "how much influence does your leader actually have in determining ... policy", and they assessed team member's control "how much influence do team members have in determining ... policy?" They then added the values they got for leader's control and team-members' control to measure the total amount of control in the organization or subunit. Despite these differences, our results are in good general agreement with theirs.

In Table 7.4 we generated several measures for the total amount of control. All of them showed significant correlations with the performance variables. The strongest correlations with performance variables are found in the last row of Table 7.4: (DUBEHAM + DUOUTPT). We can interpret this new aggregate variable as the total amount of control in a dydadic relationship. Tannenbaum *et al.* (1968) defined managerial control as the extent of a manager's influence in determining the team members' behavior. This relationship is reflected in our variable, DUBEHAM, since the managerial behavioral control can show its impact on performance through team-members' behavior. Team-member control refers to the amount of control exercised by team members on the manager or other team members in some cases; in our study this is best reflected in the variable DUOUTPT, which is a team member's outcome control of other team members.

	Explanation	EFFI	EFFE	TIME
DUBEHAM + DUBEHAT	Total amount of behavioral control	.565**	.524**	.270*
DUOUTPM + DUOUTPT	Total amount of outcome control	.394**	.404**	.268*
DUBEHAM + DUBEHAT + DUOUTPM + DUOUTPT	Total amount of behavioral and outcome control	.569**	.555**	.329*
DUBEHAM + DUOUTPT	Total amount of control in dydadic relationship	.613**	.569**	.351**

Table 7.4. The zero-order correlations among total amount of control and performance variables.

(**: $p<0.01$ and *: $p<0.05$)

Tannenbaum *et al.* (1968) found that the correlation between the total amount of control and effectiveness ranged from 0.29 to 0.45. In our case, the correlation between effectiveness and the total amount of control in the dydadic relationship (DUBEHAM + DUOUTPT) was 0.569 ($p<0.01$). Tannenbaum *et al.* operationalized performance variables by effectiveness items similar to our items for the effectiveness variable. They showed empirically that the total amount of control can best explain performance (effectiveness) among a set of control variables and their transformed variables. In our case this holds true in that the total amount of control in a dydadic relationship had the best correlation with the effectiveness variable. Also note tnat the correlation between the total amount of control and effectiveness was the most significant:

the correlation between total amount of control and efficiency was lower than the correlation between DUBEHAT and EFFI, and the correlation between the total amount of control and TIME was relatively not much higher than the correlation between DUOUTPT and TIME. Thus, our result is consistent with their findings. However, compared to their studies, our findings for the total amount of control explain effectiveness better because in our case we used multiple indicators and multiple informants.

Given the support we found for the hypothesis that control variables can explain performance, a more detailed analysis of the pattern of control between managerial control and team-member control was conducted. Using the median values for DUBEHAM and DUOUTPT, we split the 41 I/S planning and design teams into four subgroups as shown in Figure 7.1. We then examined the average values of performance variables (EFFI, EFFE, and TIME) in the appropriate cell and found that the degrees of managerial behavior control and team-member outcome control were consistent with our previous discussion. First, when both high managerial behavior control and high team-member outcome control were operating (Cell One), the performance variables were the best, and when both were low (Cell Four), all the performance variables were the worst. Second, when either low managerial control or low team-member control was achieved, the performance variables were not greater than those in Cell One, but were better than those in Cell Four. Although we can compare neither Cell One to Cell Two nor to Cell Three because of the small sample size ($n = 5$ for Cell Two and Cell Three), we can compare Cell One and Cell Four, using the t-statistic. The values of the t-statistics for EFFI, EFFE, and TIME were 3.93, 3.28, 1.72 (all significant at $p = 0.01$), which supports the claim that teams with high managerial behavior control and high team-member outcome control are

	High managerial behavior control	Low managerial behavior control
High team member outcome control	n = 15 EFFI 5.364 EFFE 5.427 TIME 4.913 Cell 1	n = 5 4.813 5.200 4.790 Cell 2
Low team member outcome control	Cell 3 4.940 4.820 4.650 n = 5	Cell 4 4.313 4.594 4.216 n = 16

Figure 7.1. Performance variables and the degree of control by type.

better performers compared to teams with low managerial behavior control and low team-member outcome control.

From the discussion in this section, significant variations in performance variables can be explained by control variables (supporting our hypothesis H1). This was especially true for managerial behavior control, which was strongly correlated with efficiency variables and for team-members outcome control, which was significantly correlated with the effectiveness and the time-to-market of the I/S design teams. Since control variables assessed by team members are more significantly related to performance variables than those assessed by project managers, we will focus on control assessed by team members in the analysis that follows.

7.3. Managerial Control and Its Enablers

To test hypothesis H2, that the manager's task understanding (TUND), the availability of measurement (MEAS), and the ease of vertical communication (VCOM) have significant effects on the manager's behavior control, and H3, that the manager's task understanding, the availability of measurement, and the ease of vertical communication have significant effects on the manager's outcome control, zero-order correlations are presented in Table 7.5.

	Managerial behavior control	Managerial outcome control
Task understanding (TUND)	.491**	.316*
Measurement (MEAS)	.304*	.346*
Vertical communication (VCOM)	.321*	.494**

Table 7.5. The zero-order correlation between managerial control and its enablers

(**: $p<0.01$ and *: $p<0.05$)

All our control variables were strongly correlated with both managerial outcome and behavior control variables as assessed by team members. Ouchi (1979, 1977), Ouchi and Maguire (1975), and Eisenhardt (1985) claimed that as managers understand the means-ends relationship better, they will exercise more behavior control and that as the cost of measurement is reduced, they will use more outcome control. Based on our data we cannot reject their hypotheses.

Ouch (1977) and Eisenhardt (1985), however, made an assumption that the manager or organization (or subunit) can use only one type of managerial control, either behavior control or outcome control, but not both. For example, in Eisenhardt's (1985) work, behavior control is operationalized by pay plans in which pay is either by salary or hourly rate, and outcome control is operationalized by commissions for the sales persons. However, this is a weak assumption, which sometimes cannot be justified. For example, some organizations use outcome control, such as commissions, for the sales persons, and at the same time use behavior control, such as how many calls each sales person must make during a given day. Therefore, we believe that both behavior control and outcome control can be operative in the same I/S planning and design teams.

To test this claim, we examined the correlation between DUBEHAM and DUOUTPM. The correlation coefficient was 0.2443, which is not significant ($p>0.05$). Therefore, behavior and outcome controls could not be substituted for one another in our cases. [In a separate study, Ouchi and Maguire (1975) found the similar result that these two types of control could not be substituted for one another.]

Ouchi and Maguire (1975) and Ouchi (1977) also measured managerial control by asking the manager which control strategy he used. In our study this question is reflected in MBEHAM and MOUTPM. If we ignore communication variables (as they did in their empirical analysis), our result is quite consistent with their findings. Behavior control (MBEHAM) can be best explained by manager's task understanding ($r = 0.446$, $p<0.01$), and outcome control (MOUTPM) can be best explained by the ease of measurement ($r = 0.379$, $p<0.01$).

However, as we found in the previous section, a manager's self-assessments of his control variables were not good predictors of performance variables. Thus, we knew we needed to focus on the managerial control variables assessed by team members. In addition, we claimed that communication between the project manager and team members could affect managerial control.

Therefore, we focused on the relationships among the control variables assessed by team members and control enablers including the ease of vertical communication. Table 7.5 show that all control enablers (TUND, MEAS, and VCOM) were significantly related to both managerial outcome control and behavior control. In the case of managerial behavior control, TUND was the most significant correlate, as Ouchi and Eisenhardt found, but in the case of managerial outcome control MEAS was not the most significant variable. Although MEAS was more highly related to behavior control (statistically there was no difference, at the level of $p = 0.05$) than TUND was, VCOM was most significantly related to outcome control.

To perform a more stringent test of Ouchi and Eisenhardt's claims that managerial behavior control is determined by task understanding and that managerial outcome control is determined by the availability of measurement, we ran two partial correlation tests. The results are shown in Tables 7.6 and Table 7.7. If their claims were true, the partial correlation coefficients should not have been significant.

The results of the partial correlations show that even controlling for task understanding variable, MEAS was significantly correlated with DUBEHAM. In most studies on organizational control (Ouchi, 1977, 1979; Eisenhardt, 1985; Peterson, 1984), the ease of measurement refers to the availability of outcome measures. However, in the context of I/S planning and design, measurements

	Managerial behavior control	self-report
Measurement (MEAS)	.282*	.193
Vertical communication (VCOM)	.186	.149

Table 7.6. The results of partial correlations controlling for TUND.

(**: $p<0.01$ and *: $p<0.05$)

	Managerial outcome control	self-report
Task understanding (TUND)	.294*	-.051
Vertical communication (VCOM)	.430**	.308*

Table 7.7. The results of partial correlations controlling for MEAS.

(**: $p<0.01$ and *: $p<0.05$)

are not restricted to outcome measures. In fact, Chalykoff (1988) claimed that one of the main benefits of using information technology was making the behavior measures available to organizations. Since the project manager does not see the I/S product until it is finished, behavior measures would enable the project manager to intervene effectively in team members' behavior (one could also argue that these are interim output measures). Thus, the availability of measurement can contribute to managerial behavior control.

Table 7.7 shows that TUND and VCOM were significantly related to managerial outcome control as assessed by team members, even controlling for MEAS. Schmitt and Kozar (1978) presented an example of an unsuccessful process of information system development. They found that infrequent communication between the project manager and team members during the design process resulted in weak managerial control, such as giving vague objectives and criteria for the system. Also, without the manager's task understanding, it would be hard for the manager to exercise any type of control.

Based on the discussion above we cannot reject our two hypotheses H2 and H3, that the manager's task understanding, Availability of measurement, and ease of vertical communication are strongly related to both managerial outcome control and behavior control. Also, note that both types of control can be operative in the same I/S planning and design team and that all control enablers contribute to both control variables (managerial behavior control and managerial outcome control).

7.4. Team-Member Control and Its Enablers

Team members have two roles in I/S planning and design teams: the designers who provide computer-related knowledge and the domain representatives who provide business knowledge. Therefore, we measured each role's control variables and each role's enablers separately. However, we found that we could not differentiate the designers' influence from that of the domain representatives (see Section 6.3.2). We believe the reason was that, at least in our case, the designers and domain representatives work as a team. Kaiser and Bostrom (1982) also found that once users (in our case, domain representatives) are officially involved in the design (i.e., become members of the design team), they are assimilated and work together with the team. Thus, we averaged the value of designers' and domain representatives' control variables to refer to team-member control. The two dimensions of team-member control, outcome control and behavior control, will be denoted by DUOUTPT and DUBEHAT.

On the other hand, team-member control *enablers* were significantly different, depending upon the roles. For example, designers' skills are not the same as domain representatives' skills. Therefore, there are two team-member control variables and eight team-member control enablers (four control enablers for two team-member roles). To examine whether some team-member control enablers could be aggregated, we produced correlations for each enabler with designers and domain representatives as shown in Table 7.8. There are four dimensions of team-member control enablers - skill (SK), internal motivation (MO), task-related feedback (TF), and horizontal communication (CO) - and there are two types of team members - designers (D) and domain representatives (U). Thus, in our notation, SKD refers to the skill required for the designer's role and SKU refers to the skill required for the domain representative's role. No significant correlations between SKD and SKU, between MOD and MOU, and between TFD and TFU were found. However, there was a significant correlati between COD and COU. Since communication for each role was measured by intra-team communication, we believe COD and COU reflect the same theoretical variable - horizontal communication among team members. Therefore, for further analysis, COD and COU will be averaged and denoted by COT.

	SKD	SKU	MOD	MOU	TFD	TFU	COD	COU
SKD	1.000							
SKU	0.021	1.000						
MOD	0.375	0.170	1.000					
MOU	0.051	0.287	-.006	1.000				
TFD	0.281	0.456	0.274	0.380	1.000			
TFU	0.243	0.233	0.174	0.337	0.363	1.000		
COD	0.398	0.524	0.523	0.168	0.635	0.301	1.000	
COU	0.281	0.557	0.220	0.322	0.437	0.375	0.646	1.000

Table 7.8. The zero-order correlations between team-members control enablers

Zero-order correlations (Table 7.9) were used to test hypothesis H4, that the team-member's skill, internal motivation, task-related feedback, and ease of communication have significant effects on the team-member's behavior control and hypothesis H5, that these variables have significant effects on the team member's outcome control.

In general, designer control enablers were more significantly correlated with team-member control than domain representative control enablers were, reflecting the fact that designers take the initiative in planning and designing an information system. One can argue that this result is due to aggregating designer control and domain representative control, creating a systematic bias. To examine this claim, we produced zero-order correlation matrices between designer control enablers and designer control and between domain representative control enablers and domain representative control, shown in

	Team member behavior control	Team member outcome control
SKD	.532**	.362**
SKU	-.042	.179
MOD	.223	.222
MOU	.056	.114
TFD	.116	.208
TFU	-.172	.120
COT	.073	.408**

Table 7.9. The zero-order correlations between team members control enablers and team member control.

(**: $p<0.01$ and *: $p<0.05$)

Tables 7.10 and 7.11. The general patterns of Tables 7.9, 7.10, and 7.11 are

	Designer behavior control	Designer outcome control
SKD	.510**	.383**
MOD	.170	.166
TFD	.142	.128
COD	.141	.276*

Table 7.10. The zero-order correlations between designer control enablers and designer control.

(**: $p<0.01$ and *: $p<0.05$)

generally quite the same except for one case (the correlation between domain representative outcome control and SKU). Among the correlations between

	Domain representative behavior control	Domain representative outcome control
SKU	-.105	.280*
MOU	.067	.166
TFU	-.220	.133
COU	.030	.441**

Table 7.11. The zero-order correlations between domain representative control enablers and domain representative control.

(**: $p<0.01$ and *: $p<0.05$)

enablers and control, the significant correlations were between designer's skill and designer's behavior control, between designer's skill and designer outcome control, between communication and designer outcome control, between domain representative' skill and domain representative outcome control, and between communication and domain representative outcome control. Therefore, in general, the correlations shown in Table 7.9 seem valid.

Behavior control by team members (assessed by DUBEHAT) was most significantly correlated with designer's skill. This supports Mills' (1983) and Manz and Sims' (1980) claim that self-control can be implemented when team members' skill can be trusted. In the context of I/S planning and design teams, the designer's skill is no doubt the most important factor for team members in taking initiatives in developing an information system. However, team-member behavior control was not correlated with performance variables. Thus, we have not provided support for the notion that skill can affect performance through designer behavior control. This issue will be discussed in greater detail in the next section.

Team-member outcome control (DUOUTPT) was strongly correlated with designer's skill and communication. Thompson (1967) and Mills (1983) observed that increased peer or horizontal communication is likely to occur in self-managed situations because supervision has shifted to the realm of the experts, who in some areas are more task-competent than the formal manager. In the context of I/S planning and design tasks, communication among team members is extremely important because no single individual may have complete knowledge of the information system to be built. First, the different kinds of knowledge each individual role brings should be meshed into a coherent design schema. Second, no single individual can build an entire system by himself, because in general, building an information systems takes more than one man-month hours.

In the self-control literature, most studies focused on skill, motivation (Mills, 1983; Manz and Sims, 1980; Cummings, 1978; Cherns, 1976; Curry *et al.*, 1986), and task feedback (Cherns, 1976; Lawrence and Lorsch, 1967; Thompson, 1965; Powers, 1973; Campion and Lord, 1982). However, there were few studies which examined communication and its impacts on self-control. On the other hand, communication was one of the most frequently studied subjects in the I/S planning and design literature, especially the interactions among designers and users. For example, Boland (1978), Henderson (1988), and Robey and Farrow (1982) theorized about and empirically tested the effect of interactions among designers and users. They argued that a high level of mutual influence through effective communication will lead to improved design products. White and Leifer (1986) asked 68 design teams to list five factors that they thought led to successful system development. They reported that team members' skill and abilities, including both technical skills and communication skills, are most important.

From the discussion above and based on our data, we cannot reject our two hypotheses (H4 and H5) that the team member's skills and ease of horizontal communication have significant effects on both the team members' behavior-based control and outcome-based control. However, task-related feedback and internal motivation were not strongly correlated with team-member control variables. Also, communication, which has been studied in depth in I/S research, was strongly correlated with team-member control, suggesting that communication should be included in the self-control literature.

7.5. Control Enablers and Performance

Control enablers were hypothesized to affect performance through their impacts on control variables. These relationships were expressed explicitly in hypotheses H6 and H7. H6 states that managerial control enablers affect performance through their impacts on managerial control, and H7 states that team-member control enablers affect performance through their impacts on team-member control. These two hypotheses assume that control enablers can affect performance, but if we control for managerial control and team-member control, there will be no significant correlations among control enablers and performance variables.

Managerial Control Enablers

To examine whether there were significant correlations among managerial control enablers and performance variables, the zero-order correlations were produced in Table 7.12. There were significant correlations between TUND and

	EFFI	EFFE	TIME
Task understanding (TUND)	.283*	.090	-.012
Measurement (MEAS)	.313*	.449**	.202*
Vertical communication (VCOM)	.124	.043	.179

Table 7.12. The zero-order correlations between managerial control enablers and performance variables.

(**: $p<0.01$ and *: $p<0.05$)

EFFI, between MEAS and EFFI, and between MEAS and TIME. However, when we controlled for the managerial control variables (DUBEHAM and DUOUTPM), there was only one significant correlation, between MEAS and EFFE as shown in Table 7.13. I/S planning and design involves an abstract activity in that the manager cannot see the tangible product until it is developed in its final form. Thus, if concrete measurements are available, work can be done more effectively. Since there was only one significant correlation between managerial control enablers and three performance variables when we controlled for managerial control, in general, we cannot reject H6, that managerial control enablers affect performance only through their impacts on managerial control.

	EFFI	EFFE	TIME
Task understanding (TUND)	-.070	-.186	-.196
Measurement (MEAS)	.127	.356*	.111
Vertical communication (VCOM)	-.197	-.182	.069

Table 7.13. The partial correlations between managerial control enablers and performance variables, controlling for managerial control (DUBEHAM and DUOUTPM).

(**: $p<0.01$ and *: $p<0.05$)

<u>Team Member Control Enablers</u>

To examine whether there were significant correlations between team member control enablers and performance variables, zero-order correlations were produced in Table 7.14. There were significant correlations between several team-member control enablers and performance variables. Controlling for team-member control variables (DUBEHAT and DUOUTPT) does not reduce the extent of significant correlations, as shown in Table 7.15. So our results do not provide support for our hypothesis that team member control enablers shows their impact on performance variables only through team member control enablers.

The above conclusion is frustrating because it seems that team-member control enablers, which have not been included in predicting performance in the organizational control literature, can directly affect performance variables. However, the above conclusion is consistent with previous work in the small group behavior literature (Gladstein, 1984; Hackman and Morris, 1975; McGrath, 1984). In this literature, group performance (team performance) is

	EFFI	EFFE	TIME
SKD	.552**	.408**	.387**
SKU	.174	.291*	-.024
MOD	.408**	.446**	.162
MOU	.001	.139	-.120
TFD	.168	.296*	-.045
TFU	.194	.259	.007
COT	.367**	.510**	.235

Table 7.14. The zero-order correlations between managerial control enablers and performance variables.

(**: $p<0.01$ and *: $p<0.05$)

	EFFI	EFFE	TIME
SKD	.484**	.169	.318*
SKU	.104	.201	-.085
MOD	.343*	.364*	.089
MOU	-.104	.115	-.214
TFD	.088	.214	-.123
TFU	.209	.292*	-.025
COT	.250	.407**	.128

Table 7.15. The partial correlations between managerial control enablers and performance variables, controlling for team-member control (DUBEHAT and DUOUTPT).

(**: $p<0.01$ and *: $p<0.05$)

assumed to be the function of inputs and processes (McGrath, 1984). Input variables establish the group structure or framework for group interaction.

When interactions actually commence, process variables begin to act upon the initial inputs. Note that these inputs and process variables correspond to our control enablers and control variables. For example, Hackman and Morris (1975) and Gladstein (1984) identified several dimensions of inputs in a group process, such as skills, effort, performance strategy. To some extent, these input variables are reflected in our control enablers. For example, skills and motivation (which reflects effort) are theorized in our study to be control enablers.

Group process refers to specific modes of interaction (Hackman and Morris, 1975; Gladstein, 1984). According to Hackman and Morris (1975), process variables can be measured in terms of how team-members' efforts are brought to bear on the task, how performance strategies are used in carrying out the tasks, and how the team-members' knowledge and skills are used by the group for task-related work. Gladstein (1984) used the variables of open communication, supportiveness, conflict, and discussion of strategy to refer to coordination and control of group activities. We believe that these process variables are reflected in our control variables to some extent.

Gladstein (1984) empirically showed that the input variables can affect group performance both directly and indirectly through performance variables. This is consistent with our findings that control enablers can affect performance, both directly and indirectly through their impacts on control variables.

For example, we found that skill, which was identified by Hackman and Morris (1975) as one of the important input variables in group performance, was strongly related to group performance variables. The designers' skill can affect performance variables both directly and indirectly. For EFFI the correlation coefficient was 0.552 and the partial correlation coefficient (controlling for team-member control) was 0.484; for TIME the correlation coefficient was 0.387

and the partial correlation coefficient (controlling for team-member control) was 0.318; and all were significant at $p<0.05$. Thus, even though our data did not support H7, that team-member control enablers can affect performance only through their impact on team-member control, we have found that team-member control enablers can affect performance directly and indirectly. In the next section we will discuss the direct effects and indirect effects of control enablers on performance variables using a theory from the small group behavior literature.

7.6. Control Theory and Small Group Behavior Theory

Based on our findings that control enablers can affect performance both directly and indirectly though control enablers, we can now integrate the previous control theories and propose a new model of team performance. Our model is similar to small group behavior theory and can extend it by operationalizing process variables more effectively. Since the recent work by Gladstein (1984) represents one of the first attempts to pose and to test a comprehensive model of group performance (effectiveness), we can adopt her model to link control theory to small group behavior theory.

The general model of Gladstein was divided into inputs, processes, and outputs. Her inputs appeared at the group level and organizational level and can directly or indirectly (through process variables) affect group effectiveness. On the other hand, the process variables directly affect group effectiveness. The task variable was introduced as a moderator of the process effectiveness relationships. Her model was tested, using a sample of approximately 100 sales groups. Although her model explained much of the variance in self-reported effectiveness, it was not related to actual sales, and the moderating effects of task were not supported.

We propose a model of team process as shown in Figure 7.2. Note that two important dimensions are excluded in Figure 7.2: task complexity and boundary management. In our study, task complexity was controlled for to some extent; all of the teams are composed of 5 to 10 people, and their tasks are on I/S planning and design. Boundary management refers to managing the boundary with those groups in which interaction was required during and following design activities (Gladstein, 1984). Because the domain representatives were official team members in our study, the need for this boundary management was also controlled for, to some extent[2].

Figure 7.2 shows that our control enablers are viewed as input variables and that managerial control and team member control as process variables that reflect how the team works together.

The model shown in Figure 7.2 posits a causal relationship between: (1) control enablers and performance variables; (2) control enablers and control variables; and (3) control variables and performance variables. As we discussed in the previous section, our data can support claims for (2) and (3). For claim (1), we can decompose the relationship between control enablers and performance

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2. One can argue that including domain representatives on the design team does not reduce the need for boundary management. This might be true, because as Kaiser and Bostrom (1982) claimed, once domain representatives are assimilated into the design team, it is possible that they do not represent those they are expected to represent. In this case, the boundary management should be done to achieve high performance. We believe this should be studied in future research.

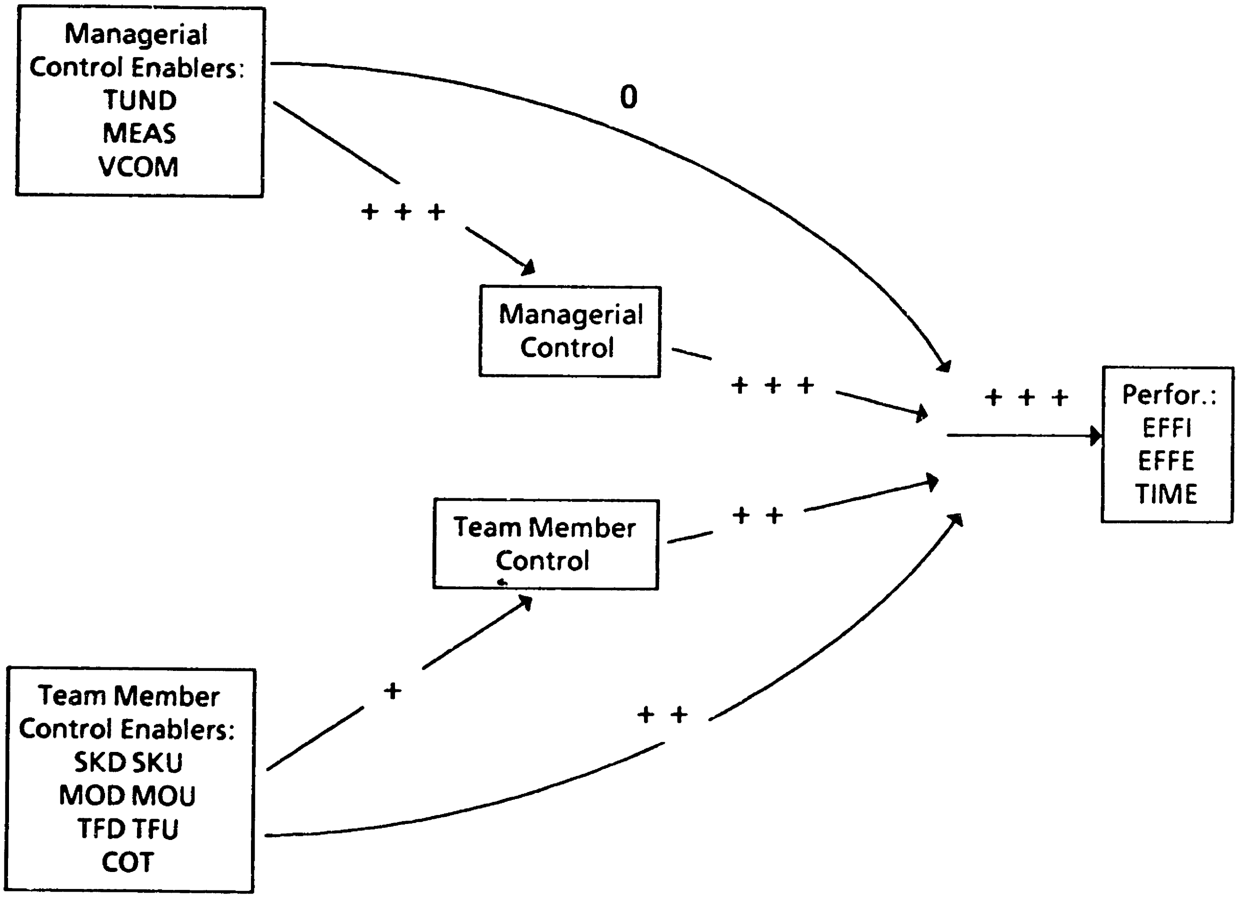

Figure 7.2. The team process model.

+ + + : all significant
+ + : half of correlations significant
+ : less than third of correlations significant
0 : no effect at all

variables into direct effects and indirect effects. Following Duncan (1971), Alwin and Hauser (1975), and Prescott *et al.* (1986), the following equation was adopted for decomposing the association between control enablers and performance variables for the empirical model:

Corr (enabler, performance) = direct effects + indirect effects

+ unanalyzed effects

However, in our case, since the number of theoretical variables were large (17) and the sample size was small (41), we cannot perform the above test rigorously. The following analysis in Table 7.16 should be viewed as exploratory[3].

As Table 7.15 shows, managerial control enablers do not have a significant direct effects on the EFFI variable. However, there are significant direct and indirect effects of the team-member control enablers on EFFI. One reason for this is that managerial control manifests its effect on performance variables through only its impact on control variables. Suppose that the level of managerial control enablers (manager's task understanding, ease of measurement, and ease of vertical communication) is high but that managerial control is not high; in this case there might be little or no relationship between managerial control enablers and performance variables, since I/S planning and design is done mainly by the team members. On the other hand, team member control enablers (skill, motivation, task-related feedback, and horizontal communication) could directly affect performance variables, since high levels of these variables would enable team members to do their jobs better in and of themselves - that is, the fact that the team members were self-directed, which is how we define team-member control, would not be a necessary constraint for understanding performance.

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3. Since this is an exploratory analysis we did not include EFFE and TIME. For a confirmatory analysis we will need a larger sample size (more than one hundred).

	Correlation	Direct effect	Indirect effect	Unanalyzable
TUND	.283	.062	.302	-.081
MEAS	.313	-.013	.188	.148
VCOM	.124	-.276	.166	.235
SKD	.552	.384	-.090	.257
SKU	.174	.113	.005	.056
MOD	.408	.005	-.013	.427
MOU	.000	.148	-.025	-.023
TFD	.168	-.432	-.006	.605
TFU	.194	.015	.005	.128
COT	.367	.342	-.008	.033

Table 7.16. Decomposition of direct and indirect impact of control enablers on EFFI.

(**: $p<0.01$ and *: $p<0.05$)

Based on this argument, we believe that the revised team process model shown in Figure 7.2 which combines control theories with small group behavior theories, can explain a significant portion of variance in team performance variables. According to this model, control enablers provide a structure within which the interaction among process variables occurs. Group interactions can be represented by the patterns of interaction reflected in the control variables.

Using our data, we can explore the power of this model. Since there are many theoretical variables and a small sample size, we cannot perform rigorous statistical tests. However, the data summarized in Figure 7.2. show that a significant portion of variance in the control variables and performance variables can be explained with the model proposed. More research (with a large sample size) is needed to provide stronger support for this model.

7.7. Chapter Seven Summary

Empirical tests of our team process model suggest that most of the hypotheses we proposed have explanatory power in describing casual relationships between team process interactions and performance. That is, control enablers are significantly related to control variables and control variables are significantly related to the performance variables. We also found that some control enablers were significantly related to the performance variables. Moreover, controlling for the control variables did not reduce significantly the degree of correlation between these control enablers and performance variables. Therefore, we cannot eliminate the possibility that control enablers directly affect performance. This finding was consistent with previous research in small group literature. A new model was proposed and an exploratory analysis was undertaken. However, because the sample size was small, these findings are not definite and more studies are required.

In our study, team-member outcome control, which reflects the interactions between designers and domain representatives (user), was found to be an important predictor of performance variables. Equally or more important, project managerial control (especially behavior control) was found to be an important predictor of performance variables as well. Unfortunately, managerial control has received little attention in the I/S planning and design research. Therefore, more studies on managerial control are required.

CHAPTER EIGHT. AN EMPIRICAL TEST OF THE IMPACTS OF COMPUTERIZED DESIGN AIDS

This chapter discusses the empirical test we did of the impacts of computerized design aids on the team process and the performance of I/S planning and design teams. In Section 8.1 we discuss our measurement model for the usage of computerized design aids. In Section 8.2 we evaluate the general pattern of usage of computerized design aids and in Section 8.3 we examine the impact of design aids on the performance of design teams and on the team process.

8.1. Measurement Model of Computerized Design Aids

In Chapter Two we noted that, although a detailed and specific characterization of computerized design aids is central to studying their impact on the performance of a design team, the review of empirical literature revealed that we do not have adequate definitions or a standardized characterization of design aids in terms that allow us to compare and contrast systems and generalize results across studies.

Henderson and Cooprider (1988) claimed that a useful characterization of design aids should have a correspondence with key design behaviors. That is, rather than defining computerized design aids in economic terms (e.g., costs), technological terms, (e.g., PC-based or networked), or in terms of other general characteristics, the characterization of design aids should be directly related to specific functionality. Henderson and Cooprider developed a functional model for computerized design aids, based on interviews with designers. In addition, they identified specific 98 features of computerized design aids, which they classified into the general categories of representation, analysis, transformation, control, cooperative , and infrastructure functionality. They performed empirical tests to assure that these 98 features are exhaustive functional descriptors of current design aids and that these features can be classified into six dimensions.

In this study we adopted Henderson and Coouprider's (1988) questionnaire[1]. We changed the wording slightly after discussion with Henderson and Cooprider (the questionnaire is reproduced in Appendix 7). For each of the 98 items the respondents could answer a Lickert scale with seven alternatives ranging from "never use" (1) through "use daily" (4) to "use extensively" (7). We administered this questionnaire to all project managers, designers, and domain representatives. In the case of domain representatives, we added a cover letter saying that, if they do not use computerized design aids, they need not fill out the design-aid usage questionnaire. The response rate for each category of team members is shown in Table 8.1.

The response rate for the design-aid usage questionnaire was smaller than that for the team process questionnaire. During follow-up telephone interviews we found that the probable reasons for this pattern were that the design-aid usage questionnaire was difficult to answer and that designers, in general, used only a small number of the 98 design aid features we surveyed. In some cases, they commented that most of the features were not applicable to their projects; therefore, there may be response bias operating in the data.

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1. The author greatly appreciates John C. Henderson and Jay G. Cooprider for allowing the use of their questionnaire in this research.

	# of questionnaires sent	# of group process questionnaires returned	# of design aid usage questionnaires returned	# of design aid usage questionnaires analyzed
Project manager	48	48	42	38
Designer	96	79	70	63
Domain representative	96	57	4	0

Table 8.1. A summary of responses for design-aid usage questionnaire.

Only four domain representatives filled out questionnaires. One possible reason for this low response rate may have been that our cover letter gave them an excuse not to fill out the time-consuming questionnaire even if they did use design aids. However, the follow-up interviews indicated that, in fact, most of the domain representatives did not use computerized design aids at all. Since the number of using them was insignificant, we excluded the domain representatives' responses from further analyses. Note also that we analyzed only teams which provided all the relevant information including team process information and performance information.

Analyzing our design-aid usage questionnaires entailed two difficulties. First, we could not check the reliability of the items. The general way to check the reliability of the items for this type of questionnaire would be to ask the same questions in several ways or of different persons. However, since there were 98 items, this was practically impossible. Thus, we could use only a single self-report to evaluate the usage of design aids. The rationale for using self-report is that the person who uses the features can describe his usage behavior best. Although we employed several measures to reduce the self-report bias, we could not test the degree of self-report bias.

Second, depending upon the types of roles, the usage pattern of design aids may be different. For example, the project managers may use project management tools more extensively than team members, and the designers, compared to the project manager, may use tools for checking design validity more often. In addition, the overall level of use may be different; for example the project manager may use design aids less than the designers. Therefore, for further analysis, the design-aid usage behavior will be discussed separately for the two roles: the project manager and the designer.

8.2. The General Pattern of Usage of Design Aids

As we mentioned before, in order to evaluate design-aid usage, we used the model of design aid features developed by Henderson and Cooprider (1988). They used the following steps to develop their 98 features of computerized design aids. First, leading designers of CASE (Computer Assisted Software Engineering) related technology were interviewed to generate a set of critical functions that could be of value to an I/S planner and designer. Second, to refine ambiguous items, the complete set of generated functions was reviewed by 25 top practicing designers familiar with CASE technology. Third, an independent group of 34 I/S designers experienced in CASE technology evaluated the list of features generated by the second step. Finally, available CASE products were compared in terms of the features generated by step two.

There were several issues of concern to us in using their model of design aids for our research. First, although their 98 features cover most of the current CASE technology available, no single product has all 98 features. Second, since some of their features are technologically advanced ones, identified by leading CASE experts, we were concerned that all 98 features might not be used by designers and project managers in general.

A third concern is related to the fact that design technology is relatively new. As Orlikowski (1988) and Kemerer(1989) have noted, since design aids have not been used extensively, there may be learning effects involved in using them. The relevance of the learning curve to our research is that, although a given technology may have a number of design features, the user may use only one or two of them.

Therefore, in the following section we evaluate the extent of usage for each feature Henderson and Cooprider identified. The discussion is ordered according to their proposed dimensions.

8.2.1. The Representation Dimension

The representation dimension was defined as a functionality that enables the user to define, describe, or change a definition or description of an object, relationship, or process (Henderson and Cooprider, 1988). The extent of usage is shown in Table 8.2. As Table 8.2 shows, the use of the representation functionality was minimal. Among the 38 design teams we surveyed, most of the features were not used extensively. More than half of the design teams we surveyed used none of these features. The most frequently used feature was representing a design in terms of data models. Since this feature is offered by all current CASE technology, this result is not surprising.

	# of persons using the feature (out of 101)			# of project managers using the feature (out of 38)			# of teams where designers used the feature (out of 37)		
	No use	Low use	Heavy use	No use	Low use	Heavy use	No use	Low use	Heavy use
T5	22	32	**47**	9	12	**17**	5	13	**19**
T11	72	19	10	27	7	4	25	9	3
T21	49	30	22	17	11	10	18	13	6
T23	46	33	22	21	10	7	12	16	9
T29	28	40	**33**	13	14	**11**	8	17	**12**
T31	23	37	**41**	11	13	**14**	5	15	**17**
T44	36	33	**32**	18	9	**11**	8	18	**11**
T52	50	31	20	15	17	6	17	16	4
T53	60	28	13	22	11	5	19	17	1
T55	51	29	21	23	9	6	14	16	7
T62	57	27	17	21	10	7	19	13	5
T63	42	38	21	23	9	6	12	18	7
T66	34	42	25	16	14	8	10	17	10
T70	64	24	13	26	8	4	20	14	3
T75	42	36	23	17	12	8	14	16	7
T76	54	36	11	23	11	4	17	17	3
T83	69	21	11	25	8	5	24	12	1
T92	62	24	15	23	9	6	22	12	3

Table 8.2. The extent of usage of the representation dimension.

The six most widely used features can be classified into three categories, as Henderson and Cooprider recommended. The first category is the general notion of knowledge representation and acquisition. This category was measured in questionnaire items asking about usage of features that draw diagram lines exactly where wanted and show an object's attributes by selecting it in a diagram. The second category is the ability to combine and sort diverse representations. This category was reflected in items concerning usage of a feature that maintains a single master definition of each process, objects, etc. and simultaneously displays several screens showing different versions. The third category, the ability to use alternative modes of representation, was reflected in items concerning the usage of features that enable a design to be represented in terms of process models, flow models or data models. Most of the early computerized design aids focused on these features, such as process flow diagrams, functional charting, or entity modeling that reflect alternative means to represent concepts or phenomena.

The representation dimension provides a context in which designers can interpret results of decision-making processes and use the results as inputs for the next stage of the design process. Since most widely existing CASE tools contain these features, these features can be used by designers effectively. Schon (1984) and Zachman (1986) identified the process of evolving abstractions and presenting them in a communicable form as essential activities in planning and design. Since managers can generate several different representation schemes with these features, the project managers might use them effectively as well. Examining the extent of usage by roles reveals that project managers and designers use these features very similarly.

8.2.2. The Analysis Dimension

This dimension captures the functionality that enables the user to explore, simulate, or evaluate representations or models of objects, relationships, or processes (Henderson and Cooprider, 1988). With the widespread use of AI concepts in the development of design aids, analysis features are included in

	# of persons using the feature (out of 101)			# of project managers using the feature (out of 38)			# of teams where designers used the feature (out of 37)		
	No use	Low use	Heavy use	No use	Low use	Heavy use	No use	Low use	Heavy use
T1	79	17	5	28	8	2	31	5	1
T2	54	26	19	26	7	5	15	15	6
T4	45	27	21	21	11	6	15	14	8
T6	36	38	26	16	10	11	11	17	9
T8	38	33	29	19	9	9	12	15	10
T9	49	29	22	19	8	10	19	13	5
T20	44	36	21	20	10	8	12	22	3
T25	60	23	18	23	6	9	20	13	4
T26	53	26	22	20	7	11	18	14	5
T30	49	33	19	23	7	8	14	17	6
T32	61	22	18	23	7	8	21	12	4
T38	68	19	14	27	6	5	21	4	2
T48	61	26	14	27	7	4	21	12	4
T77	76	16	9	29	5	4	26	10	1
T80	85	10	6	33	3	2	28	8	1
T87	56	29	16	20	11	7	19	15	3
T91	65	20	16	28	5	5	21	11	5
T93	71	18	12	29	3	6	25	8	4
T94	75	17	9	27	6	5	27	9	1

Table 8.3. The extent of usage of the analysis dimension.

most design aids. However, as Table 8.3 shows, these features were not used extensively in our sample. Moreover, the most-used analysis features comprised only a small part of the analysis capabilities. They were as follows: (1) identifying where predefined criteria or rules have been violated and (2) searching a design for objects with specified characteristics, both can be classified as consistency checking. More advanced features of this dimension, such as exploration and evaluation features were almost never used by any of our I/S planning and design teams.

Also, we found that project managers used these features more than designers did. Project managers may be in a better position to do proactive analysis to design an effective system because they need to compare and evaluate different alternatives.

In some aspects, these features are similar to the functional building blocks of a decision support system. As Keen and Scott Morton (1978) found, these analysis features can be used to increase effectiveness, not to increase efficiency. The usage of the analysis functionality is marginal when these features are first introduced, but as time goes on, they are likely to be used more frequently. Thus, as the users gain more experience, we believe these features will be used more as was the case with decision support systems.

8.2.3. The Transformation Dimension

Henderson and Cooprider (1988) defined the transformation dimension as the functionality that executes a significant planning or design task, thereby replacing, or substituting for, a human designer/planner. As Table 8.4 shows, only three features in this dimension were used often. They are (1) providing documentation as a by-product of design, (2) generating screen mock-ups, and (3) propagating a change in an object to all the places the object appears. However, the main features of the transformation dimension, such as

	# of persons using the feature (out of 101)			# of project managers using the feature (out of 38)			# of teams where designers used the feature (out of 37)		
	No use	Low use	Heavy use	No use	Low use	Heavy use	No use	Low use	Heavy use
T3	63	21	16	26	5	6	22	10	5
T27	79	10	12	30	3	5	26	9	2
T28	65	23	13	25	9	4	22	12	3
T33	25	41	35	11	13	14	5	20	12
T46	35	35	31	13	15	10	9	20	8
T47	62	20	19	24	7	7	19	12	6
T49	35	35	31	18	10	10	7	18	12
T50	71	18	12	27	7	4	24	11	2
T51	52	32	17	21	13	4	17	15	5
T72	67	19	15	28	5	5	22	11	4
T74	75	18	8	29	8	1	25	11	1
T78	42	36	23	18	11	9	14	19	4
T90	68	19	14	28	7	3	22	12	3

Table 8.4. The extent of usage of the transformation dimension.

generating executable code from a screen mock-up or performing reverse engineering, were almost not used at all.

The follow-up interviews with several design teams revealed that these features were not reliable in the current existing tools. As Zachman (1986), Hackathorn and Karimi (1988), and Henderson and Cooprider (1988) noted, the transformation dimension requires embedding intelligence in the design aids. For example, the ability to automatically generate executable codes may require expert systems and AI technology. Thus, today's technology may not be perfect yet for this type of feature. In most cases these features are missing in commercialized packages.

8.2.4. The Control Dimension

The control dimension can be defined as the functionality that enables the user to plan for and enforce rules, policies, or priorities that will govern or restrict the activities of team members during the planning or design process (Henderson Cooprider, 1988). Table 8.5 shows that, in general, project managers use these features more than designers. Note that only the features of traditional project management, such as providing project-management information and maintaining a record of who is responsible for each part of project are used often, and only by project managers. These features are classified as resource-management-control features (Henderson and Cooprider, 1988).

The second type of control features - access control features - which were identified by Reifer and Montgomery (1980) and Houghton and Wallace (1987), were little used by project managers and designers. Access control concerns issues of security and authorization. Since I/S planning and design activities require cooperation rather than this type of access control, these features were not used often by our I/S planning and design teams.

8.2.5. The Cooperative Dimension

Henderson and Cooprider (1988) defined the cooperative dimension as the functionality that enables the user to exchange information with other individuals for the purpose of influencing the concept, process, or product of the

	# of persons using the feature (out of 101)			# of project managers using the feature (out of 38)			# of teams where designers used the feature (out of 37)		
	No use	Low use	Heavy use	No use	Low use	Heavy use	No use	Low use	Heavy use
T7	53	30	17	27	5	6	15	16	6
T14	57	29	15	26	8	4	18	17	2
T15	46	35	20	15	15	8	13	17	4
T16	70	19	12	28	5	5	23	11	3
T17	52	32	17	19	11	8	15	21	1
T37	62	29	10	25	10	3	25	9	3
T39	51	31	19	21	11	6	15	17	5
T40	67	23	11	28	5	5	22	14	1
T43	58	31	12	22	12	4	21	15	1
T57	54	30	17	20	12	6	17	16	4
T60	51	31	19	21	13	4	16	16	5
T61	35	37	29	11	15	12	11	20	6
T65	66	24	11	24	10	4	25	10	2
T68	66	24	11	25	10	3	25	11	1
T73	43	30	28	15	9	14	14	20	3
T82	81	13	7	30	4	4	29	8	0

Table 8.5. The extent of usage of the control dimension.

planning and design team. As Table 8.6 shows, only one feature of this functionality was used extensively, i.e., sending messages to others. This feature is basically an electronic-mail type of feature.

Henderson and Cooprider (1988) also identified features that facilitate the group process. These features were not used often by our design teams. The reason for this might be that the current design aids do not have this capability.

	# of persons using the feature (out of 101)			# of project managers using the feature (out of 38)			# of teams where designers used the feature (out of 37)		
	No use	Low use	Heavy use	No use	Low use	Heavy use	No use	Low use	Heavy use
T18	36	22	43	18	7	13	11	13	13
T19	91	9	1	34	3	1	36	1	0
T41	68	18	15	27	3	8	27	8	2
T42	42	28	31	20	9	9	10	18	9
T59	53	29	19	25	9	4	14	17	6
T64	78	16	7	31	5	2	26	10	1
T84	52	30	19	21	10	7	19	14	4
T85	45	33	23	19	14	5	10	21	6
T86	78	11	11	29	4	4	18	14	5
T98	76	14	11	30	3	4	14	17	6

Table 8.6. The extent of usage of the cooperative dimension.

However, some of the tools have these features. For example, PLEXSYS technology can choose between several structured group processes and adopt the technology to facilitate the execution of the particular approach chosen. With more understanding of the group process we believe that these features will emerge as important ones in future.

8.2.6. The Infrastructure Dimension

The infrastructure functionality refers to helping individual users understand and use design aids effectively (Henderson and Cooprider, 1988). As Table 8.7 shows, these features are used often by both project managers and designers. One possible explanation for this usage pattern is that since computerized

	# of persons using the feature (out of 101)			# of project managers using the feature (out of 38)			# of teams where designers used the feature (out of 37)		
	No use	Low use	Heavy use	No use	Low use	Heavy use	No use	Low use	Heavy use
T10	19	65	17	9	24	5	7	28	2
T12	38	33	30	21	9	8	10	18	9
T13	31	27	43	15	10	**13**	6	17	**14**
T22	22	40	39	10	12	**16**	5	17	**15**
T24	46	34	21	19	14	5	16	16	5
T34	42	40	19	20	10	8	13	19	5
T35	51	31	19	23	7	8	15	16	6
T36	76	16	9	31	5	2	26	10	1
T45	48	26	26	19	11	8	13	16	8
T54	64	23	14	25	7	6	22	12	3
T56	33	33	35	15	13	**10**	10	12	**15**
T58	83	14	4	32	4	2	32	4	1
T67	23	30	47	9	13	**16**	6	14	**17**
T69	49	34	18	23	11	4	11	20	6
T71	76	13	12	31	2	5	24	12	1
T79	68	18	15	30	5	3	17	15	5
T81	62	27	12	29	6	3	16	17	4
T88	39	34	28	19	11	8	7	21	9
T89	39	42	20	20	11	7	12	22	3
T95	82	13	6	31	4	3	29	7	1
T96	61	25	15	26	5	7	21	12	4
T97	27	44	30	11	16	**11**	7	21	9

Table 8.7. The extent of usage of the infrastructure dimension.

design aids are relatively new developments, the user might appreciate the help from the design aids. This explanation is confirmed by the data. Table 8.7 shows that the most-used features are (1) providing quick reference to basic commands/functions, (2) providing on-line help, (3) providing options about how to interact with the tools, (4) graphically magnifying a model to see greater levels of detail, and (5) preparing, editing, storing, sending, and retrieving documents.

Henderson and Cooprider claimed that those features used extensively by most I/S planning and design teams fall into the category of a passive functionality in that the user not the design aid itself, must take actions. The proactive features that use domain knowledge so that design aids can take actions to support the users were not used by most of the I/S planning and design teams.

8.2.7. Summary of the Findings on Usage Behavior

The above findings on the usage behavior of computerized design aids raised several issues concerning the potential risks involved in testing our hypotheses on the impact of computerized design aids. First, the extent of design-aid usage was quite limited: none of the features were used extensively by more than half of the design teams we surveyed. This is surprising in that, while our I/S planning and design teams might not constitute a representative sample, they are teams which are believed to use computerized design aids extensively. As Kemerer (1987) and Orlikowski (1988) found, there are many companies which are attempting to introduce and to sponsor computerized design aids, but the real use of design aids is not great yet.

A second potential risk is that, while Henderson and Cooprider's (1988) questionnaire items are valid in terms of the availability of existing design aids as a group, no single CASE tool has all the features included in our survey. The following comments from survey respondents reflect the realities of design-aid usage at the present time:

"I am tired of filling out the questionnaire, most of the questions are not applicable to our projects."

"I guess that your questions are futuristic questions."

"Could you recommend the vendors who are selling these features?"

"If we had had this type of tool, it would have reduced a significant amount of time."

A third risk, as we noted in Chapter Two, arises from the fact that a design aid can consist of several features for managing a software product over its life cycle. As such, each designer or project manager might use different features of the design aid. Therefore, the aggregation based on a dummy variable (use versus non-use of a design aid) cannot provide a sufficient measure of usage patterns. Tables 8.2 through 8.7 confirmed this claim, which was reinforced when we examined the raw data. Thus, we believe that an appropriate characterization should be the use of specific features, not the use of a design aid as a whole and certainly not the availability of the tool itself.

There are a small number of features which are used relatively extensively. Among the six dimensions of design aids, the representation and infrastructure dimensions were used most often. The representation features are the original theme of CASE technology, and most current tools include these features. In the infrastructure functionality, only "help"-related features are used often. This trend might be changed in the future as the users of design aids become more experienced. The control and the cooperative dimensions were used the least. As Cooprider and Henderson (1988) claimed, the target of current design aids is to increase individual productivity, not team-related productivity. Therefore, in the future, team-related features may be developed more. Among the features included in the control and the cooperative dimensions, the users did use the E-mail type of functionality and the project-management functionality. We found that the usage pattern of the project manager was quite different from that of the designer. For example, the project managers used the project management features of the control functionality more extensively than the designers did. Therefore, analyses should be undertaken separately for each role type.

In the following analysis we will focus only on the most often-used features. But note that, because of our focus on a small number of features, our analysis should be considered strictly exploratory.

8.3. The Impact of Computerized Design Aids on the Performance of I/S Planning and Design Teams

To test the hypothesis that design aids can affect the performance of the design teams, zero-order correlations between the usage of design aids and performance variables were produced and they are shown in Table 8.8. As we have indicated earlier, the performance variables are efficiency (EFFI), effectiveness (EFFE), and time-to-market (TIME).

For the purpose of this analysis, we will use the following six dimensions of design aids, which we have described in detail earlier: representation (REP), analysis (ANA), transformation (TRA), control (CON), cooperative (COO), and

	EFFI	EFFE	TIME
MREP DREP	.062 -.151	.095 -.186	.067 -.188
MANA DANA	-.090 -.089	.048 -.170	-.002 .064
MTRA DTRA	-.119 .131	-.033 -.012	-.022 .112
MCON DCON	.097 .321*	.282* -.020	.095 .273*
MCOO DCOO	.330* .174	.321* .274*	.288* .088
MINF DINF	.100 .236	.160 -.022	.161 .287*

Table 8.8. The zero-order correlations between the use of design aids and performance variables.

(**: $p<0.01$ and *: $p<0.05$)

infrastructure (INF) functionality. We represent the usage of each dimension with either an M or a D: an M indicates the project manager's usage of each dimension, and a D indicates the designer's usage of each dimension. Note that in the analysis only features used extensively were included (they were indicated in Tables 8.2 through Table 8.7 in bold-face type).

As shown in Table 8.8, none of the representation, analysis, and transformation dimensions were significantly correlated with performance variables. On the other hand, there were strong significant correlations between the control functionality and the performance variables, and between the coordination functionality and the performance variables. Henderson and Cooprider (1988) claimed that the representation, analysis, and transformation dimensions can have direct impacts on individual productivity, while at the team level, control and coordination technology can help effect synergy among team members and increase the validity of the product. The results of our analysis are consistent with their claims. They used the term "production technology" to refer to the representation, analysis, and transformation dimensions, and the term "coordination technology" to refer to the control and cooperative dimensions.

The lack of direct effects of the representation, analysis, and transformation (production) technology could have two possible causes. First, it could be that the existing features of the current technology do not support these functions well enough. As Henderson and Cooprider (1988) found, the current design aids have only limited analysis and transformation dimensions. In addition, they found that the existing tools provide support for a relatively passive design-aid environment, that is, they enable a designer to capture and present an idea or to transform a well-defined concept. However, the current technology cannot aid the critical thinking processes.

Second, the representation, analysis, and transformation technologies may contribute to team performance only indirectly, in that they are helpful mostly in increasing individual productivity, while team activities comprise the greater percentage of the activities of an design team. One indicator of the individual's contribution to team performance is that, as Jones (1986) has pointed out, individual activities such as "coding" account for only 15 percent of the software costs of large systems. Therefore, it is likely that team performance can be better leveraged by technologies that support group rather than individual processes, that is, by control and cooperative (coordination) technologies.

The designer's use of the infrastructure functionality was significantly related in our study to the time-to-market. We believe that this result may reflect the fact that this functionality can enable the portability of skills, knowledge, and methods, and so promote standardization of efficient practices primarily through standardized interfaces between various activities of the design life-cycle. Thus, the use of the infrastructure technology might decrease the time to generate information systems.

Hypothesis H8 states that design aids have significant effects on the performance of design teams and that the impact of design aids on team performance will be significant through control variables and control enablers. To test the latter part of H8, the following analyses were undertaken. First, the correlations between the usage of each dimension and each control enabler were tested. Second, based on Figure 7.1., we compared the usage patterns of several features depending upon the degree of control in each I/S planning and design team.

The manager's use of production technology in general was not related to any managerial control enablers. However, the use of the representation dimension was slightly correlated with the ease of vertical communication ($r = 0.2152$, $p < 0.09$). Since the representation functionality can enable the project manager to produce process flow diagrams, functional charts, or entity models in communicable forms, this technology can facilitate communication among the project manager and team members.

The manager's use of the cooperative dimension was not strongly related to the managerial control enablers, but it was related to team member control enablers. The correlation between MCOO and SKD was 0.496 ($p < 0.01$), and the correlation between MCOO and MOD was 0.324 ($p < 0.05$). Since the only feature often used by the project managers was electronic mail, we cannot generalize this result. However, it is possible that such a generalization is warranted because increased unstructured communication among project manager and designers might help designers become more proficient in task-related activities and make them more motivated.

The designers' use of production technology (the representation, analysis, and transformation dimensions) was not related to the designer control enablers. This was surprising in that production technology was developed to support designers in developing information systems. As we discussed above, there are two possible explanations for this absence of significant correlations. First, most of the current technology still lacks in analysis supporting features and transformation supporting features. Second, although this technology can increase individual productivity, it does not contribute significantly to the processes most important for team performance.

However, the designers' use of the control dimension was strongly correlated with the manager's task understanding ($r = 0.354$, $p < 0.01$). This is not surprising since the designers' use of the project management-type of control functionality can give the manager a better understanding of what is going on in I/S planning and design activities. Also, the designers' use of the cooperative functionality was strongly related to the designers' skill, motivation, and ease of communication. This again is consistent with the normative concept that designers should work as a team, and thus, technology that can facilitate the group process is helpful.

In sum, we can conclude that the usage of control and cooperative features can increase the manager's task understanding, and the designers' skill and motivation. Production technology was not strongly correlated with control enablers. We believe that, at this stage of its development, the technology is not useful for analysis and transformation functions and is, in addition, aimed at the individual level of performance, not the team level.

To examine the impact of computerized design aids on control variables, we generated the following four corollaries of hypothesis H8:

Corollary 1: In Cell One teams (those with high managerial control and high team-member control), both project managers and designers use design aids extensively.

Corollary 2: In Cell Two teams (those with low managerial control and high team-member control), designers use design aids extensively, but project managers do not.

Corollary 3: In Cell Three teams (those with high managerial control and low team-member control), project managers use design aids extensively, but designers do not.

Corollary 4: In Cell Four teams (those with low managerial control and low team-member control), both project managers and designers do not use design aids extensively.

Since managerial behavior control and team member outcome control were most significantly correlated with performance variables (see Chapter Seven, Section 7.2), we chose to use only these variables for further analysis. Also note that, although all items in our questionnaire could be classified into six dimensions, the designer and the manager may use a specific feature extensively and may use the other features less. Therefore, in the following analysis the unit of analysis is the feature in order to examine usage patterns for each feature.

Figures 8.1through 8.3 show the results of our feature analysis. Since the samples sizes of Cells Two and Three are only five and four, respectively, we

	High managerial behavior control	Low managerial behavior control
High team member outcome control	Representation MT5: 3.9 DT5: 3.9 MT29: 3.2 DT29: 3.0 MT31: 3.8 DT31: 3.5 MT44: 3.0 DT44: 2.6 Analysis MT6: 3.1 DT8: 3.1 MT9: 2.6 MT26: 2.3 Transformation MT33: 3.5 DT33: 3.0 MT49: 2.3 DT49: 3.6 MT46: 2.8 n = 14 Cell 1	Representation MT5: 3.2 DT5: 5.0 MT29: 2.8 DT29: 3.0 MT31: 2.4 DT31: 4.0 MT44: 2.0 DT44: 3.0 Analysis MT6: 2.4 DT8: 1.3 MT9: 2.4 MT26: 2.2 Transformation MT33: 2.8 DT33: 3.0 MT49: 2.8 DT49: 4.3 MT46: 2.6 n = 5 Cell 2
Low team member outcome control	Cell 3 Representation MT5: 2.8 DT5: 2.8 MT29: 1.3 DT29: 3.6 MT31: 2.3 DT31: 3.1 MT44: 1.8 DT44: 3.0 Analysis MT6: 1.5 DT8: 2.3 MT9: 1.5 MT26: 1.8 Transformation MT33: 1.8 DT33: 3.5 MT49: 1.8 DT49: 2.7 MT46: 2.0 n = 4	Cell 4 Representation MT5: 2.7 DT5: 3.3 MT29: 2.8 DT29: 3.1 MT31: 2.6 DT31: 3.2 MT44: 2.6 DT44: 3.1 Analysis MT6: 2.4 DT8: 2.8 MT9: 2.3 MT26: 2.5 Transformation MT33: 3.0 DT33: 3.0 MT49: 2.4 DT49: 2.6 MT46: 2.5 n = 16

Figure 8.1. The use of production technology and control variables.

cannot test Corollaries 2 and 3 meaningfully, although the general pattern of usage seemed consistent with these corollaries. First, as we expected, the teams with both high managerial control and high team-member control exhibited a

	High managerial behavior control	Low managerial behavior control
High team member outcome control	control MT61: 3.3 MT73: 3.5 Coordination MT18: 3.6 DT18: 3.3 n = 14	n = 5 Control MT61: 3.2 MT73: 2.0 Coordination MT18: 1.6 DT18: 1.3
Low team member outcome control	Control MT61: 2.8 MT73: 2.8 Coordination MT18: 3.0 DT18: 5.1 n = 4	n = 16 Control MT61: 2.5 MT73: 2.4 Coordination MT18: 2.7 DT18: 2.9

Figure 8.2. The use of coordination technology and control variables.

high degree of usage of each feature of the design aids by both project manager and designers. The teams with low managerial control and low team-member control exhibited a low degree of usage of each feature of the design aids by both project manager and designers. When we compared Cell One and Cell Four's usage of 29 features (in terms of the means for each feature), the average use of each feature by Cell One teams was greater that that of Cell Four teams with only three exceptions -- features MT26, DT29, and DT44. However, the amount of violation was not large (the maximum difference was less than 0.5). Therefore, our data are not inconsistent with our Corollaries 1 and 4. Based on these findings and our findings in Chapter Seven that when managerial behavior

	High managerial behavior control	Low managerial behavior control
High team member outcome control	Infrastructure MT13: 3.2 DT13: 3.4 MT22: 4.2 DT22: 3.7 MT56: 3.0 DT56: 3.1 MT67: 4.3 DT67: 4.0 n = 14	Infrastructure n = 5 MT13: 3.2 DT13: 1.3 MT22: 3.2 DT22: 3.7 MT56: 2.6 DT56: 3.0 MT67: 2.2 DT67: 3.0
Low team member outcome control	Infrastructure MT13: 2.0 DT13: 3.8 MT22: 2.3 DT22: 2.4 MT56: 2.0 DT56: 2.5 MT67: 2.5 DT67: 3.0 n = 4	Infrastructure n = 16 MT13: 2.9 DT13: 3.4 MT22: 2.5 DT22: 3.4 MT56: 2.3 DT56: 3.1 MT67: 2.9 DT67: 3.2

Figure 8.3. The use of infrastructure technology and control variables.

control and team-member outcome control were both high, the performance was the highest, and when both of them were low, the performance was the poorest, we can partially support our hypothesis H8 that design aids can affect team performance through control variables.

Second, the differential pattern of usage of each feature of the design aid is most striking in the control and coordination dimensions. As we mentioned before, these two features were more highly correlated with performance variables than the other features were. Thus, this finding also supports H8 in that project managers and team members in Cell One used these two features much more frequently.

8.4. Chapter Eight Summary

Although one of the trends in the current practice in software development is to use computerized design aids, we found that the extent of the usage was actually quite limited. However, since the existing tools include many features and these tools are relatively new, there may be learning effects involved in their use. As in the case of decision support systems, implementation or introduction of these tools might be an interesting subject for future research.

Since in our analysis we focused on only a small number of features that are used extensively, our findings, summarized as follows, should be viewed as exploratory:

First, of the dimensions of design aids, the coordination and control features have the most significant impacts on performance variables. Since most I/S planning and design work is done at the team level, not the individual level, these dimensions should be developed further in the future.

Second, teams with both high project manager control and high team-member control use design aids more extensively compared with teams with low project manager control and low team-member control.

Third, the use of design aids has significant impacts on control enablers and control variables. Thus, design features should be developed focusing on how they can affect the ability of team members to work together.

Fourth, in studying the impact of computerized design aids, we need to focus on an appropriate characterization of design aids, because the availability of features and the real use of these features can be significantly different.

CHAPTER NINE. SUMMARY AND CONCLUSIONS

This chapter reviews the results of this study, discusses the implications from both theoretical and managerial points of view, and speculates about future research directions.

9.1. Summary of the Study

There are two major trends in the current practice of I/S planning and design. They are the team approach to I/S planning and design and the use of computerized design aids. The first purpose of this study was to provide a line of research that can be used in managing I/S planning and design <u>teams</u> more effectively. As such, we needed to develop a model which attempts to explain how team members work together as a team. The second purpose of this study was to understand how computerized design aids can affect the performance of I/S planning and design teams. Many organizations are already claiming the benefits of increasingly powerful computerized design aids on individual productivity. The impact of these design tools on the productivity of I/S panning and design <u>teams</u>, however, is yet to be proven.

In reviewing the empirical literature on the impact of design aids in Chapter Two, we found three problems that might account for the inconsistent findings in this work. The first and the most important was the lack of an underlying theory of design behavior. Since most information systems are developed by a number of individuals, understanding the team process should be the first step in researching I/S planning and design. There is an extensive literature about how teams work together, including work based on organizational control theory, small group theory, new product development theory, and communication science. This literature formed the backbone for our research on managing I/S planning and design teams and should play a fundamental role in future research.

The second problem we found in the literature was the lack of a standardized characterization of computerized design aids, which prevented researchers from comparing different technologies and from making generalizations about the research results that go beyond the narrow circumstances in which they were observed. We claimed that we needed to characterize design aids in terms that correspond to the underlying design behavior in I/S planning and design. Since Henderson and Cooprider's (1988) characterization focused on identifying features that have a correspondence to design behavior, we adopted their model in this study.

The third problem in the literature was that most of the studies have had problems in measuring performance variables. Most studies have used either the number of source codes generated or used a single designer to assess performance measures. Since most I/S products will be used by non-I/S personnel, the above approaches might not be valid indicators of team performance. Although we cannot provide a panacea for these problems, we have suggested ways to increase the validity and reliability of the measures for performance. In our study, performance variables were assessed by non-team stakeholders who were defined as individuals who were not formal members of the project but who were affected by the output of the team or could affect its performance. Examples included senior executives and client personnel not formally on the project.

In Chapters Three and Four, we proposed a theory for a model that could be used to explain team performance, and we discussed how computerized design aids could affect the performance of design teams. Because design teams are composed of a number of individuals, including the project manager, designers, and users, we realized we needed to understand the underlying interactions. Since organizational control theories have been concerned with the pattern of the interaction between individuals, we chose to extend these theories. First, based on Tannenbaum (1968), team performance was hypothesized to be related to the pattern of influence among the project manager, designers, and domain representatives. In the context of I/S planning and design, a project manager contracts with designers and domain representatives to develop an information system. Tannenbaum and his co-workers tested whether, in this relationship, the greater the total amount of control by the project manager, by the designers, and by the domain representatives, the greater the performance of the team would be. Second, based on Ouchi (1977), Eisenhardt (1985), Mills (1983), Slocum and Sims (1980) we identified control enablers which could increase managerial control, designer control, and domain representative control. Lastly, we theorized that computerized design aids could affect performance through these control enablers and control variables.

Chapter Five discussed the research design used in this study. Recent practice of I/S planning and design emphasizes joint decision-making and the attendant notion of team activity as the relevant unit of analysis. Thus, we chose to use a key informant method as the basis for data gathering. The key informant method enables one to collect information in a social setting by surveying a selected number of informants (Seidler, 1974). In this case the key informant assumes the role of reporting on the patterns of behavior of a team, not the individuals. However, this method may introduce considerable measurement errors. Based on Huber and Power (1985), Seidler (1974), and Silk and Kalwani (1982), we identified three threats to validity with key informant analysis: motivational barriers, perceptual cognitive limitations, and lack of information. To protect the validity of key informant analysis, we took extreme caution. For example, we avoided asking questions directly related to the informants' personal interests, and we used validated questions and anchored them to the specific I/S projects in which the informant were involved.

In Chapter Six we tested the relationships among the measured variables and the theoretical constructs we intended to study. Since we used multiple indicators and multiple key informants, we could test for the internal consistency of the operationalizations, as well as convergent validity and discriminant validity. Our data on all control variables and control enablers except for one set passed the above tests. The exception was the set of the domain representative control enablers, in which the designers' and the project manager's assessments were not in agreement. The designers consistently underreported the domain representative control enablers. Since this finding was consistent with previous MIS findings (e.g., Keider, 1984), we used only the project manager's assessments of domain representative control enablers.

Since the previous empirical work on organizational control theory used only self-report on the control variables, we included self-report on the control variables. The control given by the manager might be different from the control received by team members, for example, as in the case of the manager's monitoring the design process but not actively intervening in it. Therefore, control given was assessed by self-report and control received was assessed by the individuals who were the targets of the control.

In testing the relationships between measured variables and theoretical variables, we found that the data could not differentiate between designer control and domain representative control. One explanation for this finding is that, since designers and domain representatives work as a team, there are strong and frequent interactions among these members. Designers are expected to build a system with help from the domain representatives, and the domain representatives are expected to work with designers on system development and to evaluate the information system with help from designers. However, project managers are more concerned with managing their design teams than with the details of system design. Thus, we classified two types of role control in this study: project manager control and team-member control (including designer control and domain representative control).

Chapter Seven tested the team process model we proposed in Chapter Three. Performance variables were most significantly correlated with the project manager's behavior control and the team-members' outcome control. The designers and the domain representatives have different skills, role perceptions, and mental schemas which must be combined through their protocols of interaction into a final outcome (Boland, 1978). Thus, team members should primarily work not by themselves, but as parts of a team. In this study, team-member behavior control refers to self-control in executing a team member's own tasks, whereas team-member outcome control can be viewed as collegial control, such as providing feedback on performance. Therefore, it is reasonable that outcome control by team members explained significant variations in the performance variables. The important role of the project manager is to help give direction to the interaction process in I/S planning and design. The project manager should be explicitly involved in assigning team members to specific tasks and helping them execute these tasks (behavior control).

The data also showed that the manager's task understanding, the availability of measurement, and the ease of vertical communication had significant effects on the managerial control of the project, whereas skill and the ease of horizontal communication had significant effects on the team-member control. Our data on the relationships among control enablers and control variables make two contributions to organizational control theories. First, unlike previous studies on organizational control, we found that outcome control and behavior control can be operative at the same time. Second, our communication variables, which were not included in the previous organizational control studies, but which were a major focus in previous I/S design studies, were significantly related to our control variables.

Although our theory was developed primarily by integrating diverse approaches to control from organizational control theories, we found that our results were similar to those of small group behavior theories. The general model of small group behavior is divided into inputs, processes, and outputs (Gladstein, 1984; Hackman and Morris, 1975). Input variables establish the team structure or framework for group interaction. When interactions actually commence, process variables begin to act upon the initial inputs. Note that these inputs and process variables corresponded to our control enablers and control variables. Gladstein (1984) empirically showed that the input variables can affect group performance both directly and indirectly through control variables. We found the same result, that is, that control enablers can affect performance directly and indirectly though control variables. In future research, combining control theory and small group theory might provide an avenue for understanding design behavior in more detail.

Chapter Eight explored the impact of computerized design aids on the performance of I/S planning and design teams. Although many organizations claim that they used design aids frequently, we found that only a small set of features were actually used extensively. Thus, we focused on those features used extensively. In general, use of production technology which can be used to increase individual productivity was not strongly related to performance variables, but use of coordination technology was relatively strongly correlated with performance variables. Since most I/S planning and design work is done at the team level, not at the individual level, these technologies should be developed further in the future. In general, we found that in the teams with both a high level of managerial control and a high level of team-member control both project managers and designers used design aids more extensively than teams with lower levels of both kinds of control.

9.2. Research Implications

Theoretical Contributions: The first major theoretical contribution of this study was providing a theoretical base which can explain the performance of I/S planning and design teams. As we noted, the current practice of I/S planning and design is a team approach. However, in the MIS field, there has been little research which examined how team members work together as a team.

Our second theoretical contribution is the demonstration that performance variables were strongly correlated with managerial control. Most MIS research in I/S planning and design has focused on user involvement, but not on managerial involvement in I/S planning and design. Developing information systems requires a number of individuals, including domain representatives (users), designers, and a project manager. Thus, we believe that the role of the project manager, who is concerned with managing the different perspectives each team member brings to I/S planning and design, should be studied in depth.

Our third theoretical contribution is the integration in our model of diverse approaches to organizational control. From the perspective of organizational control theory, some studies have examined the relationships among control variables and performance, while some have focused on the relationships among control enablers and control variables. Our integration of these diverse approaches produced promising results. Moreover, our general results found confirmation in those from studies using small group behavior theories. Since small group behavior theorists have had difficulty in operationalizing process variables, we believe that control theories may be helpful in this regard.

Our fourth theoretical contribution is the team process model proposed in Chapter Three. We believe that this model may be a useful starting point for examining the impact of design aids on the performance of design team. Our focus on team process, that is, how team members work together as a team, should be extended.

Methodological Contributions: Although planning and designing information systems is done by a team composed of individuals with diverse roles, the previous empirical work in this area has not reflected this reality. In our study of I/S planning and design, the focus was on how team members work together as a team. Our plane of observation, therefore, was not that of the individual, but that of the team. Measurement of team collectivity and other organizational characteristics required research methods different from those used to measure the characteristics of individuals. Correspondingly, the unit of analysis for empirical research was the team. Our first methodological contribution, therefore, was the adoption of key informant analysis to I/S planning and design. Based on the previous work using key informant analysis in the fields of sociology, marketing, and strategy, we identified several threats to key informant analysis and we developed techniques for counteracting these threats in Chapter Five.

Our second methodological contribution was the generation of an item pool summarized in Appendices 1 through 5. Many organizational control theory studies have used only a single indicator to measure control variables. Our instrument appears to be robust and should be useful in futures studies, although minor modifications could be made based on the empirical analyses we performed.

Our third methodological contribution was the finding that self-report overestimated or underestimated the theoretical constructs we intend to measure. For example, in our study we assessed managerial control and managerial control enablers through self-report and non-self-report, and we found that the project manager always overestimated his influence and his control enablers. Moreover, our evidence suggests that if an analysis is performed based on control variables assessed by the project manager and control enablers assessed by the project manager, we may be doing no more than testing the project manager's own implicit theory on his behavior. Most previous empirical studies of organizational control have used self-report; we challenge the validity of such studies.

Managerial Implications: The results of this study should have useful and interesting implications from the managerial perspective in that we studied two of the most important current practices of I/S planning and design: the team approach and the use of computerized design aids. The first major implication is that the importance of managerial control should not be underestimated and that managerial control was the best predictor of the performance of design teams. Specifically, our results indicate that the project managers should probably be involved in managing design tasks explicitly; providing only performance feedback is not enough. Since designers and domain representatives bring different perspectives, skills, and expectations to I/S planning and design, managing the interactions among these different roles and individuals is the most challenging job for the project manager.

A second finding of interest to managers was that collegial control was found to be more important than self-control in I/S planning and design, because, we believe, team members should work primarily as a team, not by themselves. The interactions among team members were found to be important predictors of effectiveness and time-to-market. To enable effective interactions, communication among team members should be frequent and easy. Organizations should provide an atmosphere that can make frequent exchanges of ideas possible.

Another study finding that managers may find interesting is that the impact of computerized design aids aimed at increasing individual productivity was found to be only marginal. This might be disappointing to the companies which try to install so-called CASE technology. However, our finding does not mean that CASE technology is not important at all. It is important to remember that most of the features of the CASE technology were not used extensively by our I/S planning and design teams. Moreover, our unit of analysis was the team, not the individual. Some participants spoke highly of the CASE technology since designers' jobs were made much easier and more effective with CASE technology. However, others commented that the features of the current technology were not appropriate to the specific project they were undertaking. Since CASE technology is relatively new, this result may no longer reflect reality as the users gain more experience.

A fourth finding of interest to managers is that current CASE technology is missing much of the analysis and transformation features. These features might be included in the future generation of CASE technology. Moreover, based on our analysis, we believe that features that can facilitate group interaction should be included as part of CASE technology. We found that even simple E-mail can increase performance variables.

9.3. Future Research Directions

There are four major areas which need to be addressed to extend the findings of this study. These research directions are discussed below.

Better Measures of Team Performance: In our study we used subjective measures of team performance, although we took several precautions in obtaining these measures. Objective measures can provide another avenue for this kind of research. For example, the cost and the profitability of information systems can be real indicators of the success of I/S planning and design. However, finding these measures is easier said than done. Better measures of team performance can contribute substantially to research on I/S planning and design.

Integration of Group Theories with Control Theories: Guided by control theories, we tested our model of the performance of design teams. The findings were similar to those of studies based on small group behavior theories. Therefore, in the future, combining group theories and organizational control theories may be a promising avenue for research. Particularly, boundary management by the design team, which has been found to be important by small group theorists (Gladstein, 1984; Ancona and Caldwell,1987) might be an important topic for future research. For example, one possible research question is to determine whether, even though domain representatives are usually involved in I/S planning and design team, design team should still manage boundary management with clients (users).

Managerial Control and Performance: We used leadership theories and control theories to measure managerial control and control enablers. These theories are concerned with general management issues. Since the managerial control of the project was found to be extremely important in this study, we should refine these theories in the context of I/S planning and design.

The Impacts of Computerized Design Aids: In our case, since most of the features of design aids were not used extensively, our findings should be viewed as exploratory. As the users become more experienced with these features, the results of future studies may be different. Therefore, more research on the impact of computerized design aids should be done in the future.

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Appendix 1. Managerial Control Enablers Questions

In the following you will be asked about your manager for the XXXXX project. Please respond to how accurate the following statements are.

My project manager in the XXXXX project .....

	Operationalization	Mean	Standard deviation
TUND1	understands our project members' jobs very well.	5.04	1.41
TUND2	is fully aware of the relation between this project and the mission of the organization.	5.36	1.24
TUND3	knows and understands the problems faced in our project members' jobs.	4.96	1.31
MEAS1	uses quantitative measures to evaluate our project team members' performance.	4.24	1.53
MEAS2	easily checks how much our project team members accomplish on their assigned jobs.	4.62	1.33
VCOM1	Communication between the project manager and our project team members occurs very frequently.	4.99	1.58
VCOM2	It is hard for the project manager to communicate with our project team members.	5.39	1.49

Appendix 2. Designer Control Enablers Questions

In the following you will be asked about designers/analysts on the XXXXX project team. If you are a representative of this role, please indicate your feelings about the role in general not just your personal experience. Please respond to how accurate the following statements are.

	Operationalization	Mean	Standard deviation
SKD1	Designers/analysts have the experience and skills to act independently in performing their day-to-day duties on the XXXXX project team.	4.97	1.27
SKD2	Designers/analysts have the experience and skills to act independently in unusual and unexpected job duties on the XXXXX project team.	4.55	1.26
SKD3	Designers/analysts have a high level of technical and system knowledge about information systems relevant to the XXXXX project	5.03	1.39
MOD1	Designers/analysts in the XXXXX project work hard enough to get the task done well.	5.58	1.13
MOD2	Designers/analysts in the XXXXX project could put more effort into their work than they do at present.	5.17	1.45
TFD1	Because of the nature of the tasks that designers/analysts perform, it is easy for designers/analysts to see when they've done something exceptionally well in the XXXXX project.	4.56	0.90
TFD2	Designers/analysts receive many "clues" about how well they are performing as they carry out their work in the XXXXX project.	4.77	0.95
COD1	Designers/analysts frequently talk to other team members in the XXXXX project.	5.77	1.09
COD2	It is easy for designers/analysts to consult with other XXXXX project team members about problems.	5.95	1.00

Appendix 3. Domain Representative Control Enablers Questions

In the following you will be asked about client/domain representatives on the XXXXX project team. If you are a representative of this role, please indicate your feelings about the role in general not just your personal experience. Please respond to how accurate the following statements are.

	Operationalization	Mean	Standard deviation
SKU1	Client/domain representatives are fully aware of the relation between this project and the mission of the organization.	5.21	1.36
SKU2	Client/domain representatives know who will affect and who will be affected by our project very well.	5.02	1.48
SKU3	Client/domain representatives have a high level of business knowledge relevant to the XXXXX project.	5.25	1.41
MOU1	Client/Domain representatives on the XXXXX project work hard enough to get the task done well.	4.74	1.39
MOU2	Client/Domain representatives on the XXXXX project could put more effort into their work than they do at present.	4.06	1.68
TFU1	Because of the nature of the tasks that client/domain representatives perform, it is easy for client/domain representatives to see when they've done something exceptionally well in the XXXXX project.	3.96	1.25
TFU2	Client/domain representatives receive many "clues" about how well they are performing as they carry out their work in the XXXXX project.	4.19	1.22
COU1	Client/domain representatives frequently talk to other team members in the XXXXX project.	4.96	1.53
COU2	Client/domain representatives frequently talk to customers/user	5.10	1.39
COU3	It is easy for client/domain representatives to consult with other XXXXX project team members about problems.	5.57	1.15

Appendix 4. Managerial Control Questions

How accurate do you think the following statements are in describing your manager for the XXXXX project.

My project manager in the XXXXX project ....

	Operationalization	Mean	Standard deviation
OUTP1	gives our project team members a lot of feedback about how they are doing.	4.62	1.50
OUTP2	gives our project team members frequent feedback about performance.	4.20	1.51
ROLE1	explains the level of performance that is expected of our project team members.	4.49	1.39
ROLE2	lets our project team members know what is considered good job performance.	4.14	1.51
ASSI1	carefully defines what jobs our project team members are to do.	5.06	1.25
ASSI2	gives our project team members specific work assignments.	5.18	1.43
PROC1	develops procedures to guide our project team members' work.	4.51	1.53
PROC2	explains to our project team members how their jobs should be done.	3.56	1.48

Appendix 5. Team-Member Control Enablers Questions

Please indicate the extent to which you agree or disagree with each of the following statements.

For work relating to the XXXXX project.....

	Operationalization	Mean	Standard deviation
OUTPD1	designers/analysts give other project team members a lot of feedback about how they are doing.	4.49	1.47
OUTPD2	designers/analysts gives project team members frequent feedback about performance.	4.29	1.46
OUTPU1	client/domain representatives give other project team members a lot of feedback about how they are doing.	4.37	1.34
OUTPU2	client/domain representatives gives project team members frequent feedback about performance.	4.08	1.35
BEHAD1	designers/analysts have significant freedom as to what they will do in our project.	4.25	1.54
BEHAD2	designers/analysts have significant freedom as to how they do their work in our project.	5.10	1.34
BEHAU1	client/domain representatives have significant freedom as to what they will do in our project.	4.30	1.43
BEHAU2	client/domain representatives have significant freedom as to how they do their work in our project.	4.87	1.38

Appendix 6. Performance Questions

The following questions ask you to compare the XXXXX project team to other teams. In relation to other comparable project teams you have served on or observed, how does the XXXXX project team rate on each of the following.

	Operationalization	Mean	Standard deviation
EFFI1	The efficiency of team operations.	4.49	1.25
EFFI2	The amount of work the team produces.	4.99	1.23
EFFI3	The team's adherence to schedules.	4.64	1.60
EFFI4	The teams adherence to budgets.	4.04	1.58
EFFE1	The quality of work the team produces.	5.14	1.16
EFFE2	Effectiveness of the team's interactions with people outside of the team.	4.67	1.28
EFFE3	The team's ability to meet the goals of the project.	4.91	1.45
TIME1	The team could have done its work faster with the same level of quality.	4.30	1.66
TIME2	The team met the goals as quickly as possible.	4.75	1.42

Appendix 7. Design-Aid Usage Questionnaire

Representation Dimension

T5. The user can use the tools to represent a design in terms of data models, such as entity relationship models, semantic models, etc.

T11. The user can choose a first-cut model from among stored generic models, rather than starting from scratch. For example, the user can "sketch" or outline a model, then search a library of models for one that matches its general form.

T21. The user can simultaneously display several screens that show different versions of past or current work, e.g., two or more levels of detail of a process model.

T23. The user can instruct the tools to redraw the diagram on the screen so that it is uncluttered and easy to read.

T29. The user can use the tools to represent a design in terms of process or flow models such as input/process/output, dataflows, state transition, etc.

T31. The user can maintain a single master definition of each specific process, object, relationship, etc. that appears in the design.

T44. The user can have the tools show the attributes or characteristics associated with an object or process by selecting that object or process in a diagram.

T52. The user can use the tools to represent the structure or authority relationships of the organization for which the target system is being developed (e.g., functional or hierarchical diagrams).

T53. The user can represent relationships between critical information requirements and goals or objectives.

T55. The user can identify and store for internal use complex objects that consist of many entities or processes, e.g., an entire business process flow model could be labeled as an object and referred, accessed or moved with a single operation.

T62. The user can maintain an inventory/description of the existing systems with which the target system will interact.

T63. The user has naming convention flexibility. For example, the tools can allow aliases, hierarchical naming, classes of variables, etc.

T66. The user has the option of drawing (or "pinning") the lines in a diagram exactly where s/he wants them. For example, in a case where the tools would automatically connect the bottom of one box with the top of another, the user can instead have the line drawn between the boxes' sides.

T70. The user can combine processes or objects/entities that are found to be structurally equivalent.

T75. The user can construct several types of models (e.g. data, process, functional) to represent different types of design information.

T76. The user can adapt or customize the language, methodology, or convention (e.g., Yourdon, Jackson, BSP) used for representing objects, information needs or processes.

T83. The user can map the existing systems onto a functional/hierarchical description of the client organization.

T92. The user can move back and forth between different types of models easily. For example, the user can switch to a high level architecture model while working on physical implementation.

Analysis Dimension

T1. The user can use analytical decision aids such as statistical or simulation models to measure the performance of the software being developed. For example, s/he can conduct analyses such as the optimal clustering of records in a physical data base environment.

T2. The user can detect and analyze system errors resulting from execution of the target system.

T4. The user can trace the relationships between specifications at a detailed logical level (e.g., entities/relations) and the content of planning efforts (e.g., goals, objectives, etc.).

T6. The user can analyze a model to identify where predefined criteria or rules have been violated. For example, the tools can check that input-output relationships are consistent from level to level, i.e., that all flows depicted at one level are exhaustively included in more detailed levels (level-to-level balancing).

T8. The user can search the current design (e.g., using an index, queries, or a "find" feature) for objects with specified characteristics.

T9. The user can search the design for complex relationships. For example, if the user specifies a process flow, the tools can check to determine if the process exists in the design.

T20. The user can use the tools to identify the differences between separate versions of a document, diagram, etc.

T25. The user can check for unnecessary or redundant connections in a model and identify simplifications that can be made.

T26. The user can compare and/or test for consistency between a function/process model and an object/entity relationship model.

T30. The user can detect inconsistencies, e.g., inconsistent definitions of terms, inconsistent process models within a user perspective, etc.

T32. The user can search the current design for objects (e.g., entities, goals, relationships, etc.) that are similar to, but not necessarily exactly the same as, a proposed object.

T38. The user can ask the tools to identify what impact a proposed design change would have on the overall progress of the project. For example, if a key module must be redesigned or if a new module is added to the design, the tools can estimate how the schedule of deadlines and deliverables will be affected.

T48. The user can check for structural equivalence of objects/entities or processes based on comparisons of their domains, relationships, etc.

T77. The user can ask the tools to identify what would happen (what additional changes would have to be made) if s/he makes a specified change in the design.

T80. The user can ask the tools to suggest alternative approaches to problems based on the way in which similar problems were previously solved.

T87. The user can select a portion of the design (containing a number of entities, processes, etc.) in order to perform an operation on it. For example, the user could identify a set or object and relationship and move them in one operation.

T91. The user can simulate the production environment in which the target system will operate in order to integrate it with the existing environment.

T93. The user can estimate the process or performance characteristics of a design (response time, for example).

T94. If the user develops a set of limited perspectives (e.g., differing user views of a data model), the tools can recommend a general model incorporating all of them.

Transformation Dimension

T3. The user can generate executable code from a screen mockup.

T27. The user can generate executable code in several procedural languages such as COBOL, ADA, or C.

T28. The user can convert a logical specification into a physical specification. For example, s/he can transform a logical user view into a physical specification or can convert a logical layout of a report into a physical specification for a particular terminal environment.

T33. If the user changes any occurrence of an object or term that is used more than once in the design, that change can be propagated automatically to all other places it appears.

T46. The user can get documentation as a by-product of the design. That is, the tools can generate documentation (e.g., definitions of variables, accepted domains for variables) from the information in the design, so that the user does not have to document the design separately.

T47. The user can use the tools to create templates for tasks and deliverables. That is, for a particular type of project, the tools can generate a sequence of standard tasks and deliverables to be completed.

T49. The user can generate screen mockups.

T50. The user can generate code compatible with a variety of physical environments, e.g., multiple data base management schemes, multiple TP monitors, etc.

T51. The user can transform a high level representation into a more detailed representation, e.g., a data flow diagram into a draft version of a structure chart.

T72. The user can generate standard code for generic programs such as table processing, data access, utilities, etc.

T74. The user can do reverse engineering. For example, s/he can go from a physical to a logical level, from procedural code to a structure chart or pseudo code, etc.

T78. The user can import data from, and export data to, external files and/or other packages. For example, the user can move data from an external data dictionary into the tools dictionary.

T90. The user can generate executable versions of a design to use in testing or to show to clients.

Control Dimension

T7. The user can instruct the tools to ignore temporarily a problem/inconsistency so that s/he can continue to work as though this problem did not exist.

T14. The user can specify who can review various parts of the design work.

T15. The user can get assistance from the tools in analyzing or establishing priorities for managing the project. For example, the user can conduct a critical path analysis in developing a task plan.

T16. The user can manage the quality assurance path for a project. For example, when a designer indicates that a module is finished, the tools notify the designated reviewer for that piece.

T17. The user can get management information for more than one project. For example, the user can track an individual's total work load across all the projects that person is working on or can track the total manhours or dollars expended by all the ongoing projects in the group.

T37. The user can specify who can modify various parts of the design work.

T39. The user can maintain a list of the stated requirements for the design and track how they are being satisfied.

T40. The user can alter the rules that control the way the tools perform certain functions. For example, the user can change how often individuals' work spaces are automatically reconciled with the master version of the design or can vary the way that changes are propagated throughout the design.

T43. The user can follow a set of priorities or rules in merging separate versions of a document, diagram, etc. For example, where two versions of the same document exist, the tools can be instructed to select specific portions of each for the merged version.

T57. The user can use the tools to estimate how long a specific task or project will take to complete.

T60. The user can instruct the tools to automatically maintain a record of the changes made in the design, including who made them and when.

T61. The user can get project control information from the tools such as actual versus planned progress, estimated time to completion, dollars spent versus budgeted, budgeted manhours remaining, etc.

T65. The user can instruct the tools to "freeze" a portion of the design to protect it from changes.

T68. The user can instruct the tools to automatically remind members of the project team about approaching deadlines.

T73. The user can maintain a record of who is responsible for each part of a design or work product.

T82. The user can use the tools to produce metrics for comparing various projects, e.g., project complexity, team performance, or measures of structural quality.

Cooperative Dimension

T18. The user can send messages to others who use the tools.

T19. The user can provide feedback or input anonymously, e.g., in secret balloting to prioritize potential projects.

T41. The user can use the tools to maintain a dialogue with other users of the tools. For example, s/he can assign messages to an issue/topic and can link to other messages associated with that topic.

T42. Several users can concurrently use the same database, dictionary, diagram, etc.

T59. The user can build a catalog of macros that other users can access.

T64. A group of users can work simultaneously on a single task. For example, several members of a team can simultaneously revise a diagram, each using his/her own keypad, mouse, etc. to mark up the diagram.

T84. The user can electronically attach notes or comments to objects, structures, or processes that will be seen by anyone who accesses those parts of the design.

T85. The designer can work interactively with the end user of the target system to evaluate design alternatives. For example, the designer and client can run a prototype repeatedly or easily rearrange screen mockups.

T86. The user is automatically notified if someone makes a change to the design that affects the work that s/he is doing. For example, if an interface to the module the s/he is working on is changed, the user will be notified.

T98. The user has group interaction support. For example, the tools support activities such as group voting, or the use of group process techniques such as brainstorming, Delphi techniques, etc.

Infrastructure Dimension

T10. The user can use instructional materials (videotapes, manuals, training guides, etc.) to learn the tools.

T12. The user can get on-line help specific to the context in which s/he is working. For example, the tools can explain how a command is generally used in the portion of the design in which the user is working or can show why the user's attempted usage is incorrect.

T13. The user has options on how to interact with the system, for example, once the user has become familiar with the tools, s/he can use an "expert mode" or key word commands to invoke particular features, thereby avoiding sequences of time-consuming menus.

T22. The user can graphically magnify or "zoom in on" a diagram or model to see parts of it that cannot be shown at a higher level (because of clutter), or can "pull back from" a detail-level portion to examine how it fits into a higher level diagram.

T24. The user can develop, run, and store completely customized reports using his/her own formats.

T34. The user can build templates or examples of work done by his/her group for use in tutorials or learning exercises.

T35. The user can build his/her own customized models or templates and store them in a general access library.

T36. The user can identify external sources of information on specific topics. For example, the user can ask the tools to provide a list of books or experts in the area of structured data modeling techniques.

T45. The user can "browse" in other segments of the tools while using the graphics mode. For example, the user can look up definitions of terms before creating a new relationship in a model.

T54. The user can find out from the tools <u>why</u> a part of the design has been identified as inconsistent.

T56. The user can use a keyboard template, reference cards, or other such aids for quick references to basic commands and functions.

T58. The user's pattern of previous errors can be used by the tools to anticipate his/her mistakes.

T67. The user can prepare, edit, store, send, and retrieve documents (both text and graphics) using the tools.

T69. The user can get individual change pages, i.e., revisions of selected portions of the documentation.

T71. The user can link a design to a library of models, systems, or executable modules for testing. For example, the user can link to financial algorithms to run simulations.

T79. The user can backtrack by undoing the most recent series of commands. For example, the user can take back the last 5-10 commands if it appears that s/he is moving in the wrong direction.

T81. The user can instruct the tools to store versions of the design at specified points in the design process so that s/he can "roll back" to look at an earlier version or to restart the design process at an earlier point.

T88. The user can generate presentation-quality printed reports and documents using the tools or by linking them to another system. For example, the user can prepare a final version of a deliverable combining graphics and text.

T89. The user can generate outputs in a variety of media, e.g., tape, floppy diskettes, plotter printout, or electronic transmission to the client's mainframe.

T95. The user can get an explanation of <u>why</u> an action or alternative has been recommended.

T96. The user can incorporate his/her own "macro" procedures of frequently-used series of commands into the tools' menus or command structure.

T97. The user can get on-line help for a specific command or feature. That is, the tools can provide standard examples of the correct syntax or usage of a command.