

MANAGEMENT-DRIVEN INTEGRATION

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**CIFE Technical Report
Number 96
July 1994**

STANFORD UNIVERSITY

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Summary: CIFE Technical Report Number 96

Title: **Management-Driven Integration**

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Date: July 1994

Funding: CIFE Seed Project

Abstract: This report describes needs for integration identified by senior and project managers. The study examined integration needs at the project and company level, and focused on three major areas: integration benefits, mechanisms for integration and barriers to integration. The benefits include operational and strategic performance improvements. The barriers include contractual, organizational, behavioral and technological factors. Mechanisms to increase integration fall into these same categories. The research also identified a set of managerial issues that inhibit investments in integration: the need for front-end investment, the uncertainty of integration benefits, issues related to distribution of such benefits, repetitiveness of utilization of integration mechanisms, and requirements for organizational change. Increased conformance of actual integration to the desires of managers requires actions to overcome these issues.

Subject: The subject of this report is needs for integration at the company and project level, mechanisms to achieve this integration, and barriers that managers face.

Objectives/Benefits: The purpose of the study was to identify the importance of integration for project and company performance, and mechanisms that management can use to increase integration. The results can assist in increasing the level of integration in firms and on projects and in guiding future research to provide techniques and tools that support management's needs for integration.

Methodology: The research method included the following activities: literature review to describe the background of integration in construction and manufacturing; model development to describe potential benefits and mechanisms of integration; data collection by interviews with project and senior managers in owner's and contractor's organizations; data analysis to identify mechanisms managers use, benefits identified, and barriers to increased integration.

Results: The study identified operational and strategic benefits from integration. Operational benefits include improved project cost effectiveness, reduced schedule, increased safety, and prevention of claims, as well as improved logistics management and cash flows. Strategic benefits were identified for both owners and contractors. Facility quality, speed of delivery and cost effectiveness are important determinants of competitiveness for corporate owners. For contractors, integration is an organizational capability that results in competitive benefits (increased ability to win contracts) as it reduces the customers risk.

Barriers to integration include contractual, organizational, behavioral and technological factors. Contractual arrangements may prevent the participation of downstream actors in upstream decisions (i.e. contractor's involvement in design), and may reduce motivation for integration, as the incentives of different participants may not be aligned. Responsibility allocation and

incentives tied to functional performance promote sub-optimum decisions and complicate conflict resolution. Lack of inter-personal, communication and negotiation skills were identified as important behavioral barriers. The major technological barrier is the problems in communication between different computer systems.

Contractual, organizational and technological mechanisms were identified as means to increase integration at the project and inter-organizational level. Contractual means to facilitate project integration include value engineering provisions, design-build contracts, and contractual incentives that align the objectives of project participants. Organizational mechanisms include establishment of cross-functional teams with decision-making authority, implementation of partnering and TQM, and training of team members in inter-personal skills. Technological mechanisms include computer applications that enable electronic exchange of data and knowledge between functions.

At the inter-organizational level, joint ventures and strategic alliances are formal integration mechanisms. Less formal mechanisms include development of long-term relations between firms (owners, designers, contractors and suppliers). Such semi-formal relations that developed over time and are based on good previous experience, mutual trust, and respect. Technological mechanisms include development of computer applications that link different organizations beyond the context of a specific project.

Despite the identified benefits, there are important disincentives for investment in integration. For example, development of integration mechanisms may require significant investment. Furthermore, the competitive pressures that many firms face today may prevent the front-end investment required. The study identified a set of managerial issues that create barriers in making these investments. These issues are: the need for front-end investment, the uncertainty of integration benefits, issues related to distribution of such benefits, repetitiveness of utilization of integration mechanisms, and requirements for organizational change.

The identification of integration benefits, mechanisms and barriers suggests several implications for practitioners and researchers. The first implication is the central *role of owners* in increasing integration. Owners can gain important benefits from integration, and they must be the first to make such investment. This investment could mean selection of a contractor who has greater "integration capabilities", training personnel in integration skills, distribution of benefits from project success, and organizational changes that promote integration.

Research Status: This report completes the CIFE seed project that supported it. The results may guide future research to develop managerial techniques and information technology tools that foster integration to achieve the benefits that managers identified in the research.

ACKNOWLEDGMENTS

The work presented in this thesis was supported by the Center for Integrated Facility Engineering at Stanford University. CIFE's support is greatly appreciated. The writer would also like to sincerely thank the managers in DPR Construction, Bechtel Corp., Homer J. Olsen Construction, Atkinson Construction, Dillingham Construction N. A., Ehrlich-Rominger, and other organizations, who prefer to remain anonymous, who found time in very demanding schedules to explain the importance of integration for their corporations. Last but not least, I would like to thank Professor C. B. Tatum for his continuous support.

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Introduction

The U.S. architecture-engineering-construction (AEC) industry, with business receipts for new construction put in place, ranging between five to nine percent of GNP during the past four decades (Guile and Quinn 1988), is a crucial sector of the economy. AEC supplies the public sector with infrastructure facilities and the manufacturing sector with capital facilities. Thus, the performance of the AEC industry is a major factor in the nation's growth.

This important sector of the economy is characterized by an extremely high degree of fragmentation. Fragmentation exists both within individual phases of the facility development process (e.g. the design phase), as well as across phases (e.g. planning, design, construction and maintenance). This fragmentation is reflected in both the performance of construction projects, as well as the overall performance of the industry. The direct implication of fragmentation is that requires a large number of specialists from many different organizations (and with different objectives) to coordinate their decisions and actions in order to meet the customers needs. Therefore, improvement of project and company performance requires effective mechanisms for coordination and integration.

The purpose of this research is to increase understanding of the needs for integration between the participants of the facility development process, and identify effective strategies and mechanisms for increasing integration. Understanding the benefits from and barriers to integration, and identifying effective technological and organizational integration mechanisms will assist managers in developing effecting integration strategies. Thus, the primary objectives of the study are the following:

- 1- identify needs for and benefits from integration in engineering and construction projects and firms,
- 2- identify mechanisms for integration used by managers in AEC firms and construction projects, and
- 3- identify barriers to integration, and critical managerial concerns.

The findings of the study address the following issues: 1) benefits from integration, 2) integration barriers, 3) integration mechanisms, and 4) managerial barriers to integration. The identification of operational and strategic benefits from integration is the first finding. Operational benefits refer to benefits from improved project performance, and include improved cost effectiveness, schedule reduction, increased quality and safety and prevention of claims. Strategic benefits refer to competitive advantages for both owners and contractors and include increased market performance.

The study identified four sets of barriers: contractual, organizational, behavioral, and technological. Increasing integration requires elimination of these barriers, and investment in integration mechanisms. The study identified three types of mechanisms that managers deploy to increase integration at the project as well at the inter-organizational level: contractual means, organizational, and technological. Finally, the study identified five managerial issues that may prevent integration. These barriers are: 1) need for front-end investment, 2) uncertainty of benefits, 3) distribution of benefits, 4) repetitiveness of utilization of integration mechanisms, and 5) requirements for organizational changes. The study concludes that to increase integration, practitioners and researchers need to further address these issues.

This report consists of seven chapters. The first chapter examines the problem of fragmentation, the root causes and its implications for construction projects and the industry, and identifies the need for integration. Chapter two presents the objectives and methodology of this research. Chapter three reviews organizational behavior theories as well as manufacturing and construction literature related to integration, and develops a framework that identifies the factors that create need for integration, the mechanisms for effective integration, and the strategies that managers can follow at the project and company levels to increase integration. Chapter four reports the data collected through interviews with project and senior managers. Chapter five presents the findings from the study. Chapter six identifies the managerial implications and challenges with regard to integration. Finally, chapter seven develops recommendations for practice and research.

CHAPTER ONE - Background and Problem Statement

This section describes the problem of fragmentation in the construction industry, examines the implications for construction projects and the industry, and identifies the emerging need for integration.

1.1 Fragmentation in the AEC industry

The degree of fragmentation in the U.S. AEC industry is unparalleled in any other manufacturing sector. Many of the European and Asian competitors in construction are also much more integrated. The AEC industry consists of over 1,400,000 establishments of which 930,000 have one employee and the remainder have an average of ten employees (Howard et al., 1989). The fragmentation extends both vertically, that is between participants of different project phases, such as designers and contractors, as well as horizontally -between participants in the same project phase, such as design specialists. Lack of integration among planners, designers, constructors, and facility users results in significant problems and misses important opportunities for improved project performance.

This fragmentation is a consequence of two major factors: the complexity of the constructed facilities, and the high degree of specialization in design and construction.

Complexity of product. A construction facility consists of a large number of interacting functions and components. The larger the number of components, and interdependencies, the higher the complexity of the product. The interdependence of the components and functions of the facility result in interdependence between the organizational roles (specialists) who are responsible for these components.

Specialization. Specialization is a direct result of the division of labor and tasks among organizational positions and among organizations. Specialization allows the organization to take advantage of particular skills possessed by a member and fosters the development of such skills through repetition and learning. Such specialization,

however, results in fragmentation of knowledge. Specialists decision-makers have narrow knowledge, and may not understand the implications of their decisions on other parts of the production system. For example, a designer typically will not know the implications of his decision on the contractor's performance (in terms of budget and schedule), as he is not be aware of the construction methods available to the contractor or other project-specific constraints.

The complexity of a facility along with the high degree of specialization between disciplines and within each discipline results in a large number of project participants, each with different knowledge and objectives. It is not uncommon, for example, to find 20 separate design firms involved in various aspects of a high-rise building's definition. However, as specialization increases, the interdependencies between specialists increases, and coordination becomes essential. Furthermore, the different objectives of the participants create a source of conflict. As each party tries to make the best arrangement for its own interests, conflict arises between participants in different organizations.

1.2 Impact of fragmentation

The above factors contribute to fragmentation of the facility development process. Thus, each unit is performing its task without consideration of the requirements or constraints of subsequent functions, and suboptimization and inefficiencies arise. This fragmentation has significant implications both for the performance of the construction project as well as the industry's performance. Sub-optimum decisions, changes with significant consequences for budget and schedule, and disputes plague construction projects. For example, the Construction Industry Institute (*Cost of Quality Deviations in Design and Construction*, 1989) found that only the direct costs from design and construction changes in industrial facilities account for approximately 12% of project costs. Fragmentation not only results in errors, changes and inefficiencies but also reduces the ability of the project organization to respond to unanticipated events and changed conditions. Thus, fragmentation is a crucial contributor to the productivity and competitiveness problems that U.S. firms face today.

Another area where fragmentation has a not-obvious but significant consequence is the difficulty in implementation of advanced construction technology. According to Howard et al. (1989), European and Japanese competitors operating in less fragmented industries have taken the leadership in several construction technologies.

1.3 The emerging need for integration

Increased complexity of constructed facilities, new owners' requirements for functionality and efficiency, and increased competition, create significant pressures on AEC firms to improve their performance. At the same time, the high degree of specialization, although it provides strong technical knowledge and flexibility, creates a strong need for coordination between process participants. Thus, the more differentiated the organizational structure, the more difficult will be to coordinate the activities of the various subunits and the more bases for conflict will exist among participants. Hence, more resources and effort are required to coordinate the various activities and to resolve conflicts among members if the organization is to perform effectively.

Increasing integration of the facility development process is therefore, imperative. AEC firms must devote more resources and effort to coordinating the various activities and organizational subunits if the organization is to perform effectively. Identifying effective mechanisms for integration, and eliminating barriers should be a primary concern of owners, engineers, contractors and other project participants.

Means for increasing integration are both technological and organizational. In recent years, advances in computer technology provide significant opportunity for integration of the facility development process. However, for the technology to have a significant impact, institutional, organizational, and human barriers need to be eliminated (Williams 1991). While there is a general agreement between researchers and practitioners on the need for integration, there is a lack of understanding of how integration actually affects performance, and what organizational and technological mechanisms are most effective. Thus, management lacks a structured approach for evaluating means for and benefits from integration.

CHAPTER TWO - Research Design

This section defines integration as used in this research and presents the research objectives and methodology.

2.1 Integration

According to Lawrence and Lorch (1967), integration is defined as the process of achieving unity of effort among the various organizational subsystems in the accomplishment of the organization's tasks. As discussed earlier, the need for integration stems from differentiation and interdependence between organizational subunits. The higher the differentiation, the more difficult it will be to coordinate the activities of the various subunits and the more bases for conflict will exist among participants. Thus, more resources and effort must be devoted to coordinating the various activities and to resolving conflicts among members if the organization is to perform effectively (Lawrence and Lorch, 1967).

Integration requires exchange of information and knowledge between the interdependent subsystems. Furthermore, integration requires joint decision-making. March and Simon (1958) have identified the degree of "requisite integration" as the "felt need for joint decision-making", that is whether task characteristics make it possible for organizational subsystems to operate independently of each other, or require continual collaboration in making decisions before a given subsystem may act. This need becomes stronger as the fragmentation of knowledge between specialists increases.

This research examines integration from the perspective of the facility development process. In the context of this research, integration is defined as *the organization's ability to simultaneously take into consideration the constraints and requirements of all interdependent participants in order to meet customer's requirements in the most efficient way*. Thus, upstream subunits need to: 1) take into consideration the

requirements and constraints of downstream subunits, and 2) make the decision that meets customer's needs in the most efficient way.

The factors that create need for integration and the mechanisms to increase integration are further examined in chapter three (literature review).

2.2 Research objectives

The purpose of this research is to increase understanding of needs for integration in engineering and construction projects. The research focuses on identifying needs for integration as viewed by senior and project managers, and identifying actions that managers take to increase integration. Identifying barriers to integration and effective means to overcome these barriers will assist managers in developing strategies that will most effectively improve performance on projects and in firms. Thus, the following objectives structure the research:

- Identify needs for and benefits from integration in engineering and construction projects and firms. This includes performance problems due to lack of integration and benefits from increased integration.
- Identify organizational and technological means for integration used by managers in AEC firms and construction projects.
- Identify barriers to integration, and critical managerial concerns.
- Support integration-technology development by CIFE.

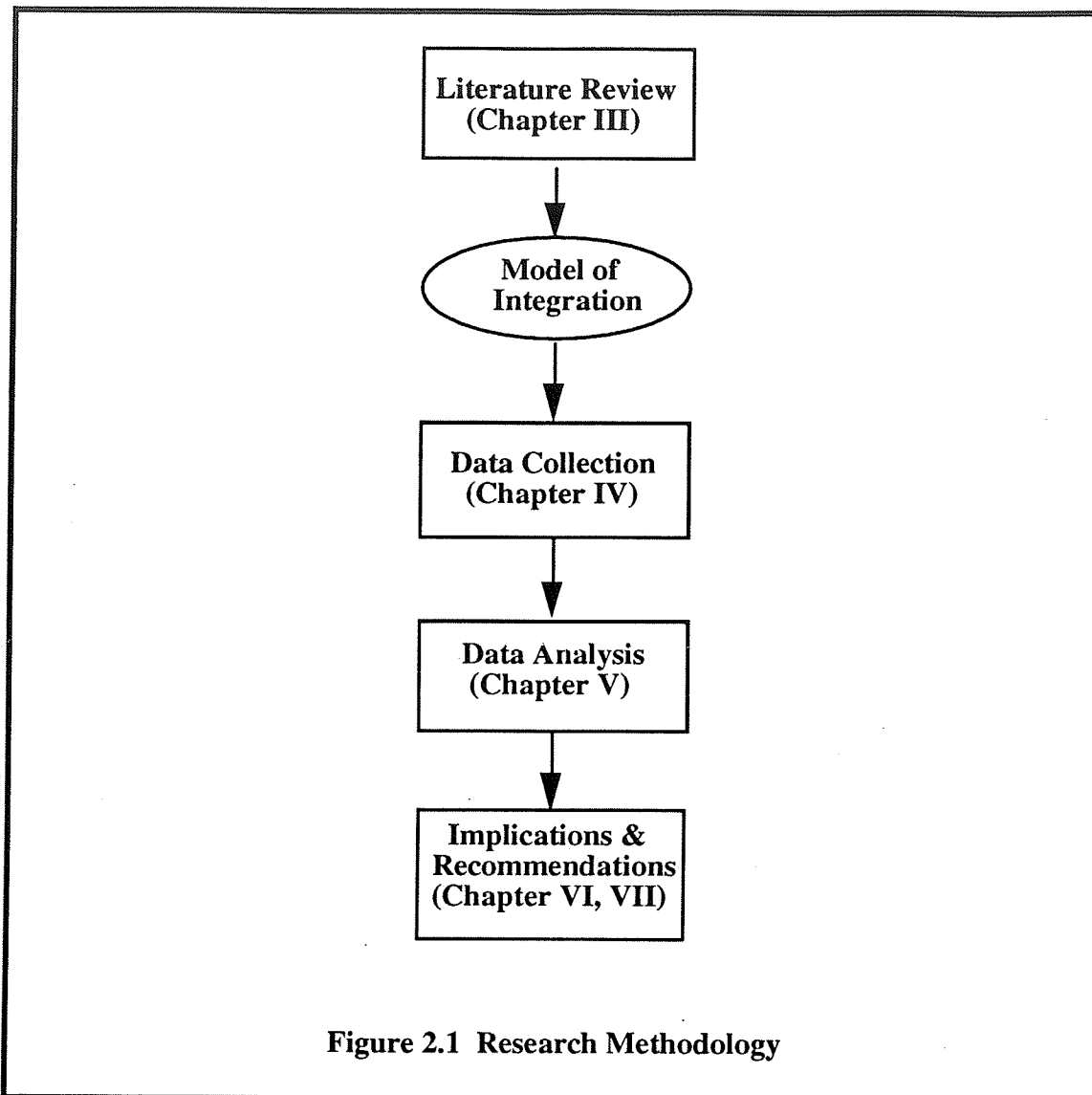
2.3 Research methodology

The methodology includes the following tasks as shown in Figure 2.1:

2.3.1 Literature review

The literature review is presented in Chapter III. The goals of the review are the following:

- *Identify need for and benefits from integration.* This includes the importance of integration for organizational performance, problems due to lack of integration, and conditions that create increased need for integration.
- *Identify mechanisms for integration.* The second major objective is to investigate mechanisms for integration, and identify contractual, organizational, and technological means that managers can use to increase integration.



The integration literature related to this research has been classified according to two dimensions: sources of literature, and organizational level of integration that the literature addresses. Organizational theories, manufacturing, and construction literature related to integration are the three sources utilized in this study. The study identifies two levels of integration: cross-functional and inter-organizational. The cross-functional level addresses integration between functions within the same organization and corresponds to integration at the project level. Because construction projects are temporary organizations, with each functional group usually belonging in a different firm, integration *between firms* is examined separately under inter-organizational integration.

2.3.2 Integration model

Based on the integration literature, a model of integration has been developed. The model identifies the importance of integration for firm and project performance and the factors that determine the effectiveness of integration. The model identifies the factors creating need for and benefits from integration in construction projects. Based on the theory and the empirical evidence from the literature review, the model also identifies the organizational and technological means for integration, and the actions that senior management can take to increase integration.

The model was subsequently used to guide data collection from project and senior managers concerning the implications of integration for project and company performance. The integration model is presented in Chapter III.

2.3.3 Data collection

The theoretical framework developed in Chapter III provided the basis for data collection. The data presented in Chapter IV were collected through interviews with project and senior managers in owner, architect engineer and construction organizations. The interview guide used in data collection (see Appendix A) was structured to identify the following issues:

- i. *General characteristics* of firm, type of projects, and type of markets.
- ii. *Needs for and benefits from integration*. Managers were asked to identify the importance of integration for project and company performance, in order to identify needs for and benefits from integration.
- iii. *Mechanisms for integration*. Managers were then asked to identify the mechanisms used by their firms to increase integration both at the project level, as well as at the inter-organizational level.

2.3.4 Data analysis

Chapter V analyzes the findings from data collection. The analysis focuses on the following issues:

- i. *Benefits from integration*. The analysis identifies two categories of benefits (operational and strategic) resulting from integration at two levels (project level and inter-organizational level).
- ii. *Barriers to integration*. This section identifies four major barriers to integration: contractual, organizational, behavioral and technological.

- iii. *Mechanisms for integration.* The study identified three major categories of integration mechanisms: organizational, contractual, and technological. These means are used to increase integration at both the project and the inter-organizational level.

2.3.5 *Implications and recommendations*

Chapter VI examines the actions that managers need to take to increase integration and the reasons that prevent managers from trying to overcome the identified barriers. Finally, Chapter VII summarizes the study and develops implications for practice and research.

- i. Implications for practice identify actions that managers can and should take to increase integration.
- ii. Implications for research address the need to develop methods to evaluate the impact of different integration mechanisms and the benefits from integration. This is important for managers to justify investment in organizational and technological integration mechanisms.

CHAPTER THREE - Literature Review

This section first provides a review of the literature related to integration, and then develops a theoretical framework. The literature review is based on background from organizational behavior, manufacturing and construction. The framework was subsequently used to guide data collection regarding the implications of integration for project and company performance.

3.1 Objectives of literature review

The purpose of the literature review was to gain background from previous research and empirical evidence related to integration. The specific objectives were:

- Identify needs for and benefits from integration. This includes the importance of integration for organizational performance, problems due to lack of integration, and conditions that create increased need for integration.
- Identify mechanisms for integration. The second objective was to investigate mechanisms for integration and identify contractual, organizational, and technological means that managers can use to increase integration.

3.2 Classification of literature

As shown in Figure 3.1, the integration literature related to this research can be classified according to two dimensions:

1. Sources of literature, and
2. organizational level of integration.

Level of Integration

Source	Intra-organizational (cross-functional)	Inter-organizational
Organizational behavior	<p>Thompson (1967) Lawrence and Lorch (1967) Galbraith (1973, 1977) Nadler and Tushman (1978)</p>	<p>Pfeffer and Salancik (1976) Astley & Fombrun (1983) Williamson (1975, 1979, 1991) Eisenhardt (1989) Borys & Jemisson (1987a, b, 1989)</p>
Manufacturing	<p>Porter (1980) Hayes, Wheelright & Clark (1988) Wheelright and Clark (1992) Takeuchi and Nonaka (1986) Whitney (1988) Turino (1992) Anderson (1990) Lee (1992) Leuenberger (1988) Putnam (1985) Liker et al. (1992) etc.</p>	<p>Child (1987) Powell (1987) Teece (1992) Johnston & Lawrence (1988) Helper (1984) Miles and Snow (1984, 1986, 1992)</p>
Construction	<p>Business Roundtable (1982) CII (1986, 1989, 1991) Paulson (1976) Tatum (1986, 1987, 1990) Sanvido Howard (1992) Teicholz (1989) Teicholz and Fisher (1993) Williams (1991)</p>	<p>Eccles (191a, b) Stinchcombe (1986) Ashley et al. (1989)</p>

Figure 3.1 Classification of integration literature

3.2.1 Sources of literature on integration

The sources of integration literature are classified into three groups: i) organizational behavior, ii) manufacturing related literature, and iii) construction related literature. All three sources are reviewed with a focus on the needs and mechanisms for integration. Manufacturing and construction related literature are reviewed primarily as sources of empirical evidence concerning integration issues faced by companies in these sectors.

3.2.2 Level of integration

This research classifies the integration literature in two groups: i) cross-functional, and ii) inter-organizational. The cross-functional level addresses integration between functions within the same organization. In construction, this corresponds to integration at the project level, and addresses the means for and benefits from integration between project participants. However, because construction projects are temporary organizations, with each functional group usually (but not always) belonging in a different firm, the issue of integration *between firms* becomes important, and deserves separate examination. In the following section, the literature on cross-functional integration is first reviewed, and subsequently, the inter-organizational integration is examined.

3.3 Cross-functional integration

3.3.1 Organizational behavior

Organizations are designed to divide work and coordinate the divided work in order to achieve the desired result. The interdependence between the organizational subunits creates need for coordination. Thompson (1967) identifies three main types of interdependencies: pooled, sequential and reciprocal, which can be managed with different coordination mechanisms. However, the degree of coordination required also depends on the organizational environment as well as the task characteristics.

Lawrence and Lorch's classic study *Organization and Environment* (1967) pointed out that under conditions of environmental uncertainty and complexity, the best performing organizations are **both** highly differentiated **and** highly integrated. They are differentiated in that members of subunits assume different cognitive and emotional orientations in order to cope with the conditions of their sub-environments. They are integrated in that members of subunits, in spite of the differences in orientation, are able to collaborate in order to achieve "unity of effort". Thus, under conditions of

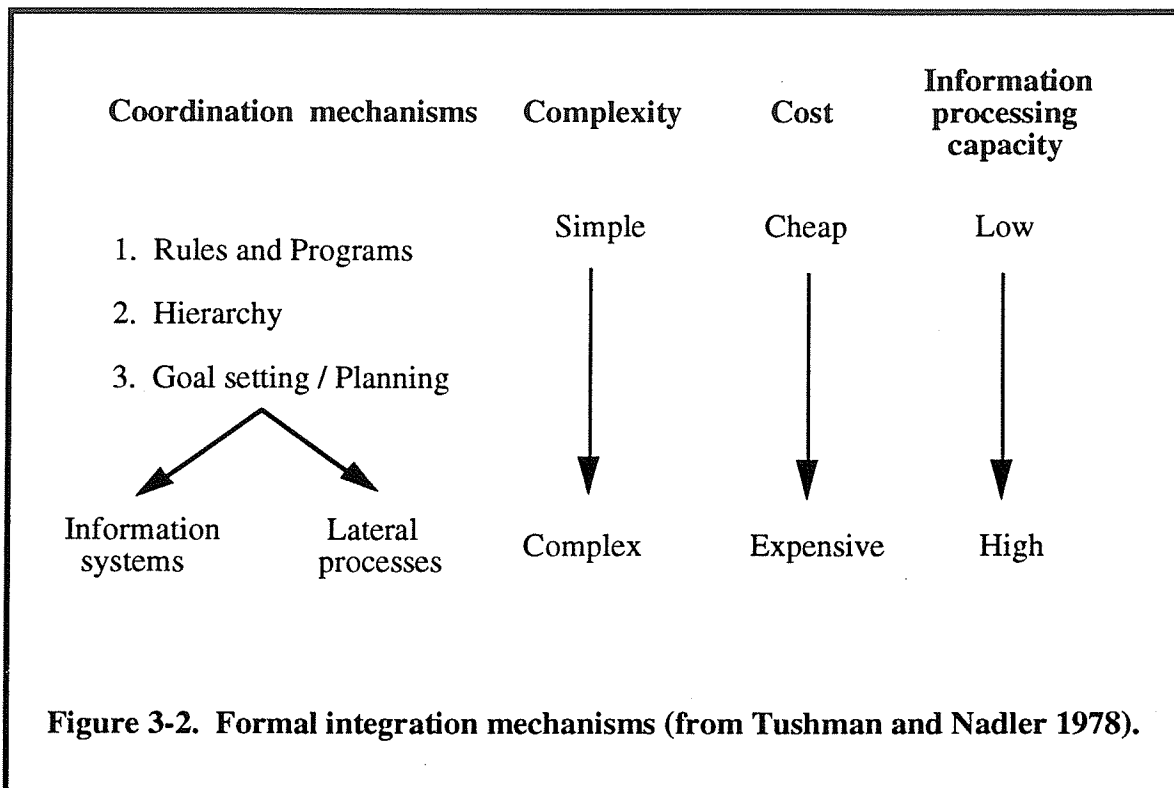
environmental uncertainty such as changing markets and technologies, and increased pressure for efficiency, organizations need to be integrated for rapid and effective response to environmental demands. In Lawrence and Lorch's study, integration was needed between Marketing, Engineering (R&D) and Production primarily due to the necessity to develop new products and processes and constantly modify existing ones.

Information processing theories of organization make similar arguments regarding the need for integration. Galbraith (1973, 1977) proposes that "the greater the task uncertainty, the greater the amount of information that must be processed among decision-makers during task execution in order to achieve a given level of performance" (Galbraith 1973, p. 4). Uncertainty is defined as the difference between the amount of information required to perform the task and the amount of information already possessed by the organization.

The amount of information required is a function of: (1) the diversity of outputs provided (such as the number of different products, services or clients), (2) the number of different input resources (such as the number of different specialists involved in the task), and (3) the level of performance required. Thus, the greater the diversity of inputs and outputs, and the higher the performance requirements, the greater the number of factors and interrelations between factors that must be considered simultaneously when making decisions. Tushman and Nadler (1978) also argue that organizations will be more effective when there is a match between information processing requirements facing the organization and information processing capacity of the organization.

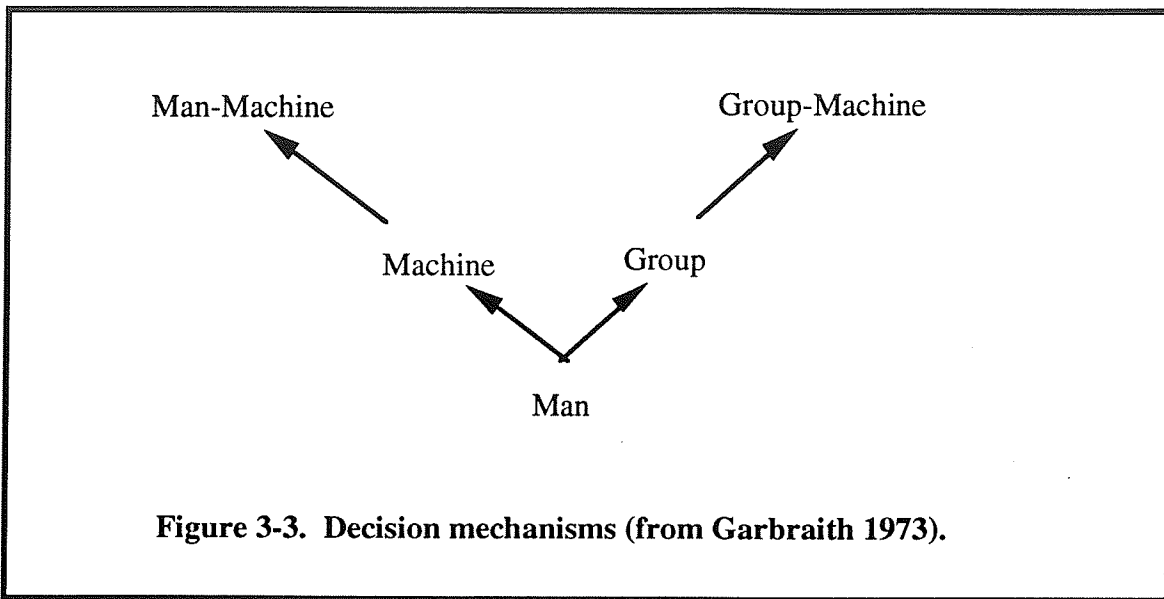
Differentiation and integration also have an inverse relation, as the differences in subunits often create difficulty in achieving integration among them. Thus, despite the need for both differentiation and integration, many organizations achieve only differentiation, with the minimum of exchange taking place across functional boundaries. Integrated organizations were found to utilize a variety of formal and informal coordination mechanisms designed to promote the flow of ideas, information and resources across departmental boundaries.

Galbraith (1973, 1977) and Tushman and Nadler (1978) identify the following coordination mechanisms shown in Figure 3-2.



Rules and procedures are the simplest method for coordinating interdependent subunits by specifying the appropriate responses to job related situations. However, when a response is developed to a new situation, the decision-maker has to take into account all the affected subtasks. Thus, a *managerial hierarchy* is created to handle the information collection and problem-solving. *Goal setting* brings decision-making at the subtask levels. However, to avoid implications to other subtasks, organizations perform centralized detailed planning and set goals for each subunit.

As task uncertainty increases, organizations have two primary ways to improve the capacity of decision mechanisms to process information and select the best alternative course of action (Galbraith 1973 and 1977, Tushman and Nadler 1978): (1) information systems, and (2) lateral relations. The first method originated from developments in information technology, while the second is based on group decision-making. Figure 3-3 illustrates decision mechanisms based on these two concepts.



In the past, *information technology* has supported routine decisions. Recent developments in computer technology have increased the computer's ability to assist with less structured problems. Man-machine decision mechanisms utilize the computer as a decision-making tool. For problems that are less quantifiable, group decision-making is considered more effective (Tushman and Nadler 1978). Finally, the use of computer to assist group decision-making (group-machine) is needed in order to include global data.

Lateral processes may be *informal*, such as voluntary information exchange, and cooperation for problem-solving, as well as *formal*. Superordinate goals, organizational environment and culture that promote cooperation (similar to Ouchi's "clan" culture), and physical proximity of subunits can facilitate direct contact and informal cooperation between subunits. However, an important reason for formalization is that such processes do not always arise spontaneously, especially in highly differentiated organizations (Galbraith 1973, 1977). Formal lateral processes include liaison roles, task forces, cross-functional teams, integrators roles, and matrix organizations.

Liaison roles and *task forces* have low coordination capacity. *Cross-functional teams* with representatives from each function are permanent units that follow a project from the beginning throughout its completion. However, the effectiveness of teams depends on the establishment of effective management systems, as follows. An *incentive system* that promotes cooperation and joint problem-solving is necessary (although not sufficient) for team effectiveness. Teams must also have adequate *decision-making*

authority, or the advantages of bringing decision-making to lower levels will not occur. Effective *conflict resolution* is also critical. According to Galbraith (1973), the problem facing the differentiated organization is how to obtain overall task integration among departments without reducing the differences that lead to effective subtask performance. Thus, conflict should not be resolved by changing the subunits' goal orientation but by searching for new alternatives which satisfy the different sub-goals. *Group and interpersonal skills* are essential for effective problem-solving and group decision-making. Interpersonal competence can result from either selection or training. Team building activities reduce threat and create a climate where confrontation can be accepted.

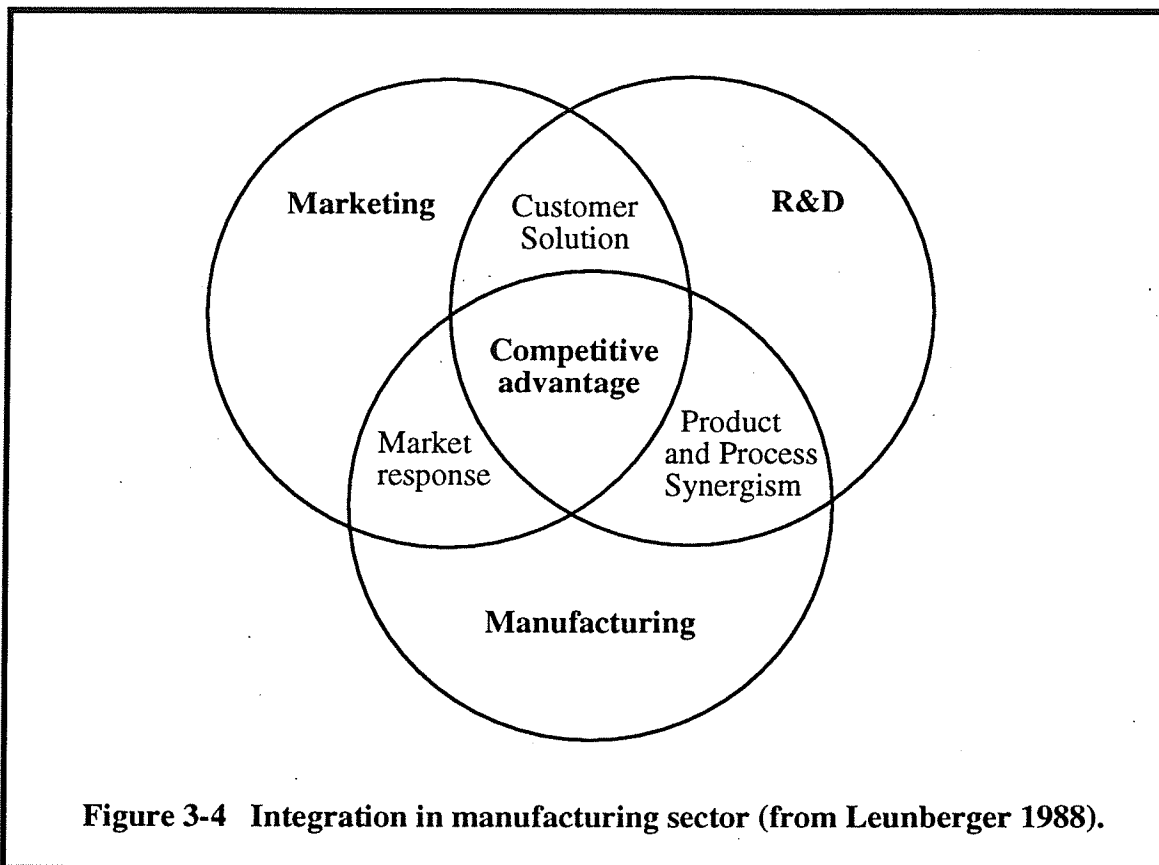
Team decision-making often raises the question of power and leadership especially when consensus cannot be achieved. Departments with high status and power, and members with exclusive access to information may dominate decision-making. When uncertainty and complexity increase these problems also increase, and the need arises for an integrating role to bring a global viewpoint into the decision process. The task of the integrators (typically called project, or product managers), is not to do the work, but to coordinate the decision-making process across the interdepartmental units. The influence of integrators may be based only on expert power or can be strengthened with formal authority as well (with control over the budget, participation in planning, and approval power on decisions). When the formal authority of the integrators becomes high, a dual authority system is established, and the organization becomes a *matrix*. In the matrix structure the integrating managers enter into the reward system in a legitimate manner, and have their own resources on a full time basis.

Organizational theories on cross-functional integration provide the following premises useful for this study: First, the uncertainty of the organizational environment and the task uncertainty and complexity create need for integration. Second, the greater the integration, the higher the performance of the organization. Third, means to increase integration are organizational and technological. Organizational means include teamwork and appropriate management systems necessary to make teams effective (incentives, decision-making authority, and inter-personal skills). Technological means refer to the use of information technology for information exchange and decision-making.

3.3.2 Integration in manufacturing

There is a large body of literature concerning the need for and benefits from integration in the manufacturing sector. Porter (1985) identifies the management of

linkages between activities in the production chain as a major source of sustainable competitive advantage. He argues that because the activities in the value chain are interdependent, the way one activity is performed affects the performance of other activities. By managing the linkages within its own value chain as well as between different value chains, a firm can both reduce its product costs, and increase its differentiation. For example it can change/simplify the way it performs some of its activities to facilitate the customers operations, thus increasing differentiation, or it can increase inspection by suppliers to eliminate inspection activities and quality problems in its own value chain. As shown in Figure 3-4, Leunberger (1988) argues that competitive advantage requires integration between marketing, engineering (R&D) and manufacturing.



In recent years there has been an increased emphasis on linking the design of new products and processes with cost, quality and efficiency. Concepts such as design for manufacturability (DFM), and design for assembly (DFA) have emerged. In manufacturing, cross-functional integration is now considered the cornerstone of concurrent engineering and successful new product development and competitive

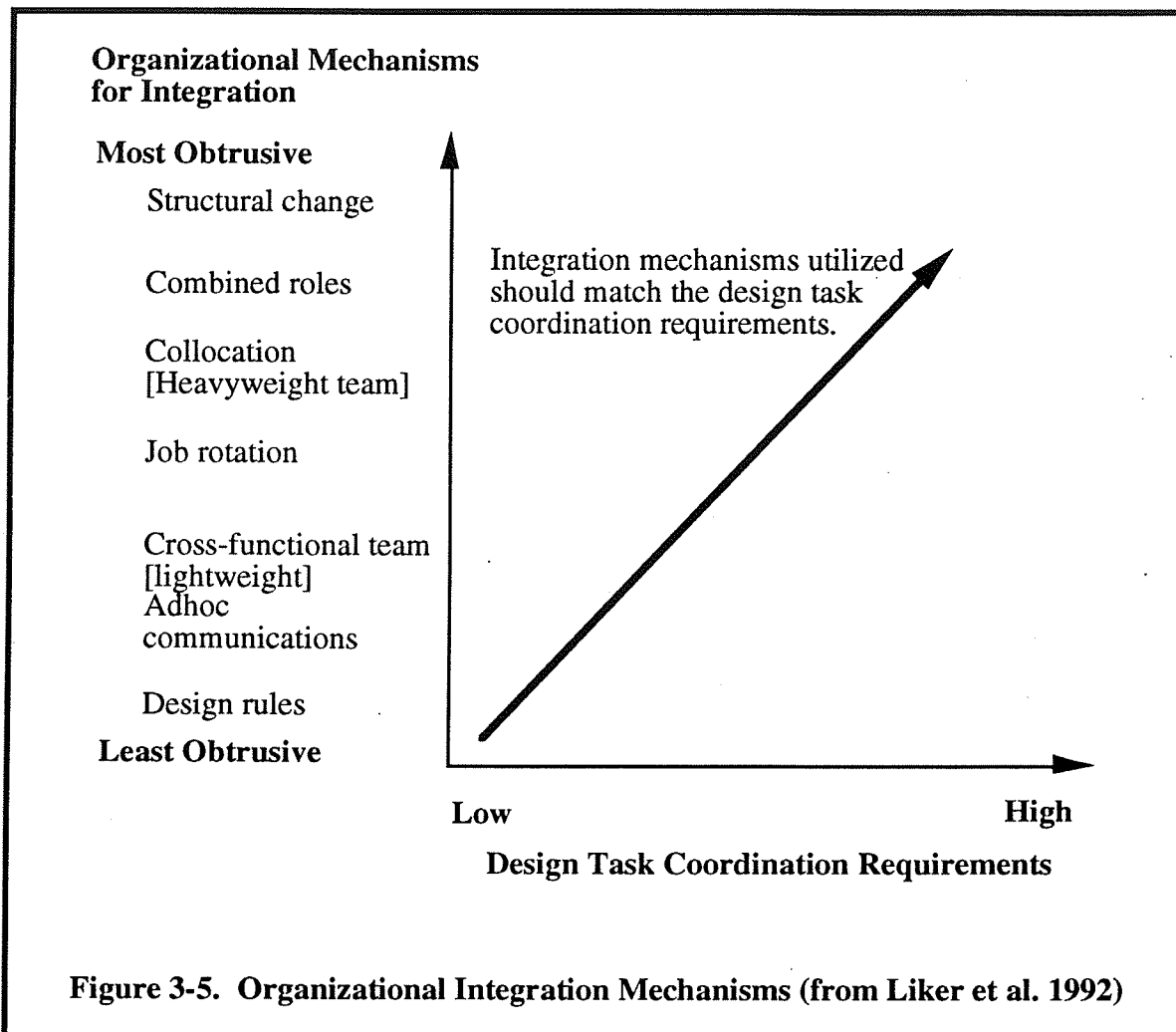
advantage (Hayes, Wheelwright and Clark 1988, Wheelwright and Clark 1992). Thus, integration determines both manufacturing costs and efficiency as well as cost of logistics, distribution and serviceability (Lee 1992).

Several researchers and practitioners have criticized the traditional process of new product development and called for increased integration. Whitney (1987) underlines the strategic importance of new product design, and the need to involve manufacturing in order to reduce time to market, and cost effectiveness. Anderson (1990), and Cleland (1991) argue that the "linear" development process is filled with engineering changes, delays and increased costs. Takeuchi and Nonaka (1985) identify the need for manufacturing organizations to abandon the old sequential approach to the development of new products, and use a holistic method with overlapping development phases and self-organizing project teams. Putnam (1985) argues that integration facilitates advanced thinking about product manufacturability, testability, and serviceability, and contributes significantly to getting the product right the first time. Finally, time to market has been identified as one of the most important benefits from integration.

The importance of structuring effective development teams to promote integration is stressed throughout the manufacturing literature. Dean and Sushman (1989) describe the use of a dedicated cross-functional team as an integrating mechanism. Takeuchi and Nonaka (1986) liken the integrated approach to product development to a rugby game where there is continuous interaction between the team members of a multi-disciplinary team. Consistent with the organizational literature, Takeuchi and Nonaka (1986) emphasize the importance of establishing an evaluation and reward system based on team performance, and an organizational environment and culture that promotes informal cooperation.

Wheelwright and Clark (1992) describe four types of teams for new product development: (1) functional teams, where the members stay at their functional departments; (2) "lightweight" teams, where the members perform their work at their department and coordinate through periodic meetings, and the project manager has a "liaison" role; (3) "heavyweight" teams where team members are collocated and the project manager has a strong integrating role with formal authority (matrix structure); and (4) autonomous teams, under the directions of a product manager. According to Wheelwright and Clark (1992), heavyweight team structures are particularly promising, yet absent in many large organizations. As shown in Figure 3-5, Liker et al. (1992)

identify the following organizational mechanisms for integration and argue that they need to match the coordination requirements of the design task. The mechanisms vary with respect to the organizational changes required from simple design rules (such as rules for manufacturability rules), to structural change and establishment of matrix or product oriented organization.

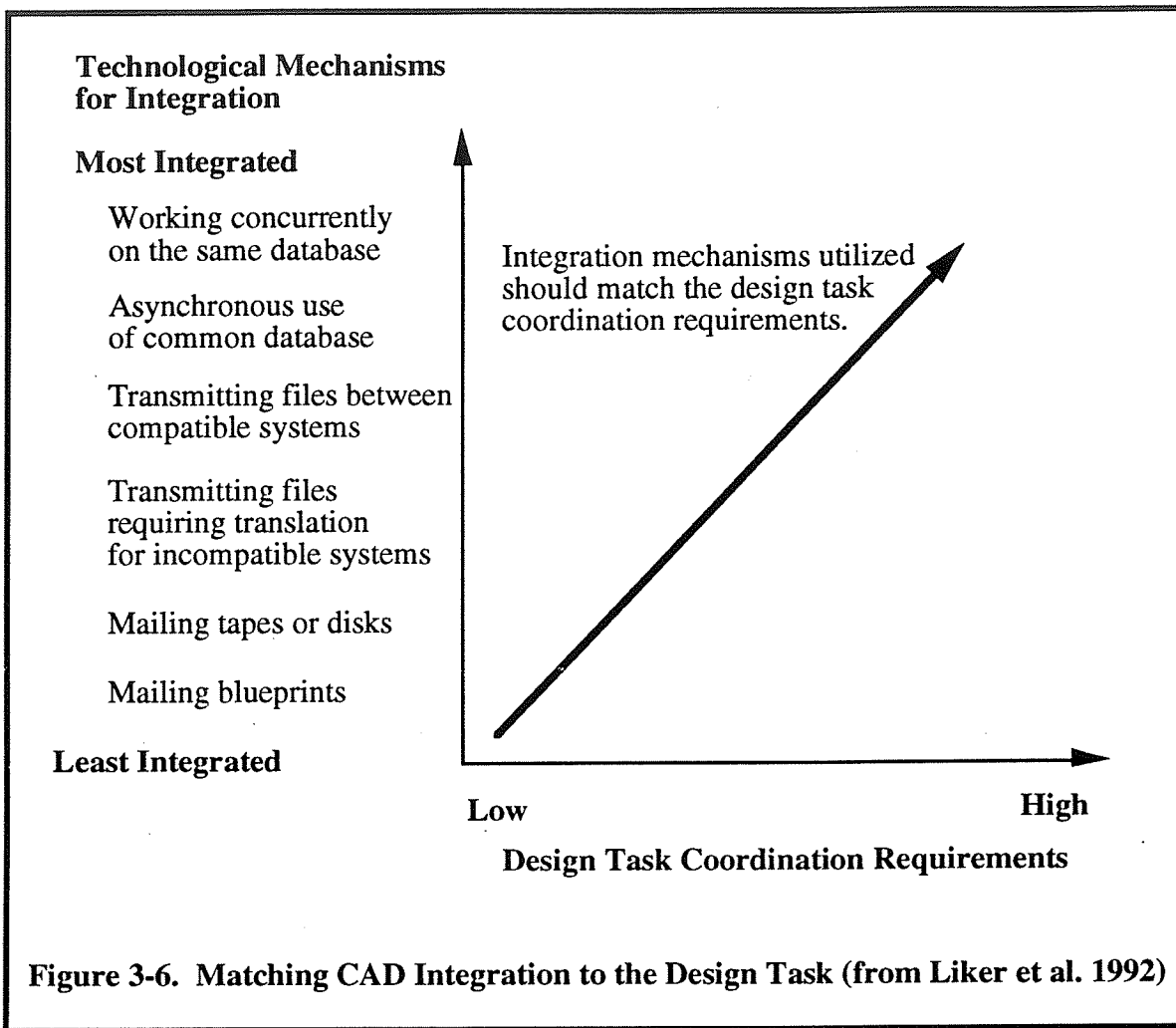


In addition to product and process engineers within the firm, the integrated development team interfaces closely with outside vendors and suppliers, as well as with distributors and customers. These interactions are critical for responsiveness to market changes, cycle-time reduction, and increased performance. Leuenberger (1986) sites the establishment of strong relations with materials and equipment suppliers as a key lesson Hewlet Packard learned during the development of Vectra PC. The changes in the

relationships with vendors are examined further in the section of inter-organizational integration.

Recent developments in computer systems have the potential to greatly improve and support integration. Advanced systems such as sophisticated databases, electronic interchange of data, and intelligent support for group interaction are under development. Wheelwright and Clark (1992) describe four generations of computer systems that progress from automating existing tasks to creating a fully integrated system for managing the product development process, and the information, data, and knowledge it requires. First generation systems address automation of functional tasks. Thus, designers work with a CAD system that allows examination of alternative designs. Similarly, manufacturing uses a CAM system that enables evaluation of alternative machining processes, and automated programming of machining tools. Finally, marketing uses its own database to access customer information on sales, models, warranties, and complaints. The systems however, do not communicate electronically; drawings and other documents have to flow between disciplines, and problem-solving *across departments* is difficult.

Second generation systems include interfaces and communication links between design and manufacturing. At this stage, marketing still communicates with paper, and while CAD/CAM apply to the current design, previous experience from marketing and manufacturing is not captured. Third generation systems link the databases between design, manufacturing and marketing and establish a common interface between them. The combined database tracks historical experience with the product, and provides tools for engineers and marketers to analyze the data and establish important interrelationships. The system also provides the ability to send and receive messages, and allows storage of notes, test results, etc. Fourth generation systems take integration one step further by using a network diagram to structure the relationships between design parameters and customer requirements. This allows engineering, manufacturing and marketing to work together as a team and define important parameters, attributes and interrelations. As shown in Figure 3-6, Liker et al. (1992) identify similar stages of CAD integration.



Today, despite the potential for improvement offered by information technology, the expected benefits have not been realized due to technical problems (such as problems in communication protocols between different systems) and organizational fragmentation (Liker et al. 1992). Table 3-1 reviews the organizational fragmentation barriers to CAD utilization.

**Table 3-1. Organizational Fragmentation Barriers to CAD Promises and Solutions
(from Liker et al. 1992)**

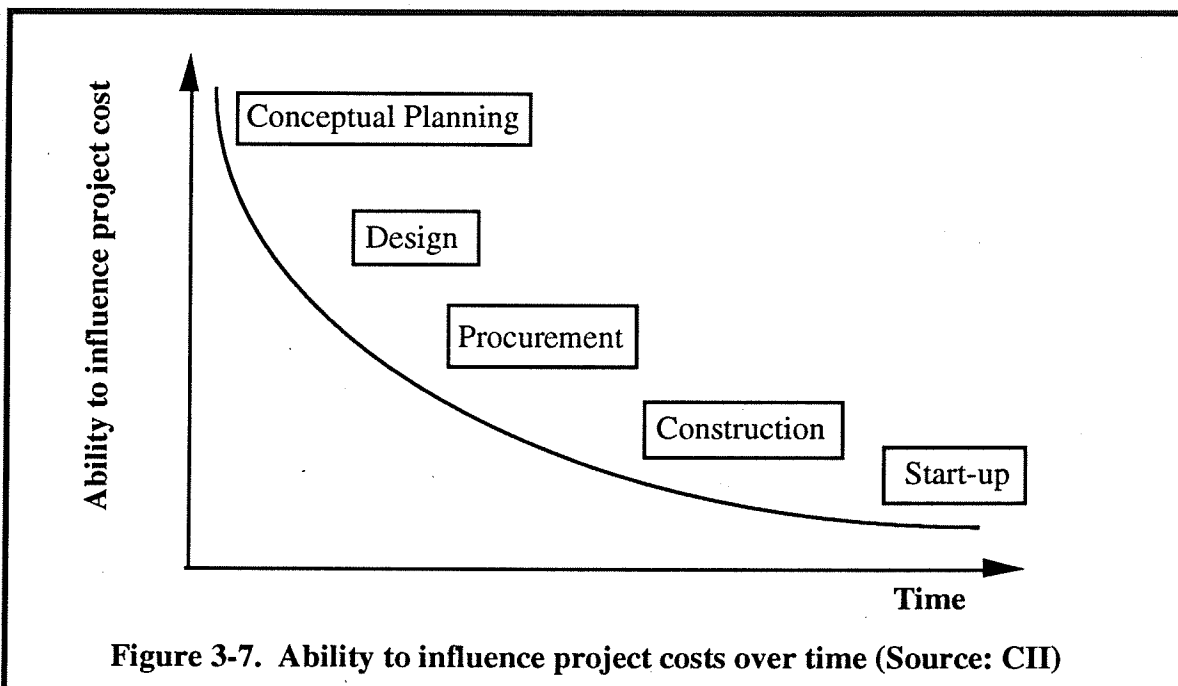
CAD Promise	Organizational Fragmentation Barrier	Integration Solution
Automation of routine tasks	Coordination needed to develop design standards and parametric design programs	Integrate across CAD users
Complete 3-D picture	Design engineers rarely use CAD	Better integrate jobs of design engineers and designers
	Designers threatened by engineers using 3-D	Better integrate jobs of design engineers and designers
	3-D design often overkill for the design task	Integrate design task and CAD use.
Integrated CAD/CAM	Brick wall between design and manufacturing	Integrate design and manufacturing
	Incompatibility of CAD with vendors who NC machine parts	Integrate vendors into process
	CAD designers do not understand the requirements of CAM	Integrate CAD and CAM users
Integrated CAD/CAE	Analysts use stand-alone CAE tools but don't use CAD	Better integrate jobs of CAE specialists and designers
	Design engineers trust physical models over abstract analysis results	Better integrate design engineers and CAE specialists
	Automatic mesh generation programs are inadequate	Better integrate CAD and CAE technologically
	CAE departments are understaffed and too slow	Increase staff capable of using CAE, and integrate it into the design process
Paperless design process	Suppliers and customers rarely have compatible CAD systems	Integrate customers and suppliers
	Protocols such as IGES are not very good	Develop better technology for integration of disparate CAD systems.
	CAD systems do not effectively support group work	Develop technology suited to groups at work

Manufacturing literature of cross-functional integration provides as with the following main points: First, integration during product design is critical for performance of new products in term of time-to-market, manufacturability and total life-cycle costs. Second, mechanisms to increase integration include cross-functional teams and information technology.

3.3.3 *Integration in construction*

Construction integration research has focused primarily on constructability improvement. Many construction researchers and practitioners have identified the importance of integration early in the design process. The Business Roundtable Construction Industry Cost Effectiveness Project (1982) concluded that the participation of construction experts in the conceptual development and planning of a project is essential for project cost effectiveness, as it enables more informed decisions, better scope definition, design customization to meet construction needs and constraints, and selection of design alternatives for least costly construction.

The Construction Industry Institute (CII) investigated ways to improve constructability during conceptual planning, detailed design, procurements, and field operations. As shown in Figure 3-7, the ability to influence costs is highest at the earlier stages .



Integration during conceptual planning is needed in order to: (1) identify the customer's requirements, (2) establish clear project objectives and scope, (3) identify the project context and the critical constraints and priorities that will guide decision-making and trade-offs, and (4) develop a project execution plan that considers the major construction methods. A critical issue during conceptual planning is integration within the owner's organization. As a recent study on industrial facilities quality reveals (Ferguson and Teicholz 1992), different sub-populations in the customer's organization have different requirements and needs, which may be conflicting.

Paulson (1976) identified the close relationship between expenditures and the impact of design decisions on the construction and operation costs of a facility. In recent years construction researchers and practitioners have identified the need for early involvement of construction ("Constructability: A Primer" 1986, Tatum 1987, 1990). CII ("Cost of Quality Deviations in Design and Construction" 1989) has found that only the direct costs of quality deviations in design and construction account for 12.4% of project costs (in industrial projects), and design inefficiencies are the major cause of such deviations. Thus, to prevent problems and subsequent changes, waste, rework and delays, the design needs to take into consideration the constraints and capabilities of downstream systems (i.e., vendors, procurement and construction).

Integration during construction is important for two reasons: (1) coordination of action, and (2) responsiveness for problem-solving. Coordination between designers, suppliers and owner's representatives is needed to improve the efficiency of the construction process by reducing delays (e.g. waiting for instructions and drawings, materials and components, or inspections). Responsiveness for problem-solving during task execution is unavoidable when task uncertainty is high at the beginning of the task. In a survey of 408 project managers Pinto (1990) found that planning (in terms of midcourse corrections) continues throughout construction and remains critical factor for project success. Integration during construction will result in increased responsiveness and ability to resolve unexpected problems fast and with high quality solutions, thus reduce both production costs as well as transaction costs through elimination of claims and disputes (Howell and Mitropoulos 1993).

The means for increasing integration within the project organization are organizational as well as technological. Organizationally, it involves the establishment of cross-functional teams with owner's, designer's, contractor's and vendor's representatives.

However, for effective teamwork, management must establish appropriate systems (such as incentive and reward systems, and procedures for effective decision-making), and the team members must have the necessary interpersonal skills, cooperative attitudes, and decision-making authority. The project environment, and the degree to which it supports cooperation is critical requirements for integration. Birrel (1981) reports that the relationships between the managers are so essential that many subcontractors do not assign a foreman until they know who will be the contractor's superintendent. The foreman's selection is then based on how well he has cooperated with the superintendent in the past. Nam and Tatum (1992) identify the long-term relations and professionalism of participants as important factors contributing to integration.

In recent years, two movements new to construction attempt to increase project success, and improve productivity through increasing integration: partnering, and total quality management (TQM). Partnering has focused on building effective teams between the project team members as the primary means to improve projects' performance. This allows fast identification and resolution of problems and prevents disputes (Cowan 1985, "Partnering: A Concept for Success" 1991). Senior management's support to establish cooperative climate, team-members' training in group skills and problem solving, and increased decision-making authority to site personnel are the essential attributes of partnering. However, these changes are not without cost and the front-end investment required for developing these capabilities may be an important barrier.

The recent TQM movement has led many organizations to focus on improving their business processes. According to the Construction Industry Institute (Total Quality Management: The Competitive Edge, 1990), a key to increased organizational performance and competitiveness is the improvement of those upstream processes that provide directives, information and resources to those involved in direct work. Thus, TQM focuses on improving the coordination between interdependent functions in order to better serve their "internal" and "external" customers and increase effectiveness and productivity.

Advanced computer tools provide a key opportunity for increased integration and a technological response to the fragmentation in AEC industry (Howard et al. 1989). Teicholz and Fisher (1992) define computer integrated construction (CIC) as a business process that links the project participants into a collaborative team through all phases of a project. Ideally, each team member should be able to share data with any other member

on a real-time basis. CIC technologies include relational databases, artificial intelligence applications for design and construction, and systems for dynamic simulations.

The improved coordination that CIC can offer can result in significant operational and strategic benefits (Tatum 1990, Teicholz and Fisher 1992). Rapid production of high quality design, fewer errors and field changes, and reduced waste and rework can significantly improve project quality, cost effectiveness and schedule. Competitive benefits for AEC firms include the ability to rapidly respond to changing customers' needs and offer new products, development of distinct competencies, and reduction of project life-cycle cost.

However, for effective implementation of CIC, the following requirements must be met. Cooperative business relations between the firms that participate in a project are essential; adversarial relationships and defensive attitudes impede the sharing of information across organizational boundaries. Integration of computer systems to permit construction input to design, and concurrent product and process development is currently a technological barrier. Finally, the development of electronic linkages with the customer and the operators of the facility is needed to provide the data required for operation and maintenance.

In a study of barriers to CAD in AEC industry, Mahoney et al. (1990) found that lack of trained people, lack of standards, and the cost of CAD systems are the biggest barriers for adoption of CAD in US and Japanese companies. Also, Russel and Teicholz (1993) found that the major barriers to electronic data exchange are the lack of neutral CAD file exchange standards, legal requirements for stamped and signed documents, uncertainty regarding the legal standing of electronic records, and a lack of technical knowledge.

Construction literature provides the following premises related to this study: First, the greater the integration during planning, design and construction, the greater will be the project performance (in terms of cost effectiveness, schedule performance, and lack of claims). Second, teamwork and information technology are the two mechanisms for increased integration. Factors that affect teamwork effectiveness include incentive and reward systems, decision-making authority to team members, inter-personal skills and cooperative working relationships between project participants. Information technology also provides the ability to share information and knowledge across functions.

In the previous section we reviewed the literature related to integration within an organization. As shown in Figure 3-8, this corresponds to integration of the different functions and participants at the level of a project organization. However, construction projects are temporary multi-organizations, as the functional specialists belong in different organizations and come together only for the duration of the project. It is therefore essential to examine the mechanisms that are used to manage the interdependencies between these organizations, as they have important implications for the ability to integrate the project organization.

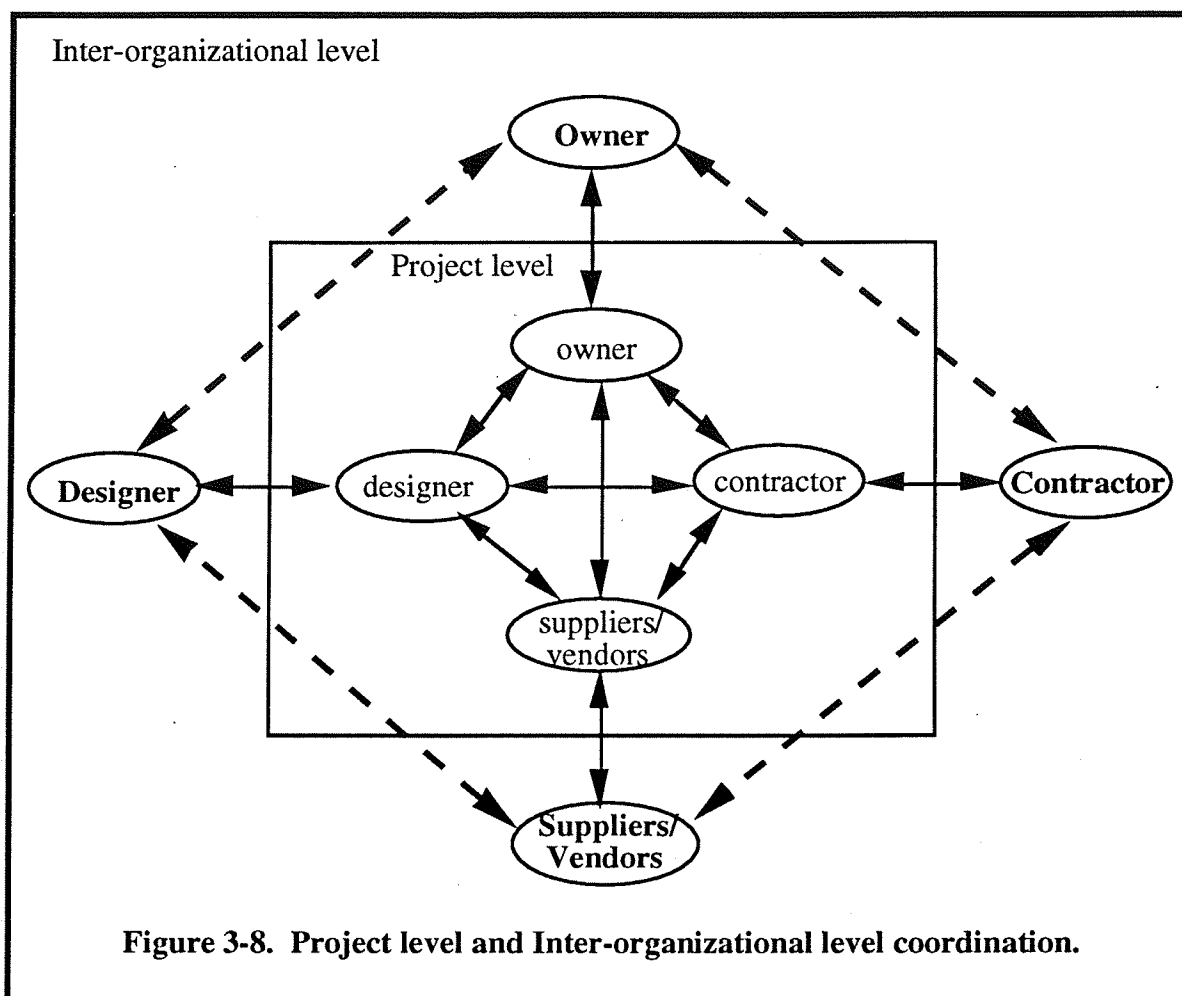


Figure 3-8. Project level and Inter-organizational level coordination.

The following sections present a review of organizational theories, as well as manufacturing and construction literature related to the means for inter-organizational integration, and the effectiveness of different approaches.

3.4 Inter-organizational integration

Markets and *Hierarchies* (formal organizations) are typically presented as the two poles for the allocation and control of resources. In *Markets*, resources are allocated through bargaining over prices, while formal organizations are based on authority relations. In recent years however, a proliferation in the variety and complexity of organizational forms has been observed in a number of industries. Many of these new forms (referred to as hybrid organizations, networks, quasi-firms, and value-adding partnerships) represent *strategic alliances* between organizations (Snow and Miles, 1984, 1986, 1992, Bryan and Jemison 1989, etc.). Strategic alliances are alternative ways to organize transactions and can take many different forms. In the following section, the organizational theories related to the inter-organizational relations, and the main mechanisms for organizing transactions (markets, hierarchies and strategic alliances) are reviewed.

3.4.1 Organizational behavior

Resource dependence and social ecology theories are first presented in order to identify the forms that inter-organizational integration can assume. Then, transaction cost economics and agency theory are reviewed in order to examine what governance structures are most efficient under specific circumstances in order to minimize the costs of the exchange between the parties.

Resource dependence theory

From a resource dependence perspective, Pfeffer and Salancik (1978) argue that the need to acquire resources creates interdependencies between organizations and external units. An organization's task environment is defined as those features of the environment relevant to the organization as a production system. This includes the sources of inputs, markets for outputs, competitors and regulators. Since no organization generates all the resources necessary for goal attainment, organizations are forced to enter into transactions. How important and how scarce these resources are determine the nature and extend of organizational dependence.

While all organizations are dependent on suppliers and customers, which partners are selected and the terms of the transaction are partly determined by the organization. Thus, managers will attempt to make arrangements to control critical resources, or at least reduce the uncertainty as to their availability. According to Scott (1992), one of the major contributions of the resource dependence perspective is to discern and describe the

strategies employed by organizations to change and adopt to their environment. Pfeffer and Salancik distinguish between two types of interdependencies: *symbiotic* interdependence, which occurs when two or more organizations differentiated from each other exchange resources, and *commensalistic*, or competitive interdependence that occurs when organizations compete for the same resources. Methods that the organizations use to protect from or influence their environment include buffering and bridging techniques (Pfeffer and Salancik 1978).

Buffering techniques focus primarily on protecting the organization from changes in the environment, while bridging increases the coordination with other organizations. As Pfeffer and Salancik state (1978, p.43): "the typical solution to problems of interdependence and uncertainty involves increased coordination which means increasing the mutual control over each other's activities". The primary bridging techniques include the following:

Contracting is the most common technique used for exchange and coordination between different organizations. Contracting is defined as "the negotiation of an agreement for the exchange of performances in the future" (Thompson 1967, p.35). As we shall see later, transaction cost theory argues that there are limits to how much uncertainty can be handled by contracts.

Mergers and acquisitions. The most drastic strategy used by organizations in relating to critical units of their environment is to absorb these units placing them under a single hierarchy.

Joint ventures are formed when two or more firms create a new organization to pursue some common purpose.

Hierarchical contracting (Stinchcombe 1985) is a coordinating mechanism that combines some of the "arm's length" features of contracts with other control features usually associated with authority relations.

Cooptation is the incorporation of representatives of external groups into the decision-making, or advisory structure of the organization, typically in the Board of Directors. *Associations* are arrangements to allow similar organizations to work in concert to pursue mutually desired objectives. Finally, organizations develop *government connections* as an attempt to influence the policies that affect them.

Davis et al. (1990) argue that depending on the extent and importance of the symbiotic interdependence involved, the mechanisms employed range from short-term contracts to vertical mergers (ownership). Until recently, the stronger and most effective

ties were considered those based on ownership. In recent years, however, many organizations have entered into alliances that do not entail change of ownership, and organization theorists have begun to recognize the importance of networks, or hybrid organizations.

Social ecology

The Social Ecology approach makes arguments similar to the resource dependence perspective and emphasizes the dynamics of multiple interacting populations in total communities, which collectively are able to attain a measure of independence and protection from the environment (Astley and Fombrun 1983). The theory responds to population ecology which argues that, at the macro level, historical, political, economic and social factors determine the fate of whole populations of organizations, and the actions of single organizations count for little in the long-run course of events. However, according to social ecology theory, organizations can increase the probability of their survival by responding to environmental change collectively rather than individually.

Drawing an analogy from bioecology, Astley and Fombrun (1983) identify two basic ways of adapting to the environment: *individual* adaptation and *communal* adaptation. Communal adaptation occurs when a specific form of organization is adopted across individual units so that the aggregate of individuals becomes transformed into a collectivity with some degree of unit character. Communal adaptations are of two kinds: *commensalistic*, exhibited in competitive interaction) and *symbiotic*, where organisms make dissimilar demands on the environment. Under symbiosis, different organizations can supplement the efforts of one another, thus becoming mutually interdependent. Thus, organizations can reduce their dependence on the environment by increasing their dependence on other organizations. This theory explains the development of long-term strategic alliances between organizations in the value-chain. This type of alliance is becoming more common.

Strategic alliances

Strategic alliances, often referred to as hybrid organizations, networks, quasi-firms, and value-adding partnerships) are alternative ways to organize transactions, and have a variety of purposes and take many different forms (Snow and Miles, 1984, 1986, 1992, Borys and Jemison 1989, etc.). Borys and Jemison (1987a, 1987b, 1989) define hybrids as "organizational arrangements that use resources and/or governance structures from more than one existing organization". This definition encompasses a broad range of

organizational combinations of various sizes, shapes and purposes, some of which are formalized organizations, while others are informal long-term relations between separate organizations, as both the motivation for collaboration and the organizational form vary widely. Borys and Jemison (1987a, 1987b) identify eight types of hybrids: mergers, acquisitions, equity alliances, joint ventures, technology transfer agreements, license agreements, marketing and purchasing agreements. The first four involve the development of [semi-] independent organizations, while the other four types involve less formal arrangements between the parent organizations.

Strategic alliances enable firms to undertake activities that are beyond the scope of their existing capabilities or risk profiles (Powell 1987). Such activities yield benefits from technological, and operational synergies. Organizations related by industry, product, technology, or geography, can employ hybrids to gain rapid access to markets, new technologies, or other complementary assets. Related firms may also create synergies from economies of scale by merging their production capacity. Another type of synergy may be captured by two organizations with complementary skills (e.g. a production-oriented firm may combine with a marketing-oriented firm) or complementary technologies (e.g. a software and hardware-oriented firm).

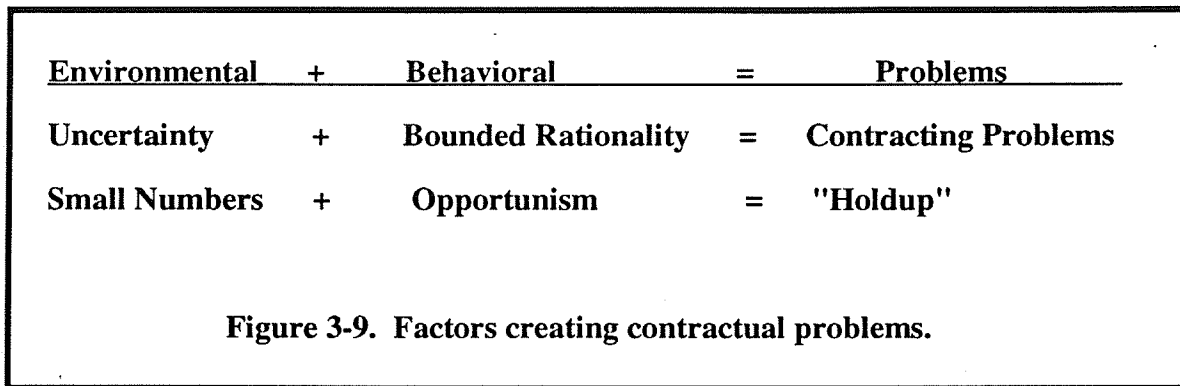
Strategic alliances however, are not a new phenomenon. Powell (1987) observes their existence in several craft industries such as construction, textiles and publishing, as well as in hi-tech industries such as computers, semiconductors and biotechnology. The need for better adaptability to changing markets, the limits of the large organizations, the diffusion of sources of know-how and the need for fast access to such knowledge, and the powerful role played by reciprocity and reputation are the primary factors identified by Powell to account for the proliferation of hybrids. Reputation, trust, and "tacit collusion" characterize these forms (Thorelli 1986, Powell 1987). A long-term perspective is the cornerstone of such networks, as it enables more give-and-take, and because stability and security in the relationship encourage the search for new ways to do the task.

The primary research question that arises is *what governance structures are most efficient under specific circumstances in order to minimize the transaction costs of the exchange between the parties?* Agency and transaction costs theories address this issue, and are examined below.

Transaction costs theory

The contract is the formal governance structure of exchange transactions between organizations. The contract is "...a promise or a set of promises for the breach of which the law gives a remedy, or the performance of which the law in some way recognizes as a duty" (McNeil 1974, p.693). Classical contracting corresponds to the ideal market transaction where: 1) the nature of the agreement is carefully defined and limited with formal administration governing the transaction, 2) all relevant future contingencies pertaining to the supply of a good or a service are described, and remedies are prescribed for a party's failure to perform as promised, and 3) the parties identities and relations are irrelevant (Williamson 1979).

However, classical contracting is inappropriate for long-term transactions executed under conditions of uncertainty. As shown in Figure 3-9, Williamson's framework of Market Failures (1975) explains how the combination of two sets of environmental and behavioral factors leads to contractual problems and the risk of one or another party being "held up".



First, due to bounded rationality -- the limited capabilities of the human mind and language-- not all potential contingencies can be anticipated. Gaps remain in contracts as uncertainty makes impossible or prohibitively costly to write, execute and enforce complete full contingent claims contracts. Second, the appropriate adaptations for many contingencies and their cost are not evident until the situation materializes. Finally, the impossibility of complete communication between people makes elimination of ambiguity impossible (McNeil 1974), and hard contracting gives rise to argument over the truth if changes are ambiguous (Williamson 1979). Since gaps in contracts are unavoidable, a mechanism is needed to govern contract adaptations to the evolving circumstances.

In the absence of opportunism, the gaps would be filled in an adaptive sequential way (Williamson 1979). However, when the transaction involves high degree of asset specificity, "small number" situations occur where either party has great power to bargain over the disposition of any gains whenever a proposal to adapt the contract is made by the other party (Williamson 1979). In such situations, although both parties have a long-term interest in effective adaptations of a joint profit maximizing kind (integrative bargaining) they also have an interest in appropriating as much of the gain as they can (distributive bargaining) on each occasion. Thus, an excessively opportunistic party can exploit or "holdup" the other in order to maximize their own gains.

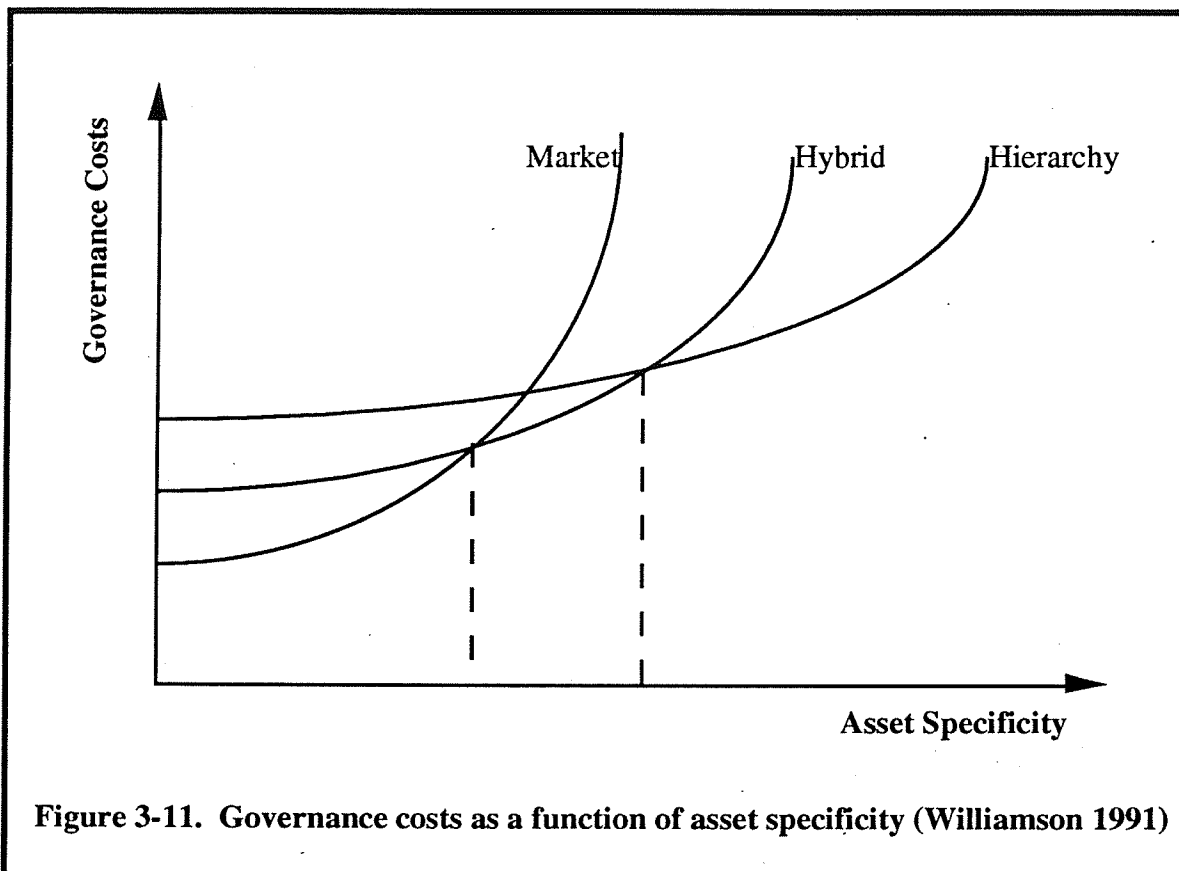
Transaction cost theory focuses primarily on asset specificity, transaction frequency and uncertainty as the determinants of what governance structure is required (Williamson 1979). As shown in Figure 3-10, an idiosyncratic occasional transaction (e.g. construction of a plant) which does not justify internalization, requires a trilateral governance structure, with a third party as arbitrator to provide assistance in resolving disputes.

		Investment characteristics		
		Nonspecific	Mixed	Idiosyncratic
Frequency	Occasional	Market Governance (Classical Contracting)	Trilateral Governance (Neoclassical Contracting)	
	Recurrent		Bilateral Governance (Relational Contracting)	
			Unified Governance	

Figure 3-10. Matching governance structures with commercial transactions (Williamson 1979).

A more effective way would be to increase the parties ability to reach mutual follow-on agreement. For this, two things are critical: 1) an agreement on admissible dimensions for adjustments such that flexibility is provided under terms that both parties have confidence; and 2) the spirit within which these adaptations are effected. Thus, the relations between the parties are critical in order to promote cooperative behavior.

In a comparative analysis of different structural alternatives, Williamson (1991) compares markets, hierarchies and hybrids with respect to their transaction-cost effectiveness for different task characteristics. As shown in Figure 3-11, when asset specificity is low, the market is the most effective mechanisms for fast response. However, when asset specificity becomes high, disturbances require more coordination, and the hybrid mode is most effective for medium asset specificity.



According to Williamson, the different contract law, incentive intensity, the effect of reputation, coordination instruments, and administrative controls affect the cost effectiveness of the three governance structures in responding to unanticipated disturbances.

Agency theory

Agency theory deals primarily with the question of how to design appropriate incentive systems (contracts). Agency theory is concerned with resolving two problems that can occur in an agency relationship (Eisenhardt 1989). The first is the agency problem that arises when (a) the goals of the principal and the agent are in conflict, and (b) it is difficult or expensive for the principal to verify the behavior of the agent. The second is the problem of risk sharing which arises when the task is uncertain and the principal and agent have different risk preferences. The simple model assumes risk-averse agent and goal conflict, and the theory focuses on the *task characteristics* (uncertainty and measurability), as well as *the parties characteristics* (goal incongruence and attitudes towards risk) in order to identify if outcome-based or behavior-based contracts are most efficient for a specific situation. Agency theory has many similarities with the transaction cost perspective, as they both assume self-interest and bounded rationality, and the outcome-based contracts correspond to markets, while behavior-based contracts correspond to hierarchies. Outcome uncertainty is also a common variable.

The heart of the agency theory is the trade-off between (a) the cost of measuring behavior (which increases with task complexity and uncertainty, and goal conflict), and (b) the cost of transferring the risk to the agent and measuring outcomes (which increases with task uncertainty and risk aversion of the agent). Outcome-based contracts are considered better in aligning the agent's and principal's goals. However, if task uncertainty is high, the cost of shifting the risk to the agent becomes high, and behavior-based contracts may be more efficient, depending on the cost of monitoring the agent's behavior. In turn, this cost depends on the parties' *goal congruence and long-term relations* that make it easier or unnecessary to monitor the agent's behavior.

One "solution proposed by the agency theory is to relax the assumption of goal conflict, so that the need (and the costs) of monitoring behavior are reduced. This corresponds to Ouchi's proposition that under conditions of uncertainty and performance ambiguity hierarchies fail, and a different governance structure based on goal congruence ("clan culture") is required (Ouchi 1980). At this point it is important to note that goal congruence does not mean that the parties have the same goal, but that they can accomplish their goals simultaneously. Development of long-term relations based on trust is one effective response to the problem (Eisenhardt 1989, Powell 1987, Eccles 1981). In these cases the governance structure can be characterized as "relational contracting" (Williamson 1979, McNeil 1974).

This review of organizational theories identified the following issues related to this research: First, increased pressures from the environment create the need for stronger coordination between interdependent organizations. The higher the environmental uncertainty, the greater is the need for coordination. Second, mechanisms for integration at the inter-organizational level include contractual arrangements that align the incentives of project participants, and development of long-term relations between firms. Contractual relations affect the project participants motivation to coordinate their actions and resolve problems due to uncertainty. Inter-organizational relations facilitate integration as they develop trust and goal congruence between organizations.

3.4.2 Inter-organizational relations in manufacturing

Child (1987) identified three major risks that large organizations face under current competitive conditions: 1) demand risk, 2) innovation risk, and 3) efficiency risk. *Demand risk* is the risk of sharply fluctuating demand or even the collapse of the markets. Fluctuations in demand require firms to be flexible and able to adapt. *Efficiency risk* is the failure to match competitors unit costs. This requires increased control on operations, and greater coordination both within the firm as well as with external organizations across the value-chain. *Innovation risk* is the potential of failure to match competitors' innovations in a context of accelerated technological change. Increasing the organization's innovative capabilities requires access to sources of concepts and ideas, integration of the specialists responsible for the different technologies involved in a product, and organizational flexibility to support new and evolving product specification. Furthermore, commercialization of new products may require access to new production capabilities as well as new markets, and channels.

Teece (1992), also argues that inter-organizational cooperation is essential for effective innovation because of the diffusion of the technologies which need to be combined for the development of an innovation, and the large number of parties that participate in the entire production chain (from suppliers to customers). Thus, the scale and scope of assets needed to identify, develop and commercialize a new technology typically lies beyond the capabilities of one firm.

The above factors significantly increase the information processing requirements posed on the organization, and require changes in the organizational arrangements between firms (Child 1987), and increased utilization of information technology for coordination between organizations.

In recent years, a proliferation of strategic alliances has occurred in European and US businesses. Such alliances link together independently owned specialized assets along the value-adding chain (suppliers, manufacturers, market channels, and customers), and pose characteristics similar to the Japanese *keiretsu* - an organizational network based on cooperation and mutual shareholding among a group of manufacturers, suppliers, and financing companies (*Learning from Japan*, 1992).

Powell (1987) observes that because of the erosion of their profits and market share, U.S. automakers have chosen to sacrifice some of their bargaining power vis-a-vis suppliers in order to get more innovative products and faster response to market needs. Helper (1984) reports increasing length of suppliers contracts from one year to three to five years, more joint design work between manufacturers and suppliers, sole sourcing arrangements rather than cut-throat competition, and cooperation to reduce defects in the suppliers' products. Thus, instead of inspecting every piece supplied to them, the automakers have almost eliminated inspection, yet defect rates are much reduced. These new collaborative arrangements involve less monitoring, but are more flexible and adaptive. However, before they enter into such arrangements, the automakers decide which suppliers are worth investing in a long-term relationship, and which components can be obtained on the basis of price rather than quality.

Johnston and Lawrence (1988) refer to the "value-added partnership" (VAP) as a set of independent companies that work closely together to manage the flow of goods and services along the entire value-added chain, and pay particular attention to the role of information technology in inter-organizational coordination. As shown in Table 3-2, new computer tools provide a significant potential for increased coordination across organizational boundaries, and between hierarchical levels.

Table 3-2. New technological tools help create VAPs (Johnston and Lawrence 1988)

Tools	Implications
Minicomputers and PCs; user friendly languages; inexpensive, general purpose software packages	Drastically improves the economics of small scale, providing wider access to information power to include the smallest organizations and the lowest organizational levels.
Data standards; bar codes	Enable rapid, inexpensive, accurate capture and use of information in electronic form, lowering transaction costs between firms.
Information networking capability	Permits instantaneous sharing of information between organizations with shared interests, thus increasing speed and economy of coordinated response to market changes.
Computer-aided design	Improves speed and economy of response to customer needs by improving coordination between organizations in design functions.
Computer-aided manufacturing	Permits use of just-in-time practices between organizations.

Manufacturing literature offers two premises related this study: First, increased pressures from the competitive environment lead organizations to developing stronger relationships with other organizations in the value chain. Second, mechanisms for inter-organizational integration include strategic alliances and long-term contractual arrangements, as well as increased utilization of information technology for exchange of information between firms.

3.4.3 Inter-organizational integration in construction

Construction projects involve a large number of different parties, each with its own objectives. Their participation is governed by a contract, which determines the exchange of construction materials and services for money. The contract provides the formal governance structure and determines roles and responsibilities, the incentive and reward system, and the basis for adaptation of the agreement in the face of uncertainty. However, the uncertainty and "small numbers" situations that are present in construction projects create significant contractual problems.

Uncertainty means that projects cannot be completely planned before they begin. Stinchcombe (1985) identified the following sources of uncertainty: uncertainties of the client about what it will want, uncertainties of specifications, technical and cost uncertainties, environment, client ignorance, commercial and legal uncertainties in the client-contractor relations, uncertainty due to interdependencies, and problems of observability of contractor defaults, so that without continuous intervention the client does not know whether the contract performance has been delivered or not. Furthermore, a construction project is an "idiosyncratic transaction of bilateral monopoly". This means that once a project begins, the owner's ability to turn to other contractors, and the contractor's ability to turn to sell his product to other owner is limited and costly (if not impossible).

In construction two basic types of contracts are used: fixed price and cost reimbursable (Ashley 1989). Under a fixed price contract, the contractor agrees to perform the work for a stipulated sum and assumes the risk of any impact that uncertainty may have on the project. There are five major variations of fixed price contracts: (1) lump sum or "hard money contracts"; (2) unit price contracts, where payment is based on units of work actually completed, with unit costs and estimated quantities specified; (3) fixed price contracts with escalation provisions, where price adjustments are permitted on cost of certain materials, labor or other factors beyond the contractor's control; (4) fixed price contracts with a bonus or penalty adherence to scheduling; and (5) guaranteed maximum contracts, which contain a price ceiling and penalty or bonus for cost over / under-runs.

There are also five major variations of cost reimbursable contracts: (1) percentage fee contracts, where the contractor is reimbursed for costs and a percentage of costs; (2) fixed fee contracts, in which the contractor is reimbursed for cost plus a stipulated fee to cover administrative expenses and profit; (3) incentive fee contracts, where the contractor is reimbursed for costs plus an incentives fee for achieving certain cost or schedule goals; (4) performance fee contracts, where the fee varies according to agreed upon criteria on which the contractor's performance is rated; and (5) conversion contracts, where a reimbursable contract may be converted to a fixed price or guaranteed maximum contract.

Traditional fixed-price contracts prevent high degree of integration by separating product and process design (Nam and Tatum 1992) and limit contractor's and suppliers'

input to the design. Moreover, the contractual focus on risk and responsibility allocation reduces the incentives for cooperation and integration. Finally, contractual inequity (real or perceived) has significant negative effect on parties working relations, thus reducing integration (Ibbs and Ashley 1987). Contractual arrangements that support integration include design-build, and build-operate-transfer (BOT) contracts. Such contracts allocate the task of designing and constructing the facility to a single organization which may have in-house design capabilities, or can select its partners. In such cases, there is significant potential for integration between all participants, but the actual integration depends on the degree of cross-functional integration, as examined earlier.

Development of long-term relation between owners, engineers, contractors and suppliers, which are based on trust and reputation are often utilized as complementary to contractual agreements. In a study of the relations between contractors and sub-contractors, Eccles (1981a) characterized the "quasi-firm" as the primary governance structure used in the construction industry. The "quasi-firm" is a network of firms based on long-term relations that includes the prime contractor and special trade subcontractors, and enables firms to gain the benefits of market, bilateral and unified governance structures. Understanding the importance of the site organizations, contractors tend to see the contractual arrangements as more ephemeral and less consequential for the success of the project than this informal organization that controls the work on site. As trust and ability to solve problems in a cooperative manner become critical, contractors tend to develop stable and continuous relations with their subcontractors over a long period of time (Birrell 1981, Powell 1987). Finally, Nam and Tatum (1992) in a study of construction innovations have identified long-term relations, and owner's involvement and leadership, as important non-contractual means of integration.

From the construction literature, the following points are identified: First, the formal contractual arrangements affect the participants goal congruence and integration capability. Second, development of informal long-term relations is important for integration, as it enables project participants to work together effectively.

Table 3-3 summarizes the observations from the literature review and focuses on the issues related to this study.

Table 3-3. Summary of key observations derived from literature review.

Integration literature (Level and source)	Key observations
Intra-organizational level - organizational theory	<ol style="list-style-type: none"> 1. Environmental uncertainty increases need for integration. 2. Task uncertainty and complexity increase need for integration. 3. Increased task integration results in higher performance. 4. Mechanisms for increased integration include organizational means (lateral relations) and information technology. 5. The effectiveness of lateral relations depends on: <ul style="list-style-type: none"> - incentive and reward system - decision-making authority - inter-personal skills - integrator's skills
Intra-organizational level - manufacturing literature	<ol style="list-style-type: none"> 1. Integration during new product development is critical for product success and competitiveness. 2. Mechanisms to increase integration include organizational means (cross-functional teams) and information technology. 3. The effectiveness of product development teams depends on: <ul style="list-style-type: none"> - incentive and reward system - decision-making authority - integrator's skills - organizational environment supporting cooperation
Intra-organizational level - construction literature	<ol style="list-style-type: none"> 1. Integration during planning, design and construction is essential for project performance. 2. Mechanisms to increase integration include organizational means (teamwork) and information technology. 3. Teamwork effectiveness depends on: <ul style="list-style-type: none"> - incentive and reward system - decision-making authority - inter-personal skills - informal relations and environment supporting cooperation - project manager's skills
Inter-organizational level - organizational theory	<ol style="list-style-type: none"> 1. Pressures from competitive environment require increased coordination between organizations. 2. Inter-organizational integration is more likely to be developed with firms that control critical or highly specific resources. 3. Mechanisms for inter-organizational integration are formal (contracts) and informal (long-term relations based on trust). 4. Contractual arrangements affect integration through incentives. 5. Informal relations support integration through increased goal congruence.

Table 3-3 (continued) Summary of key observations derived from literature review.

Integration literature (Level and source)	Key observations
Inter-organizational level - manufacturing literature	<ol style="list-style-type: none"> 1. Increased competitive pressures create need for greater coordination between organizations. 2. Mechanisms to increase integration include formal arrangements, informal relations and information technology. 3. Formal arrangements include strategic alliances, joint ventures, and changes in procurement policies. 4. Informal relations are based on long-term cooperation and trust. 5. Information technology provides opportunities for increased integration between different organizations.
Inter-organizational level - construction literature	<ol style="list-style-type: none"> 1. Contractual arrangements affect integration as they determine the participants' incentives. 2. Long-term relations between organizations increase goal congruence between project participants and integration.

Based on these observations the following section develops a model of integration for construction projects and organizations. The model is based on the propositions identified from the literature review concerning the importance of integration for project and firm performance. It provides the basis for data collection.

3.5 Model of integration at the firm and project level

This section describes a model of integration developed based on the literature review. This model identifies the importance of integration for firm and project performance, and the factors that determine the effectiveness of integration. As illustrated in Figure 3-12, the model identifies the factors creating the need for integration and the benefits for construction projects. Based on the literature, the model also identifies the organizational and technological means for integration, and the actions that senior management can take to increase integration.

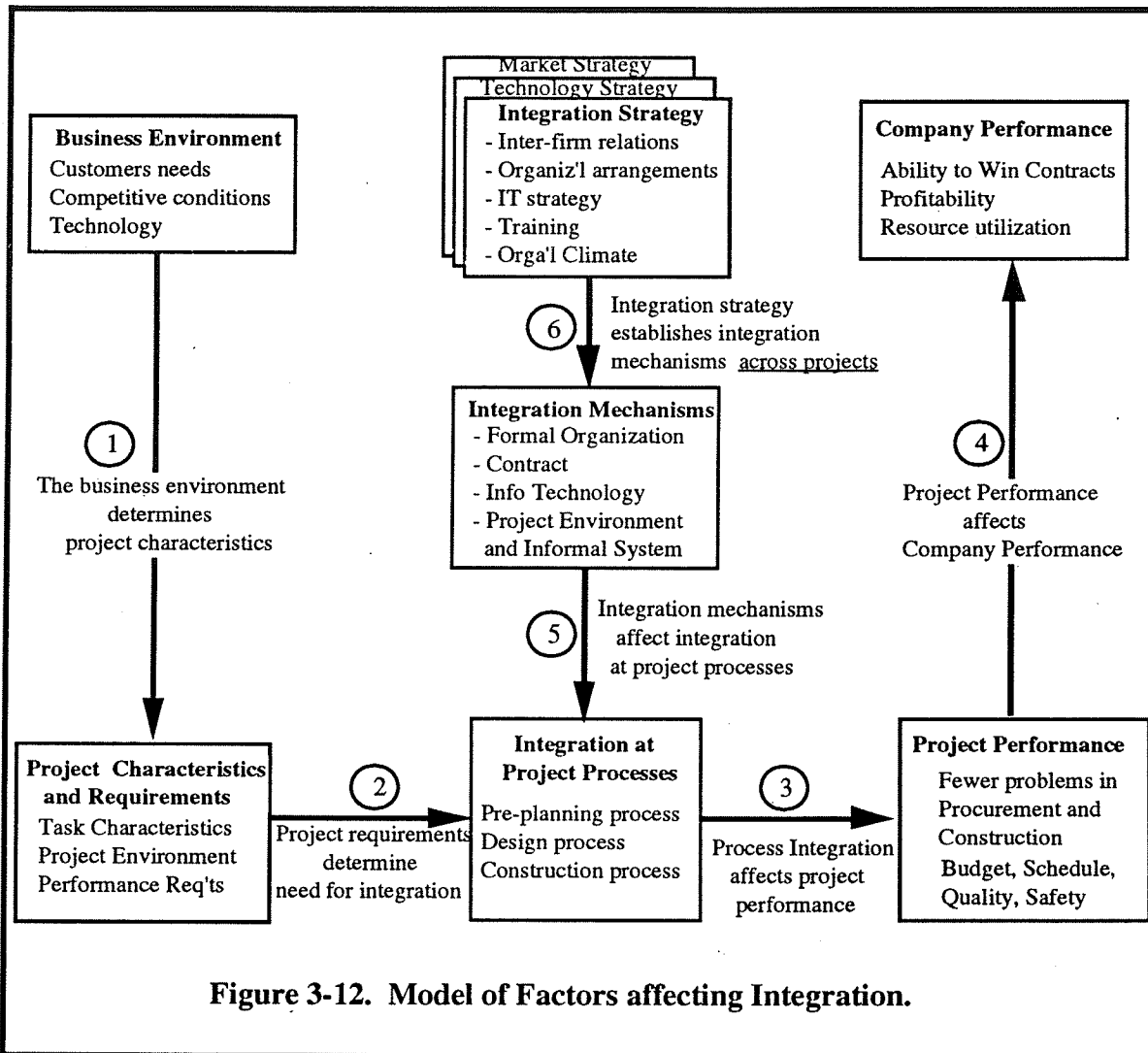


Figure 3-12. Model of Factors affecting Integration.

3.5.1 Business environment and implications for project characteristics

The first proposition of the model addresses the needs for integration. As shown in Figure 3-12, the conditions in the business environment (changing customer needs, competitive conditions, environmental concerns, and technology) pose new requirements on construction organizations. As a result, projects become more complex and their environment more hostile, while the performance requirements related to cost and schedule increase.

3.5.2 Project characteristics creating need for integration

The second proposition of the model refers to the need for integration at the project level. As project uncertainty, complexity and performance requirements increase, and the need for integration during project design, planning and execution increases. The degree of task uncertainty is determined by the following factors:

Task characteristics. Project size and complexity determine the number of different components and their interdependencies as well as the number of different participants and resources to be coordinated.

Project environment. Environmental hostility and dynamism increase task uncertainty.

Performance requirements. Task uncertainty increases with increased performance requirements (e.g. speed of task execution).

Task uncertainty reduces the effectiveness of the plans and requires more decision-making during task execution. However, all projects do not have the same need for integration; thus, the need for integration is lower for simple projects that involve small complexity and well understood methods and technologies.

3.5.3 Process integration and project performance

Operational benefits from integration fall into two categories. The first is avoidance of problems that result due to lack of integration, such as extensive changes, rework, delays and claims. The benefits from integration, however, go beyond prevention of problems, and include increased ability to understand owner's needs and to identify the best alternative design and methods to meet these needs.

3.5.4 Project performance and implications for company performance

Projects' performance is critical for overall company's performance. Reducing the time of facility development and increasing efficiency and effectiveness are critical determinants for competitiveness, as they increase the company's reputation, efficiency

and utilization of resources thus increasing the firm's profitability, asset turnover, and ability to win more contracts.

3.5.5 Mechanisms for integration

From the literature review the following four sets of factors are identified as affecting the effectiveness of integration at the project level:

1. contractual arrangements,
2. formal organizational arrangements
3. project climate and informal organization
4. information technology

Contractual Arrangements.

As noted earlier, the contract is a primary mechanism determining the parties' formal relationships within the specific project. It provides the formal governance structure and determines roles and responsibilities, the incentive and reward system, and the basis for adaptation of the agreement in the face of uncertainty, and it has significant impact on the participants behavior with respect to integration.

Traditional fixed-price contracts reduce or prevent integration by separating product and process design. Contractor's and suppliers design input is limited in design reviews and value engineering proposals. However, the degree to which this occurs depends on the incentives and costs of this mechanism. The contractual focus on risk and responsibility allocation may reduce the incentives for cooperation when problems arise. Although contractual arrangements can facilitate integration, they are not sufficient for achieving high degree of integration. They need to be supplemented with appropriate organizational arrangements, use of information technology and a cooperative project environment.

Formal organizational arrangements.

The formal arrangements determine how the parties work together and coordinate their actions. Organizational arrangements include the formal processes for coordination and decision-making, the incentive and reward system, and conflict resolution processes. Team building and group decision-making processes are considered essential elements of integration in both manufacturing and construction. Moreover, to increase the effectiveness of the decision-making teams the following requirements must be met:

- a. the teams must have decision-making authority

- b. the teams must have effective conflict resolution practices
- c. team-members must have interpersonal and negotiation skills
- d. project managers must have cross-functional experience and a global perspective
- e. the physical arrangements must facilitate information exchange and cooperation (e.g., collocation of teams).

Information Technology

The significance and potential of information technology for integration has been identified by several researchers. Telecommunication and computer tools can provide significant improvements in both the design and construction phases through automation of structured tasks, decision-making assistance in complex tasks, and enhanced communication between specialists. CAD systems have the potential of improving the design process in the following ways: automation of routine design task, storage and retrieval of previous designs with the use of Databases, 3-D views, design reviews for interference checking, CAD to CAE data communication, data communication from CAD to construction applications, accurate and rapid quantity take-off, and communication with customer. Electronic data exchange can facilitate communications and coordination of the participants during construction, and facilitate transactions.

Project Climate and Informal Organization

The uncertainty surrounding construction projects requires goal congruence and increased informal communication for timely identification and resolution of problems. Good relations promote cooperative behavior and increase the organization's ability to solve problems and resolve conflicts thus reducing both production and transaction costs. A project environment that supports cooperation, teamwork and learning has been identified as a necessary requirement in both manufacturing and construction. Organizations with long-term relations and good previous experience are more integrated as goal congruence is higher, and shared norms and culture facilitate cooperation.

3.5.6 Integration strategy

The ultimate purpose of strategic management is to develop organizational capabilities that are difficult for competitors to match over the long-run (Hays, Wheelwright and Clark 1988). The ability to increase integration in the value-chain (including integration within the organization and with the other organizations that influence the firm's performance) is an important source of competitive advantage.

The actions that management can take at the company level to increase integration fall into the following five areas:

1. strategic alliances with owners, designers and suppliers
2. formal organizational arrangements
3. cooperative organizational environment
4. investment in information technology, and
5. mechanisms for learning across projects.

Strategic alliances

Alliances with other construction participants include the establishment of long-term relations, development of special contracts to facilitate integration at the early project phases, and changes in work processes of both organizations in order to improve overall performance. The benefits from long-term relations reflect at both the project and company performance. For example building good reputation and customer's trust reduces the customer's perceived risks, and the establishment of work processes and norms increases project efficiency, cooperation, and problem-solving.

Formal organizational arrangements

Formal organizational arrangements refer to policies that affect the way the work is organized within the construction firm and the interaction of the divisions. They involve the formal coordinating mechanisms, establishment of project teams, basis of incentive and reward system, and policies concerning project manager's role. Policies related to human resources are also important and include requirements for cross-functional experience for specific positions (e.g. project managers), job-rotation policies and training in interpersonal and negotiation skills can facilitate cooperation with the representatives of other organizations during the projects. Organizational policies may create barriers to integration. For example, concerns of resource utilization may prevent construction personnel's participation during the design process, and opportunities for significant improvements may be lost.

Organizational environment

The degree to which the organizational climate tolerates mistakes, and supports cooperation between functions and across organizations is important factor affecting integration. Such an "clan" culture is based on goal congruence, and is essential for integration.

Information technology strategy

Technological integration refers to the degree to which information systems are used to link functions within the firm as well as different firms. For technological integration to become possible, both technical as well as organizational barriers need to be addressed. Development of long-term relations can facilitate such a decision since the benefits from this investment will be long-term.

Learning across projects

The establishment of mechanisms that allow structured use of past history and knowledge provide the means for improving the facility development process on future project. Mechanisms for integration across time (longitudinal integration) include Quality Circles, Total Quality Management, and Process Re-engineering.

The development of such integration mechanisms require top management's decision to invest in such means. Thus, understanding the benefits from integration is the first necessary step. By identifying problems from lack of integration and evaluating the effectiveness of integration mechanisms, this research will provide managers guidance for decision-making concerning integration.

The model of integration described in this chapter provided the basis for development of interview guides and data collection from project and senior managers concerning integration. The interviews with managers will identify if the propositions of the model with regard to integration needs, benefits and mechanisms are valid and complete. Furthermore, this study expects to identify barriers that may prevent managers from taking action to increase integration.

CHAPTER FOUR - Data Collection

The theoretical framework developed in Chapter III provided the basis for data collection. Data were collected through interviews with project and senior managers in engineering, construction (AEC and construction-only) and owner's organizations. The interview guide developed to structure the data collection (appendix A) addressed the following issues:

1. General characteristics of firm (owner, general contractor, AEC firm), type of projects (heavy civil, industrial, commercial, housing) and type of markets (public, private or both).
2. Motivation for integration. In order to identify operational and strategic benefits from integration, managers were first asked to identify the importance of integration for project and company performance. Operational benefits focused on improvements in project performance (such as cost savings, schedule reduction, and quality improvements). Strategic benefits focused on implications for the firm's market performance, particularly the ability to win contracts.
3. Mechanisms for integration. Managers were then asked to identify the mechanisms used by the firm to increase integration at the project level as well as at the company level. Mechanisms for project level integration addressed contractual, organizational, and technological means. With regard to company level integration, the managers were asked about the extent of inter-organizational relations between the firm and other parties (owners, designers, contractors and suppliers).

The participating companies and interviewees position are listed in Table 4.1.

Table 4.1 Participating firms.

Case #	Firm	Project Type	Market Type	Interviewee position
1	EPCM*	Industrial	Private	Project Manager
2	General Contractor	Commercial buildings	Private	Senior Manager
3	EPCM	Industrial	Private	Senior Manager
4	General Contractor	Industrial	Public	Project Manager
5	General Contractor	Heavy civil Industrial	Public Private	Senior Manager
6	Owner	Industrial	Private	Project Manager
7	General Contractor	Heavy civil Industrial Commercial	Public Private	Senior Manager
8	Owner	Industrial	Private	Senior Manager
9	Architectural Engineering	Commercial buildings	Public Private	Senior Manager

* EPCM = Engineering - Procurement - Construction Management

This chapter describes the data collection phase. Data from each interview was first summarized in a case study. Then, each case was returned to the interviewee for review regarding accuracy and approval for publication.

In this chapter, a summary of each case study and a discussion of the main findings is presented. The case studies are presented in Appendix B. The case studies represent the views of the interviewed managers. The analysis and interpretation of the findings reflects the author's opinion.

4.1 Case # 1: Retrofit paper mill project

Firm type: EPCM (Engineering-Procurement-Construction Management)

Project type: Industrial

Market: Private

Position: Project Manager

Summary and discussion

This case describes the facility development process of a retrofit paper mill project, identifies the problems encountered and examines the root causes of the performance problems. The project involved expansion and upgrading of a paper mill facility. The complexity of the project due to the constraints posed by the existing facility, the high degree of interdependencies between the components of the facility, and the fast-track nature of the project made it a challenging and difficult project. This case focuses primarily on problems resulting from lack of integration during the early project phases. The case identifies barriers to integration and means to increase integration.

Integration and project performance

Lack of integration during the project planning phase resulted in poor project definition. Thus, design engineers did not have a clear understanding of owner's needs and requirements. Furthermore, different expectations existed within the owner's organization. As a result, scope uncertainty was high. The complexity of the project, and the uncertainty involved required greater integration during design. However, the "arm's length" relationship between designer and owner's representatives during design, impeded cooperation and resolution of problems. This resulted in rejection of many design proposals, iterations, design rework, and delays that impacted procurement and construction.

Mechanisms for integration

Proposed means to increased integration in similar projects include contractual, and organizational arrangements. *Contractual* arrangements should take into consideration project uncertainty (e.g. degree of scope definition) in order to avoid conflict of interest and incongruent goals as in this case. *Organizational* arrangements include primarily establishment of cross-functional teams from the start of the project with participation of design, construction and vendors in order to establish clear scope, identify owner's requirements and constraints, and develop a project execution plan with

consideration of major construction methods and vendors' equipment. This is facilitated when design and construction are performed by the same organization. The investment required for increased integration is estimated at 1-2% of project costs and the benefits from integration approximately 10-20% of project cost and schedule. Finally, the role of the project manager as integrator is identified as essential in order to gain the support of the different participants and functions, and develop a cooperative environment.

Barriers to integration

Contractual arrangements, organizational arrangements, and behavioral factors were identified as the main barriers in this case. The *contractual* arrangements were inappropriate for a project with low scope definition. Thus, the owner tried to get the best project possible for the agreed price, as the optimization studies and design iterations were not to be compensated additionally. *Organizationally*, the sub-contracting of the design to another firm was a barrier to integration. The limited interactions and communication between the designers and OEG impeded joint problem-solving and decision-making. Finally, *behavioral* factors refer to the adversarial relations developed primarily between owner and designer. These problems were attributed to turf problems, and antagonistic attitude in the owner's group.

4.2 Case 2: DPR Construction

Firm type: Construction
Project type: Commercial buildings
Market: Private
Position: Senior Manager

Summary and discussion

DPR Construction is a young, aggressive and rapidly growing building construction firm. This case identifies operational and strategic benefits from integration in the context of private commercial projects, and identifies means for integration both at the project level and at the inter-organizational level.

Benefits from integration

Operational benefits

Prevention of problems such as design and construction rework, and subsequent changes and delays are identified as important implications for integration. Rework is

especially costly for both designer and contractor, and "doing it right the first time" is essential. However, the benefits from integration go well beyond prevention of problems. The increased understanding of owner's needs, and the ability to participate in design decisions increases the ability to identify the most cost effective solutions to customers' needs. Integration with designers is essential in order to consider construction methods, logistics and suppliers constraints for which the designers are not aware of.

Strategic benefits

Reputation is a critical factor for the contractor's ability to be selected for private projects. Successful projects result in repetitive businesses from corporate clients, and attract new clients. Moreover, integration within the firm (with the implementation of TQM and information technology) and increased coordination with suppliers and subcontractors results in continuous performance improvement (e.g. safety record, process improvement).

Mechanisms for integration

Project level integration

Extensive teamwork with designers and suppliers throughout the project, is the primary integration mechanism. Contractually, the firm does not take any special measures. Because designer and contractor are different organizations, integration depends to a large degree on the owner's strategy; the timing of contractor selection, and the support for his participation in design.

Good working relations are important determinant of successful cooperation between designer and contractor. To increase the effectiveness of project teams, the firm provides team members with training in communication and interpersonal skills, and high decision-making authority. Implementation of TQM is another mechanism for integration, primarily within the firm.

Information technology is also used to facilitate communications between the participants. This includes electronic exchange of data and drawings between site and office, and communication of systems used for different construction functions (e.g. scheduling, estimating). Electronic exchange of drawings with designers and owners has been used in two projects, but technical barriers (communication problems between different systems) limit more extensive utilization.

Inter-organizational level integration

Developing and nurturing relations with owners, designers and suppliers is important for establishment of trust and a cooperative project environment. The firm has extensive information exchange with its customers, even when a specific project does not exist. Relations with designers are based primarily on previous experience. The small number of designers in the contractor's specific market creates opportunities for cooperation on subsequent projects.

Cooperation with suppliers and subcontractors is more extensive. The company has reduced the number of its suppliers to a few pre-qualified ones. Cooperation extends beyond projects, with participation in seminars, and continuous efforts to improve work procedures and methods for mutual benefits.

Integration barriers

Owner's leadership, working relationships between the parties, and technical issues are identified as critical factors for integration. Owner's leadership is needed to support design-construction integration at the early project phases, by selecting the contractor early, and involving him in the early design decisions. Behavioral factors are also important determinants of effective integration. Designers may not be willing to accept the contractor's input or criticism of the design. Development of relations based on mutual trust and respect is important for identifying alternatives that meet all parties needs. Finally, problems in communication of different computer systems used by owners, designers and contractor are a technological barrier to integration.

4.3 Case #3: Bechtel Corporation

Firm type: EPCM
Project type: Industrial
Market: Private
Position: Senior Manager

Summary and discussion

This case identifies the need for integration in industrial process plants, and examines the following issues: 1) operational and strategic benefits from integration, 2) strategies to increase integration at the project and inter-organizational level, and 3) barriers to integration.

Integration benefits

Operational benefits identified include reduced project cost and time, increased facility quality, and increased safety. Consideration of construction, procurement, and operations constraints results in solutions that are more cost effective from a global project point-of-view. Increased ability to understand and meet customers' needs is essential for competitiveness in the industrial facilities market, and the primary source of *competitive benefits*. This is a result of the firm's experience and continuous relations with owners and vendors.

Integration mechanisms

The primary means for integration at the *project level* are contractual, organizational, and technological. EPC contracts with design, procurement, and construction performed by the same firm provide the highest potential for integration. However, contractual means alone are not sufficient to solve the problem of fragmentation between disciplines, and additional organizational mechanisms are used. *Organizational* mechanisms include the establishment of dedicated *cross-functional teams*, *incentives* and rewards based on overall project performance as well as functional performance, training in interpersonal and teamwork skills, and selection of cross-functionally trained and experienced project managers, with a global, rather than functional viewpoint. Technological mechanisms provide capabilities for exchange of information between disciplines. Moreover, the development of simulation systems enables concurrent examination of alternatives from the perspective of both design and construction.

Development of strong long-term relations with owners and vendors is the primary means for *inter-organizational integration*. Relations with owners include strategic alliances and joint ventures for development of technology to meet owners' needs. Prequalification and establishment of long-term cooperation with a smaller number of vendors are means used to increased integration with suppliers.

Integration barriers

Contractual, behavioral and technological barriers have been identified as most important. Owners' contracting strategy is often a barrier as it may prevent contractual integration. In this case, cooperation between different organizations is more difficult. The individuals' difficulty in working as a part of a team and accepting other members'

opinions and criticism is the primary behavioral barrier. Finally, lack of standardization of protocols between different computer systems is the primary technological barrier.

4.4 Case #4: Homer J. Olsen, Inc.

Firm type: Construction
Project type: Industrial
Market: Public
Position: Project Manager

Summary and discussion

Homer J. Olsen is a construction company operating in the public sector. This case illustrates primarily the problems from lack of integration, and identifies factors that can increase integration during construction.

Benefits from integration

The primary benefits identified are operational. Integration during design can prevent several problems during construction, and primarily changes, and specification ambiguity, which result in increased project costs and time. Integration during construction is required to resolve unanticipated problems as they arise, and prevent them from becoming disputes. Thus, integration during construction is important for responsiveness to such problems. The need for integration during construction appears to be greater when the project is complex and when the design quality is lower.

Mechanisms for integration

Value engineering is the primary mechanism for contractors' input to design. However, the integration is low as the contractor does not participate during the design. With regard to integration during construction, the decision-making authority of owner's and contractor's site personnel appears to be important for fast resolution of issues. The parties working relations also have significant effect on their ability to cooperate.

Barriers to integration

Contractual, organizational and behavioral barriers are identified. Contractual arrangements have a twofold effect: First, they prevent contractor's input in design, and second, they do not provide strong incentives for the contractor to put effort in value engineering. Moreover, designers and owners also have incentives to avoid VE because

it means rework and changes. Even when VE benefits are identified, owner's cooperation and working relations are important, as well as trust that benefits will exist and will be shared fairly.

Organizational barriers refer to the lack of adequate decision-making authority of site personnel, which results in slow response to field problems. Finally, adversarial relations and antagonistic attitudes often prevent cooperation.

4.5 Case #5: Atkinson Construction

Firm type: Construction
Project type: Heavy civil
Market: Public, some private
Position: Senior Manager

Summary and discussion

Atkinson is a large, diversified company with several subsidiaries in the construction and manufacturing sector. Atkinson Construction is the San Francisco based subsidiary that focuses on heavy construction work in the public sector. Atkinson's projects include bridges, tunnels, highways, dams, canals, and other infrastructure facilities.

This case describes benefits from integration in both public and private works, mechanisms for integration at the project and inter-organizational level, and identifies barriers for increased integration.

Integration needs and benefits

Economic benefits are the primary force for integration. From the contractor's perspective, the primary need for integration in public works is during the construction phase. The benefits from close cooperation with owner are construction cost and time reduction, improvements in logistics requirements, problem-solving due to unanticipated events, and prevention of claims. Typically, the contractor avoids proposing design changes, unless the benefits for construction are significant. Benefits from integration are estimated at no more than 5-10% of project costs, and significant schedule savings.

Strategic benefits from integration include primarily the firm's ability to bid more aggressively in projects that involve a cooperative owner. In the private sector

integration during design is important for the firm to be awarded the contract. Another force for integration comes from the owners' strategy. Thus, although the contractor typically is not involved in design, in recent years this is changing as more owners leave parts of the detailed design on the contractor.

Integration mechanisms

The firm takes several actions to increase integration both at the project level and at the inter-organizational level. In public projects, partnering is the primary integration mechanism, focusing on the construction phase. Team-building, and increased decision-making authority to field personnel are critical requirements. Training in interpersonal and teamwork skills are also essential. Implementation of TQM is another means to increase integration between construction functions. Finally, information technology provides electronic linkages between construction functions, and -- in some projects -- with designers.

At the inter-organizational level, development of informal long-term relations with some owners (in the public and private sector) enables more aggressive bidding. The firm evaluates owners based on previous cooperation. In a similar way, long-term relations have been developed with few design firms, and equipment vendors. Such relations facilitated the establishment of electronic linkages with these firms.

Integration barriers

In public projects, the contractual arrangements are the primary impediment to integration. First, the contract prevents input in design, and second reduces the incentives for the contractor to suggest improvements. The investment required in engineering services, and the uncertainty involved regarding the acceptance of the proposal reduces the contractor's motivation. Finally, even when the contractor knows a better way to do the project (which however would require design changes) he cannot account for it in competitive bidding.

On private projects, the contractual barriers are low (but depend on the owner's strategy), and the incentives are strategic rather than operational, e.g. integration with designer is important in order to identify most cost effective alternatives and win the contract. In these cases, effective teamwork with designers and cooperative working relations are essential.

Finally, the primary barriers for integration technology include the following: (a) difficulty to justify the investment, (b) reluctance of other parties (owners and designers) to provide access to their information due to liability considerations, (c) unfamiliarity with the technology, and (d) technical problems of communication between different systems.

4.6 Case #6: "Process Corp."

Firm type: Owner
Project type: Industrial
Market: Private
Position: Senior Project Manager

Summary and discussion

The "Process Corp." is a large customer of construction services, with a \$4-5 billion annual capital budget. Facilities include refineries, cogeneration plants, chemical and process plants, offshore/onshore production facilities, etc. This case presents the benefits from integration from an owner's perspective, and examines the mechanisms used to achieve integration.

Integration benefits

The company estimates the operational benefits from integration at early project phases at about 10-20% of total project cost and time, as well as improved cash flow. These benefits stem from the ability to establish and communicate the scope of the project, and increased ability to select the most cost effective design, construction, and procurement alternatives.

Strategic benefits result from the speed of facility development, and higher plant quality. Speed of development is crucial for responsiveness to market demands, and higher quality translates into reduced downtime and operational costs.

Integration mechanisms

The above benefits result from the involvement of all key participants (owner, designers, contractor, vendors and operators) in project planning and design. This is accomplished through contractual, organizational and technological means. Contractually, the owner uses EPC contracts, with one firm responsible for design,

procurement, and construction. Bonuses for budget and schedule performance provide additional incentives for integration.

Organizationally, the project organization is structured as a matrix. The work is performed through strong cross-functional teams with decision-making authority. To improve team effectiveness, the owner invests heavily in training team members to develop inter-personal skills. This investment ranges from 0.1% to 0.5% of total engineering cost.. Information technology is used widely, and electronic linkages with AEC firms are established.

At the interorganizational level, integration takes the form of strategic alliances and long-term relations with EPC firms and vendors. This is important so that the designers and contractors understand the owner's needs and objectives, and the company's culture and "way of work". The development of mutual trust and culture and the long-term perspective of the relationship, increases goal congruence and reduces the probability of opportunistic behavior. Information technology capabilities of AEC firms are important criterion for selection of partners. The long-term cooperation facilitates development of electronic linkages and "owner-specific" applications, which may have not been justifiable for one project only.

4.7 Case #7: Dillingham Construction North America

Firm type: Construction
Project type: Heavy civil, industrial, commercial
Market: Public, Private
Position: Senior Manager

Summary and discussion

Dillingham Construction Corporation is a large, diversified construction company. This case describes benefits from integration, mechanisms to increase integration, and barriers to integration.

Integration benefits

Like the other construction-only firms, Dillingham's primary concern is integration during the construction phase. The motivation is the effective resolution of problems that arise during construction, and avoid claims. The benefits are considered

significant, although hard to measure. The reason is that integration prevents additional costs that might have occurred without integration. Despite the difficulty of measuring such costs, the benefits are considered sufficient to justify investment in integration mechanisms. Development of long-term relations with public agencies, which are based on trust and cooperation, also have competitive benefits, as the firm can pursue some contracts more aggressively, and increase the probability of winning projects.

In the private sector, there is strong incentive for integration at the early project phases. The benefits are both operational and strategic. Integration with designers and owners at the planning and design phases is essential in order to identify the most cost effective ways to meet customers' needs, and win the contract. Finally, long-term relations with private owners increases the firm's competitiveness, as it reduces the owner's risk. Thus, the firm can be selected for a project even if it does not make the lowest offer.

Integration mechanisms

For Dillingham, partnering is the most important integration mechanism, and the firm tries to implement it on all projects. This requires investment in training project personnel in teamwork, giving more decision-making authority to project teams, and using facilitators to improve the effectiveness of the teams. CQI is another means to increase integration both within the firm as well as with other project participants. Information technology is used to establish electronic linkages within the firm. At the inter-organizational level, strong long-term relations with some owners, designers and suppliers have been developed but are informal and based on previous experience.

Integration barriers

In the public sector, the contractual framework is the major barrier to integration. Even under these conditions, however, there are significant benefits from integration during construction. In the private sector, owners can benefit the most from integration during early project phases. In both cases, the owners' role in achieving integration is critical in order to provide incentives for integration, and develop the appropriate project environment. For project success, owners need to take action to increase integration between project participants. This requires selection of contractors based on qualifications and reputation, front-end investment in training and teamwork, additional compensation for engineering services offered by the contractor, and incentives for overall project performance. However, due to the highly competitive conditions, most

owners now use low price as the only criterion, and avoid investing in increasing integration.

4.8 Case #8: “Manufacturing” Corporation

Firm type: Owner
Project type: Industrial
Market: Private
Position: Senior Manager

Summary and discussion

“Manufacturing Corporation” is a \$1.6 billion micro-processor manufacturing organization. The firm is a large customer of construction services, with approximately \$500 million annual expenses in capital projects. Facilities include hi-tech manufacturing and fabrication plants. This case examines the benefits from integration from the owner's perspective, and presents the mechanisms used to achieve integration.

Reason for integration

The fast-track nature of the firm's projects, and their technological and environmental requirements require increased integration, to achieve project objectives.

Integration benefits

The firm recognizes operational benefits from integration, in terms of reduced project cost and schedule. These benefits stem from the ability to establish and communicate the scope of the project, prevent changes and delays, and improved quality of decisions (due to increased ability to select the most cost effective design, construction, and procurement alternatives). Strategic benefits result from the speed of facility development, and higher plant quality. Speed of development is crucial for responsiveness to market demands, and higher quality translates into reduced downtime and operational costs.

Integration mechanisms

The above benefits result from the involvement of all key participants (owner, designers, contractor and operators) in project planning and design. This is accomplished through contractual, organizational and technological means. Contractually, the owner uses EPC contracts, with one firm responsible for design, procurement, and construction.

Organizationally, the work is performed through strong cross-functional teams. Alignment meetings are held early in the project to clarify objectives and scope, and select the best design and construction alternatives. To improve teamwork effectiveness, the owner also provides training in inter-personal skills, and group decision-making (meetings management). The company also invests in information technology to automate tasks and establish electronic links with EPC firms and vendors.

At the interorganizational level, the company has developed strategic alliances and long-term relations with EPC firms and vendors. The significant company-specific technical knowledge makes the development of long-term relations important. Long-term relations enable EPC firms to better understand the owner's needs and become familiar with the owner's requirements. Thus, designers and contractors are in better position to meet the firm's requirements. The development of mutual trust and the long-term perspective of the relationship increases goal congruence and provides incentives to the company's partners for continuous cooperation. The long-term cooperation also facilitates development of electronic linkages.

Barriers

Behavioral issues are identified as significant barriers, and the need for increased training in inter-personal skills is felt.

4.9 Case #9: Ehrlich-Rominger

Firm type: Architectural / Engineering

Project type: Commercial / Industrial

Market: Private

Position: Senior Manager

Summary and discussion

Ehrlich-Rominger is an architectural / engineering firm specializing in hi-tech buildings, such as data processing centers and biotech laboratories. Its clients include developers, large manufacturing firms, etc. This case identifies operational and strategic benefits from integration in the context of private commercial building projects, and identifies means for integration both at the project level and at the inter-organizational level.

Reason for integration

The increased complexity of building facilities and the fast-track nature of the projects are identified as two critical factors increasing the need for integration. Integration is required between all key project participants (owner, designers, contractor, users and approval authorities) in order to take into consideration all project requirements and constraints.

Benefits from integration

Prevention of problems such as design and construction rework, and subsequent changes and delays are identified as important operational benefits from integration. Cost savings between 5% - 10% of total project costs and reduced schedule are the primary operational benefits. Increased understanding of owner's needs, and the ability to identify the most cost effective solutions to these needs have significant competitive benefits as well. Reputation is a critical factor for the engineer's ability to be selected for private projects, as it reduces the customer's risk and increases the probability that the project will be on-time and within budget. Successful projects result in repetitive businesses from corporate clients, and attract new clients.

Mechanisms for integration

The means for project-level integration are contractual, organizational and technological. Development of long-term relations is the major mechanism for inter-organizational level integration.

Contractually, the use of design-build contracts facilitates integration between designers and contractors, and enables the contractor to offer pre-construction services. The owner's role is critical because this contracting strategy requires contractor's selection not on the basis of price, but on reputation and ability to have successful cooperation. The firm often undertakes design-build contracts and selects the contractor to work with.

Organizationally, the primary integration mechanism is the establishment of cross-functional teams and extensive teamwork with designers, contractor and owner throughout the project. Trust and good relations are considered essential requirements for effective teamwork and project success. The firm has a strong cooperative culture and has always applied the principles of "partnering". Information technology is also considered essential for integration. The firm uses 2D and (to a lesser degree) 3D CAD, primarily as means to increase coordination between design disciplines. The firm is

planning to expand the use of 3D CAD to increase integration with clients and contractors as well. Long-term relations with clients, design consultants and contractors are important for establishment of trust and a cooperative project environment. Such relations are based primarily on previous experience.

Integration barriers

Contractual, organizational and behavioral issues are identified as the major barriers. Traditional contracting practices prevent contractor's input during design. Owner's leadership is needed to support design-construction integration at the early project phases, by selecting the contractor early, and involving him in the early design decisions. Organizational arrangements may also limit interactions and prevent cooperation between project members. Finally, behavioral factors such as lack of project members inter-personal skills and willingness to cooperate may create significant barriers.

4.10 Data collection summary

Table 4.2 summarizes the major findings from each case study. Column (1) indicates the case study and the type of organization interviewed. Column (2) presents the major reasons for integration according to the interviewed managers. Column (3) summarizes the identified benefits from integration and major problems due to lack of integration. Mechanisms for integration at the project and inter-organizational level are listed in column (4). Finally, column (5) presents the major barriers to integration. The analysis of data is presented in the next chapter.

Table 4.2 Summary of data from case studies

(1) Case #	(2) Reasons for Integration	(3) Problems / Benefits	(4) Mechanisms	(5) Barriers
1 Retrofit paper mill project	Integration in Planning and Design is essential for project performance Project complexity and uncertainty require greater integration	Lack of integration results in: - Scope uncertainty - Design iterations, rework and delays - Delays in subsequent processes Potential benefits: 10-20% of project costs	Project level Contractual - EPC contracts - Incentives to align goals Organizational: - Cross functional teams - PM as integrator	Contractual arrangements did not support goal congruency Organizational arrangements limited interactions and communications Behavioral factors (antagonistic attitudes, turf problems) impeded cooperation
2 DPR Construction	Improve project performance - Cost, schedule, quality Improve competitive position - Understand clients needs - Reputation	Project benefits - Prevent changes, rework, delays. - Identify cost effective solutions to meet owners' needs. Strategic benefits - Reputation and repetitive businesses from corporate clients - Standardization and innovation - Continuous improvement	Project level - Early involvement and teamwork between key participants - Lower level of decision-making - Training in interpersonal skills - Information technology Inter-organizational level - Strong relations with Owners, Designers, Suppliers - Frequent info. exchange	Owners' limited understanding of importance of integration Organizational arrangements Behavioral factors (attitudes and working relations) Technological factors - lack of standards for electronic data exchange
3 Bechtel Corp.	Improve project performance - Cost, schedule, quality, safety Improve competitive position - Understanding clients needs - Reputation	Project benefits - Reduce changes, rework, delays. - Identify cost effective solutions to meet owners' needs. Pot. benefits: 10-20% of project costs Strategic benefits - Reputation and repetitive businesses from corporate clients - Technology development to meet customers' needs	Project level - Contractual - Organizational (matrix structure) - Training in interpersonal skills - Information technology Inter-organizational level - Joint ventures and strategic alliances with owners, - Long-term relations with selected qualified suppliers	Owners' contracting strategy Organizational arrangements Behavioral factors - Adversarial attitudes - Turf problems - Working relations Technological factors - Systems communication
4 Homer J. Olsen Construction	The need for integration is greater when projects are complex, and uncertainty high.	Lack of integration during design results in: - Errors, omissions - Low constructability of design Lack of integration during Construction results in: - Slow response to problems, delays, extra costs, claims	Project level Contractual (Value Engineering) Organizational (decision-making authority to site personnel) Behavioral (relations and attitudes)	Contractual - Prevents Contractor's input in design - Incongruent goals Organizational - Low authority to site personnel Behavioral - Competitive attitudes

(1) Case #	(2) Reasons for Integration	(3) Problems / Benefits	(4) Mechanisms	(5) Barriers
5 Atkinson Construction	Integration during construction to improve construction efficiency Improve competitive position Owners' tendency to leave part of design on contractor	Project benefits - Early identification of problems, fast and effective resolution of issues, prevention of claims Potential savings: 5-10% of project cost Strategic benefits - Increase ability to win contracts	Project level - Partnering (focus on construction) - Training in teamwork - TQM - Information technology Inter-organizational level - Relations with owners, designers and vendors - Information technology	Contractual - Lack of strong incentives to commit required resources for design reviews Barriers to technological integration - Difficulty to evaluate benefits - Requires new capabilities and significant resources - Owner's and designers resistance - Technological problems
6 "Process Corp."	Project complexity, fast-track nature Increase project cost effectiveness Reduce schedule Improve facility quality	Project benefits - Determine needs; avoid "gold-plating" - Reduce cost, time Potential benefits 10-20% of total costs Competitive benefits - Fast response to market needs - Reduced plant downtime - Reduce operating expenses	Project level - Contractual (EPC Contracts) - Organizational (team building, lower level of decision-making, training in teamwork) Inter-organizational level - Strategic alliances - Information technology	Behavioral - Lack of inter-personal skills - Resistance to IT
7 Dillingham Constr. NA	Integration during construction to improve construction efficiency Improve competitive position	Project benefits - Early identification of problems, fast and effective resolution of issues, prevention of claims. Potential savings: 5-10% of project cost Strategic benefits - Reputation - Increase ability to win contracts	Project level - Partnering (focus on construction) - Training in teamwork - CQI - Information technology Inter-organizational level - Long-term relations with owners, designers and vendors/subs	Contractual - Owners' focus on low bid - Prevent contractor's input - Low incentives for design review Behavioral - Adversarial attitudes
8 "Manufacturing Corporation"	Project complexity, fast-track nature increase need for integration Project success important for market response	Project benefits - Set scope, prevent changes, delays - Reduce cost, time Competitive benefits - Fast response to market needs - Reduce operating expenses	Project level - Contractual (EPC contracts) - Organizational (team building, training in meeting management) Inter-organizational level - Strategic alliances - Information technology	Contractual - Traditional contracting may result in low coordination Behavioral - Lack of inter-personal skills
9 Ehrlich- Rominger	Project complexity, fast-track nature increase need for integration.	Project benefits - Set scope, prevent changes, delays - Reduce time, cost 5-10% Competitive benefits - Reduce customer's risk - Increase ability to win contracts	Project level - Design-build contracts - Teamwork (chere, fly-specs) - Cooperative culture (partnering) - Information technology Inter-organizational level - Long-term relations with owners, designers and contractors	Contractual - Traditional contracting may result in low designr-contractor coordination Behavioral - Adversarial attitudes - Lack of inter-personal skills

CHAPTER FIVE - Research Findings

This chapter analyzes and presents the findings from data collection. The analysis focuses on the following issues: reasons for integration, integration benefits, mechanisms for integration at the project and company level, and barriers to integration. The analysis is based on summary of the data and identification of repeated points. The analysis first presents the project characteristics that create need for integration. Then, the operational and strategic benefits resulting from integration at the project and inter-organizational levels are identified. The major barriers to integration are then presented. Subsequently, the analysis identifies three categories of integration mechanisms: organizational, contractual, and technological. These means are used to increase integration at both the project and the inter-organizational level. Finally, the analysis examines the managerial issues and considerations that may prevent project participants from taking action to increase integration.

5.1 Reasons for integration

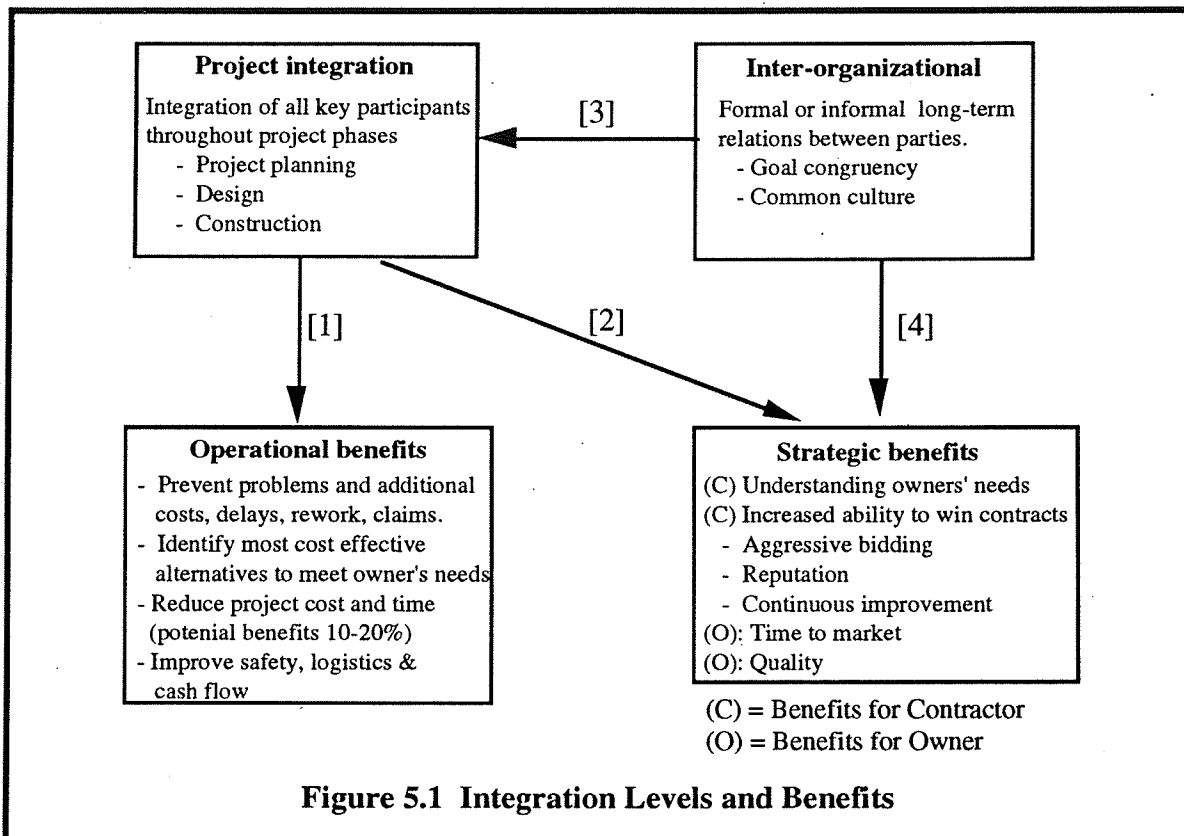
Increased schedule pressures, project complexity and uncertainty were identified by the interviewed managers as the primary factors creating need for integration. For example, owners recognized schedule as critical for project success and considered integration key factor in schedule performance. The three factors identified require higher ability to make good decisions about critical project components. Critical components are those that if changed will have a significant impact on the project's quality, cost or schedule. For example, decisions about long lead-time items are critical for the performance of fast-track projects. Also, decisions about project scope are critical because if changed, will require extensive design, procurement and construction changes.

To make high quality decisions about critical components decision-makers should make sure that these decisions are not in conflict with constraints / requirements of other components (or downstream processes). For example, decisions regarding the structural steel of a fast-track building need to take into consideration users' needs, code requirements, vendors' constraints and construction capabilities. Thus, for high quality

decisions, key actors (those participants who determine the decision's requirements and constraints) need to exchange information and knowledge, and make joint decisions. Conditions of complexity, uncertainty and schedule pressures increase the need for integration because there is higher probability that constraints and requirements will be unidentified and changes will be needed. Hence, greater integration is needed to make high quality decisions and reduce the probability of changes due to unidentified requirements.

5.2 Integration benefits

As shown in Figure 5.1, operational and strategic benefits result from integration at the project and inter-organizational level. Operational benefits refer to increased project performance, while strategic benefits refer to increased competitiveness for both contractors and owners. Such benefits result from integration of project participants in different project phases (project level), and development of long-term relations between owners, designers, contractors and suppliers (inter-organizational level).



The following sections first present the operational (relationship [1]) and strategic benefits (relationship [2]) from integration. Then, the effect of inter-organizational integration on project integration and operational benefits is examined (relationship [3]). Finally, relationship [4] depicts how inter-organizational integration results in strategic benefits.

5.2.1 Project integration and operational benefits

This section first examines problems and inefficiencies that result from lack of integration. Then, it presents benefits from integration that go beyond prevention of problems. Figure 5.2 illustrates a non-integrated project organization, and problems that result from lack of integration.

Project phases Actors	Planning	Design	Constr Plann- Procurement	Construction	Operations
Owner	Define scope (requirements and constraints)				
Designer		Select alternatives to meet Owner's functionality requirements			
Contractor			Select methods to meet Owner's time and cost constraints	Build the facility	
Suppliers/ Vendors			Bid on selected components	Fabricate and deliver	
Users					Operate / Use
Resulting problems	- Scope uncertainty - Unidentified needs and constraints	- Sub-optimum alternatives - Low constructability of selected alternatives - Changes, rework	- Changes, rework delays, additional costs	- Changes, rework delays, additional costs, claims	- Facility may not meet operators' or management's needs - Increased costs

Figure 5.2 Role of key participants in phases of a non-integrated project and resulting problems.

As the case of the retrofit paper mill project illustrated, lack of integration during project planning may result in scope uncertainty and unidentified needs and constraints. Lack of integration within the owner's organization (planners, financial managers, and operators) results in unidentified and conflicting requirements of different functions. This, in turn, results in scope changes or disagreement about scope. Lack of integration with external parties (designers, vendors and contractors) may result in scope ambiguity and unclear priorities, which in turn causes changes, rework and delays in subsequent processes.

Lack of integration during design has similar implications; design decisions may be uneconomical from a construction viewpoint, and design information may not be communicated to contractors or vendors. Thus, design and construction rework, delays and increased costs are a direct result of lack of integration. Similarly, unidentified vendors' constraints and requirements result in design iterations, changes and delays.

Contractors that operate primarily in the public sector focused on the need for integration during the construction phase. Integration during construction is needed to increase the organization's ability to respond to unanticipated conditions and problems. Lack of integration results in slow and ineffective decision-making, delays, increased costs, and claims. According to managers from Homer J. Olsen, Atkinson Construction and Dillingham Construction, claims prevention is a major concern of contractors operating in the public sector.

Operational benefits from integration are not limited to prevention of problems; increased cost effectiveness, reduced schedule and improved safety are important gains. Figure 5.3 illustrates the role of key participants in the integrated project organization, and lists the identified benefits. Managers in construction and owners' organizations estimated that savings from the integrated approach to project development range between 10-20% of total project cost and time.

An integrated approach to facility development enables better scope definition and increased cost effectiveness. Better scope definition results from identification of requirements and constraints and communication of these objectives to all participants. Involvement of operators, designers, contractors and vendors enables early identification of potential conflicts and prevents scope changes. Cost effectiveness is improved because of increased ability to identify alternatives that optimize the overall project

performance, rather than design decisions. For example, modularization and pre-fabrication may not appear beneficial to the designer, but they result in significant project benefits due to improved quality (enable construction in a controlled environment) and schedule (permit more activities to be performed simultaneously).

Project phases Actors	Planning	Design	Constr Plan.- Procurement	Construction	Operations
Owner	Define scope (requirements and constraints)	Provide clear directives on needs and constraints		Cooperate to resolve unanticipated problems	
Designer	Evaluate major alternatives	Evaluate alternatives to meet Owner's functionality requirements		Cooperate to resolve unanticipated problems	
Contractor	Examine major constr. methods; provide input on cost effectiveness, schedule, logistics	Evaluate alternatives against cost, schedule and logistics constraints		Build the facility Cooperate to resolve unanticipated problems	
Suppliers/ Vendors	Provide input on special equipment and components	Evaluate alternatives against fabrication and lead time constraints		Fabricate and deliver	
Users	Provide input on actual needs and requirements	Evaluate alternatives with regard to operability & maintenance			Operate / Use
Resulting benefits	<ul style="list-style-type: none"> - Define scope and design basis - Set priorities - Identify actual needs and prevent "goldplating" - Develop Project Execution Plan 	<ul style="list-style-type: none"> - Joint decision-making to select optimum alternatives - Concurrent product and process design - High constructability of selected alternatives - Eliminate changes and rework 		<ul style="list-style-type: none"> - Increased cost effectiveness 10-20% - Shorten schedule 10-20% - Improve safety - Prevent changes, rework and claims 	<ul style="list-style-type: none"> - Facility meets operators' and management's needs - Reduced cost of operations & maintenance

Figure 5.3 Role of key participants in phases of an integrated project and resulting benefits.

Taking vendors' capabilities and constraints into consideration is especially important when the facility involves special components (where the vendors perform a significant part of the design), and when components involve high labor costs or have long lead times. Thus, early involvement of vendors is needed to select those alternatives

that optimize the overall project performance. Finally, integration also results in improved safety. For example, one firm redesigned steel column connections to allow crews to work faster and safer. In another example, the design of foundations specifically considered excavation safety requirements.

Integration during construction requires the contractor and the owner to identify and resolve potential problems before they have an impact on the project. Moreover, it can also result in opportunities and benefits for the contractor and the owner. For example, on a highway project, the contractor (Atkinson Construction) and the owner were able to shorten a 36-month project by 15 months by reducing the need for temporary routes. On another project, the same contractor cooperated with owner and designer to eliminate the need for a temporary cofferdam. Finally, taking construction constraints into consideration facilitates management of logistics and improves cash flow for owners and contractor.

5.2.2 Project integration and strategic benefits

Owners and contractors identified strategic benefits from project level integration. For the owner, quality of the facility, speed of delivery, and cost are essential for competitiveness. For example, avoiding "goldplating" and reducing downtime are primary considerations for the owner of process facilities. This owner involves plant operators in the planning and design phases to prevent goldplating and evaluate design alternatives from an operations and maintenance perspective. Vendors and contractors are also involved during design to identify the most effective alternatives that meet the owners' requirements.

Strategic benefits were identified for engineering and construction organizations in both the private and public sectors. Firms in the private sector consider project integration essential for two reasons: First, integration during design is critical in order to identify the most cost effective solutions to owners needs and win the contracts. Second, project performance increases the contractor's reputation and reduces the client's risk, increasing the contractor's ability to win more contracts from corporate clients. In the public sector, although the lowest bid is the primary criterion, reputation and previous project performance do have impact on competitiveness because they affect how aggressively the contractor will bid. Thus, when the contractor has good relations and previous experience with a public owner the contractor's perceived risk is lower and his bid more aggressive.

5.2.3 Inter-organizational integration and project integration

Cooperative relations also facilitate project level integration. Developing common norms, and understanding each other's culture and way of working enables better cooperation during projects. Because the parties identify mutual benefits from their cooperation, goal congruence increases. Moreover, the expectation of future benefits eliminates the motivation for opportunistic behavior in the short-run. Thus, inter-organizational relationships increase the motivation for integration (due to mutual gains in the short and long run), and the ability to achieve integration (due to goal congruence, understanding of each other's culture and way of work, and development of common norms).

5.2.4 Inter-organizational integration and strategic benefits

Most of the firms participating in this study have established inter-organizational relations with other firms, although in different degrees of formality. Such relations are developed primarily with clients and suppliers of important resources. For example, contractors in the commercial building sector who subcontract a significant part of the work considered strong relations with subcontractors very important. For example, DPR considered long-term relations with suppliers, subcontractors and customers as very important. Similarly, Atkinson Construction (heavy civil contractor) has stronger ties with equipment suppliers. Owners identified long-term relations with engineering and construction firms as important for two reasons: First, due to the high volume of design and construction services required, and second, due to the need to understand the owner's specific requirements, culture and way of working.

Corporate relationships were considered important by contractors in both the private and the public sector. In the private sector, DPR, Bechtel, Dillingham and owners recognized that long-term relationships enable contractors to better understand the needs of their corporate clients and build trust between the organizations. These conditions reduce both the customer's and the contractor's risk and increase the contractor's probability of winning the contract, even without the lowest offer. Relations with designers are similarly important. Construction firms that do not have in-house design capabilities have established informal (but strong) relations with a small number of well respected designers to win design-build contracts through joint proposals. For example, Dillingham and Atkinson Construction have established strong relations with few designers. Such relations have also resulted in development of electronic linkages

between organization that cooperate often. For example, DPR has established electronic linkages with one major customer, and Atkinson Construction has developed electronic links with a designer and a vendor.

In the public sector, cooperative relations and good previous experience with public owners reduces the contractor's risk and enables more aggressive bidding. Contractors believe that good relations and long-term cooperation with suppliers and subcontractors reduces the suppliers' bid, further increasing the contractor's ability to bid aggressively. One construction firm that did not appear to have long-term relations with few suppliers or subcontractors is operating in the public works sector, and identified the need for flexibility and low bid pressures as the primary reasons. Development of long-term relations with a few suppliers or subcontractors would result in reduced flexibility and would reduce the competition between suppliers.

5.3 Barriers to integration

To realize the benefits from integration, several barriers need to be overcome. The interviewed managers identified contractual, organizational, behavioral and technological factors as the most important barriers to integration.

5.3.1 Contractual barriers

Contractual arrangements may prevent integration in two ways. First, they may prevent involvement of contractors or suppliers in design decisions. This is the case in the public sector, where the contractor is selected after the design is "complete". In this contractual framework the only way for the contractor to influence the design is through value engineering proposals. However, this mechanism has several disadvantages, which are examined in a following section. Similar contractual barriers also exist in private projects. Thus, depending on the owner's contracting strategy, the contractor may be selected after the design is complete, and may not have any input in design.

Second, the contract establishes the basis for rewarding project participants. However, the incentives may promote incongruent goals and prevent integration. For example, the use of separate contracts for design and construction provides incentives to both designers and contractors to minimize their own costs. Opportunities for integration and development of more cost effective solutions are lost. Furthermore, in some cases contractors were reluctant to participate in design, even when the contract permitted it

because they felt that their engineering services were primarily benefiting the owner and they were not adequately compensated for these services.

In summary, contractual barriers result from institutional requirements (in the public sector) and the owner's contractual strategy (in the private sector). Contractual means to support integration are examined in the next section. Finally, the managerial barriers that may prevent owners from using these means are also examined in a later section.

5.3.2 *Organizational barriers*

Organizational characteristics may create organizational barriers. Thus, even when contractual arrangements offer potential for integration (as in design-build contracts), organizational factors may impede integration. Lack of joint responsibility, lack of decision-making authority to lower organizational levels, and organizational culture were identified as factors affecting integration.

Lack of joint responsibility and lack of decision-making authority at lower levels are organizational characteristics that prevent integration. In a differentiated organization each function focuses on performing the task that it is responsible for, without considering the implications of its decisions in other functions. However, integration requires joint decision-making. Overcoming this barrier requires several changes. First, changes are needed in the performance evaluation and incentive systems that determine the responsibilities of each function. Second, increased decision-making authority by project personnel can accelerate decision-making during construction and increase responsiveness to unanticipated events. Thus, issues of accountability and liability, and formal procedures affect speed of decision-making.

All managers recognized the importance of working relations and organizational culture for integration. Antagonistic attitudes and competitive behaviors reduce the motivation and capability to cooperate. In this environment, mutual benefits appear impossible and a win-lose mentality prevails. For example, functional differentiation and turf problems make it difficult for designers to accept criticism or suggestions for improvement from each other or from the contractor. A culture that values cooperation and teamwork as means for achieving a superordinate goal is needed to promote goal congruence and voluntary cooperation. Development of a cooperative culture between members of different organizations seems to be a significant benefit from long-term inter-

organizational relations. To improve the working relations and establish effective problem-solving procedures, almost all firms engaged in partnering effort as we examine in a later section.

5.3.3 Behavioral barriers

Another important barrier to integration exists at the inter-personal level. Lack of inter-personal, communication and negotiation skills reduces team members' effectiveness and their ability to perform joint problem-solving. All interviewees acknowledged the importance of such skills. All but one of the nine interviewed firms train their employees to develop such skills. Training programs are not limited to the company's employees; in many cases they are offered to all project personnel. For example, the owner of process facilities provides training to all project participants at the beginning of a project.

Interpersonal skills are essential for project managers who play the role of integrator. To ensure that project managers have these skills, owners and contractors use two methods: selection and training. All firms acknowledge the importance of project managers' inter-personal skills and select for these positions experienced individuals with good past performance. Furthermore, they continue to provide training to project managers.

5.3.4 Technological barriers

Technological problems prevent the use of information technology as an integration mechanism. First, lack of standards and technical problems create difficulties in communication between different computer systems. Second, each party needs only part of the information available to another party. For example, a contractor may need equipment dimensions from vendor for use in schematics. However, the vendor's system has much more details than the contractor needs, and some "filtering" is required.

These problems increase the costs and limit the payoff of the technology. First, the investment required to develop such systems is usually high because it requires high technical skills. Second, such skills are not usually available in-house. Third, several applications may be limited to a specific project or partner. This reduces the degree of utilization and subsequently the payoff. For example, an application that solves the communication problem between specific systems will not work for other systems, thus limiting the degree of utilization. These factors create economical barriers to more

extensive utilization of information technology. These managerial barriers are examined in a later section.

External barriers include the reluctance of other organizations to exchange information electronically. Many owners and designers feel uncomfortable with new technology for the following reasons: possible loss of control over documents, liability concerns because documents are not stamped, and possible errors in electronic transfer. Finally, the documents may include proprietary information or knowledge that designers do not want to disclose.

The major barriers to integration are summarized in Table 5.1

Table 5.1 Contractual, Organizational, Behavioral and Technological Barriers to Integration

Barriers	Implications for Integration
Contractual	Prevent contractors input in design Lack of incentives promote incongruent goals
Organizational	Low incentives for cross-functional integration Reward systems tied to functional performance Low decision-making authority to project personnel creates delays and inefficiencies Antagonistic attitudes and turf conflicts reduce goal congruence and prevent cooperation
Behavioral	Lack of interpersonal skills impedes communication, problem-solving and conflict resolution
Technological	Lack of standards , and problems in communication between different systems increase costs Limited utilization reduces payoff Liability concerns impede information exchange across organizational boundaries

5.4 Integration mechanisms

This section presents the integration mechanisms used by the interviewed firms. The mechanisms are classified according to two dimensions: 1) the level of integration they address (project or inter-organizational level), and 2) the type of mechanisms. Three types of mechanisms were identified: a) contractual, b) organizational, and c) technological. These mechanisms support each other; all are required for most effective integration. Figure 5.4 provides a classification of the observed mechanisms.

	Project level	Inter-organizational level
Contractual	Value engineering (not integration) Design-build contracts Performance incentives	Strategic alliances and joint ventures
Organizational	TQM (within firm) Partnering Cross-functional teams Training in group skills	Informal relations TQM (with external customers)
Technological	Electronic linkages between construction applications	Electronic linkages between design - procurement - construction - vendors Electronic linkages with associations

Figure 5.4 Contractual, Organizational and Technological Mechanisms for Integration.

5.4.1 Mechanisms for project integration

This section describes the contractual, organizational and technological mechanisms for integration at the project level.

Contractual mechanisms

Contractual mechanisms for integration include value engineering provisions, design-build contracts, and contractual incentives.

Value Engineering (VE) is the traditional mechanism that allows a contractor to influence the design. The contractor can review the design and propose design changes for cost savings after the contract has been awarded. However, there are several difficulties in changing a completed design.

1. For the contractor, VE requires investment in engineering time and services, and will not proceed unless the benefits from the changes are significant. Moreover, VE may delay the starting of construction, a major concern for the contractor.

2. Even when the contractor identifies a more cost effective alternative solution, there are several reasons for the owner and designer to reject it. For example, the intent of the initial design decisions may not be obvious, or may have been affected by "political" forces within the owner's organization. In any case, after the design issues have been settled, owners are reluctant to re-examine the design decisions.

3. Designers also have reasons to resist changes because VE involves rework and additional costs for them. Moreover, designers may resist "criticism" of their design.

Value engineering is not a real integration mechanism as the contractor does not participate in the design and his knowledge and constraints are not taken into consideration in the design decisions.

Design-Build contracts. Design-build contracts place the responsibility for the entire Engineering-Procurement-Construction process under the same organization, and have the highest potential for integration because they allow the contractor to participate in design and offer opportunities for constructability improvement and increased cost effectiveness. Design-build contracts may be awarded to one EPC firm with in-house design and construction capabilities or to an engineering-only or construction-only firm, which can select its engineering or construction partner.

Contractual incentives. Incentives are used to align the designers' and contractors' interests with the owners. Such incentives include extra compensation for contractor's pre-construction services and participation in design, and incentives for budget performance and early completion.

Organizational mechanisms

Organizational mechanisms for integration include several forms of teamwork and the management systems needed to increase team effectiveness. Such mechanisms are used for different purposes, or in different project phases.

Cross-functional teams. The use of matrix structure and cross-functional teams from the early design phases is a strong integration mechanism used by EPC firms and contractors involved in private work. Getting all the key project participants involved as early as possible is a primary consideration for management. For example, in order to increase integration, Bechtel appoints a cross-functional team when a project is still at the proposal phase. The team includes key representatives from design, procurement and construction, as well as an estimator and a scheduler. This core team is headed by a project manager, and it remains together throughout the project. Additional staff is added from the different functions as needed.

Other mechanisms for cross-functional integration include “charrettes” and “fly-specs”. Both these mechanisms refer to a group of representatives of project participants who work together intensively for one to three days. They differ in the timing and purpose of teamwork; “charrettes” are performed at the early design stages, while “fly-specs” are thorough reviews of a completed design.

While cross-functional teams can facilitate integration, their effectiveness depends on the willingness and ability of the functional representatives to cooperate in improving total project performance. An evaluation system based not only on functional expertise, but also total project performance is needed to provide incentives that support integration. Finally, changing the attitudes and behaviors of employees, and the overall company culture is an important factor and challenge for integration.

Training in group skills. In addition to teamwork, almost all firms interviewed provided employees with training in interpersonal and negotiation skills. These skills support all other organizational integration mechanisms (TQM, partnering, cross-functional teams). For example, one owner provides teamwork training on all projects. The cost of such a training program depends on the size of the project, and the number of participants.

Partnering. Partnering focuses on increasing the effectiveness of teamwork between project participants, and develop cooperative attitudes and inter-personal skills. This is accomplished by establishing project teams with increased decision-making authority, training participants in teamwork, and using facilitators to assist the teams. On public projects partnering focuses on the construction phase of the project. Cooperation continues throughout the project with periodic meetings and problem-solving, and joint reviews and evaluations of the team's performance. The contractors believe that the major contribution of partnering is that it promotes an environment of cooperation and good will, and provides a forum where project participants can discuss and solve problems in a timely manner.

Total Quality Management. TQM is used by several contractors primarily as a learning mechanism for improving over time the work processes within the firm. The concept of internal and external customers enables employees to identify and resolve coordination problems, especially those generated within the firm. In some cases, TQM is also used in projects to address problems of coordination between the designer, owner, contractor, and suppliers. Some firms are expanding their TQM effort to include external organizations, i.e., subcontractors and vendors. For example, DPR is expanding its TQM program to improve coordination with external parties.

Technological mechanisms

These mechanisms refer to the use of information technology as an integration tool.

Links between construction applications were used by almost all construction firms. Although they increase integration between construction functions, i.e. scheduling, estimating and cost control, and establish links between office and site, they are limited by the boundaries of the firm. Larger AEC firms are also using systems that link design - construction and procurement but again, within the firm's boundaries.

5.4.2 Mechanisms for inter-organizational integration

The means for inter-organizational integration include development of long-term relations and information technology. Long-term relations vary significantly in terms of formality and extent of cooperation. For the purpose of this report, such relations are classified under contractual and organizational mechanisms. Contractual means include

the more formal arrangements such as strategic alliances and joint ventures, while the organizational ones refer to less formal cooperation.

Contractual mechanisms

Strategic alliances and joint ventures. Strategic alliances include strong "semi-formal" long-term relations between EPC firms and owners, as well as relations between contractors and design firms. The owners interviewed have selected a small number of highly qualified EPC firms and established long-term cooperation. Cooperation extends beyond specific projects; the partners exchange personnel and work together on technology development. In a similar manner engineering-only and construction-only firms (such as Ehrlich-Rominger, Atkinson Construction and Dillingham) have established long-term relations with a few preferred designers and contractors in order to submit joint proposal, or form joint ventures for design-build projects.

Organizational mechanisms

Informal relations. In most of the cases the inter-organizational relations with owners, designers, and suppliers (vendors and subcontractors) are informal; they have developed over time and are based on repetitive successful cooperation.

In the public sector, although formal alliances with public owners cannot be established, relationships are based on previous working experience. Contractors evaluate owners with respect to cooperative attitude and receptiveness to the contractor's needs, and consider this in bidding. Establishing long-term relations with owners is a primary consideration for several firms in the private sector. Some contractors continue to exchange information with their customers even when a specific project does not exist. Relations with owners enable better understanding of customers' needs, development of trust, and increased ability to win contracts.

Relationships with designers enable contractors in the private sector to become aware of projects early, and increase their chances of winning these projects. In design-build projects, contractors can select designers with which they have strong cooperation as partners, and work together from the early design phase on concepts and methods to improve project effectiveness.

Relationships with suppliers (vendors and subcontractors) are also based on previous experience. Although price is a key criterion for selection of suppliers,

reputation, financial stability and previous successful cooperation are also very important. Thus, in many cases, a better qualified supplier is selected, even if his price is not the lowest.

TQM with "external" customers. A stronger mechanism for inter-organizational integration is the implementation of TQM to include external "customers" and "suppliers", i.e., subcontractors and vendors. The goal is to improve their work processes and achieve mutual benefits. For example, DPR's management believes that there is large potential for mutual benefits from strong relations with suppliers and focuses on establishing long-term relations with a few selected vendors and subcontractors. Suppliers are treated as partners and are invited to training sessions or technical presentations. These relations enable the contractor and suppliers to cross each other's boundaries and improve the overall work processes. For example, DPR tries to improve those areas that affect suppliers (e.g., pay subcontractors within three days from receiving a progress payment). Another possible area for collaboration and improvement is the alignment of the subcontractors' safety programs with the contractor's program.

Technological mechanisms

Information technology is another mechanism that firms use to increase integration with other organizations. Applications include primarily electronic links between organizations, and some systems that are tied to specific partner needs or knowledge.

Links between owner - design - procurement - construction. As identified earlier, communication problems between different systems increase the cost of linking them. Furthermore, the limited utilization reduces the payoff of such investments. Also, issues of liability arise when a computer application crosses organizational boundaries. Despite these problems, most of the firms interviewed are establishing electronic interfaces with external project participants. For example, DPR has developed the capability to exchange CAD data with one of its major customers. The "Process" firm and its major contractors also have similar capability. One contractor has established electronic linkages with an equipment vendor and can directly access service manuals, parts books, capacity charts, and other technical information from the vendor's database.

Integration related computer applications do not include only electronic linkages, but also systems that embody knowledge related to a specific partner. For example, an

EPC firm that has long-term cooperation with the "Process" firm has developed a system that embodies the owner's specifications and knowledge of the refinery process. Although development of this customer-specific application has limited payoff, it creates an incentive for both parties to continue their cooperation in the future and increase the payoff for both sides.

Development of inter-organizational relations seems to facilitate the use of information technology as it increases the payoffs from repetitive use of applications that may could not be justified for use on one project. Moreover, corporate relations facilitate resolution of problems created from access to each others' data. For example, liability concerns may be lower when the organizations sharing data have strong relations based on trust and previous cooperation.

Electronic links with associations. One contractor has electronic linkage with AGC's on-line system, which allows the firm to access scanned drawings and specifications for public projects that are out to bid.

The previous sections identified benefits, barriers and mechanisms related to integration. It is important however, to examine these integration issues from a managerial perspective. Thus, the following chapter address the question of what are the concerns and problems that management faces in order to increase integration.

CHAPTER SIX - Managerial Implications

This chapter identifies managerial implications resulting from the findings. The implications address actions that managers must take to increase integration, and obstacles that currently prevent managers from taking such actions.

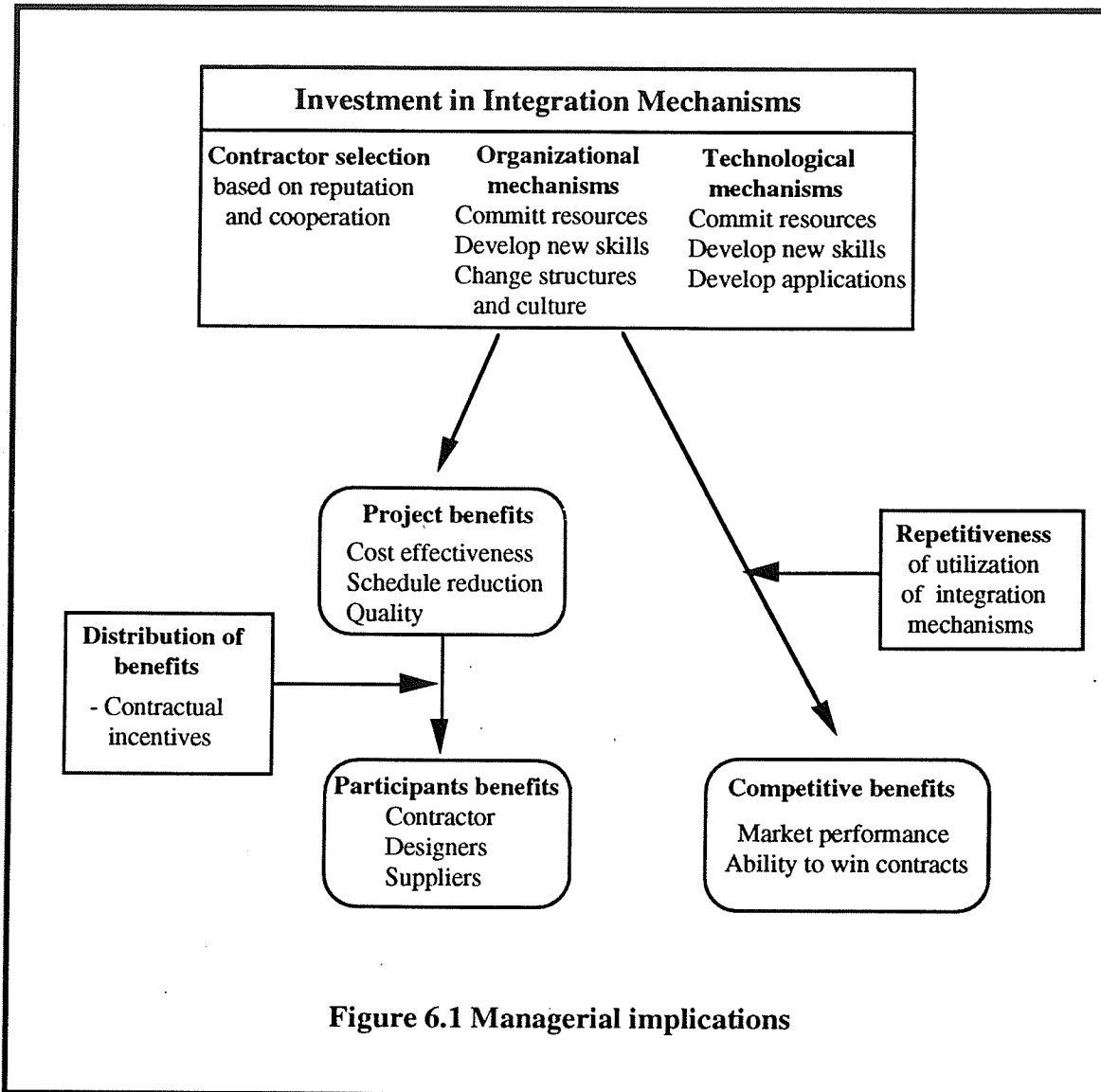
As Figure 6.1 illustrates, integration requires investment in appropriate organizational and technological mechanisms and development of related skills. This investment results in improved project performance. The benefits for each participant depend on the distribution of project benefits, and are determined by the contractual incentives. Finally, the competitive benefits and the pay-off from investment in integration depend on the ability to utilize these mechanisms across several projects. Thus, requirements for front-end investment from all participants, uncertainty of benefits, distribution of benefits, repetitiveness of utilization of integration mechanisms, and requirements for organizational changes, are identified as important managerial actions required for increased integration.

6.1 Investment requirements

The first managerial obstacle in increasing integration is the required investment. Investment is required by all parties. First, owners need to select contractor based on reputation, previous cooperation and integration capability. This is largely an economic decision. For example, this may require selection of contractor who does not have the lowest offer. However, the benefits from increased integration may prevent inefficiencies, disputes and increased costs, and improve overall performance.

Designers, contractors and vendors need to develop the essential organizational capabilities (e.g. structures and teamwork skills) and commit the resources and personnel during the early planning and design phases of a project. This however, may delay start

of construction and will increase front-end costs. One interviewee estimated these costs at about 1-2% of project costs.



Investment is also needed for development of technological skills and applications to increase integration. Because of the technical problems, and the high specificity of integration applications, organizations cannot buy such systems "off-the-shelf". This means that they need to be developed in-house, which creates need for strong development skills, and not simply skills to use the applications.

However, there are important reasons preventing investment in integration. One factor is the competitive conditions that many owners face today. Although these pressures create greater need for integration, they may also prevent front-end investment.

6.2 Benefits uncertainty

One factor that reduces motivation to invest is the difficulty to identify the benefits from integration. For example, it may be difficult for owners to justify selection of a contractor with higher "integration skills" when he has a higher bid than competitors. Will the savings from increased cooperation exceed the additional costs? Evaluating the impact of integration on project performance is difficult even after the project has been completed (i.e. to what degree did integration affect performance?), and it is much more difficult to evaluate the benefits at the beginning. Mechanisms for measurement of project performance and improvements (i.e. TQM, and benchmarking) are essential to identify the benefits from integration.

The benefits from integration technology are also hard to measure. While the impact of information technology is easier to measure when it automates a specific task, the benefits from increased integration are very hard to evaluate. The primary reason is that it does not automate pre-existing tasks (this would allow comparing costs and benefits), but enables organizations to work in new ways that were not possible previously, and especially making decisions with more information.

6.3 Distribution of benefits

A third important factor has to do with the distribution of benefits to the participants. Even when contractors, designers and suppliers believe in the benefits from integration, their motivation to make the investment in skills, personnel time, and information technology depends on how the benefits are distributed. Some of the contractors interviewed felt that most of the benefits are appropriated by the owner. Even when they are compensated for their engineering services (e.g. their participation in design and constructability input) contractors feel that they are not adequately compensated for their innovativeness or expertise.

6.4 Repetitive utilization of skills

The ability to frequently apply the integration mechanisms determines to a large degree the payoff of the investment. Organizational capabilities are easy to utilize across projects, because teamwork and problem-solving skills apply to any context. This

problem, however, is important for integration technologies. In this case, the payoff from an investment in developing electronic links between computer systems depends to a large degree on the frequency of using these linkages.

As identified previously, the lack of standards increases the cost of computer interface development. Moreover, the project participants are different from project to project. Thus, electronic linkages or other integration applications can be typically used only for specific projects, customers, or designers. Such "application specificity" results from a) technical reasons (lack of standards), b) knowledge specificity (systems related to a specific customer, designer, or other party) or c) project characteristics. Thus, in most cases the investment is justified only on a project by project basis, and the payoff is limited.

In general, it appears that there are two ways to increase utilization and payoffs of integration technology: 1) reduce specificity through standardization, or more "general use" applications, and 2) increase cooperation with same parties. Thus, (in addition to the other benefits) development of strategic alliances permits higher utilization of integration technology and larger payoffs. On the other hand, the development of customer specific application also creates an incentive for repetitive cooperation.

6.5 Organizational changes

Last but not least, integration requires significant organizational changes in structure and culture. The managerial challenge is to increase integration without sacrificing the benefits from specialization and differentiation. This requires new structures, increased group decision-making, decentralization and increased authority to teams, new incentives and evaluation systems, and training in [additional] non-technical skills. It also requires changes in the organizational culture to support and promote teamwork and cooperation with other functions and organizations. Such changes however, are slow and hard especially for larger, more bureaucratic organizations.

This chapter identified the key challenges management faces in increasing integration. The following chapter summarizes the study, and identifies implications for researchers and practitioners.

CHAPTER SEVEN - Conclusions and Recommendations

The purpose of this study was to increase understanding of management needs for integration, and identify integration benefits, mechanisms and barriers. The researcher first reviewed integration literature. This resulted in the development of an integration model, which guided data collection regarding benefits from and mechanisms for integration. The findings of this study suggest several conclusions and recommendations with respect to the need for integration and the managerial actions required to develop this capability. This chapter provides a summary of the study and develops recommendations for practitioners and researchers.

The researcher reviewed organizational behavior, manufacturing and construction literature to gain background from previous research and empirical evidence related to integration. The study examined literature on intra-organizational (cross-functional) and inter-organizational level of integration. The literature review first identified need for and benefits from integration. This included the importance of integration for organizational performance, problems due to lack of integration, and conditions that create increased need for integration. The review also identified mechanisms for integration. This task identified contractual, organizational, and technological means that managers can use to increase integration.

The findings from the literature review were summarized in the integration framework presented in chapter three. The framework described the conditions that create increased need for integration, project and company benefits from integration, and mechanisms to increase integration. The framework was used to guide data collection. Analysis of the data focused on whether or not the integration needs, benefits and mechanisms identified in the background are used by managers in construction and owners' organizations.

7.1 Research findings

The findings support the integration needs and mechanisms identified in the framework. First, managers identified problems from lack of integration, as well as significant operational and strategic benefits from integration. Second, managers are using contractual, organizational, and technological mechanisms to increase integration at the project and company levels. Third, it appears that the pressures for improved performance create greater need for integration. However, competitive pressures reduce the availability of resources invested in developing integration capabilities. The identification of managerial challenges and the reasons for not increasing integration was a new finding. The following section summarizes the major findings of the study.

7.1.1 Integration benefits

The identification of operational and strategic benefits from integration is the first finding. Operational benefits refer to benefits from improved project performance, and strategic benefits refer to competitive advantages. Operational benefits include improved project cost effectiveness, reduced schedule, increased safety, and prevention of claims, as well as improved logistics management and cash flows. These benefits result from integration during all project phases.

The study identified strategic benefits of integration for both owners and contractors. Facility quality, speed of delivery and cost effectiveness are important determinants of competitiveness for corporate owners. The results from this research support findings of previous research that integration increases facility quality (Ferguson and Teicholz 1992). For contractors, integration is an organizational capability that results in market benefits (increased ability to win contracts) as it reduces the client's risk. As identified previously, increased integration results in improved project performance due to increased ability to identify cost effective ways to meet customers' needs, and greater ability to respond to unanticipated problems. For owners this means reduced risk of inefficiency, and for contractors it means enhanced reputation, and higher ability to win contracts.

7.1.2 Integration barriers

Contractual, organizational, behavioral and technological factors were identified as primary barriers to integration. Contractual arrangements may affect integration in two ways; first, they may prevent the participation of downstream actors in upstream decisions (i.e. contractor's involvement in design). Second, they may reduce motivation

for integration, as the incentives of different participants may not be aligned. Owners' leadership in overcoming such barriers is critical.

Characteristics of the formal and informal project organization also raise strong barriers. Responsibility allocation and incentives tied to functional performance promote sub-optimum decisions and complicate conflict resolution. Furthermore, competitive attitudes and antagonistic relations between participants make integration hard even when formal arrangements support teamwork. Issues of individual behavior are also important. Lack of inter-personal, communication and negotiation skills were identified as an important barrier by all managers, and almost all firms are investing in improving such skills. Problems in communication between different computer systems, combined with the lack of standards impede the utilization of information technology as an integration tool. These problems increase the required investment and limit the payoff.

7.1.3 Integration mechanisms

Contractual, organizational and technological mechanisms facilitate integration at the project and inter-organizational levels. Contractual means to facilitate project integration include value engineering provisions, design-build contracts, and contractual incentives that align the objectives of project participants. Organizational mechanisms include implementation of TQM, partnering, establishment of cross-functional teams with decision-making authority, and training of team members in inter-personal skills. Technological mechanisms include computer applications that enable electronic exchange of data and knowledge between participants.

Inter-organizational integration refers to the development of long-term relations between project participants (owners, designers, contractors and suppliers). Many firms have developed such relations with customers and suppliers of important resources; they differ in the degree of formalization and intensity. Contractual mechanisms involve more formal relations such as joint ventures and strategic alliances. Organizational mechanisms include less formal relations that developed over time and are based on good previous experience, mutual trust, and respect. Technological mechanisms include development of computer applications that link different organizations beyond the context of a specific project. Such linkages were observed between contractors and professional association (AGC), as well as with designers, suppliers and owners that contractors frequently work with.

7.1.4 *Managerial issues for integration*

Establishment of contractual, organizational and technological mechanisms for both project and inter-organizational integration requires investment which is often significant, and is a management decision. The study identified a set of managerial issues and considerations to address in making these investments.

Five issues were identified as important managerial challenges. These are the need for front-end investment, the uncertainty of integration benefits, issues related to distribution of such benefits, repetitiveness of utilization of integration mechanisms, and requirements for organizational change.

7.2 *Implications for practice and research*

The identification of benefits, mechanisms and barriers to integration suggests several implications for practitioners and researchers. The recommendations for practice address actions that managers in owners and contractors organizations need to take to increase integration, and the recommendations for research address focus on the need for further investigation of the managerial issues.

7.2.1 *Implications for practice*

The most obvious implication is the central *role of owners* in increasing integration. The reasons are two; first, owners (especially corporate owners with large investment in capital facilities) can gain important benefits from increasing integration, because their competitiveness is affected by the performance of the facility development process. Even public agencies, which may not face competition, can have significant benefits especially when their resources are becoming more and more limited, while at the same time the demand for their services is increasing.

Second, the owner is the first actor who needs to make an investment in integration. This investment could mean selection of a contractor who does not make the lowest offer, but has greater "integration capabilities", investment in training personnel in integration skills, distribution of benefits from project success, and investment in making organizational changes that promote integration. Several progressive owners in the public and private sector are already making these investments. Contractual arrangements that facilitate integration and provide incentives to other parties to make similar investments (by sharing the benefits from integration with project participants) are also owner's responsibility.

Understanding the benefits from integration is a critical issue that can facilitate the investment. Benchmarking the performance of their projects and evaluating the impact of integration can provide strong evidence supporting justification for the required investment, and identify new opportunities for improvement.

Designers, contractors and vendors also need to make this investment. After all, integration is an organizational capability as important as technical expertise, although more difficult to develop, as it is embedded in the management system and organizational structure and culture; as Itami (1987) characterized it, it is an "invisible asset" and it is just as essential for competitiveness as the more visible corporate resources. However, development of this capability requires resources and people who are not doing "a day's work for a day's pay". This requires that management takes a long-term perspective. At this point, we need to clarify that "long-term" perspective does not mean that benefits will occur far in the future, but a vision for how the organization should operate. Thus, integration should become part of a firm's strategy and should be aligned with the other dimensions of strategy (market, technology, human resources, etc.)

7.2.2 Implications for research

Developing methods to evaluate the benefits from integration, and the impact of various integration mechanisms on project performance is the first area where research and practice can converge. This would enable managers better understand the mechanisms and benefits from integration, and researchers can increase their understanding of the factors that affect organizational performance. The relationship between integration during the design phase and project performance should be the focus of attention, as design affects the performance of all downstream processes as well as total life-cycle costs. Investigation of the competitive performance of firms with different organizational characteristics and integration capabilities could also provide useful insights about the importance of integration for organizational performance.

Research in the area of information technology is another critical requirement. In this area, research is needed in two different, but complementary, dimensions. The first one addresses the technical side, where it appears that there is need for reducing the "specificity" of integration applications. This includes development of applications that can be used as "translators" between many different systems, or methods that will reduce the cost of developing "partner-specific" applications.

The second area is the management side of information technology. Probably the most useful work in this area should focus on developing methods to evaluate benefits from information technology. As mentioned previously, such benefits are hard to measure before the implementation (although easier to measure in retrospect), because the technology enables organizations to create services and customer benefits that were not previously able to do. Such research should focus on the implications of computer technology for the *work process* rather than isolated tasks.

Another important issue is the identification of organizational changes required to enable effective utilization of information technology. Despite the integration potential of information technology, significant benefits may not occur before organizations change the traditional sequential process of facility development. Thus, organizational changes may have to be deployed together with technological changes.

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APPENDIX A - INTERVIEW GUIDE

1. BACKGROUND

- Company, size, number of employees, volume of work
- Primary markets and customers
- Products and services offered
- General characteristics of projects the firm undertakes
- Market conditions and primary competitors

2. IMPORTANCE OF INTEGRATION FOR PROJECT PERFORMANCE

- How important is integration of the project participants for project performance?
- In which phases of the project can integration result in significant benefits?
- How important is construction and suppliers input during design?
- What are the most important problem resulting from lack of integration?
- What are the most significant barriers to integration?
- What specific actions, efforts or investments does the company make to increase integration with other project participants?

Contractual provisions

- How important are the contractual arrangements for project integration?
- Does your firm take any special contractual measures to increase integration?

Organizational Arrangements

- What organizational arrangements do you use to increase integration between Owner-Designer(s)-Construction and Suppliers?
- Are cross-functional project teams formed for each project?
- Is construction involved early in design?
- Are Vendors and Subcontractors s involved in design and planning?
- How important is the role of Project Manager?
- Is team performance used as basis of incentive/reward system?

Training and HR policies (related to integration)

- Is cross-functional experience required for PM or other positions?
- Do you provide training in interpersonal and/or negotiation skills?

Organizational climate

- How important are the work relations with other parties for project success?

Information technology

- To what extent do you use information technology to increase integration between project participants? (e.g. Do you use electronic data transfer in your projects?)
- What benefits do you identify / expect from use of IT?

3. IMPORTANCE OF INTEGRATION FOR COMPANY PERFORMANCE

- How important is for the company's success (in terms of ability to win contracts, satisfy owners, increase competitiveness, enter new markets) the ability to have long-term cooperation with Customers, Designers, Suppliers, or other parties (e.g. technology suppliers).
- What are the primary motivation and benefits from establishing long-term relations with other parties?
- What specific actions, efforts or investments does the company make to increase integration and cooperation with other firms?

Relations with owners

- Does the firm has long-term relations with Owners?
- Does the firm develop alternative contracts with Customers? (e.g. partnering, risk sharing, joint ventures, etc.)?
- Does the company try to expands the range of its services in order to establish stronger relations with customers?
- Have you established electronic linkages with customers?

Relations with designers

- Does the firm have design capabilities in-house? (No -- Some -- Full)
- Does the firm has any long-term relations, or other special arrangements with designers?

Relations with vendors, suppliers, subcontractors

- How much of the value-added is outsourced?
- How important are strong relations with suppliers?
- What are the major problems due to low coordination with suppliers?
- Procurement policies
 - Does the company has long-term relations with suppliers?
 - Do you try to involve suppliers/vendors early in the design process?
 - Do you try to educate suppliers / subs in specific areas of interest (e.g. safety, quality control, etc.)?
 - Have you established supplier awards programs?
 - Have you established electronic linkages with suppliers?

Utilization of information technology

- Strategic importance of IT for company's future?
- Importance of IT for increased integration?
- To what extent is IT utilized for integration between functions (Design-Procurement-Construction)?
- To what extent is IT utilized for integration with other firms (Customers, suppliers, agencies)?

APPENDIX B - CASE STUDIES

B-1 Case # 1: Retrofit paper mill project

Firm type: EPCM (Engineering-Procurement-Construction Management)

Project type: Industrial

Market: Private

Position: Project Manager

This case describes the facility development process of a retrofit paper mill project, identifies the problems encountered and examines the root causes of the performance problems.

Project description

The project involved expansion and upgrading of a paper mill facility. The following characteristics made it a challenging and difficult project: the complexity of the project due to the constraints posed by the existing facility, the high degree of interdependencies between the components of the facility, and the fast-track nature of the project. Any decision for a specific component (equipment, mechanical and electrical systems, etc.) had direct implications for the other components/systems.

Project organization

An international EPCM firm was responsible for providing engineering management, procurement, and construction management services. The owner specified the subcontracting of the engineering services to a specialized design firm. The project involved international procurement and there were long lead times for fabrication and delivery of specialized equipment. Construction was to be performed by local contractors. Thus, procurement had to develop procurement packages for equipment as well as contract packages for the local contractors to bid, and needed the highly inter-related drawings and engineering specifications as soon as possible.

A large engineering group within the owner's organization was responsible for approval of the design. The owner's engineering group (OEG) felt that they could do the design and manage the project in-house. An antagonistic attitude among contractor, designer and OEG emerged early in the project.

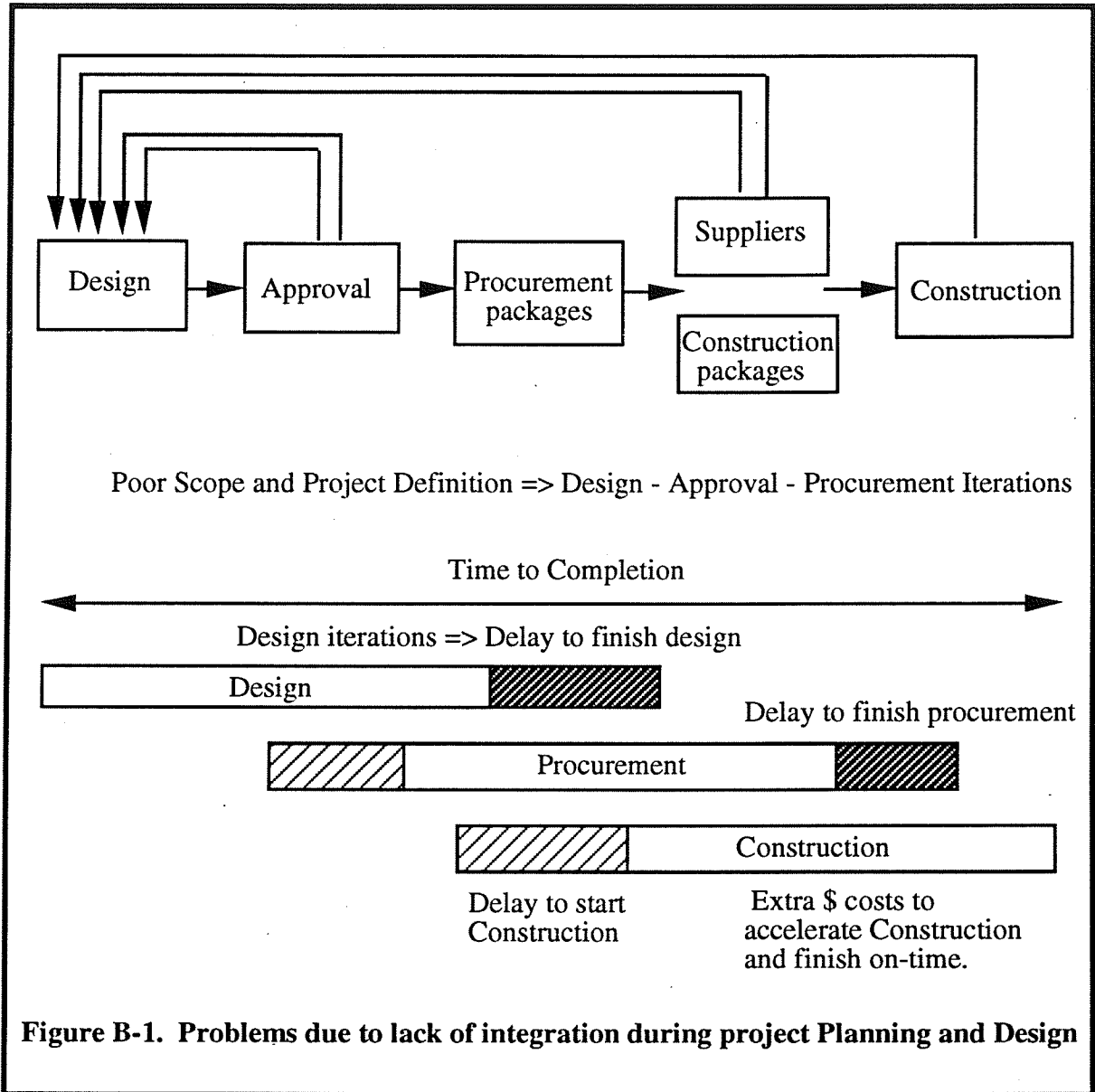
The facility development process

During the project definition phase, the project objectives and scope were defined only in general terms, and provided the basis for the contractual agreement. The contract was target price incentive/penalty, with tight completion dates and significant penalty/bonus for completion. Design was to be performed by a specialized design firm, and then it had to be approved on an on-going basis by the Owner (OEG). Subsequently, procurement had to take bids from qualified manufacturers and vendors to provide the equipment, and develop the construction packages for the subcontractors. Construction was to proceed in parallel with design and procurement (fast-track) in order to achieve the schedule milestones.

Problems and delays started as soon as the first design documents were submitted for approval to the OEG. The OEG was rejecting the designer's recommendations, which resulted in continuous iterations of the design. The owner's management and the OEG had different expectations and goals, which created significant problems. Thus, the absence of well defined scope and requirements created the need for strong cooperation between the owner's and designer's engineers. Furthermore, OEG took an arm's length perspective to the process. The physical separation and problematic communication of engineering and OEG, as well as the antagonistic relations, complicated any resolution of technical disagreements and resulted in repetitive rejections of the designer's proposals.

At the same time, the OEG requested that the designer perform "optimization studies" to compare the performance of different equipment options. This required additional unexpected work for the designer as well as extensive input from vendors, who were invited to make multiple presentations to the owner. The involvement of international vendors in the loop caused further design iterations and delays. The large number of special components required extensive vendor design. Thus, the designers had to wait for the vendors to complete the detailed design of a specific component before the related design could be fixed. In turn, design delays resulted in subsequent delays in procurement and construction. Thus, 18 months after the project was started, Procurement was significantly behind schedule, as many long lead-time components had not been ordered and only 25% of the subcontractors' work packages had been prepared, versus the planned 60%. Figure B.1 illustrates the implications of these problems for the facility development process.

This situation created dissatisfaction and tension between the owner, the designer, and the contractor. The designer realized that his design costs were much higher than expected, and felt that "he was not hired to perform optimization studies". As the design was delayed, owner's senior management became dissatisfied with the designer and the EPCM firm. Finally, the delays resulted in conflict between OEG and construction project manager who was unable to start construction.



At this point, the PM was replaced. The new PM put pressure on OEG to finalize decisions so that procurement could develop construction work packages. Also, significant additional resources were required in order to accelerate the detailed design

phase. As a result of the front-end delays, construction started with a significant delay. At the same time the contract had a fixed completion time which was critical to the owner. In order to accomplish the contract deadlines construction had to be accelerated, which required extensive overtime and additional resources.

Another significant problem during construction was the high rate of waste and rework. Due to the designer's inability to take accurate measurements of the existing facility, many components (particularly piping) did not have accurate dimensions, and resulted in a large amount of waste. Despite these problems, construction achieved very high performance rates - 20% of total construction per month, for 3-4 months - and the project was completed with only a small delay. However, the construction costs were significantly larger than initially estimated.

Root causes and mitigating factors

The central problem in the case was the front-end delays that occurred during design. As depicted in Figure 1, the continuous rejections by OEG, design iterations, and extensive vendor design reduced the time available for construction and resulted in a large budget overrun. The waste and rework during construction was a second problem. The root causes can be found in the following factors: 1) project complexity and uncertainty, 2) poor project definition, 3) inappropriate contractual framework, 4) inappropriate organizational arrangements, 5) adversarial relations between owner's and designer's representatives, and 6) inaccurate measurements of existing facility. The large experience and capabilities of the EPCM firm were the main mitigating factors that reduced the cost and schedule impact of the above problems.

Project characteristics

The large complexity of the project limited the designers' ability to make stable decisions early, because of the high degree of interdependencies between the components. In addition, the need for special components required extensive design input from international vendors. Furthermore, the schedule requirements were extremely tight, as completion time was critical.

Poor project definition

Poor project definition was the primary cause of design iterations and delays. During the project definition phase, the project scope was established only in general terms, without identifying the actual technical requirements and priorities. Furthermore, some major difficulties, risks and operational problems remained unknown and

unresolved. The unclear scope resulted in different expectations between owner's management and OEG. Thus, OEG was continuously questioning the design proposals and requesting evaluation of different alternatives in an effort to get the maximum scope and highest possible level of plant automation. The absence of stable directives and criteria for design development and subsequent evaluation of the design, resulted in significant problems with approvals, many design iterations, and resultant delays.

Contractual framework

The target cost penalty / bonus contract was ill suited to the complexity and uncertainty involved in this type of project. Although the contract did not directly contribute to the front-end delays, it determined the financial implications of the design delays for each party. Shifting the risk to the contractor reduced the owner's incentive to cooperate with the designer and contractor for solving unanticipated problems during design and construction. Thus, the OEG focused primarily in optimizing the facility's functionality without consideration for construction costs or schedule which they regarded as someone else's problem. The subcontracting of design services reduced the contractor's control over the design. Furthermore, the designer's incentives were not aligned with those of the contractor; the designer's incentive was to minimize design manhours and optimize design without consideration of the total project costs.

Organizational arrangements

In addition to the contractual barriers, the organizational arrangements prevented the establishment of a cohesive project team and effective coordination. The communications between designer's and owner's engineers were not effective; the two groups were acting largely separate from each other, and their interaction was primarily review of the designer's work.

Adversarial relations

The adversarial relations between OEG and designer limited cooperation between the two engineering groups for establishment of design criteria and resolution of differences. In addition to the unavoidable role conflict between the engineering groups (designer wants to minimize own costs, OEG wants to maximize facility functionality), antagonistic attitudes were developed from the beginning of the project as OEG had resisted the idea of bringing an outside designer to perform what they believed they could have done in-house. Thus, problems due to "turf" considerations were present to a very large degree in this project.

Inaccurate measurements of existing facility

This problem resulted in procurement of wrong components, additional construction delays, and significant waste.

Mitigating factors

The EPCM firm had been selected not only for procurement expertise but labor relations, work planning, and subcontract management skills as well. The ability to develop "work arounds" and revise schedules efficiently while keeping the multiple subcontractors under effective control reduced the cost growth and schedule impact. This enabled very high rates of quality construction placement as engineering completed in increments and expedited procurement. In essence the owner had the benefit of this "capability insurance" which is often critical in bringing poorly defined international projects to successful completion.

Recommendations for increasing integration

The following actions should be taken to address these problems.

Increase integration in project definition phase

The effectiveness of the preplanning phase is the critical determinant of project success, and if successfully performed can reduce total project costs by 10 - 20%. The critical "deliverables" of this phase are the following: 1) identification of owner's needs, constraints and priorities, and 2) development of a thorough project execution plan that identifies the critical uncertainties and risks, and prevents unrealistic expectations.

Identification of owner's requirements and priorities requires first integration *within the owner's organization*. Representatives of corporate clients have different roles, incentives and objectives. A consistent problem in industrial facilities is the diverse requirements and unresolved priorities within the different divisions and functions in the owner's organization. Unless these requirements and priorities are identified and agreed upon, it is difficult to establish criteria to guide trade-offs and decision-making, and the design may be influenced by internal "political" considerations.

The development of a comprehensive project execution plan before the contract price is agreed is needed in order to identify the critical uncertainties and risks involved in the project, so that owner's expectations are realistic and the contract takes these risks into consideration. This requires early involvement of all participants and the establishment of a cohesive project team. Thus, integration during the preplanning phase

has the highest leverage for improving project performance. The investment required for increased integration is estimated at 1-2% of project costs and the benefits from integration approximately 10-20% of project cost and schedule. Availability of personnel and internal policies may, however, prevent integration at this early stage, especially since the contract has not been awarded yet. Furthermore, no-one wants to highlight the risks to the owner in fear of losing the contract to the competition.

Organizational arrangements

In the case of complex, unique projects, the organizational arrangements are critical determinants of integration. First, the entire EPC process needs to be controlled by one organization in order to increase coordination and align to the extent possible the parties incentives. This arrangement also facilitates the participation of all key players early in the process. However, establishing a *cohesive* project team requires more than formal arrangements. It requires primarily motivation and willingness of different specialists to cooperate and accept opinions and criticism from other disciplines. Turf problems and issues of professional pride seem to be the primary barrier to real integration within large organizations, as well as between different organizations.

"Capability insurance"

Where project definition or other uncertainties are present, the owner should consider his ability to rescue a project should trouble develop. Selecting a management contractor with a proven record in solving unforeseen problems is an effective way of providing this insurance.

Role of project manager

In this case, the critical role of the project manager in providing leadership and creating a cooperative environment within the team and the representatives of other parties is emphasized. The PM needs to be able to generate the support of his team as well as the cooperation of the other parties agents. Thus, the PM needs to have a diverse technical experience (in order to be able to understand the position and interests of the parties) and have strong interpersonal and negotiation skills, able to establish trust with other parties, identify and resolve conflicts and harmonize diverse interests.

B-2 Case 2: DPR Construction

Firm type: Construction
Project type: Commercial buildings
Market: Private
Position: Senior Manager

Background

DPR Construction is a young, aggressive and rapidly growing building construction firm. The company was established in 1990 with offices at Redwood City and Sacramento, and offers construction services primarily to corporate clients for small-medium size biotech and pharmaceutical facilities, medical labs, senior housing, offices microelectronics, etc. Almost all of DPR's work (95%) is negotiated contracts with a guaranteed maximum price. The firm follows a differentiation strategy by focusing on complex and difficult projects. The quality (functionality) of the facility and the speed of construction are the most important factors for satisfying the clients. The fact that DPR's market consists of corporate clients with repetitive businesses, makes the firm's reputation a critical factor for its success.

During the first years of operations DPR has been very successful, despite the unfavorable condition of the economy. As shown in Table B-1, the company has had a large growth in volume of work, and in November 1993, DPR was ranked as the fastest-growing private firm in California. In 1993 DPR opened new offices in San Diego.

Table B-1. Volume of contracts

Year	Volume (in \$1,000s)	
1990	\$400	First year of operations
1991	\$30,000	
1992	\$80,000	
1993	\$110,000	Estimated

Factors contributing to DPR's success

According to DPR's management the following factors contribute significantly to the company's success:

Customer orientation. According to DPR's management the company is "customer-driven" rather than "ROI-driven". The company's primary objective is "to meet or exceed customers expectations" in every way. This is critical for the firm's reputation and its ability to win more contracts from the same corporate clients, as well as from new clients.

Strong technical skills. DPR construction personnel have varied experience with small and large construction projects. A strong emphasis is also placed on continuous technical training to stay aware of developments in materials, equipment and new methods.

Expertise in the FDA approval process is very important for the type of facilities DPR builds. Any omissions and errors can cause significant delays in licensing a facility, thus delaying the owner from delivering his products to the market.

Strong safety program. In 1992 DPR received several AGCA Safety Awards for lowest incident rate among firms in its size category, as well as for no lost time injuries during that year..

Furthermore, DPR believes that a critical factor for both project and company success is its ability to achieve a *high degree of integration* between the project participants. Integration between owner, designer, subcontractors and suppliers is considered critical in order to best utilize the firm's capabilities and expertise. The reason why integration is important is twofold: First, it enables DPR to better understand their customers needs and constraints, and second, it enables the company to satisfy these needs in the most cost effective way.

Strategies to increase integration

To achieve high degree of integration DPR focuses in the following areas:

Early involvement in design.

DPR tries to persuade the owners to appoint the contractor at the early design phase thus facilitating concurrent design of the facility and the construction process. Early contractor's participation and pre-construction services enable better understanding of owner's and designers' requirements and constraints and identification of cost and time reduction opportunities without reducing the quality of the facility.

Relations with owners

Establishment of strong, long-term relationships with owners is a primary concern for DPR. At the project level, it enables better understanding of customer's expectations, constraints and priorities, and results in well defined project scope and avoidance of unnecessary expenses. DPR is also trying to inform owners about risks and cost implications of design decisions, rather than making promises that they cannot fulfill. The establishment of strong relationship based on trust is essential for the contractor's opinion to be welcomed and accepted without suspicion. Such relationships also enable early selection of contractor and not only on the basis of price. DPR maintains its relationships with its clients even when a specific project does not exist. This way, DPR can better understand their customers objectives and needs for future projects.

Relations with designers

The primary requirement for integration is effective teamwork between the participants. Establishing good relationships based on trust with designers is critical for accepting the contractor's input, and resolving technical issues.

Relations with suppliers

DPR believes that there is large potential for mutual benefits from strong relations with subcontractors and suppliers. DPR has been focusing in establishing long-term relationships with selected vendors and subcontractors who can understand how DPR operates and will also work towards meeting or exceeding the client's expectations.

Subcontractors and suppliers are treated as partners and are invited to training sessions or technical presentations at DPR. This allows the company and its suppliers to "cross each other's boundaries" and improve the overall work processes. DPR focuses on improving those areas that affect suppliers (e.g. pay subs within 3 days from receiving progress payment). Another identified area of future collaboration and improvement is the alignment of the subcontractors' safety programs with DPR's program.

Cooperative environment.

The small size and entrepreneurial climate of the firm creates a cooperative environment free of functional or hierarchical barriers. For example, in order to maintain an informal environment, DPR's management decided not to use formal titles. Employees have increased decision-making authority; DPR provides training, etc. and has established one "prime directive" for employees behavior: "Do whatever is necessary to meet or exceed the customer's expectations". In addition, to encourage employees to

make decisions, DPR's management is willing to tolerate mistakes thus, "sharing risks" with employees.

TQM Program

DPR has established a TQM Process for improving work processes and every aspect of organizational life. In 1992, 108 opportunities for improvement (OFIs) were received from employees. 28% of them have been implemented and 45% are in process for implementation. In 1993 the company is expanding its TQM program by requesting feedback and improvement proposals from external parties (owner's, suppliers, subs, etc.). DPR particularly focuses in improving the effectiveness of work processes, as in the case of suppliers payments.

Information technology

The company has links between office systems (scheduling, estimating) as well as electronic links between office and site. Links with a designer's CAD system has been used on two projects. Electronic linkages with suppliers have not been established yet, but are in the future plans of the company.

Benefits from integration

DPR's management identifies both operational and strategic benefits from integration.

Operational benefits

DPR strongly believes that integration is one of the most critical factors for project success. Participation of construction and critical suppliers in the early design phases results in the following benefits:

1. increased ability to identify alternatives that optimize the overall facility development process rather than the design only, and
2. reduction/elimination of design, procurement and construction rework which is the main cause of delays and inefficiencies.

The primary benefits from project integration include increased ability to understand the real needs of the customers, identify the most cost effective ways to satisfy them, and establish realistic customer expectations. When engineering is designing "in a vacuum" and focus in optimizing the design without consideration of the total costs of the design decisions, opportunities for cost and time savings remain

unidentified. Furthermore, the contractor will be requesting changes in the design to do the best utilization of his own skills and suppliers capabilities, with increased rework for all participants. Thus, increased integration at the project level is critical for cost control and realistic expectations and requires early consideration of the strengths and constraints of the specific contractor and suppliers who will actually build the facility.

Strategic benefits

According to DPR's management, integration with customers, designers and suppliers goes beyond operational benefits at the project level, and results in increased ability to win contracts. Thus, understanding the customers needs and constraints, and being able to satisfy these needs in the most efficient way is critical both for repetitive businesses from current clients, and for attracting new customers. The development of a "network" with designers and suppliers also enables the company to identify early new work in the market.

Product innovation is another area of potential strategic benefits. One of DPR's plans for the future is cooperation with owners, designers and suppliers for the development of a standardized "generic" medical lab module which can result in significant cost / time reductions due to standardization.

B-3 Case #3: Bechtel Corporation

Firm type: EPCM
Project type: Industrial
Market: Private
Position: Senior Manager

Background

Bechtel's market with regard to industrial projects includes power facilities (such as cogeneration and fossil fuel), process plants (including metallurgical and petrochemical), as well as pharmaceutical and other industrial facilities. Bechtel has the capability to provide complete engineering, procurement, construction, and construction management services, and depending on the customer's contract strategy provides one or all services.

Importance of integration

Bechtel acknowledges the importance of integration and identifies both operational and competitive benefits. The benefits result from the actions that management takes to increase integration at both the project and company level. These actions include: 1) policies promoting integration at the project level, and 2) inter-organizational long-term relations with owners and suppliers.

Operational benefits

Operational benefits result from savings in project cost and time, because integration increases the *ability to select the best combination of design, construction and procurement alternatives in order to optimize the overall project performance* (in terms of schedule, cost and quality), rather than optimizing functional priorities. The main problem from lack of integration is that each function strives to optimize its own performance, rather than the entire project.

Thus, when engineering is performed without considering construction, the design may be optimized, but opportunities for improving fabrication and construction costs, time and product quality may be lost. For example, prefabrication and modularization may not be the most efficient design alternative (increased reinforcement may be needed due to transportation considerations), but can significantly reduce completion time,

because it allows activities to be performed in parallel, and off-site where conditions are more controlled.

In a similar way, procurement costs may increase by selecting more expensive components, which however, may have shorter lead times, or may enable savings in other components. Furthermore, construction input during design results in increased safety and process improvements. For example, changing the connection points of steel columns from the top of the floor to a higher point, makes the work of crews easier, faster and safer.

Strategic benefits

Strategic benefits refer to the firm's increased ability to win contracts. Integration results in improved competitiveness because of two primary reasons: 1) increased ability to understand customers' needs, and 2) increased ability to satisfy customers' needs in a more cost effective way.

Better understanding of customers' needs is a direct result of the long term relations Bechtel develops with its customers. This enables engineers to understand what are the critical features of a facility and how they serve the customer's overall business objectives. Furthermore, integration between design, construction and vendors enables the firm to identify the most cost effective combination of product and process technologies that can serve these needs.

Mechanisms to increase integration at project level

Mechanisms supporting integration at the project level include contractual, organizational (appointment of cross-functional project teams, incentives to support cooperative behavior, training in interpersonal and negotiation skills), and integration technologies.

Contractual

The ability to bring all key project participants together, depends to a large degree on the owner's contracting strategy. Thus, the primary contractual means to achieve integration between project participants is the EPCM contract, with Bechtel responsible for design, procurement, and construction of the facility. Contractual means however, are not sufficient to achieve integration.

Cross-functional project teams

A primary consideration for management is to get all the key project participants involved as early as possible. To support integration, Bechtel uses a matrix organizational structure, with separate functional departments (design, procurement, construction management, etc.). When a project is still at the proposal phase, a cross-functional team is appointed which includes key representatives from design, procurement and construction, as well as an estimator and a scheduler. This core team is headed by a project manager, and it remains together throughout the project, while additional personnel are allocated from the different functions as needed.

Another important concern is the participation of key vendors as early in the design as possible. This is particularly important because industrial facilities require extensive vendor design. To make vendor participation possible, Bechtel is changing its relationships with suppliers, as presented in a following section.

Incentives and training

While the appointment of a cross-functional team can significantly facilitate integration, the effectiveness of the team is determined by the willingness and ability of the functional representatives to cooperate for improving total project performance. Changing the attitudes and behaviors of people is identified as the most important factor and challenge for integration. To support cooperative behavior throughout the firm, Bechtel establishes a "mixed" incentives system, and provides training in interpersonal and negotiation skills.

To promote integration, Bechtel is using a performance evaluation system based not only on technical skill and functional expertise, but total project performance as well. This way, all members of the project team try to maximize joint benefits, rather than functional interests. In addition to the incentives system, Bechtel provides employees with training in interpersonal and negotiation skills, in order to enable more cooperative behavior.

Information technology

Bechtel is investing in development of computer tools that facilitate integration. The evolution of computer tools towards integration can be described as involving three "phases": The first phase involved the automation of different tasks, such as scheduling and estimating, which resulted in "islands of automation". The second "phase" involved

the electronic linking of these tasks. However, this is still "one-way communication". Recently, however, Bechtel is developing simulation tools that enable interactive examination of several design and construction alternatives.

Mechanisms to increase integration between organizations

In order to be able to provide the best value to its customers, Bechtel develops strong Inter-organizational relations with owners and suppliers.

Relations with owners

To better understand the operational and maintenance requirements of industrial clients, Bechtel has had several engineers located for a period of time at owner's plants. This way, when the owner needs a facility, the engineers are in position to design a facility that better satisfies the owner's needs. While the clients still have the freedom to select other engineering-construction firm for their future facilities, the knowledge of the customer's needs gives Bechtel a competitive advantage not only with the specific client, but also with other customers in the same market. A second area of collaboration with customers is joint research and development focusing on new technologies useful for the customers.

Relations with suppliers

Strong relations with vendors is considered very important for two primary reasons: 1) industrial facilities require extensive design input from vendors, so early participation of key suppliers is needed to take into consideration vendors constraints and capabilities, and 2) materials are a large component of total project costs, and their selection also has strong effect on labor costs. Thus, input from vendors in the early design phases is very important.

To enable participation of vendors in the preliminary design phases, Bechtel is developing long-term relations with suppliers. Under the traditional arm's length relationships the suppliers were bidding for specific items without being involved in the design phase. This creates iterations and delays, especially in the case of specialty items, where the vendor's constraints and capabilities need to be taken into consideration for selection of equipment.

Bechtel performs extensive prequalification of vendors before they get involved in a long-term relation. The long-term relations are based on trust and responsiveness, and

the willingness of suppliers to cooperate and do the additional investment required. This investment may take the form of personnel time involved in early project phases, or even modifications of supplier's operations to facilitate the project development process.

Integration barriers

Bechtel identifies three main barriers to integration. The first one is the traditional contractual framework, the second is related to human behavior, and the third refers to technological issues.

Contractual barriers

Traditional contractual relations raise barriers to integration as they fragment the facility development process. Contractual arrangements that place the responsibility for the entire EPC process under the same organization provide best opportunities for integration. However, the contract structure depends on the owner's strategy.

Behavioral barriers

Changes in the formal organizational arrangements are necessary but not sufficient to ensure integration. Integration requires further changes in the behaviors of the individuals, who will be members of a cross-functional team rather than functional specialists. Building awareness, and providing training, and an environment that supports cross-functional cooperation are perceived as main managerial challenges. Changes in incentive system, cross-functional training, training in interpersonal and negotiation skills, are the measures currently used by Bechtel.

Technological barriers

Standardization of protocols between different computer systems are the primary technological barrier to integration with owners and with vendors.

B-4 Case #4: Homer J. Olsen, Inc.

Firm type: Construction
Project type: Industrial
Market: Public
Position: Project Manager

Background

Homer J. Olsen is a construction company operating in the public sector. The firm was established in 1963 by Homer Olsen, and specializes in construction of public works, such as pipelines, waste water treatment plants, and rail transit facilities. Project sizes vary with the largest ones in the area of \$150-200M. About 50% of the projects are underground utilities. The firm does not perform design in-house. The firm focuses primarily on relatively large and complex jobs, where it can better utilize its capabilities and expertise. The number of competitors vary with the project size. In smaller projects there are up to 20 competitors bidding for the same work, while in larger projects there are about 5 - 10 other bidders.

The facility development process is the traditional process used in the public sector. The owner is responsible for the design which is performed in-house, or subcontracted to external design consultants. Construction is subsequently awarded through competitive bidding on a fixed price basis.

Integration with design

Design and construction are performed separately and sequentially. Typically, the contractors do not provide any input in design, and design decisions are made around the capabilities of qualified suppliers (No. 1 list of suppliers). Construction input may be provided by construction personnel in the owner's organization. Only occasionally, in the case of complex and difficult projects, the contractor may be asked to evaluate a design and suggest potential improvements before it is let for bidding, but this situation is very rare, and the process informal.

The formal mechanism by which a contractor can influence the design is the value engineering process (VE). Value engineering takes place after the contract has been awarded to the lowest bidder, and involves a review of the design (by the contractor), and

proposals for design changes that can result in cost savings. If the owner approves the changes, the savings are generally distributed equally between the owner and the contractor. However, the following reasons reduce the incentives for value engineering:

From the contractor's point of view, VE requires first an investment in engineering work and services, in order to review the design and propose changes. This, in turn, requires deployment of engineering skills (either within the contractor's organization, or from external consultants), and additional costs. Second, there is uncertainty concerning the approval of VE proposals, and third, there is often disagreement concerning the actual savings. Finally, value engineering proposals often cannot be acted upon soon enough to meet the project schedule. Moreover, the examination of alternative designs requires strong cooperation with owner and designers to "debug" the new solution. Thus, unless the benefits are significant, and the cooperation and relations with the owner are very good, contractors will not invest the required resources in VE proposals. From the owner's point of view, any proposal that requires design changes has to be examined and approved. Thus, VE involves additional administrative costs, and results in design rework. Under these conditions the incentives to all parties for value engineering are reduced.

Problems due to lack of integration during design

The lack of integration during design results in the following problems:

1. Identification and correction of design errors and omissions that are not discovered before construction starts. Thus, earlier contractor participation could reduce design errors and inefficiencies.
2. Lack of adequate level of detail for construction operations. The level of detail of design and specifications often creates problems due to ambiguity, misinterpretation, or lack of adequate directions. This results in a large number of RFIs (request for information), delays, schedule changes, conflict, and often claims.
3. Lack of consideration of construction constraints may result in designing something that cannot be built under the specific conditions. Delays, change orders, and claims are typical outcomes of such problems.
4. Lost opportunities for savings through more effective designs. As explained previously, value engineering provisions do not provide adequate incentives for re-examination and changes of the design.

Integration during construction

Integration between owner, designers and contractor is important in order to resolve problems that arise during construction. Problems arise due to design errors, ambiguity in plans and specs, uncertainty due to changed conditions, etc. Thus, the ability to respond to problems effectively is important. When a project is complex and difficult, the need for integration during construction is high, and responsive management by the owner is required. Also, the lower the quality of the design is, the more input is needed from the owner's construction manager.

However, the parties' ability to respond fast and effectively depends to a large degree on the owner's approach in managing and controlling the project. When an owner takes a traditional approach to responsibility allocation, cooperation with the contractor for resolution of issues is limited. No action is taken unless the contractor formally requests changes, and the formal review and approval process is performed. The issue of accountability in public agencies results in avoidance of responsibility, slow response and problem-solving, and increased costs to both owner and contractor.

An example is a recent large waste water treatment project, where the design was procured by the owner on a rush basis due to time constraints. The resultant low quality of design caused approximately 4,000 RFIs (project not completed yet), delays, rework, continuous schedule changes, and construction acceleration. Moreover, the owner's adversarial approach to construction management resulted in slow and non-cooperative response, which in turn resulted in a \$33M claim (20% of construction cost).

According to the project manager, effective integration during construction requires owner's site representatives with decision-making authority, increased cooperation, and joint problem-solving. Finally, the relations between the contractor's and owner's project managers are also important.

Mechanisms for integration

Integration with owners and designers

The firm is generally not active in increasing integration with owners and designers. The firm believes that its competitive advantage comes primarily from its ability to manage and build difficult projects, and develop improved construction methods. Informal relations that develop with some owners through repetitive

cooperation over time do however have a positive influence on the procurement and performance of projects. In general, the firm believes that owners should be more active in promoting integration.

Integration with vendors

The company does not take any specific action or have plans to develop long-term relations with just a few selected suppliers and vendors. Reliability and mutual respect are important especially when long lead-time items are involved, since schedule performance is essential. According to the project manager, the need for flexibility requires the firm to have access to several alternative suppliers and maintain a large base of suppliers to ensure that the contractor receives the best pricing at bid time as well as during the construction period.

Integration within the firm

The company takes actions to increase internal integration between the functions. First, "staff" and "production" functions are integrated, with the project manager preparing the estimates and then managing the project. Second, the firm takes action to use computer technology to increase the automation and integration of functions such as estimating, scheduling, material and equipment management.

B-5 Case #5: Atkinson Construction

Firm type: Construction
Project type: Heavy civil
Market: Public, some private
Position: Senior Manager

Background

Atkinson is a large, diversified company with several subsidiaries in the construction and manufacturing sector. Divisions of the parent company include: a Canadian firm which focuses on pulp and paper facilities, an Eastern subsidiary which focuses on industrial facilities (research labs, cleanrooms, hospitals, prisons, etc.), and a mining company. This case study focuses on the integration issues faced by Atkinson Construction.

Atkinson Construction is the San Francisco based subsidiary that focuses on heavy construction work in the public sector. Atkinson's projects include bridges, tunnels, highways, dams, canals, and other infrastructure facilities. The size of projects ranges from \$20 million to more than \$1 billion. Customers are primarily public agencies such as federal and state departments of transportation, the Corp of Engineers, the Bureau of Reclamation, etc. Although the firm also performs some work for private owners, such as utility companies, the majority of the projects are public works.

The facility development process is the traditional process used in the public sector. The owner is responsible for the design which is performed in-house, or subcontracted to external design consultants. Construction firms receive a set of drawings and specifications on which to base their bid. Construction is subsequently awarded through competitive bidding on a fixed or unit price basis.

The firm's engineering department provides specialized engineering support not readily available during projects. The department's involvement in the projects includes planning the logistics and designing the project's infrastructure, such as haul roads, batch plants, etc. The department typically becomes involved during the prebid phase, but its involvement becomes heavier after contract award.

Importance of integration

In public works, the contractor typically does not participate in the design of the facility. Coordination with owners after contract award focuses primarily on issues that affect construction performance, e.g. schedule, manpower requirements, etc. Improvements in these areas have direct benefits for the contractor, as the following example illustrates. At the McCarren runway project at Las Vegas, which involved cut-and-cover tunnels, the contractor proposed a different direction of construction, changed the sequence of construction phases, and smoothed manpower requirements, thus improving the logistics of the project. Cooperation with the owner is also critical for fast identification and resolution of unexpected problems that arise during construction, and for preventing them from becoming costly disputes.

In several cases however, the contractor has the ability to influence the design, which results in mutual benefits for owner and contractor. In public works, the primary mechanism for design-construction integration is the value engineering (VE) process. In VE, the contractor can propose changes that result in project savings. If the proposal is accepted by the owner, the savings are shared between the owner and contractor. Examples of such cases are the following:

The Grizzly powerhouse project at Northern California was a small lake-to-lake hydro-development project. The initial plans called for the construction of a temporary cofferdam around a power house, and construction of tailrace within the coffer dam. Working on a value engineering proposal with the designer (PG&E), the tail race was redesigned so that it could function as a temporary coffer dam. In this case, the contractor's involvement in the redesign was significant. The successful cooperation with owner and designer resulted in cost savings.

Another example is a highway project at Washington state which required relocating an existing part of highway 405. The initial plans called for building and tearing down several temporary routes, with a scheduled duration of 36 months. The contractor developed a different plan which reduced the number of required temporary routes by building all the new superstructure on one side of the freeway while all traffic was routed on the other side. To accomplish this, the contractor had to come up with a tressel concept that was wider and larger than the original, and had some grades and curves that did not meet the Washington DOT specs. Also, the new solution required encroachment beyond the Right of Way on some city land. Strong cooperation with the

city, the owner and the designers (which was based on the good relations with Washington DOT and the adoption of partnering philosophy), resulted in solving these problems, and in reducing the schedule by 15 months (almost half of the original schedule).

In recent years the firm is more and more frequently involved in the design process as owners tend to shift more design responsibility to the contractor by simply specifying the required function, rather than providing a complete design. The reasons may include limited owner's budget for design, weakness in the specific design discipline, or simply the owners' belief that this will result in increased cost effectiveness. For the contractor, this tendency involves both risks as well as potential rewards, depending on their expertise in the specific discipline. It also provides an incentive for development of long-term relations with designers who undertake this design task.

In private works which involve negotiated contracts, the contractor has higher ability to provide input during design. Although negotiated work is something new to Atkinson Construction, it is a rapidly growing part of its activity. In private projects, the contractor's involvement in design is important for winning the contract from the competition. In any case, problems with the allocation of costs and benefits are still important.

Because construction is rewarded for the work performed, and not for the engineering services and the expertise it provides, the company feels that the benefits from its employees ingenuity and innovativeness and their participation in design are appropriated by the owner, and the firm does not benefit in proportion to its contribution. This problem could be avoided by providing extra compensation to the contractor for engineering services (similar to design work), and by providing bonuses depending on project performance.

In general, benefits from integration are estimated at no more than 5-10% of the total project cost. However, integration can have a great impact on schedule, which may further increase benefits. The major issues that may prevent integration are summarized in the following section.

Barriers to integration

Lack of incentives for the contractor, lack of cooperative attitudes and skills, and contractual limitations are identified as three major issues that reduce the motivation and ability for integration. All of these factors are present to a large degree in US public works.

Lack of incentives

Atkinson recognizes that there is value and potential benefits from integration. However, lack of incentives and problems with the distribution of benefits reduce the contractor's benefits from (and therefore the incentives for) integration. Thus, the contractor needs to invest resources and manhours to identify a better design solution, with high risk and little time. Contractors are unwilling to commit these resources unless they are rewarded for their effort. As the contractor feels that his participation in upstream functions primarily benefits the owner, the value for the contractor usually considered low. Owners, therefore, should be more able to identify the benefits from integration and provide stronger incentives to contractors (e.g. through contractual incentives, such as bonus for early completion).

Attitudes and capabilities

Successful integration for effective problem-solving also depends on the owner's commitment to improvement, cooperation and teamwork. The owner has to be open to new ideas and changes that can result in improvements, and must be willing to commit the required resources, such as time of the designers, etc. The work relations between contractor, owner and designers are critical for successful cooperation. It is important to note that the owner's attitude and cooperative behavior are reflected in the contractor's bid, as well as on selection of the works to bid.

Contractual framework

The contractual framework not only prevents construction input during design, but also limits the contractor to a specific set of requirements (design and specifications), and prevents him from proposing a more cost effective solution, even when he knows a better way to do the job. Because any changes from the original design require owner's approval, cooperation, and distribution of the benefits, the contractor cannot account for the better solution in the bid, as the risk will increase and his benefits will be reduced. Again, owner's attitude and reputation affects the contractor's willingness to take the risk.

Company actions to increase integration

The actions Atkinson takes to increase cooperation and integration with external parties include the following three major categories:

1. Partnering
2. Strategic evaluation of owners and designers
3. Information technology

Partnering

The firm has adopted the partnering philosophy and promotes it in all projects. Within the “partnering” framework, Atkinson promotes cooperative problem-solving with owners and designers in order to improve project performance. These improvements result from the increased ability to identify and solve problems so that all parties interests are protected. In addition to preventing problems from becoming claims, partnering enables the parties to cooperate in identifying and implementing opportunities for project improvement (as in the case of the Washington DOT project).

To develop the skills required in partnering, the company has also established a company-wide training program. Courses in interpersonal and negotiation skills are provided to increase the employees ability to interact effectively with the representatives of the other parties. Finally, closely connected with the partnering effort, Atkinson's Total Quality Management program is another company wide effort that promotes integration between departments within the firm as well as with external parties.

Evaluation of owners and designers

Atkinson pays much attention to evaluating and qualifying the owners and designers that the firm works with, and tries to avoid those who are not receptive to cooperation and teamwork. For the success of partnering effort, both the contractor and the owner must be committed to cooperation and allocate the resources necessary (e.g. designers and construction personnel's time) to deal with the problems, rather than trying to avoid responsibility. Thus, the owner's attitude towards cooperation is very important, because it facilitates prevention and resolution of many problems during the project. As a result, it not only reduces the risk for the contractor (and subsequently the bid), but it results in more successful projects as well. Thus, the company goes more aggressively after contracts that involve an owner with which it has good relations and cooperation.

In private work, Atkinson has selected a few design firms for long-term cooperation. The relations with these organizations have developed over time and are based on repetitive successful cooperation. These relationships enable the contractor to work with designers from the early design phase on concepts and methods to improve project effectiveness. However, the cooperation during a project is not formally organized, e.g. with establishment of cross-functional teams, but is based on mutual understanding of each other's objectives and the development of common norms and culture.

Relations with subcontractors are not developed to large degree, primarily because only 5-10% of Atkinson's work is subcontracted. Stronger relations exist between the firm and equipment vendors, where the cooperation is closer and more extensive.

Information technology

The use of information technology is another way Atkinson uses to increase integration with external parties. Electronic exchange of drawings has been used in some projects where the designer was private. This required solution of some technical problems involved in the interface of different systems. Atkinson has also established electronic linkages with an equipment vendor and can directly access service manuals, part books, capacity charts, etc. from the vendor's data base. It also wants to be able to directly get equipment schematics to use in its CAD system. An electronic linkage with AGC's (Association of General Contractors) on-line system allows the firm to access scanned drawings and specifications of projects for which bid is solicited.

The use of computer technology enables the firm to work faster and "smarter". For example, there are obvious benefits from sending drawings electronically when the distances involved are large (e.g., a project in South America). However, the returns from these systems are not always obvious. While time and cost savings are recognized, typically it is difficult to justify the investment (which is usually large) only on this basis. The real benefits are more easily identified *in retrospect*, and the reason is that the most important benefits are stemming from the ability to do something that was not possible (or was very expensive) with the previous technology.

The barriers to integration through information technology include both internal obstacles as well as external ones. The primary internal barrier is the high cost in

combination with the difficulty to identify the benefits. Integration technology requires investment in resources, especially personnel time. Organizationally, it requires people who understand the technology, and invest significant time and effort. However, contractors are reluctant to invest in something that will not bring fast returns. Lack of immediate pay-off appears as underutilization of resources and the technology may be perceived as ineffective. Moreover, because of the technical uncertainty involved, the use of new technology may increase the contractor's time and risk.

External barriers include the reluctance of other organizations to use these systems. Many owners and designers feel uncomfortable with the technology, for the following reasons: First, they may feel that they lose control over the documents, and issues of liability may arise. Also, the documents may include information that designers do not want to disclose, as when proprietary information or knowledge is involved, or even copyrighted fonts from third parties.

B-6 Case #6: "Process Corp."

Firm type: Owner
Project type: Industrial
Market: Private
Position: Senior Project Manager

Background

The "Process Corp." is a large customer of construction services, with a \$4-5 billion annual capital budget. Facilities include refineries, cogeneration plants, chemical and process plants, offshore/onshore production facilities, etc. The typical capital cost of the major projects ranges from \$25 million to more than \$500 million.

The production from process plants is one primary source of income. With the plants operating 24 hours a day, avoiding downtime is critical. Thus, the operability, reliability and safety of the facilities are primary considerations. Technologically, the facilities are rather conservative. Proven technologies are typically used in order to reduce risk of failure and downtime. New technologies are sought primarily in the area of instrumentation, process control systems and environmental. The cost effectiveness of the projects is another important consideration as it has significant effect on the Company's overall competitiveness (by affecting its ability to utilize capital effectively), as well as on the cash flow.

In the past, "Process Corp." had its own in-house engineering group with approximately 100-200 employees, which designed the facilities the firm needed. In recent years, however, this group has been downsized to approximately 40 employees, focusing primarily on process, instrumentation, front-end design, and plant and piping layouts. The engineering group gets involved at the front-end of the facility development process (scope and conceptual estimates); the detailed design and construction is performed by specialized EPC firms, which are awarded the work through negotiated contracting.

All projects are developed and managed by the local companies that operate the plants. The development of major projects (larger than \$25 million) are usually assigned to one of the company's senior project managers. Organizationally, the majority of senior project managers reside in the company's Projects Group, which is responsible for

managing the entire facility development process from initial project conception, through feasibility analysis, funding, execution and start-up.

One mission of the Projects Group is to improve the cost effectiveness of the firm's capital facilities. Thus, the Company is responsible for developing formal techniques for measuring the performance of the project development process, and establishing effective processes and procedures to improve the entire process from scope definition to start-up. Currently, the Projects Group is benchmarking its performance against the competition and has set a goal to reduce the projects' cost and schedule. Benchmarking addresses both the cost effectiveness as well as the profitability of the facilities.

Importance of integration for project performance

Increasing the integration between project participants is considered a key factor in improving both facility quality as well as cost effectiveness. The Project Group estimates that strong integration from the early project phases can result in 10-20 percent savings in terms of project cost and schedule. Early involvement of all key participants, including the EPC firm, vendors, and the operating firm has significant benefits for the following reasons:

First, it is critical for all parties to understand the owner's and operators' needs and the objectives of the project, and to avoid ambiguity and subsequent major changes in scope and design. Second, understanding the economic constraints and considerations is also critical to avoid redundant functionality, "gold-plating" and unnecessary expenses. For example, operators always have the tendency to request high redundancy in order to prevent downtime. This attitude is typically reflected in the specifications that are developed over time for the process plants. In the past, the reliance on specifications for the design, and the lack of operator's involvement in the facility development process resulted in unnecessary redundancy and extra costs. By increasing the operators' involvement in the design, and communicating the actual project functional needs and economic constraints, much of this redundancy is avoided and the plant is closer to the required performance.

Early involvement of designers, contractor and vendors, is also important in order to identify the best alternatives that can meet the specific requirements and constraints. Vendors' input, for example, is important in decisions concerning most suitable process

equipment. To avoid the problem of "goldplating" and the probability of opportunistic behavior, and to promote cooperative behavior of project participants, the Company has moved towards development of long-term relations and alliances with key project participants, as is discussed in a later section.

Actions to increase integration at project level

To increase integration, several changes are being made both in the way the projects are organized and managed, as well as in the corporate relationships with EPC firms and suppliers. At the project level, recognizing the importance of teamwork the Company takes several actions to increase the involvement of contractor, operators, and vendors, in the early project phases.

Project scope

Establishing clear project scope and identifying the economic constraints is the first critical step for project success. This requires integration first within the owner's organization, to ensure that the needs and constraints are identified and will not be changed due to unidentified issues. Moreover, involving the key project participants and communicating the requirements and constraints is needed to avoid unnecessary costs, and to identify the best alternatives including equipment, methods, etc.

Incentives for cooperation

Incentives are another tool which can be used to improve capital project performance. The owner, has adapted the use of incentive contracts in a number of projects. Incentives are tied into areas of cost, schedule, safety, etc. The incentive programs are geared to providing a win-win relationship for both parties. Long-term cooperation and relationships are also important.

Cross-functional teams

With respect to the organization and management of the project, the Company places increased emphasis on teamwork. Thus, cross-functional teams with representatives from owner's, contractor's and vendors' organizations are assigned to various project programs/areas such as safety, evaluation of alternatives for mechanical equipment, etc. The teams are provided with clear directives about the needs and constraints and have increased decision-making authority.

Training in interpersonal skills

The owner invests heavily in providing project participants with the necessary skills for effective teamwork. For each project, facilitators are hired and training courses are organized for representatives of all parties. In a typical \$300 million project with a 36 month schedule, the company invests anywhere from 0.1% to 0.5% of total engineering cost in teamwork training. The return from such investments are estimated between 3% to 5% cost savings (for the owner), and up to 5% time savings for the overall project.

Actions to increase integration at inter-organizational level

Corporate alliances and long-term relations

The development of long-term relations with a few selected EPC firms and vendors is the second area where the Company is taking action to increase integration. According to the Projects Group, business partnerships provide excellent opportunity for improving cost effectiveness and performance of facilities. Business alliances include long-term relations with EPC firms for development of facilities and supplemental technical services (development of specification and processes for refineries), relations with vendors for selection and procurement of equipment, and technology development (especially in the area of instrumentation, e.g. distributed control systems).

The owner identifies several benefits from long-term relations. First, it seems that there is significant company specific technical knowledge and each firm has its own "way of doing things". As a result, the designers' understanding of this knowledge is considered important for meeting the firm's requirements. Thus, long-term relations with EPC firms enables them to better understand the Company's needs, and become familiar with the specific requirements and ways. Furthermore, it is considered more cost-effective than having complete in-house design capabilities. Second, having the same firms and personnel working together on more than one project, the teams become more cohesive and effective, as they get to understand not only the technical requirements but also the firm's culture, and develop effective ways to work together.

The long-term perspective avoids problems of opportunism that are common in short-term transactions, and aligns the goals of all participants. For example, EPCs and vendors have stronger motivation to meet the owner's requirements in the most cost effective way, knowing that their cooperation will continue in future projects. Thus, contractors and suppliers are willing to invest more effort to improve the cost effectiveness of each project, with the expectation of future benefits. On the other hand,

there is a risk of potential lock-in, as the suppliers (EPC firms, vendors, etc.) become more valuable and have more power than in short-term relations. This risk is addressed and the Company is evaluating its business partners on an annual basis, based on their performance.

Criteria for selection of business partners include both short-term as well as long-term issues. While schedules and pricing are always important, additional issues become important. Thus, the owner evaluates its potential partners with respect to their overall focus on quality and improvement, their long-term objectives, etc.

Information technology

While the Company does not focus internally on the development of computer systems that can facilitate facility development process, this area is an important criterion for selecting its EPC partners. The use of automation of the facility development process, and the ability to exchange 3-D drawings and other data is considered important as it reduces the probability of human errors, and facilitates design and construction.

While the owner acknowledges the importance of electronic communications, it identifies two primary problems. First, the cost of development of this capability is high. This makes the establishment of long-term relations even more important. For example, one of the Company's EPC partners has developed a database with the owner's specifications and "philosophy" of P&ID for a specific project. This database can be used for future projects and could reduce total engineering cost. It also provides a strong incentive to continue a long-term relationship with the same firm. Second, it requires new capabilities and behaviors by the end-users. For example, the plant operating personnel is not used to reviewing 3D CAD models, and prefer more traditional ways (e.g. plastic models). Thus, training and behavioral change is also required for integration technology to bring the maximum payoff.

B-7 Case #7: Dillingham Construction North America

Firm type: Construction
Project type: Heavy civil, industrial, commercial
Market: Public, Private
Position: Senior Manager

Background

Dillingham Construction Corporation is a large, diversified construction company. The firm is employee owned (55% of shares) and in 1992 it had more than \$700 million revenues. Dillingham Construction has four subsidiaries:

1. *Dillingham Construction Pacific* is the largest construction firm in Hawaii and performs all types of work including heavy construction, commercial, industrial, waterfront and housing.
2. *Watkins Engineers and Constructors* is a Florida based subsidiary focusing on engineering and construction of industrial facilities.
3. *Dillingham Construction North America* is the Pleasanton, California based subsidiary and includes commercial, industrial and heavy civil construction divisions.
4. *Dillingham Construction International* focuses primarily on U.S. funded projects in industrial, commercial and heavy construction all over the world. Resources for international projects are provided by the other subsidiaries.

DCNA's heavy civil construction division undertakes transportation infrastructure projects as well as hydro-developments. Industrial construction includes primarily waste water treatment, power plants and refinery maintenance. The commercial division focuses on office buildings, hospitals, and hi-tech facilities such as cleanrooms, medical labs, etc. DCNA's customers include both private and public owners. Almost all heavy construction work is for public agencies, such as the Corp of Engineers, Departments of Transportation, etc. Commercial projects are both public and private. In the last ten years, however, the volume of private projects has been reduced significantly. Finally, design-build contracts are very few, accounting for less than 5% of the revenue. In these cases, the design component of a project is subcontracted out to a licenced architect/engineer.

Integration with owners and designers

Integration in public works

Public projects are the primary source of income for Dillingham Construction North America. The traditional design - bid - construct process results in design and construction performed separately and sequentially. Typically, the contractor does not provide any input in design, which is performed in-house by the owner, or it is subcontracted to specialized engineering design firms.

Value engineering (VE) is the formal mechanism that allows the contractor to influence the design. In value engineering, the contractor can review the design and propose design changes for cost savings after the contract has been awarded. However, there are several challenges in changing a completed design.

1. For the contractor, VE requires investment in engineering time and services, and will not proceed unless the benefits from the changes are significant. Moreover, VE may delay the starting of construction, which is essential issue for the contractor.
2. Even when the contractor identifies a more cost effective alternative solution, there are several reasons for the owners and designers to reject it. For example, the intent of the initial design decisions may not be obvious, or may have been affected by "political" forces within the owner's organization. In any case, after the design issues have been settled, owners are reluctant to start re-examining the design.
3. Designers also have reasons to resist changes as VE involves rework and additional costs for them. Moreover, designers may resist "criticism" of their design.

The above reasons provide strong incentives to avoid changing a completed design.

Partnering. For the contractor, the primary consideration is the ability to resolve fast and effectively the problems that arise during construction. Such problems involve changes and extras that the owner requests, ambiguity concerning scope, drawings and specifications, and unexpected problems due to project conditions. When such problems arise, strong cooperation with the designer and the owner is required in order to resolve the issues and avoid costly claims. Partnering is the primary integration mechanism that DCNA uses to address this need.

In recent years, Dillingham has adopted the partnering philosophy and tries to implement it on all projects. Partnering focuses on increasing the effectiveness of teamwork between project participants, and on developing cooperative attitudes. This is accomplished by establishing project teams, training team members in teamwork, and using facilitators to assist the teams. Cooperation continues throughout the project life with periodic meetings and problem-solving, and joint reviews and evaluations of the team's performance. Dillingham believes that the major contribution of partnering is that it promotes an environment of cooperation and good will, and provides a forum where project participants can discuss and solve problems in a timely manner.

For example, in a tunnel project in Hawaii, the collapse of the portal created significant problems, need for rescheduling, and additional work. However, good cooperation with the owner resulted in fast problem solving, minimizing the additional costs and prevented the problem from becoming a dispute. In a hydro-development project, acceleration and early completion by 3 months, resulted in significant pay-off for the owner. On another project however, disagreement with a non-cooperative owner who refused to pay costs for additional work resulted in additional expenses, management time, and legal costs.

The benefits from partnering are substantial and stem primarily from the fact that it prevents problems from becoming costly disputes. For example, the total costs from a dispute can well exceed 10% of project cost, and their prevention reduces the total project costs and benefits all parties. Dillingham identifies the reluctance of some public owners to invest in partnering as the most significant barrier. Under the current highly competitive conditions in the public works market, owners receive very competitive bids, and they don't see the need for investing in cooperation in order to reduce project costs.

Integration in the private sector

In commercial and industrial projects, where more private projects exist, the opportunity for integration is higher, because the contractor can be selected before the design is complete and participate in the design phase. The primary mechanism for integration is the involvement of the construction team in the early design phase, before design decisions are fixed. Such pre-construction services focus on estimating assistance, and pointing out construction and logistics considerations that the designers are not aware of, in order to reduce total project costs. The success of integration in such projects

depends on the effectiveness of teamwork between the designer's and contractor's personnel.

According to Dillingham, contractor selection before the design is completed in order to provide pre-construction services and build the project is ideal for both owners and contractors, and offers opportunities for project savings. However, such arrangements require selection of the contractor not only on the basis of price, but primarily on quality and reputation, and cooperation for resolving problems. These criteria reduce the owner's risk with respect to actual project costs. On the other hand, competitive pressures and cost cutting considerations on the owners' side create a strong incentive for selecting the contractor with lowest offer, although the risks may be higher.

Progressive owners seriously consider not only price, but also the Contractor's qualifications and reputation. For example, a California-based power company performs extensive prequalification of contractors for its large projects. By requesting proposals from only a few qualified and financially stable firms the owner attempts to ensure that the project will be on time and within budget and that problems (if they arise) will be resolved in the most efficient way. Thus, reputation and past performance is essential for winning contracts from such corporate clients.

Inter-organizational relations

Relations in the public sector

Although formal alliances with public agencies cannot be established, as price is the only criterion for awarding a contract, informal relationships with public owners are developed based on previous working experience with an owner, and have implications for project performance. Thus, depending on the owner's reputation and receptiveness to the contractor's needs and problems, along with how well they have cooperated in past projects, Dillingham identifies those owners who treat the contractor fairly, and is more aggressive in pursuing their contracts. As the risk for development of costly problems and disputes reduces, Dillingham is able to give a lower bid than if the project was for an owner with bad reputation.

Relations in the private sector

Long-term relations with owners and designers are especially important in private works, and particularly commercial and industrial construction for the following reasons: First, relationships and contacts with designers enable Dillingham to become aware of

private projects. Second, Dillingham's relations with customers and designers, which are based on reputation and previous working experience, increase the firm's potential for selection on such projects. Finally, in projects where Dillingham is responsible for both design and construction, the company can select as partners those designers with which it has had successful cooperation. Thus, successful cooperation with designers is essential for winning private contracts, as the integration with designers enables identification of most cost effective alternatives to customer's needs. Although reputation and qualifications are very important in the private sector, highly competitive conditions in recent years create an incentive for the owners to select the contractors with the lower price.

Relations with suppliers

As in the case of owners and designers, Dillingham's relationships with suppliers (vendors and subcontractors) are based on previous experience. Interpersonal relations between the subcontractors and the contractor's project managers is a key factor. Although price is still the primary criterion for selection of suppliers, reputation, financial stability and previous successful cooperation are very important factors. Thus, in many cases, a better qualified supplier is selected, even if his price is not the lowest. Dillingham believes that good relations and strong cooperation results in having better offers from those subcontractors. However, again the more intense competitive environment creates incentives for low offers from all subcontractors and moreover, incentives to Dillingham for selecting based on low price.

Cross-functional integration

Mechanisms used by DCNA to increase integration within the firm include the adoption of CQI (Continuous Quality Improvement), and use of information technology tools.

Continuous Quality Improvement

Over a year ago Dillingham's corporate management established the implementation of Total Quality Management as a company-wide goal. The implementation of TQM started from the top, with TQM seminars for senior management, development of a corporate TQM manual, and establishment of a corporate steering committee with the participation of the presidents of all subsidiaries and corporate managers. Each subsidiary was given the responsibility to develop its own TQM program tailored to its own needs. In DCNA, the program was named Continuous

Quality Improvement (CQI) and kicked-off about a year ago. The initial step included seminars and training in group problem solving for over 100 employees, and with special seminars for "coaches" (managers responsible for CQI implementation throughout the firm).

CQI is the primary mechanism Dillingham uses to improve the way work is performed within the firm. The concept of internal and external customers is very useful as it enables employees to identify and resolve coordination problems, especially those generated within Dillingham. CQI is also important for projects as well, as it enables project participants to address problems of coordination between designers, owners, contractor and suppliers. CQI has been implemented with different success in different divisions of DCNA. The most benefits have been observed in the industrial division, probably due to more repetitive operations. The industrial division is now trying to implement the CQI concept on the job sites with training and participation of site personnel.

Information technology

All divisions are using computer applications for construction planning and control functions, such as scheduling and estimating. Computer applications are also used extensively for information management within the firm. For example, Dillingham has developed a database with bid and cost data on all previous and on-going projects, which is utilized by several departments for various purposes, e.g. marketing, bonding, estimating, etc. Dillingham has capabilities for electronic exchange of cost and quantity data between site and home office, but not for exchange of CAD drawings. CAD system for construction planning purposes is used more extensively in the commercial division.

B-8 Case #8: "Manufacturing" Corporation

Firm type: Owner
Project type: Industrial
Market: Private
Position: Senior Manager

Background

"Manufacturing Corporation" is a \$1.6 billion micro-processor manufacturing organization. The firm is a large customer of construction services, with approximately \$500 million annual expenses in capital projects. Facilities include hi-tech manufacturing and fabrication plants the capital cost of which averages \$300 million (excluding the plant's process equipment) and the schedule ranges from 18 to 24 months.

Importance of project performance for company

Manufacturing production is the primary source of income. The speed of facility development is an important factor affecting the company's ability to meet the fast-changing market needs and reduce the time-to-market of new products. Thus, the facilities are typically developed on a fast-track basis. Furthermore, the quality of the facility is critical for the quality of the product. The firm's facilities are technologically complex as micro-processor production requires class-one cleanrooms. Environmental requirements add to the complexity of the project. Finally, project cost effectiveness is another important consideration as it affects the company's cash flow and ability to utilize capital effectively.

In summary, the company's facilities present significant challenges due to technological complexity and performance requirements. Furthermore, the fast-changing market and technologies in the area of the main product create another difficulty as they often force changes in project requirements after the project has started. The firm has in-house project managers responsible for the facility development process.

Importance of integration for project performance

Integration between owner, designer, contractor and facility users is considered an important factor in meeting project's time and budget constraints and achieving required quality. Integration between project participants is essential in order to: 1) establish clear project objectives and requirements, 2) identify most efficient design and construction

alternatives to meet owner's needs, and 3) resolve problems that arise during construction, and increase ability to respond to unexpected changes in market or technology.

Thus, integration is required both within owner's organization, as well as between owner, designers, contractor and operators. Involvement of all key participants (owner, designer, contractor and operators) in the early project phases results in increased understanding of the owner's and operators' needs and the objectives of the project, and reduces ambiguity and subsequent changes in scope and design. Integration also enables project participants to identify the best alternatives that can meet the project's requirements and constraints. Finally, strong coordination between project participants is needed to respond to uncertainties caused by external factors, such as changes in market needs, technologies, etc.

To increase integration, the company takes several measures both at the project level and at the company level. At the project level, the means for integration include primarily contractual provisions and organizational structure. At the company level, the primary means for integration include development of strategic alliances and investment in information technology.

Project level integration

The primary means Intel uses to increase integration between project participants are contractual and organizational.

Contractual means

The firm typically uses design-build contracts. With one Engineering-Procurement-Construction Management (EPCM) firm being responsible for design, procurement and construction, coordination between design-construction is increased. Intel also provides contractual incentives for project performance. Performance measures that provide the basis for evaluation and bonuses include budget, schedule, safety, speed of change-order processing, etc. Long-term cooperation and repetitive businesses are another strong incentive, as the firm is a large user of manufacturing facilities.

Organizational means

Organizational means to increase integration include establishment of cross-functional teams, incentives for teamwork, and "alignment meetings" between project participants.

With respect to the organization and management of the project, the firm emphasizes teamwork. For each project a cross-functional teams is established with owner's, contractor's and operator's representatives, and works together throughout the project headed by one of the firm's project managers. Cooperation continues throughout the project life with regular meetings and problem-solving. To provide additional incentives for teamwork the firm has also established joint reviews and evaluations of the team's performance. Finally, the company trins its managers for effective meeting management.

Establishment of clear project scope and objectives is considered essential for project success. This requires integration both within the owner's organization and with designers and contractor, to ensure that the needs and constraints are clarified and will not be changed due to unidentified issues. Internal alignment meetings within the owner's organization are held to identify project needs and establish objectives. Alignment meetings between owner's representatives (including project managers, construction cost managers, etc.), designers, the construction manager and the operators are held in the beginning of the project to clarify project objectives, roles and responsibilities, and avoid later problems with scope, and subsequent delays and additional costs.

Company level integration

Development of long-term relationships with EPCM firms and vendors, and investment in information technology are company level mechanisms used to increase integration between project participants.

Long-term relations

To increase project effectiveness the firm maintains long-term relations and continuous cooperation with a few pre-qualified EPCM firms and vendors. Long-term relations and repetitive cooperation enable the EPCM firms to become familiar with the owner's specifications and requirements, and better understand the owner's needs. The benefits include increased project performance, and reduced risk that owner's needs will not be met. Criteria for selection of partners include primarily previous performance and reputation, and to some degree, the EPCM's information technology capabilities.

The firm also works with a limited number of pre-qualified vendors, with a proven record of past performance and ability to meet the owner's specifications. Criteria

for selection of vendors include both short-term as well as long-term issues. Thus, while schedule performance and pricing are important, past performance and vendor's focus on quality (e.g. use of statistical process control) are important considerations. The firm also works with vendors to assist them in meeting Intel's needs, especially when the demands exceeds the vendors' capacities.

Information technology

The company believes that information technology has strategic importance for improving the facility development process. Increasing the automation of facility development and the ability to exchange 3-D drawings and other data is considered important as it reduces the probability of human errors, facilitates coordination and reduces development time.

In the context of some new projects, the owner with its EPCM partners are making a significant investment in information technology. The objectives are to automate the firm's internal processes, and develop electronic linkages between the company, EPCM firm and vendors. The costs of this investment will be shared between the owner and its partners.

B-9 Case #9: Ehrlich-Rominger

Firm type: Architectural / Engineering
Project type: Commercial / Industrial
Market: Private
Position: Senior Manager

Background

Ehrlich-Rominger is an architectural / engineering firm specializing in hi-tech buildings, such as data processing centers and biotech laboratories. Its clients include developers, large manufacturing firms, etc. The firm has in-house capabilities for architectural, mechanical, electrical, and interior design, and cooperates with other design consultants on structural design, etc.

Importance of integration for project performance

The firm acknowledges the importance of integration for project and company success and identifies the following interfaces as essential: integration between design disciplines, integration between designers, contractors and facility users, and integration between designers and approval authorities.

Need for integration between design disciplines

Integration between design disciplines is becoming more important due to increased complexity of facilities and the large number of specialists involved in design. This increases the need for coordination of drawings between architects and engineering disciplines (structural, electrical, mechanical, etc.) to avoid errors, interferences and conflicting design decisions. Thus, low coordination results in design rework and delays and often results in field change orders, delays and increased project costs.

Need for integration with contractor

Integration between designers and builders is also considered essential for project success. The fast-track nature of many projects and the need to reduce the client's risk regarding project cost and schedule, are the primary drivers for increased designers-contractor integration. In fast-track projects decisions concerning long lead-time items have to be made very early in the project, and changing them later has a very high cost.

Thus, the ability to make good early decisions (that do not need to be changed due to unidentified constraints or conflict with other requirements) is essential. This requires early identification of construction and code constraints and requirements. Working closely with contractor and vendors is therefore important in order to determine the effectiveness of different building systems and identify the most effective alternative to meet owner's needs. Good early decision can result in significant acceleration of the project schedule and 5-10% cost savings.

The degree of integration with contractors depends primarily on the client's contractual strategy. Thus, to increase integration with contractors Ehrlich-Rominger often recommends that their clients involve the contractor in the development of the design. The integration mechanisms are examined in a later section.

Need for integration with users

Understanding the needs of the facility users (who may be a different party than the owner, as in the case of developers) is essential for the facility's functionality and project success. For example, problems arise because the users' requirements are not identified during the design (as in the case of developers who typically do not know who will be the users of the facility). Such problems may result to changes and higher costs, or reduced user's satisfaction with the facility.

Need for integration with approval authorities

The ability to identify upfront the requirements of regulatory agencies is another critical issue, especially in the case of hi-tech facilities where safety and environmental issues are central. For engineering firms this is an important capability for competitive advantage. To accomplish this, Ehrlich-Rominger establishes contact with authorities early in the project, maintains frequent formal and informal communications, and assists approval authorities do their job better by addressing the issues that are most critical for these agencies.

Integration benefits

Delays, rework and costs that can get out of control are the main problems from lack of integration. Furthermore, changes also provide potential for opportunistic behavior by contractors or subcontractors, as they may try to make the most of it. The firm identifies both operational and strategic benefits from integration. Cost savings from

integration are estimated to 5%-10% of project costs. However, the most important benefit are considered to be the significant time savings.

Strategic benefits and competitive advantage result from the company's ability to reduce the client's risk and meet the customer's and users' requirements.

Mechanisms for project-level integration

Ehrlich-Rominger uses several mechanisms for integration that include technological, contractual and organizational means, as well as development of long-term relations with other parties.

Contractual mechanisms

Design-build contracts have the potential for high degree of integration and are becoming more frequent. Under this arrangements, one firm is responsible for both design and construction. If the firm that undertakes the project does not have both engineering and construction capabilities in-house, it can select its partners. For example, Ehrlich-Rominger have frequent cooperative arrangements with some contractors and use them as partners in design-build contracts.

The contractual arrangements depend largely on the owner's strategy. Ehrlich-Rominger often advises its clients to select the contractor before the design is completed in order to provide pre-construction services. The major advantages of design-build arrangements are "one-stop buy" for the owner, and better integration between designers and contractors which can result in time and cost benefits. The primary disadvantage is that there is a limited bidding mechanism to check the competitiveness of price, and the selection is based on reputation and trust. Finally, the effectiveness of these arrangements depend on the quality of teamwork and integration between project participants.

Cross-functional integration

Maintaining in-house closely interdependent disciplines is one way the firm facilitates integration between design disciplines. For example, Ehrlich-Rominger has decided to keep both electrical and mechanical design in-house. The development of strong long-term relations with other design consultants facilitates integration with other design disciplines.

At the project level, teamwork is the primary mechanism for integration between owner, designers, contractor and facility users. Cross-functional teams typically involve owner, designers, contractor and users, and sometimes the key suppliers or subcontractors. Teamwork can take different forms depending on the timing of the team's involvement in the project. For example, it can take the form of "charrette", where the project team works together intensively for one to three days to develop the conceptual design and agree on the major design decisions. In a similar way, "fly-spec" backcheck involves cross-functional teams that thoroughly review and evaluate a completed design, and check for compliance with specifications and other requirements.

Partnering

Ehrlich-Rominger strongly believes that trust and good working relations are fundamental for effective teamwork. The firm has a strong culture that supports teamwork and cooperation. It has always operated under the principles of "partnering", and has never been involved in litigation with other project parties. The company considers all project participants as partners, and strives to maintain good relations and perform joint problem-solving. This is considered as a major reason for the firm's success.

Technological mechanisms

"Pin registered drawings" have been one of the first systems to facilitate coordination of drawings between design disciplines, improve accuracy and prevent interferences. This method enabled accurate layering of drawings and prevention of interferences, and reduced changes in the field.

In recent years, the development of 2-D and 3-D CAD systems provides the potential for further improvements in coordination of design decisions because it enables electronic sharing of all design details and improves accuracy. Ehrlich-Rominger is using 2-D AutoCAD for preparation of contract documents. 3-D CAD is presently used primarily for visualization.

The risk of losing control over drawings and the legal issues involved are identified as the major consideration in sharing electronic drawings and establishing electronic linkages between different organizations. However, development of such linkages with a few long-term clients is in the future plans of the firm.

Mechanisms for inter-organizational integration

Long-term relations

The development of long-term relations with clients, designers and contractors is another factor that contributes to increased integration. Thus, Ehrlich-Rominger evaluates and selects its clients based on their reputation and previous experience. The firm also maintains long-term relations with a small number of qualified design consultants and contractors. Such relations have been developed over time and are based on mutual respect and previous working experience.

Long-term relations contribute to both project success and competitive benefits. Project benefits include improved budget and schedule performance and increased ability to understand the client's requirements. Previous experience with same parties increases efficiency as ambiguity is reduced, and less detailing is required. Competitive benefits include reduced risk for the client, and repetitive businesses from corporate customers. In recent years, such relationships are becoming even more formalized, to the extent that some corporate owners in cooperation with designers and contractors are forming new engineering-construction firms to serve exclusively the needs of the owner.