

**EFFECTIVE USE OF INTEGRATION MECHANISMS FOR COMPLEX  
PROJECTS: AN EMPIRICAL ANALYSIS OF BUILDING PROJECTS**

By

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Submitted to the Department of Civil and Environmental Engineering  
In partial fulfillment of the requirements for the degree of  
Master of Science in Civil and Environmental Engineering

at the

MASSACHUSETTS INSTITUTE OF TECHNOLOGY  
June 1999

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Signature of Author

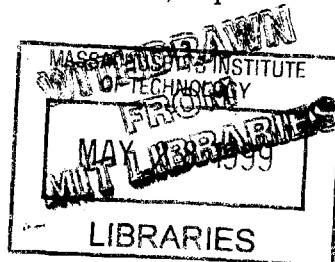
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## **ABSTRACT**

This research was pursued to study the relationship between construction project complexity and project team integration. Construction projects exhibit several dimensions of complexity, including building system complexity, site complexity, and project complexity. It was shown that project teams could work more effectively if these complexities are identified and an appropriate mechanism for integration is implemented.

The study began with the identification of the specific dimensions of complexity that are relevant to design and construction, and the definition of integration mechanisms that can be used by project teams. It was expected that high complexity requires high levels of integration, except when familiarity and high levels of trust exist within the project team. Low levels of complexity do not require integration. Using the dimensions of complexity and the measures of integration, this theory was tested through the in-depth study of seventeen building projects.

This empirical study was conducted through the use of detailed personal interviews of critical participants of building projects in Southern California. Four types of buildings were used in the seventeen detailed case studies: Medical/ Laboratory, Institutional, Office, and Other. This research was compared to a set of twenty-five general case studies, taken from information gathered from journal articles.

The results of this study reflected four trends. First, the function and purpose of a building determines its critical systems. Second, knowledge of and confidence in the capabilities of specialists reduces the need for formal interaction, particularly for intra-system complexities. Third, complexities related to the physical aspects of design and construction, such as site logistics, are best solved through coordination. Fourth, complexities related to informational aspects of design and construction, including functional relationships between systems and project objectives, are best solved through collaboration.

These findings provide the knowledge needed both to identify the types of complexity that will be encountered in specific building projects, and to provide guidance in the choice of the most effective form of project integration.

Thesis Supervisor: E. Sarah Slaughter  
Assistant Professor of Civil and Environmental Engineering



## ACKNOWLEDGEMENTS

Professor Slaughter has my sincere gratitude for her generous inputs of time, effort, and ideas. Her passion for research and her love of construction has been an inspiration to me throughout my education at MIT.

Many thanks to the National Science Foundation and to the Department of Civil and Environmental Engineering for sponsoring my educational experience at MIT. This support has allowed me to pursue my many interests in design and construction, especially building systems integration, project team dynamics, and construction management.

I am also truly grateful to the many members of the construction industry who contributed to this research. The list of people that I want to thank is extensive, but so was the knowledge and inspiration that I gained. My appreciation to: David Vadman, Gino Polizzotto, Caryn Cowin, and Randy Hartman of Bovis Construction Group; Kevin Smith, Jeff Lucas, Brett Firebaugh, and Joe Sanders of Charles Pankow Builders; Craig Smith, Magdalen Hron, Bill Quade, and Fred Gans of DMJM; Jay Leopold, John Foran, and Russell Hamilton of DPR Construction; and Terry Dooley, Joe Didone, Jeremy Dominik, Bob Morrison, and Tod Howard of Morley Builders.

Additional thanks to Terry Dooley for giving me the opportunity to be a member of the Morley team on the Los Angeles Cathedral Project and to Jay Leopold for inspiring me to philosophize about the future of the construction industry.

Most importantly, I want to acknowledge the people most dear to me. Mom, Dad, Joanna, Cecile, and Li, are the greatest blessings of my life. Their love and faith in me has helped me to find the strength to excel and to meet whatever challenges the world has in store for me.



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# **EFFECTIVE USE OF INTEGRATION MECHANISMS FOR COMPLEX PROJECTS: AN EMPIRICAL ANALYSIS OF BUILDING PROJECTS**

## **CHAPTER 1: INTRODUCTION**

The purpose of this research is to analyze the relationships between complexity in construction projects and the formal and informal interactions within the corresponding project organizations.

In the past, research has been done separately in the areas of complexity and organizational integration, but few of these studies have examined their interaction. Furthermore, little research has been done in either complexity or integration with respect to the construction industry. Much of the background literature identified for this research has been in the area of human resources and product development, specifically in relation to corporate organizations in the manufacturing industry.

The focus of this research targets the project organization, a team that forms a temporary alliance for the duration of a project. In construction, the project organizations often consist of partners who have never worked together before. This lack of familiarity causes a natural sense of distrust and cautiousness, which can be detrimental to the success of the project.

Because construction is such a fragmented industry, it can be difficult to align the goals of all of the parties in a project team. This research shows how teams can efficiently work together to meet the objectives of a building project.

The hypothesis that this research explores is that project teams work most effectively if the complexities of a project are identified and an appropriate level of integration is accomplished. The key phrase in this theory is “appropriate level of integration.” If the aspects of a project do not pose any complex problems to the project team, no or low levels of integration are expected. On the other hand, if aspects of a project are highly complex, high levels of integration should be implemented. However, when project and/or team familiarity are brought into the picture, what

is “appropriate” can also change. For instance, if one member of the team is recognized to have capabilities in an area or has a good working relationship with other members of the team, a sense of trust is established. This sense of trust can reduce the need for formal integration, even when there is a high level of complexity in the project.

Using building project data from case studies, several aspects specific to construction projects were identified by their level of complexity. Also, integration mechanisms used by the project teams and previous working relationships were examined. Through the use of the case studies, this research shows that many project teams have successfully completed building projects of various complexity using levels of integration appropriate to the situation.

The results and conclusions from this research make construction project managers aware of the importance of creating a project organization that corresponds to the projects that they are managing. A fully integrated team can be highly effective on projects of high complexity. However, it can be a waste of energy on more routine projects. The goal of this research is to provide guidance to team leaders on how to find an effective balance of integration for their specific project teams to make the construction process more efficient.

The main findings of this research are as follows:

1. The function and purpose of a building determines its critical systems.
2. Knowledge of and confidence in the capabilities of specialists reduces the need for formal interaction.
3. Complexities related to the physical aspects of design and construction are best solved through coordination.
4. Complexities related to informational aspects of design and construction are best solved through collaboration.

This thesis begins, in Chapter 2, with a look at the current literature on complexity and integration. The issues specific to the construction industry are highlighted and serve as background information for the rest of the research.

Chapter 3 lays out the framework for the research. First, the goal for the research is established. Second, types of complexity specific to building projects are defined and examples are given. Third, mechanisms used for integration of project teams are defined.

Chapter 4 outlines the methodology used to pursue this empirical research. Issues related to the benefits of using a case study approach, the process of obtaining information, the validity of the data, the representativeness of the data, and the relevance of the data are discussed.

Chapter 5 presents the data, which was collected for this research, in the form outlined in the framework. The complexities found in each case study are discussed thoroughly and the corresponding integration mechanisms are identified. Appendix 2 presents the detailed case data. Table A.1 in Appendix 4 contains a comprehensive list of the instances of complexity that were encountered on each project.

Chapter 6 is the results of the data outlined in Chapter 5. The relationships found in the data between the building project complexity and the project team integration are discussed. The results from the detailed case studies are then compared to those of the general case studies to show the representativeness of the data. Appendix 3 presents the general case data and Table A.2 in Appendix 4 contains a list of the instances of complexity that were found in journal articles.

Chapter 7 summarizes the findings of the research. In addition, suggestions for further research are presented.





## **CHAPTER 2: BACKGROUND INFORMATION**

This research analyzes the relationship between complexity in construction projects, the interactions within the corresponding project organizations, and project performance. Much of the literature that exists in relation to the construction industry is either in the form of trade publications or commercial magazines that showcase interesting projects. In these publications, very little attention is given to the dynamics of the management activities. Therefore, most of the background literature for this research comes from the areas of product development and human resources, with small amounts in the fields of architecture and construction management.

Each of the papers used as source literature focuses on one aspect of design that improves product efficiency. However, there are no studies that combine these ideas into a format that can be used as a tool to determine the type of organizational mechanisms that would be useful based on specific project needs. Also, many of the ideas are being used only in the manufacturing industry. The determination of organizational mechanisms for this research stems from the analysis of the case studies, which are based upon the type of interactions and integration that occurs within a project organization.

By looking at the organizational mechanisms that have been identified in the literature and determining new ones from the case studies, a body of knowledge will be made available to project teams when they are choosing their strategy to plan and manage a new construction project.

The background for this research uses two areas of related theory. General theory is presented, and then issues specific to the construction industry are emphasized. First, measures of complexity and the mechanisms to deal with complexity are defined according to the current literature. Second, the current literature on integration is examined, with respect to the definition of integration, the incentives for integration, the relationship between interactions and integration, and mechanisms for integration.

## 2.1 COMPLEXITY

### 2.1.1 DEFINITIONS

“Complexity is the inverse of simplicity” – C.S. Peirce

In Webster’s Dictionary (1991), the word “complex” refers to something that is composed of many interconnected parts or that is so difficult to analyze that it is hard to understand or solve.

There is no agreed upon functional definition of complexity. It is one of those things that can be generally recognized, but does not have an adequate verbal formula. The problem of defining complexity is a complex one itself because there are many dimensions to it (Benton and Srivastava, 1993). When one tries to define complexity using only a single dimension, the definition is limited, but when all of the possible dimensions are considered, the definition tends to be too complex to be of use.

Much work of the past has been tied to traditional disciplines, and the same ideas appear in different forms in the different fields of research, with little communications to identify the link between them (Green and Bossomaier, 1993). The latest trend in the study of complexity is to find a universal definition for it. Thus far, none has been made.

Physicist Seth L. Loyal (Rescher, 1998) computed an extensive inventory of definitions for complexity, which shows that the possibilities for defining complexity available are vast. Some of the dimensions of complexity in this inventory include: information, entropy, minimum description length, number of parameters, degrees of freedom, dimensions, mutual information, channel capacity, correlation, stored information, conditional information, self-similarity, stochastic complexity, sophistication, hierarchical, time computations complexity, space computations complexity, logic depth, grammatical complexity, and distinguishability.

More recently, Rescher has compiled a more structured account of the definitions of complexity that he calls the “Modes of Complexity” (Rescher, 1998). Several types of complexity are categorized and Rescher notes that the different modes of complexity do not necessarily stand together.

Table 2.1  
The Modes of Complexity (Rescher, 1998)

Epistemic Modes	Formulaic Complexity	1. Descriptive Complexity: Length of the account that must be given to provide an adequate description of the system.
		2. Generative Complexity: Length of the set of instructions that must be given to provide a recipe for producing the system.
		3. Computational Complexity: Amount of time and effort involved in resolving a problem.
Ontological Modes	Compositional Complexity	1. Constitutional Complexity: Number of constituent elements or components.
		2. Taxonomical Complexity: Variety of constituent elements, or the number of different kinds of components in their physical configurations.
	Structural Complexity	1. Organizational Complexity: Variety of different possible ways of arranging components in different modes of interrelationship.
		2. Hierarchical Complexity: Elaborateness of subordination relationships in the modes of inclusion and subsumption. Organizational disaggregation into subsystems.
	Functional Complexity	Operational Complexity: Variety of modes of operation or types of functioning.
		Nomic Complexity: Elaborateness and intricacy of the laws governing the phenomena at issue.

The “Modes of Complexity” by Rescher is an uncommon attempt to define complexity because it provides several dimensions for which a system can be measured. Many times, the definitions have few dimensions to describe complexity. The definitions that follow come from various sources and they measure complexity in one of two ways, either by structure or by effort.

### 2.1.1.1 Structure

These definitions look at the quantities involved in the entity and the way that they are arranged. Based on the sources outlined below, one can see that there are many ways that complexity can be defined, depending on the parameters that one looks at.

Benton and Srivastava (1985; 1993) have written a number of papers relating complexity to a variety of manufacturing operations. Through these papers, they have defined complexity by an entity's depth, (i.e., the number of levels in the bill of material structure), and breadth, (i.e., the number of immediate components per parent). The following diagrams show examples that illustrate these two variables of complexity. This first figure shows a simple, shallow depth relationship with a complex, high breadth relationship.

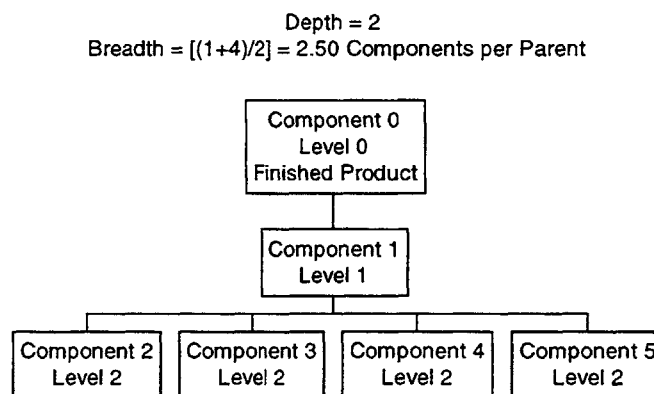


Figure 2.1 (Benton and Srivastava, 1985)  
Shallow Depth, High Breadth Complexity

This second figure shows a moderately complex depth and breadth structure.

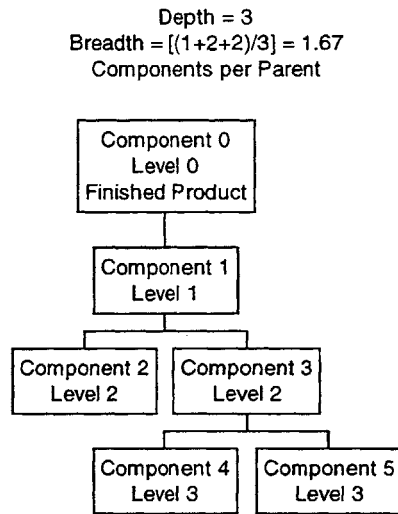


Figure 2.2 (Benton and Srivastava, 1985)  
Moderately Complex Depth and Breadth

The last figure shows a very deep (complex) structure with a very low (simple) breadth structure.

Depth = 5  
Breadth =  $\frac{5 \times 1}{5} = 1.00$   
Components / Parent

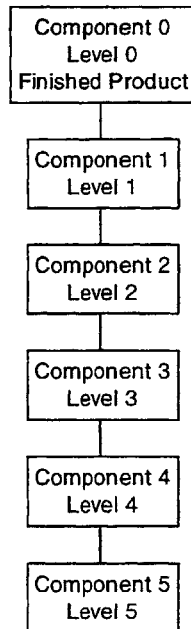


Figure 2.3 (Benton and Srivastava, 1985)  
High Depth, Low Breadth Complexity

As one can see by this example, even using a simple structural definition can be difficult. The depth and breadth complexity definitions do not go hand in hand and this can cause confusion when one wants a definite, and not conditional, definition. This same problem was found in Rescher's "Modes of Complexity", earlier in this chapter.

Guide, et al. (1997) tried to solve this problem of multiple complexity factors by combining the different types of complexity using one measure. In addition to the depth complexity, routing complexity and reassembly factors were devised. Routing complexity is defined with respect to the number of operations required in producing the product. Reassembly complexity refers to the number of units to be coordinated for reassembly. To determine a measure for the overall complexity of the product, the depth, routing, and reassembly complexity factors are multiplied. The result is used to compare to other products. Even though this process makes sense to mathematically compare systems, it does not tell us much about the complexity of the individual systems, which are rated. For instance, if a system is given a complexity rating of 4, does one know more about how to deal with it?

In one of Rescher's definitions for complexity, a system's complexity is a function of the quantity and variety of its constituent elements and of the inter-relational elaborateness of their organizational and operational make-up (1998). This definition also considers the breadth, depth and routing of a system, although not in the formulaic way as in the Benton and Srivastava and Guide et al. definitions above. One thing that Rescher introduces in this definition is the concept of the variety of the constituents. One can intuitively feel that a product with several different parts is more complex than one with the same number of identical parts. In this case, the most complex system would be one that has a large number of different constituent elements that are organized in a high-depth, high-breadth structure.

#### *2.1.1.2 Effort*

These definitions focus on the effort required to deal with the entity, whether it is a problem or a product or a system. In this case, the best practical index of an item's complexity is the effort

that has to be expended in coming to cognitive terms with it in matters of description and explanation (Rescher, 1998).

Simon (1981) defines a complex system as “a system made of a large number of parts that interact in a non-simple way, where the whole is more than the sum of the parts.” The first concept is breaking the entity, whether tangible or intangible, into parts. Take, as an example, a “problem” as the entity in question. A common method of problem solving that is widely taught is the division of large problems into smaller problems that are of a scale or configuration that the problem solver has the capabilities to solve. Sometimes this division of the problem requires much of the effort that has to be expended in the problem-solving task (Kaneko, 1998).

The second concept in Simon’s definition is the non-simple interaction between the parts. Using the same example, once a problem is broken into parts and the individual parts are solved, they must be integrated to form the final problem solution. This integration requires additional information and effort, therefore making the whole worth more than the sum of the parts. The additional information focuses on the relationships between the parts, based on initial assumptions made at the beginning of the problem-solving process. Many authors agree that complex systems are actually dominated by the interactions between their components (Green and Bossomaier, 1993; Rescher, 1998).

## 2.1.2 COMPLEXITY TOPICS SPECIFIC TO DESIGN AND CONSTRUCTION

### 2.1.2.1 *Buildings as Complex Systems*

Construction fits the definitions for complexity that were presented in the last two sections of this chapter. However, to understand the specific dimensions of the complexity of construction, one needs to look at it separately from general theory.

A building is composed of many interconnected parts, called systems. The number of systems in a building depends on the objectives for the building. The four main categories of systems in a

building are: 1) Structure, which creates the equilibrium necessary to allow the building to stand, 2) Enclosure, the systems which protect the building from penetration by the climate, 3) Services, which provide functions such as heat transfer, power supply, water supply, conveyances, and many others, and 4) Finishes, the systems which are visible from inside the building (Rush, 1986). These systems are interconnected to provide a functional building.

#### *2.1.2.2 Construction and the Modes of Complexity*

In many industries, one way to control the complexity of a product is to break the process of producing the product into parts that are manageable. Thus, through simplifying the process, one aspect of complexity is eliminated. One unique aspect about construction is the fact that both the product, a building, and the process of construction are complex. Rescher's "Modes of Complexity" (1998) provides a good framework to begin looking at the complexity of construction.

##### **Descriptive Complexity**

Descriptive complexity refers to the length of description necessary to understand the system. There are many aspects to describing a building. Some aspects include building usage, design issues, constructability issues, and community issues.

The construction process can be described by the type of delivery mechanism that is employed. Even though there are few common delivery mechanisms, such as Design-Bid-Build, Design/Build, Turnkey, and Multiple Primes, there are many variations of these mechanisms that are practiced in the industry. For instance, Design/Build can be implemented through a joint venture, a designer contracted to a constructor, or a constructor contracted to a designer.

##### **Generative Complexity**

Generative complexity relates to the length of the instructions necessary to produce the system. The construction documents from which a building is created can be hundreds of pages for each



system within the building. Also, materials and quality specifications as well as the contract documents can be books several inches thick.

The process of construction is very experience oriented. This tacit knowledge is extremely difficult to put into written form. However, some companies try to replicate some of this knowledge in the form of a standards and procedures manual.

### Computational Complexity

Computational complexity is the amount of time and effort needed to resolve problems with the system. A building has several systems that interact with each other. The more integrated the systems are, the more difficult it is to resolve problems related to these systems. Changes in one system can have effects on several other systems, which could cause more problems.

The construction industry is characterized by a process that involves numerous contracts, a hierarchy of parties, and outside agencies, all of which are involved in the construction of a building. With so many parties involved in the process, decisions and problem resolutions are, at times, complicated and lengthy affairs. Many times, some team members have personal agendas that do not coincide with the objectives of the project. These diverging goals, in addition to litigation, make problems harder to solve.

### Constitutional Complexity

Constitutional complexity defines complexity by the number of components in a system. As mentioned previously, buildings are composed of several systems. Because of the evolution of technology over time, the number of systems in a building has increased. For example, office buildings in the 1920's involved an average of 13 trades and whereas today's office building requires over 40 (Tombesi, 1997), a great increase in complexity and specialization.

Within a construction project team, there are several parties from several different companies. Many times the number of companies maps to the number of systems in the building. The total number of people on a project increases as the project proceeds, in accordance with the schedule.

### Taxonomical Complexity

Taxonomical complexity refers to the variety of components in a system. For instance, if there are a large number of components, but they are the same, it would be a simpler system than one that had many components that were unique. There are no two building projects that are exactly alike. Even if two building designs may be the same on paper, the same building is not built because of different site conditions (such as soil and rain) and project objectives (such as schedule and quality). Therefore, every building project is unique.

Similarly, the construction process is never the same. Sub-contractors try to break the construction process down to a basic level in order to make it as repetitive as possible. However, because of the custom nature of most buildings, total simplification cannot be done fully.

### Organizational Complexity

Organizational complexity looks at the variety of interrelationships of components within a system. Buildings have two main complexities with respect to interrelationships. The first complexity is the spatial relationship between systems. This relationship is based on the layout of the building. Two buildings can have the same type of plumbing system, but the relationships that this plumbing system has with the other building systems depends on the building layout, quality objectives, and user needs. The second complexity is the functional relationship between systems. Design decisions for one system may affect one or more of the other systems, which increases the complexity of systems design. Concurrent design and constructability programs are often used to facilitate the collaboration necessary to solve functional inconsistencies.

Variety in the construction process comes from the fact that project teams often consist of parties that have never worked together before. Therefore, the interrelationships and paths of

communications change with every new project. Contractors and designers try to simplify each project by recommending other companies that they have worked with before.

### Hierarchical Complexity

Hierarchical complexity refers to the elaborateness of the hierarchical relationship between the components in a system. Because a hierarchy divides a complex system into manageable chunks, which have some sort of order, a hierarchy can effectively describe the level of complexity of a system. Buildings are characterized by a hierarchy of systems that is both complex in depth and breadth. The first few layers of a generic hierarchy of systems in a building are illustrated in Figure 2.4.

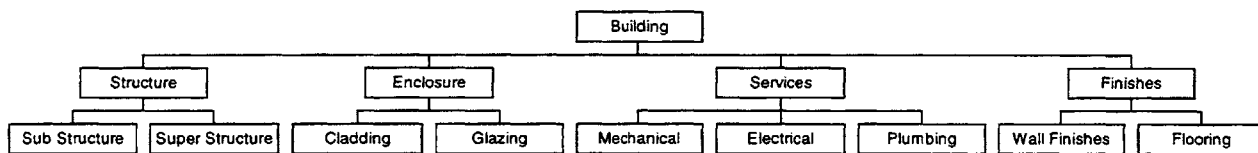


Figure 2.4  
Building Systems Hierarchy

Construction contracts also illustrate a sense of hierarchy through the use of a general contract, subcontracts, and sub-subcontracts. An intricate web of contracts determines the path of information and authority within a project.

Service providers in the construction industry experiment with several types of contract hierarchies, called project delivery mechanisms, to try to construct a building most effectively. This can reduce the amount of complexity, by customizing the information paths within the project team to the needs of the project.

### Operational Complexity

Operational complexity is the variety of operations that the system must undertake. Buildings have several uses and vary depending upon the performance requirements of the building owner

and users. Performance requirements can range from the quality of materials used in the building to the lifecycle costs of mechanical systems.

Many companies in the construction industry find themselves working on a variety of projects. For each type of project, the project team changes, the construction operations change, and the challenges that could be encountered change. Therefore, a different approach must be taken toward each project.

### Nomic Complexity

Nomic complexity refers to the elaborateness of the scientific laws governing the system. In buildings, this type of complexity varies with respect to the performance requirements and the technology used in the building systems. Sometimes building systems can be quite simple, but other times, the building systems can be so specialized that the laws governing them are quite difficult to understand. Many times, specialists are called in to deal with these complex systems. Another related issue is the functional relationships between systems. For instance, different building materials have different thermal characteristics. The thermal expansion of two adjacent building materials can be quite important to the overall integrity of the building.

The nomic complexity of construction is difficult to explain because there are no scientific rules that govern construction. The study of project organizations is not as wide spread as that of corporate organizations, the tacit knowledge of the methods of construction is taught through experience, and the breadth of the disciplines required for construction is vast. All of these components add to the complexity of determining the “rules” that govern construction.

These “Modes of Complexity” cover many topics and show that the product and process of construction is inherently complex in all of them. However, the framework of the “Modes of Complexity” lacks measurability. This research develops a framework that will cover many aspects of complexity that can be obtained through looking at the basic data of a building project. Areas that were investigated were intra-system complexity, inter-system complexity, site complexity, and project complexity. Chapter 3 (Framework) defines each of these areas.

### 2.1.3 MECHANISMS TO MANAGE COMPLEXITY

#### *2.1.3.1 Specialization*

A common way to tackle complexity is to break it into parts. Often, specialists deal with these individual parts and then put them together to form the full system. This mechanism is used in both product development and in construction.

#### *2.1.3.2 Hierarchical Organization*

Complex systems are frequently arranged in a hierarchy of elementary subsystems to make them more manageable (Rescher, 1998). In Simon's (1981) study, the systems that were arranged in this way tended to evolve more quickly than did those that were nonhierarchical. Because of the hierarchy created, there is a sequence of logical relationships, whereas with mere coordination there is just organization, lacking any unified direction.

#### *2.1.3.3 Architecture Reorganization*

Pimmler and Eppinger (1994), in their findings in a study of product development at Ford Motor Company, describe a strategy to use when tackling complexities. This approach to dealing with complexity concentrates on simplifying the interface interactions. Subsystems tend to be independent in the short run, but dependent aggregately in the long run. Also, intra-system bonds are usually stronger than inter-system bonds, which causes a possible conflict of objectives between the subsystems and the entire system (Simon, 1981; Kaneko, 1998). If one rearranges a complex system so that the interaction between the parts is simplified, the complexity of the entire system is reduced. Pimmler and Eppinger discovered that product development could be more effective if companies defined alternative architectures and design processes to ease coordinating demands. This process involves breaking the project into elements, documenting their interactions, and clustering them into chunks so that the interactions occur within the chunks, according to the strategy and capabilities of the teams. Appropriate "chunking" both illuminates the essential relationships within a system and constrains them to the problem at

hand, allowing the behavior of complex systems to be modeled and understood (Bloom et al., 1994).

Eppinger et al. (1994) also stresses the importance of re-evaluating the process used to develop manufactured products through the organization of tasks. Eppinger claims that the design process can be performed more successfully if it can be organized more sensibly. The re-organization of tasks can change the internal design issues of each task as well as the interfaces between the tasks. Tasks need not be organized into traditional subsystems; information transfer between tasks should be the key in creating task teams. The factors involved in information transfer include communication time, functional dependence, physical adjacency, reliability, and volume of information transfer.

Problem partitioning is made necessary by complexity. Decision ordering, communications of goals prior to decision making, and problem partitioning to minimize the size of the problems will solve them without rework. Also, decisions made in different sub-problems have to be checked for consistency (Vassilakis, 1997).

#### *2.1.3.4 Early Communication*

In a study done on innovative product development, fast developers use the degree of interaction among decisions, not membership in a skill category, as the criterion of assigning decisions into sub-problems. Fast developers are characterized by large amounts of communication early in the product development process. Slow developers divide a new product development problem into sub-problems functionally and limit communication between sub-problems to occur when functional groups deliver a complete design (Vassilakis, 1997).

#### *2.1.3.5 Concurrent Design*

As an item's complexity increases, so do the cognitive requirements for its adequate comprehension, although mismanagement and ineptitude can manage to complicate even simple issues (Rescher, 1998). Since each design choice can be a trade-off affecting other design parameters, collaboration is often seen as the way to bring about a better design. However,

collaboration can be a slow process. To improve the process, some activities can be represented by constraints and excluded from the design iterations to expedite the duration of the task. The constraints are agreed upon at the beginning of design so the interactions between systems are pre-defined. By simplifying the internal interactions by decreasing the number of variables in the design, concurrent design deals with both complexities at the building system level as well as those at the interface level (Eppinger et al., 1994).

## **2.2 INTEGRATION**

Many times the same tools that were used to break the problem into pieces cannot be used to put the pieces together to form a solution. Because of this fact, the study of integration, the act of incorporating or combining into a whole, should be inseparable from the study of complexity. Many times integration and interaction are used interchangeably. However, interaction is a reciprocal action between two or more things whereas integration is the incorporation of two or more entities to produce another entity (Random, 1991).

### **2.2.1 THE INTEGRATION OF KNOWLEDGE**

The definition of integration given above is a general one that can apply to all disciplines. However, integration is a term that is used loosely in many different situations. The type of integration most discussed in literature is the integration of knowledge.

A survey done on integration in organizational theory (Ettlie and Reza, 1992) depicts integration as a cross-functional act, which creates a sense of collective responsibility. It encompasses both cooperation and coordination.

In product development, as well as construction, the final product given to the customer is the work of numerous specialists, each performing a task toward the creation of the product. The task that each specialist performs is dependent on the others in order for the final product to function properly.

In general, this integration of knowledge into organizational capabilities can be viewed in the form of a hierarchy, as shown in Figure 2.5. The specialists combine their talents to complete tasks, which serve a function. These functions are combined to provide a cross-functional capability, which can be used to serve a client or to serve the organization internally.

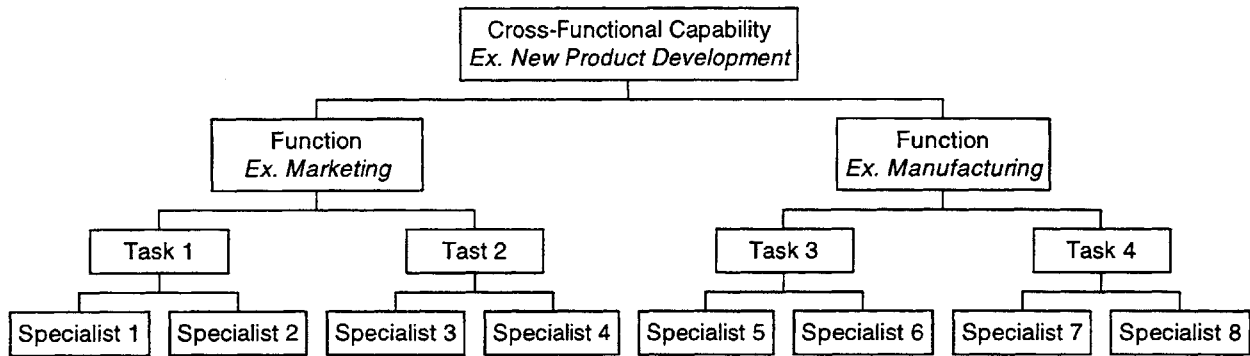


Figure 2.5 (Grant, 1996)  
Hierarchy of Contributions Made Toward New Product Development

When looking at this graphic depiction of the contributions necessary to provide a service, such as product development, one can see that the wider the span of knowledge being integrated, the more complex it is to manage. In the construction industry, the specialists are often separate companies, which further complicates the matter.

The nature of each specialist's task determines its position in the organization's workflow and the extent to which its activities are functionally interdependent with other specialists.

Dimensions of task interdependence include (Klein, 1991):

1. Time: the ordering of tasks, the deadlines that need to be met.
2. Space: the physical location of where something has to be done.
3. Quality: the specifications, tolerances, and degrees of freedom.

The interdependence of tasks determines the way decisions should be made within an organization. When individuals attempt to make independent decisions when tasks are tightly coupled with respect to the dimensions listed above, conflicts can arise. On the other hand, if tasks are not coupled and decisions are made centrally or collaboratively, resources are being



wasted. Therefore, decoupled tasks should have independent decision making, whereas coupled tasks should be coordinated, either by centrally locating decisions and/or having a group collaborate to come to a decision (Klein, 1991).

However, some components are more centrally important to the functioning of the system as a whole and have a significantly higher level of influence with respect to the other components. There is often an exchange imbalance because the needs of one component overrule those of others (Astley and Zajac, 1990).

There are three types of knowledge integration in addition to intra-organizational integration. First, there is integration by the use of a “market contract”. An example of a market contract is the contracting of an equipment vendor or other supplier. Market contracts are most efficient if the knowledge is embodied within a product (Grant, 1996). Second, there is the use of a “relational contract”. Relational contracts are best when the company cannot justify internalization of the specialization. Here, the resources are fully utilized when the boundaries of responsibility are unambiguous (Grant, 1996). Third, there is the integration with the customer, in which the service provider takes on the mentality of being part of the customer’s organization (Ettlie and Reza, 1992).

The theory on the integration of knowledge comes from product development and organizational studies. Construction project organizations bring more challenges to the integration process than corporate or manufacturing organizations because they are temporary alliances of several companies, many of which have never worked together before.

## 2.2.2 INTEGRATION TOPICS SPECIFIC TO DESIGN AND CONSTRUCTION

### 2.2.2.1 *Common Forms of Integration*

In construction, the most frequent types of integration are by the use of “market contracts”, “relational contracts”, and integration with the customer. In recent years, the construction industry has been moving toward another type of integration, called constructability.

Constructability is formally defined as the optimum use of construction knowledge and experience during all phases of the project to achieve overall project objectives (Fischer and Tatum, 1997). A more simplified definition is that constructability is the specific integration of construction-experienced specialists with design specialists.

Implementing a constructability program is not always an easy task. Fragmentation of the design and construction activities in the construction industry is due to a long history of specialization and risk aversion (Nam and Tatum, 1992). Other hindrances to constructability include the designer's lack of construction method knowledge, the fragmentation of information exchange in the industry, and the diverging goals amongst the numerous parties involved (Fischer and Tatum, 1997). However, the industry has seen that integration leads to a reduction in construction time, fewer design errors/omissions, and the use of new construction methods (Howard et al., 1989).

#### *2.2.2.2 The Physical and Functional Integration of Systems*

In building systems literature, integration takes on a definition that is related to the physical and functional relationships between building systems within a facility. Integration is an inherent characteristic of the building process, not something that is sought. Building criteria stems from human needs, which do not often coincide with particular systems, as defined, and requires integration (Rush, 1986). Integrated systems are characterized by the joint utilization of system components and the interference between system components. The biggest problem with regard to this integration is the exchange of functional information between the different technical systems. One reason why people do not like to produce highly integrated buildings is that when the building fails to meet the client's objective, there is a question as to who is accountable for the resulting damage. Accountability can be accomplished by properly allocating the responsibility for the systems. However, this process can be difficult to do when the systems are intertwined or unified (Kranz, 1998).

One goal of integration is to reduce the amount of time, material, and space employed in a building while increasing the number of activities that can be placed within it. Rush (1986) defines integration as the act of creating a whole functioning building containing and including

building systems in various combinations. He differentiates building systems integration from a system by stating that a system is a “coherent set of physical entities organized for a particular purpose” whereas integration is more complicated, based on creativity, because it does not have a specified purpose and can be implemented in many ways. The more systems there are, the more possibilities there are for different integration configurations. The more unified a building is, the more difficult it is to call out its distinct systems. One problem is that no one professional understands the system possibilities of the other systems in the building.

Rush defined five levels of integration of systems by the physical and functional way that they interact. The integration ranges from buildings whose parts are completely independent but are coordinated within a designated tolerance to buildings where the components perform multiple tasks that are inseparable.

The levels of systems integration are:

1. Remote: systems do not physically touch.
2. Touching: contact of systems without permanent connection.
3. Connected: systems permanently attached.
4. Meshed: systems interpenetrate and occupy the same space.
5. Unified: systems are no longer distinct and the same material has more than one use.

Rush visually defines these relationships by using ball diagrams. This is a great tool to show how the systems interact. Figure 2.6 shows a diagram of a typical interior floor assembly.

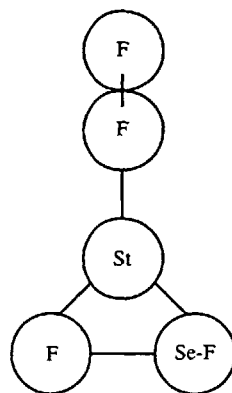


Figure 2.6  
Typical Building Section Diagram (Rush, 1986)

Starting from top to bottom, the first relationship is that of the furniture and interior partitions (F1: Finishes) with the floor covering (F2: Finishes). The furniture and partitions sit on the floor covering, thus having a “touching” relationship. The floor covering is connected to the interior floor structure and floor deck (St: Structure). The ceiling of the floor below (F3: Finishes) is attached (connected) to the bottom of the floor deck. Connected to both the floor deck and the ceiling below are the light fixtures of the floor below (Se-F: Services-Finishes). The last symbol “Se-F” represents a union relationship between the Services and Finishes. Lighting fixtures can be categorized as part of both the Services and Finishes systems because they provide light to the room below, but are also visible from the interior of the building.

Rush also touches upon another way to measure integration that he calls “visual integration” because it depends on the visual interrelationships of the systems. Visual integration mostly relates to architectural issues, but it shows how integration can be very subtle in nature.

The levels of visual integration are:

1. Not visible, no change: the system is not in view.
2. Visible, no change: the system is exposed to public view, but is not altered from what its functional application requires.
3. Visible, surface change: the system is visible to the public and only has a surface alteration made to it, with all other physical aspects unchanged, like when a pipe is painted a different color.
4. Visible, with size or shape change: the system is visible to the public and has been changed from what is simplest or most economical, for instance, when columns are not conventionally shaped.
5. Visible, with location or orientation change: the system is visible to the public, but its orientation is different (no change to shape/surface), as when columns or ducts are relocated.

In construction, the integration of knowledge is dependent upon the integration of systems in the building. Therefore, this research looks at the integration of systems in the building and determines the method of knowledge integration that occurs within the construction project organization.

### 2.2.3 INCENTIVES FOR INTEGRATION

The significance of integration, specifically constructability in the construction industry, is that it opens channels of communication between engineer and constructor and makes the communication of engineering information more effective (Muir and Rance, 1995; O'Connor and Tucker, 1986). Integration allows project team members to act collaboratively and to work toward achieving common goals.

Pocock, et al. (1996; 1997) did an indirect correlation between party interaction and project performance. First, a direct measure of delivery systems versus project performance was done with a sample of military construction projects. Using the same sample of projects, interactions among parties were defined and measured over the life of the projects. Interaction was measured by the use of a "degree of interaction" (DOI) score which is a weighted measure based on interaction frequency, duration, timing, and situation. It was concluded that the delivery systems that give more opportunity for interactions tended to have improved project performance.

Integration is also important to the survival of specialists in the construction industry. Because of the turbulence of markets and the trend to outsource services, integration in the form of strategic alliances has become a necessity. Another benefit of integration is the cross-fertilization of ideas that occurs across companies (Hull and Azumi, 1989).

By bringing the knowledge of several parties together, integration assists in achieving the best use of new technological capacity. This optimization of organizational potential can significantly improve overall systems performance (Whiston, 1989; Tatum, 1987).

In summary, integration is:

- A Mechanism to Manage Complex Problems
- An Effective Way to Communicate Information
- A Mechanism To Increase Efficiency
- A Way to Improve Project/Product Performance
- A Way to Make Companies More Competitive

## 2.2.4 MECHANISMS TO ACHIEVE INTEGRATION

### 2.2.4.1 *Information Technology*

Many sources agree that a logical way to integrate organizations is to provide some sort of information technology that is available to all of the parties involved (Grant, 1996; Whiston, 1989; Howard et al., 1989; Nam and Tatum, 1992). Large international companies, as well as local project teams have used databases, integrative software packages, intranet pages, and internet pages to make information available. This type of information technology can be used to make explicit knowledge available, to control processes, and to track the flow of information. Tacit knowledge is more difficult to make available, but companies try to do this by creating on-line standards and procedures manuals.

### 2.2.4.2 *Relationships*

The quality of relationships between people has a great impact on the degree of integration achieved by a company. Within companies that practice high levels of integration, there is a give and take relationship between the departments, early involvement of both parties in the design, and quick conflict resolution (Gupta et al., 1987; Nam and Tatum, 1992). The incentives for groups to form alliances are requirements placed by the client, for resources that they do not have, for mutual benefit, for efficiency, and for reputation (Oliver, 1990).

### 2.2.4.3 *Common Goals*

The strategic goals of the companies must overlap the production goals (Whiston, 1989). It is very difficult to integrate people if their cultures are different. For instance, when integrating an R&D department with a marketing department, the mix of the creative spirit of research may not mix well with the reality-grounded marketing outlook (Gupta et al., 1987). Cooperative goals induce the interaction that promotes solving problems because it is characterized by the exploration and integration of different ideas, whereas competitive goals make people want to stick with ordinary ideas and to avoid discussing concerns about the system as a whole.

Cooperative goals lead to levels of trust and make groups feel comfortable about transferring problems to other people, working together, and asking and giving information. People with competitive goals tend to be unwilling to assist others and unwilling to discuss through problems to mutual agreement (Tjosvold, 1990).

Joint ventures or the integration of task teams/companies can be extremely difficult because of different strategies, management processes, and objectives. The first step in integration is to find common goals that all of the parties can agree upon (Novak and Fine, 1996; Bucciarelli, 1994).

#### *2.2.4.4 Common Knowledge*

The level of common knowledge between specialists improves the efficiency of integration. If the specialists have shared experiences, vocabulary, and knowledge, communication is facilitated and there is understanding between the specialists (Barton, 1983; Grant, 1996; Muir and Rance, 1995; Whiston, 1989). This knowledge base must include specific systems knowledge as well as knowledge about the interdependency of the systems. Clear communication and comprehension of other disciplines is important. Good teams make design decisions that assist all of the systems, not ones that benefit their system at the expense of others.

#### *2.2.4.5 Repeated Tasks*

The frequency and variability of tasks determines the ease with which the task can be performed (Goodwin and Ziegler, 1998). If the same task is performed often, then the efficiency of integration will be high (Grant, 1996).

#### *2.2.4.6 Organizational Structure*

A strategy to enhance integration is to make the firm's structure of authority, communications infrastructure, and decision-making paths follow the hierarchy of the integration necessary for operations (Grant, 1996; Gulati and Eppinger, 1996). Furthermore, the structure of the hierarchy of an organization could economize the amount of communication needed to implement the

integration. A flatter organization delegates the decisions and reduces the amount of interactions needed with higher levels of the organization. Also, structuring the organization into modules can improve efficiency because it concentrates the communication effort where and when it is needed (Grant, 1996; Whiston 1989; Ettlíe and Reza, 1992). Organizations with high levels of integration have clear formal role definitions, decentralized decision making (which facilitates communication), high overall organizational participation in decisions, and a minimal amount of geographic separation (Gupta et al., 1987; Gulati and Eppinger, 1996).

#### *2.2.4.7 Appropriate Choice of Integration*

The original pressure to integrate stems from the desire to reduce costs by compressing the systems together into less materials or physical space. Some systems, such as fire/life safety and security, need to be separate because of regulations or operational needs. In addition, manufacturers do not like integration because it is often not reusable in their products and increases their liability (Rush, 1986).

Certain buildings are more prone to higher levels of integration. Buildings that require change are not good candidates for high systems integration. One reason is that if one part becomes obsolete or fails, there is a risk that the systems that are integrated with the failed system have a risk of failing also. In a building, the structural system is the system that is most difficult to change. After this comes the enclosure, the services, and the finishes, which are the easiest to change (Rush, 1986).

O'Connor and Tucker (1986) did a study on constructability improvement ideas observed on a large refinery expansion project. This study showed that specific systems had specific constructability needs. For example, structural systems needed to have a construction-sensitive design, whereas instrumentation and piping systems needed improvements in the communication of engineering information. These results show that not all systems have to have the same constructability improvements. On the contrary, in order to be effective, constructability improvements should be focussed in areas that are suitable for the individual systems.



## 2.3 SUMMARY

Theory from many fields of study forms the background literature for this research. It was very important first to establish the many dimensions of complexity and then to apply them specifically to buildings and construction. The next chapter, entitled Framework, outlines the specific dimensions that were derived from the background literature and are applicable to construction. The sole purpose of using this framework is to be able to identify and measure complexity in construction projects based on basic project data.

The theory related to integration shows the relationship between complexity and integration. In this research, integration is treated as a tool to cope with complexity. The incentives for integration are recognized and as are the ways to achieve integration. The framework for this research defines measurable variables to identify the existence of integration within project teams and the reasons why this integration occurs.



## **CHAPTER 3: FRAMEWORK**

The background literature provides the foundation for the rest of the research. It has been shown that complexity has many dimensions and is difficult to define. This research separates the different types of complexity found in building construction in order to highlight the unique aspects of each complexity. This research also builds upon mechanisms used to cope with complexity, such as specialization and various methods of communication.

Construction project teams are designed to be very hierarchical to provide flexibility and to avoid risk. However, large hierarchies lead to high levels of task interdependence and the need for some sort of integration to build a finished product. The background literature provides many mechanisms to implement integration. The integration mechanisms in the framework that follow are related to the ones in the background literature. However, the mechanisms were chosen because they are simple and easy to measure using the case studies.

### **3.1 GOAL OF RESEARCH**

Construction projects are inherently complex, and the regions of complexity within each project are different. The goal of this research is to show that each region of complexity in a construction project requires a specific type of project team integration. Exceptions are found when the different parties in a project team have worked together before, and if one party is recognized to have capabilities in their portion of the project. These two types of relationships can create a sense of trust between the team members, which can alleviate some of the need for formal communication and integration mechanisms.

Specific building designs, site conditions, and project team configurations are the main contributors to the uniqueness and difficulty of construction. Even though technical factors are the basis for construction, the management of the complicated web of relationships and the flow of information throughout the project are also critical. A construction project team is a temporary alliance of a variety of companies and characters. Owners, architects, constructors, and construction managers, among others, have different personalities, agendas, and work styles.

To further complicate matters, many times these companies have never worked together previously. Because of this lack of familiarity, there is often difficulty in coordinating information and work on the construction site.

This research looks at the challenges involved in responding to complex situations within construction projects. The results demonstrate how construction managers of future projects can cope with project complexities. It is also hoped that this research will spur further study of construction project organizations.

## **3.2 VARIABLES AND MEASURES**

The key variables of this research are complexity and integration. The data shows that when there are high instances of complexity, there are high levels of integration, except when familiarity, in the form of capabilities or relationships, is introduced.

### **3.2.1 COMPLEXITY**

For this research, complexity is defined as a situation or entity that is difficult to understand or resolve. Issues that contribute to complexity are interdependence of entities, technological elaborateness, and comprehensiveness. The background literature shows that complexity is best measured by looking at different dimensions separately. In the case of construction, three main categories of complexity were formed: system complexity, site complexity, and project complexity.

#### *3.2.1.1 Measures of Construction Project Complexity*

Each case study was evaluated for the existence of each type of complexity identified below. If a complication existed, it was measured as No/Low, Medium, or High. The data was recorded in a Yes/No fashion.

## System Complexity

System complexity refers to the challenges encountered within the project related to the technical aspects of the systems required in the building. There are two main sources of complexity related to systems, as defined below:

1. **Intra-System Complexity:** a system that is not common in standard building construction, which usually: 1) is at or beyond the state of the art; and 2) involves some sort of specialized knowledge to design and/ or install. *Examples: control systems, laboratory equipment, sound systems.*

This category was further divided into sub-measures according to the four traditional systems found in a building:

- Structure
- Enclosure
- Services
- Finishes

2. **Inter-System Complexity:** a situation when there is: 1) a complicated spatial relationship between two or more systems; 2) a functional relationship requiring cooperative design decisions for several systems; and/or 3) a logistical relationship between systems that affects the method of constructing the systems. *Examples: heavy Mechanical, Electrical, and Plumbing systems in the ceiling cavities of a building; unified structural/enclosure system; large door openings to accommodate entry of large equipment.*

Data in this category was arranged so that the relationships between the four systems mentioned above could be identified and recorded.

## Site Complexity

Site complexity refers to the difficulties related to the specific site chosen for the construction of the building. There are two main sources of complexity related to site-specific factors, as defined below:

1. **Site Logistics Complexity:** the challenge of conducting construction operations on a site that has physical constraints and/or the transport and handling of resources to and within the site. *Examples: special transportation to the site, storage and construction space.*

The logistical complexities were sub-divided into three sub-measures:

- Site Access
- Transportation of Materials
- Construction During Operations

2. **Site Special Conditions Complexity:** unexpected or unusual conditions specific to the site that cause engineering and construction method challenges. *Examples: unfit soil conditions, site-specific construction difficulties, unknown conditions.*

The site special conditions complexities were sub-divided into two sub-measures.

- El Niño – this was a storm that affected several of the construction projects
- Unknown Conditions

## Project Complexity

Project Complexity refers to the challenges related to the management and operations of the project, independent of the physical aspects of the project. Aspects of project complexity include community factors, project team organization, and objectives of the project. There are three main sources of complexity related to project factors, as defined below:

1. **Contract Management Complexity:** issues relating to the organization of a project team, which defines the way that information flows for the duration of the project. *Examples: project delivery mechanisms, staffing changes.*

Contract management complexities were sub-divided into two sub-measures:

- Management of Project Team
- Teamwork Problems

2. **Project Scope and Objectives:** issues unrelated to the design of the facility and the physical characteristics of the site, which affect and complicate the implementation of the project. *Examples: accelerated or dependent schedule, cost constraints.*

Project scope and objectives complexities were sub-divided into:

- Schedule
- Budget
- Other (includes Quality and other special Owner needs)

3. **Social:** relations with the community that add challenges or special requirements to the project. *Examples: special regulations, community complications.*

Social issues were sub-divided into two sub-measures:

- Regulations Compliance
- Community Relations

### 3.2.2 INTEGRATION

The definition of integration used for this research is the act of incorporating parts to produce a whole. In the case of this research, organizational integration is measured, as well as the interaction of parties to form a project team. The background literature lays the groundwork for the method of measurement used in this research. Integration mechanisms are used as the measure for integration because they can be identified easily and used as a scale to find the level of integration.

In many cases, a non-integrative mechanism was used to deal with complexity. To make the analysis complete, this mechanism must be addressed and is called the *Use of Specialists*. For example, a complex system or problem is delegated to a party that has the specific capabilities needed to determine the solution. Once the solution is found, the specialist passes it on to the other members of the team.

The recognition of the capabilities of specialists is important to this research because it is an instance when formal integration may not be necessary. All of the case studies were evaluated for the use of specialists and these results are presented in Chapters 6 (Results).

#### *3.2.2.1 Integration Mechanisms*

Integration mechanisms are the ways in which the project team of a construction project communicates to bring together the information necessary to implement the project. The range of integration observed in the data collected differs from no communication to intense communication and problem solving between parties at the same location. Levels of integration used in construction projects can be compared by looking at the types of mechanisms used during the course of the project.



## Scale of Interaction

1. **No Interaction Expressed:** In this case, no interaction occurs between parties. Thus, no integration occurs.
2. **Information Exchange:** This mechanism is defined as the exchange of information between parties. At this level of integration, one party makes engineering, management, and planning information (such as dimensions, forces, schedules and assumptions) available to other parties. Sometimes a party requests this information through an RFI (request for information) and other times the information is given on an FYI (for your information) basis.
3. **Coordination:** Coordination is defined as the act of arranging activities or components into proper order. In construction, coordination is observed in many ways. First, building systems can be arranged to avoid physical interference between their entities. Second, the timing of the work that people do in the on site can be arranged in an order that is most efficient to the construction of the entire building.
4. **Collaboration:** Collaboration is the act of working together to solve a problem. This mechanism results in the highest level of integration that can be accomplished on a construction project. Many times collaboration is done to ensure that information is equally available to all parties, that they all mutually understand the information, and that the information reflects the interests of each party. Decisions are made with respect to the needs of many building systems and the groups of people who are going to design and build them.



## **CHAPTER 4: METHODOLOGY**

### **4.1 EMPIRICAL RESEARCH**

This research uses empirical research to test the theory that project teams work most effectively if the complexities of a project are identified and an appropriate level of integration is accomplished. Empirical research uses data derived from experience and real situations. This research began with a review of current theory in the area of complexity and integration. From here, the theory specific to this research was developed. Finally, data from case studies of real construction projects was analyzed to identify trends, and to refine theory.

### **4.2 USE OF THE CASE STUDY APPROACH**

The case study approach was chosen as the form of research for this thesis because of the subject matter. Construction is very grounded in tacit knowledge, which is experience-related. Also, since construction projects are inherently unique and large in scale, laboratory experiments and the use of controlled samples are not feasible. Furthermore, management techniques are project specific and cannot be simulated. The use of case studies allows the researcher to obtain information about the experiences of others with respect to how issues arise and problems are solved in practice. The data collected is rich with information that is real and believable to an industry that is normally reluctant to participate in research and academia.

### **4.3 CHOICE OF PROJECTS**

Projects used as case studies were chosen based on several factors. First, all of the projects were in the Southern California area. This decision was made in order to keep location-related factors, such as regulations, weather, and work practices, constant. Second, the projects that were chosen were completed in the last five years to ensure that the interviewees could accurately remember details of the projects. Third, local offices of general contractors and construction managers were contacted so that distance from the construction site was not an issue for the project organization. Fourth, a variety of projects completed by these general contractors and

construction managers were chosen to create a sample of projects that would be representative of building construction.

The sample is divided into four general building types: medical/ laboratory facilities, institutional buildings, office buildings, and other buildings. Medical/ laboratory facilities are buildings in which medical or testing activities are performed, which usually requires special equipment and services. Institutional buildings are miscellaneous facilities used by institutions such as corporations, schools, and other social groups. Office buildings are characterized by environments in which administrative duties are performed, requiring workplace furnishing such as desks, computers, and storage. A parking garage and a low-rise residential facility were also evaluated to provide some examples of simple projects (specifically, those projects not likely to contain the complex characteristics defined in Chapter 3, Framework).

#### **4.4 DETAILED CASE STUDIES**

An Interview Data Sheet was developed and sent to general contractors and construction managers to familiarize them with the purpose of this research and to prepare them for the personal interviews. Appendix 1 shows the data sheet that was used. The purpose of the first section of the data sheet was to collect basic information about the construction company being interviewed. The second section dealt with the basic project data such as type of building, construction delivery system, cost, schedule, specifications, and location. The third section dealt with information about the project organization such as the flow of information throughout the project, the capabilities of the project team, and the previous working relationships that existed between the parties of the team.

By structuring the data sheet in this fashion, the person being interviewed would reliably give consistent answers to the questions because the two main variables (complexity and integration mechanisms) were separated.

#### 4.4.1 PRIMARY INTERVIEWS

The primary interviews were conducted by phone, or in person, at the convenience of the person being interviewed. Interviews were conducted with key players of recent or current construction projects of varying complexity in the Southern California area. Interviewees were urged to “tell the story” behind the building and the construction process. Following this introduction, specific questions from the items on the data sheet that were not addressed were asked. Using this method of interview, the interviewer was able to obtain the information in the order that the interviewee thought was most important. Table 4.1 shows the list of projects used as case studies.

The interviews were time intensive, with some interviews lasting up to two hours long. The benefit of the interview format over the questionnaire format was that more information could be obtained, the interviewer could follow up on interesting topics, and background information for the thesis topic, in general, was discussed.

Table 4.1  
Detailed Case Study Project List

Project	Building Type	Source
1. Amgen Cell Culture Building Addition	Medical/ Laboratory	ARB Construction (Foran, 1999)
2. Princess Cruises Office Tenant Improvements	Office Building	Bovis Construction (Polizzotto, 1999)
3. Mt. San Antonio College Performing Arts Center	Institutional	Bovis Construction (Cowin, 1999)
4. Metropolitan Water District Headquarters	Office Building	Charles Pankow Builders (Sanders, 1999)
5. Car barn	Other (Parking)	Charles Pankow Builders (Lucas, 1999)
6. Arcadia Methodist Hospital Patient Wing Replacement	Medical/ Laboratory	Charles Pankow Builders (Firebaugh, 1999)
7. Metropolitan Transit Authority Headquarters	Office	Charles Pankow Builders (Sanders, 1999)
8. Major Refinery Blending And Shipping Control Room	Institutional	DMJM (Hron, 1998; Degnan, 1999)
9. Rocketdyne Headquarters Renovation	Office Building	DMJM (Hron, 1998)
10. Warner Brothers Sound Stage	Institutional	DPR Construction (Foran, 1999)
11. Kaiser Medical Facility	Medical/ Laboratory	DPR Construction (Leopold, 1999)
12. Casa San Juan	Other (Residential)	Benchmark Construction (Dominik, 1999)
13. 77 <sup>th</sup> Street Police Station	Institutional	Morley Construction (Howard, 1999)
14. Parcel 1, Cerritos Office Building	Office Building	Benchmark Construction (Morrison, 1999)
15. Delta Dental Office Expansion	Office Building	Morley Construction (Morrison, 1999)
16. City Of Hope Diabetes Research Center	Medical/ Laboratory	Morley Construction (Didone, 1999)
17. Our Lady Of The Angels Cathedral	Institutional	Morley Construction (Dooley et al., 1999)

#### 4.4.2 BACKUP INTERVIEWS AND SECONDARY SOURCES

Backup interviews were conducted in a similar fashion. The backup interviews were with parties mentioned by the general contractor or the construction manager, usually the owner or the architect. These interviews were done to validate the information given by the primary source and to elaborate on other subjects important to the different parties.

Other times, a secondary source was used instead of a backup interview. The secondary sources were press releases or journal articles about the project. These sources were also used to validate the information from the primary interviews.

#### **4.4.3 CASE STUDY RECORDS**

The information obtained from the interviews and secondary sources were compiled into Case Study Records. These were organized in a fashion that would make the information comparable and easy to review. Appendix 2 contains all of the Case Study Records. The first section is a summary of the project. The second section has information about the site, the schedule, the delivery system, the critical building systems, and other project issues. The third section contains information about the project team and how the different parties within the team interacted with each other.

#### **4.5 DEFINITION OF TERMS**

The types of complexities and mechanisms for integration are defined in Chapter 3 (Framework), based upon theories and empirical studies in related areas. These definitions were used to measure the data obtained through the interviews. Because the projects are all unique, defining the terms to be used in the analysis of the results was extremely important to ensure commonality and comparability.

#### **4.6 GENERAL CASE STUDIES**

To further attempt to validate the data obtained in this research, project information from journals such as Engineering News Record, Civil Engineering Magazine, and F.W. Dodge California Construction Link provided basic project data about recent construction projects all over the country. This data was analyzed separately and the results were compared with the detailed case studies to ensure representativeness of the projects studied in detail. The General Case Study Records are located in Appendix 3. The list of instances of complexity obtained from these case studies is located in Table A.2 in Appendix 4.

#### **4.7 ANALYSIS OF DATA**

Using the definitions for complexity and integration mechanisms in Chapter 3 (Framework), the information from the case studies was measured and analyzed. In each of the analyses, the data was counted in simple frequency. The data points were related to each complexity found in each case study. Therefore, some projects have more than one complexity of each type.

The data was first arranged in matrix form (Appendix 4). Next, the relationships between building type, complexity, and integration mechanisms were identified. These relationships were recorded and trends were identified. Simple statistics were used to establish trends in the data, but the bulk of the analysis was based on the careful evaluation of the rich data that was collected on each case study.

Once trends were established, conclusions were made about the types of integration mechanisms that would be most effective in dealing with complexities common in the projects surveyed. Also, recommendations for further research are discussed.

#### **4.8 VALIDITY OF THE DATA**

The data that was collected for this research was carefully checked for validity. Case studies were used to obtain data that was from real building projects. The primary source for each project was a member of the project team who participated in the project through most of its duration. In addition to this, a backup interview with another key player in the project was conducted, or a written secondary source was sought to verify that the data obtained was accurate.



#### **4.9 RELIABILITY OF THE RESEARCH**

The research was conducted in a non-biased way. Definitions were established at the beginning of the research so that the data was evaluated consistently and efforts were made to validate the data that was used.

#### **4.10 REPRESENTATIVENESS OF THE DATA**

Even though the projects chosen for the case studies were geographically-based in Southern California, the data from this research can be representative for the construction industry in general. The aspects of the projects that were evaluated in this research, specifically system complexity, site complexity, and project complexity, are common to all construction projects, regardless of where it is located. In addition, an effort was made to show that the results of the research could be duplicated using examples of projects from around the country. This was done through the evaluation of projects showcased in journal articles. Lastly, the project categories chosen for the case studies provide a variety of different types of building projects.



## CHAPTER 5: DETAILED CASE STUDIES

Using the definitions for complexity and integration mechanisms found in Chapter 3 (Framework), the information from the case studies can be measured and analyzed. Through the use of case studies, this research shows that many project teams have successfully completed building projects of various complexity using levels of integration appropriate to the situation.

This chapter is devoted to outlining the information that was gathered from the case studies. The data for these case studies is provided in Appendix 2. Chapter 6 shows the results and conclusions derived from this information.

### 5.1 PROJECT 1: AMGEN CELL CULTURE BUILDING ADDITION

General Project Category: Medical/Lab

Owner: Amgen

Architect: Fluor Daniel

Constructor: ARB (CM/GC)

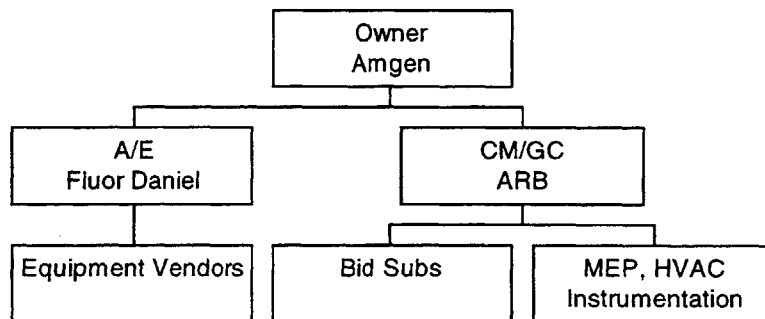


Figure 5.1  
Project 1: Organizational Chart

The project is a \$9.6 million, 2-story 6,000 SF building addition to existing facilities. It is structural steel construction and has an exterior insulation and finish system (EIFS) that matches the existing buildings. This building houses a cell culture growing process and is best described as consisting of cleanroom manufacturing labs.

At the time, ARB was already doing a project at the Amgen campus and was approached by Amgen to see if they could do this project in 6 months. Amgen wanted to start production of trial batches of a product as soon as possible. Normally it would take 18-20 months for the design, construction and validation stages, but Amgen wanted it to be done in 10-12 months. ARB did the preliminary schedule given certain assumptions, one of which was no budget constraints. The project was managed in a Design-Build fashion on a cost-plus basis, with lesser trades bid out.

Table 5.1  
Complexity and Integration Matrix  
Project 1: Amgen Cell Culture Building

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High		2	1	1		1
	Medium						
	Low						
Inter-System Complexity	High	2			1	2	1
	Medium						
	Low						
Site Complexity	High						
	Medium	2				2	
	Low						
Project Complexity	High	3			2	2	
	Medium						
	Low						

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

### INTRA-SYSTEM COMPLEXITY

This project had two examples of system-level complexity. The first instance is the process control system. This system was sub-contracted to a company that *specializes* in instrumentation. The second instance was the equipment used to do the steps in the cell culture process. The equipment required for this process had to be custom-made from multiple equipment vendors all over the world. In addition to the necessity of *specialists*, the Engineers and the Owner's engineering staff *collaborated* to design and specify the equipment necessary for the patented process. This *information* was passed onto the Vendors and the General Contractor (GC).

## INTER-SYSTEM COMPLEXITY

Because the equipment was being manufactured all over the world, there was a long lead time for these products. The aggressive construction schedule made it necessary for the construction of the building to go on before the equipment arrived. This first example of inter-system complexity resulted in the need to *coordinate* the erection of the steel, the enclosure of the building, and the installation of the finishes with the arrival of the equipment. The second example of inter-system complexity in this project is the relationship of the process-control system with the plumbing and electrical systems as well as with the equipment. The Mechanical, Electrical, and Plumbing (MEP) systems within the building were *coordinated* so that it followed the production process in the most efficient way. Also, the GC created a database in which all of the *information* about the equipment and instrumentation was *coordinated* and made available to the process-control Sub-Contractor. Lastly, the process-control Sub-Contractor made several cross-country trips to visit with the Engineer to *collaborate* and establish the process required for production.

## SITE COMPLEXITY

The building was being constructed on the Amgen campus. At this time, there was a lot of simultaneous construction. The large amount of construction resulted in challenges with access, storage, and deliveries. The Owner facilitated weekly meetings in which all GCs involved in ongoing projects actively participated in the *coordination* of the construction activities. Also, during the construction of this facility, California received an unusual amount of rain, called the El Niño storm. Construction activities were carefully *coordinated* so that the site was enclosed as soon as possible.

## PROJECT COMPLEXITY

The main challenge of this project was to complete construction in an extremely short period of time. The schedule was accomplished by putting the GC in charge of *coordinating* the Designer and the Sub-Contractors to implement an aggressive schedule. The GC facilitated this schedule by dividing the design into routing design and detailed design. The routing *information was given* to the Sub-Contractors early in the project and the Sub-Contractors did the detailed design of the MEP and Heating, Ventilation, and Air Conditioning (HVAC) systems. Lastly, in order to turn the building over to the Owner sooner, the validation of the systems (discussed below) was conducted in parallel to the construction of the building.

A second challenge was the way in which the contracts were awarded. Even though the project was contracted to be Design-Bid-Build, it was delivered in the Design-Build fashion. The GC had management responsibility over the Designer and the Sub-Contractors and their work was *coordinated* accordingly. Furthermore, the Sub-Contractors made a major contribution to the design.

The last project-related challenge is related to regulations from the U.S. Food and Drug Administration (FDA). Because this facility was producing a product governed by the FDA, all of the equipment and systems had to be formally tested and validated. This required testing and documenting all 1,300 instruments. The GC was the central source for information and the Owner had a team of people devoted to the validation of the systems. This *information was collected and formalized* for the FDA.



Table 5.2  
Complexity and Integration Matrix  
Project 2: Princess Cruises Office Building

Complexity Levels		Integration Mechanisms				
		No Specialist	Specialist	Interaction Level		
				No Interaction	Information Exchange	Coordination
Intra-System Complexity	High		1	1		
	Medium					
	Low					
Inter-System Complexity	High					
	Medium					
	Low	2		1		1
Site Complexity	High					
	Medium	1			1	
	Low	1		1		
Project Complexity	High	3			1	2
	Medium					
	Low					

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

#### INTRA-SYSTEM COMPLEXITY

The computer and data center was the single most important system in this building. It was crucial that this system be operational 24 hours/day. A *specialist* in this type of equipment was brought into the project to design and build the system.

#### INTER-SYSTEM COMPLEXITY

There was no special type of inter-system complexity in this project. However, since the Construction Manager (CM) emphasized teamwork, there were several *coordination* meetings to make all of the contractors aware of the schedule for the work that was going to be done.

#### SITE COMPLEXITY

Because of an uneven rock shelf, there were problems with the pile driving. The contractors *informed* the GC about this and actions were taken to cut the piles so that the tops of the piles would be at the same level.



## PROJECT COMPLEXITY

Since Bovis and Princess Cruises were owned by the same parent company, Princess Cruises held all of the sub-contracts for the tenant improvements. The shell and core contracts were held by the building's developer. Bovis had to *coordinate* the Sub-Contractors to keep construction on schedule.

Furthermore, the shell and core construction was significantly behind schedule so the tenant improvements had to be on a compacted schedule. Bovis had to provide extra *coordination* for this.

The local inspector overseeing the project required many redundancies built into the project. The CM complied with these requirements as the *information* was made available.

### 5.3 PROJECT 3: MT. SAN ANTONIO COLLEGE PERFORMING ARTS CENTER

General Project Category: Institutional

Owner: Mt. San Antonio College

Architect: CHCG Architects

Constructor: Bovis (CM), Cal-PAC (GC)

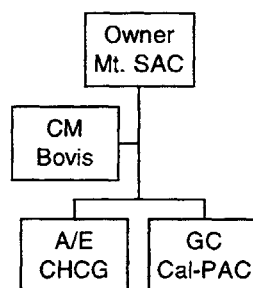


Figure 5.3  
Project 3: Organizational Chart

The Mt. SAC Performing Arts Center is located on the Mt. San Antonio College campus. It is a \$16 million, 2-building, 65,000 SF complex, consisting of a large theater (5500SF and 410 seats) and a smaller recital hall (2500SF). Other components include a dance studio, band room, rehearsal room, and offices. It is constructed of structural steel with a brick façade and its highest point rises 73 feet high.

Bovis has a long-standing relationship with the facilities department at Mt. SAC and is doing several construction and maintenance projects throughout the campus.

Table 5.3  
Complexity and Integration Matrix  
Project 3: Mt. SAC Performing Arts Center

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High						
	Medium		1	1			
	Low						
Inter-System Complexity	High						
	Medium	2				2	1
	Low						
Site Complexity	High						
	Medium	1				1	
	Low	1		1			
Project Complexity	High	2			1		1
	Medium						
	Low	1		1			

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

### INTRA-SYSTEM COMPLEXITY

The staging and theatrical systems required in the building created a challenge that was solved through the use of theater *specialists*.

### INTER-SYSTEM COMPLEXITY

The main concern for this building was acoustics, because of its use for performance art. Acoustical considerations were made with the placement and selection of electrical and mechanical systems. The Engineers *collaborated* to find the most acoustically optimal solution, and the placement of the systems had to be carefully *coordinated*. There was some trouble with the installation of the HVAC system because not enough room was allotted for it, but the Architect and CM *coordinated* this.

## SITE COMPLEXITY

The El Niño storm hit California during the construction of this building, which required a little more *coordination* on the part of the CM.

## PROJECT COMPLEXITY

Cost escalation was the first problem that the project encountered. Because of the Northridge earthquake, the prices for construction went up significantly. Labor and materials were in short supply. Value engineering and *collaboration* between the CM and the Architect resulted in a building that the Owner could afford.

Because this building was on the campus of a public school, a division of the State Architect's Office was required to oversee the project. The addition of this outside agency created many additional requirements for the CM and the Architect. All changes and requests for information in the project were recorded and submitted for approval. This *method of information exchange* was a long process and added onto the schedule of the project.

### 5.4 PROJECT 4: METROPOLITAN WATER DISTRICT HEADQUARTERS

General Project Category: Office Building

Owner: Metropolitan Water District of Southern California (MWD)

Architect: Gensler

Constructor: Charles Pankow Builders (GC)

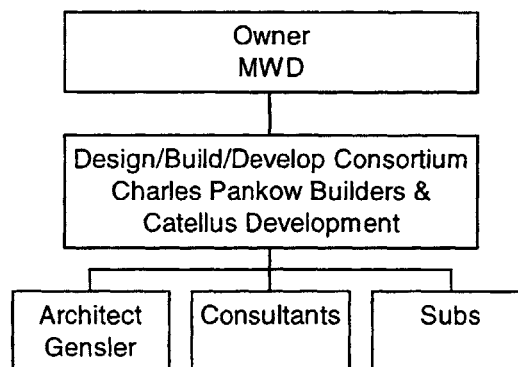


Figure 5.4  
Project 4: Organizational Chart

The Metropolitan Water District of Southern California (MWD) Headquarters is an administration office building for a large public agency. The \$135 million, 12-story 536,000 SF structure is a conventional cast-in-place ductile concrete frame with pre-cast pre-tensioned beams and mildly reinforced concrete slabs. Pre-cast concrete panels are used for the exterior enclosure. It also includes 2 levels, or 370,000 SF, of below-grade parking. Structural design of the building was very important to the Owner. This was reflected in the budget that was allotted for it.

Another main objective was that the building be cost efficient. There was careful consideration of layout, systems, and finishes to reduce costs. The ground floor of the building also includes a boardroom, cafeteria, committee rooms, and an art gallery.

Table 5.4  
Complexity and Integration Matrix  
Project 4: MWD Headquarters

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High		2		1		2
	Medium						
	Low						
Inter-System Complexity	High	1					1
	Medium						
	Low	1		1			
Site Complexity	High	1				1	
	Medium	1				1	
	Low						
Project Complexity	High	3			3	1	1
	Medium						
	Low	1		1			

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

### INTRA-SYSTEM COMPLEXITY

There are two examples of system complexity on this project. The first instance is a software-based building management system. The challenge was obtaining enough information to understand the needs of the Owner. The system Vendor (*specialist*) had meetings with the GC

and Owner to *collaborate* on the quality specifications and performance requirements of the system.

The second system of interest was the structural system. The GC was using a new splicing technique for the concrete structural system, and the Owner was concerned about the system. The Owner required the GC to provide *documentation* that proved that the system worked. The GC had to *collaborate* with the Structural Engineer (*specialist*) to come up with a system that worked to the requirements of the Owner.

### INTER-SYSTEM COMPLEXITY

There was a conflict in the construction methods necessary to construct the structure and the enclosure. The enclosure was designed to be isolated from the structure, with the panels hung from the top of the structure. However, the construction method for the structure required that the enclosure be put in from the ground up. To resolve this conflict, the GC *collaborated* with the Structural Engineer to produce a method in which the exterior panels were supported until the top of the structure was secure. After the structure was completed, the panels were hung as they were designed.

### SITE COMPLEXITY

The El Niño storm provided rain delays, and the GC had to *coordinate* the work more carefully. Also, the site was located at the main train station in Downtown Los Angeles. Access and storage space were difficult to find, but the GC *coordinated* with the authorities and with the landowner (the partner in the joint venture, Catellus Development) to arrange for solutions.

### PROJECT COMPLEXITY

There were three interesting political challenges on this project. The first was the issue of cost. In the past, the MWD had been criticized for excessive spending. Therefore, cost minimization was extremely important. They required alternatives (*information exchange*) for every design

and construction decision and *collaborated* with the GC to build the most efficient building possible.

The second interesting challenge came about when it was discovered that the site was an ancient burial ground. The GC had to *coordinate* work around the archeologists in the area, and *information had to be given* to the tribes about the arrangements that had to be made for reburial of the bodies.

The last challenge was the extra work required when working with a public agency. The GC had to provide *documentation* for every trade, alternatives for every system, and extensive information about the whole construction process. This extra documentation took a lot of extra effort, but resulted in creating an Owner that was very knowledgeable about its building.

**5.5 PROJECT 5: CARBARN**

General Project Category: Other  
Owner: First Commercial Corporation (FCC)  
Architect: HNA Pacific  
Constructor: Charles Pankow Builders (GC)

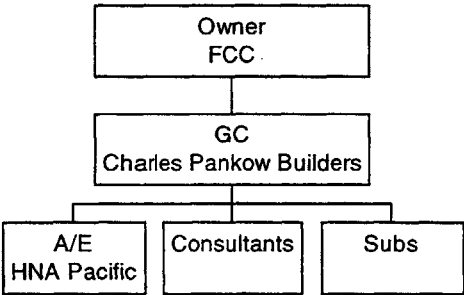


Figure 5.5  
Project 5: Organizational Chart

The Carbarn is a typical 540,000 SF parking structure with over 1000 parking spaces, 1 level below ground and 3 suspended decks. Services include valet parking (for approximately 60 spaces) and a valet drop-off space. Also, there is a 1000SF office/lobby for the valet service. A carwash will be added in the near future. The beams, columns, and spandrel panels (structural by Los Angeles Unified Building Code standards) are pre-cast concrete. The slabs and ramps were

constructed of cast-in-place concrete. The exterior stairs were located at the corners of the garage and they had structural steel canopies.

Table 5.5  
Complexity and Integration Matrix  
Project 5: Car barn

Complexity Levels		Integration Mechanisms				
		No Specialist	Specialist	Interaction Level		
				No Interaction	Information Exchange	Coordination
Intra-System Complexity	High					
	Medium					
	Low	1		1		
Inter-System Complexity	High					
	Medium					
	Low	2		2		
Site Complexity	High		1	1		
	Medium					
	Low	1		1		
Project Complexity	High					
	Medium					
	Low	3		3		

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

#### INTRA-SYSTEM COMPLEXITY

There were no special system complexities in this project.

#### INTER-SYSTEM COMPLEXITY

There were no special interactions between the systems in this project.

#### SITE COMPLEXITY

The site was almost all uncertified fill. The Structural Engineer (*specialist*) had to design two types of foundations and two types of retaining walls for this project.

## PROJECT COMPLEXITY

This project was straight-forward in nature.

### 5.6 PROJECT 6: ARCADIA METHODIST HOSPITAL WING REPLACEMENT

General Project Category: Medical/Lab

Owner: Arcadia Methodist Hospital

Architect: HKS

Constructor: Charles Pankow Builders (GC)

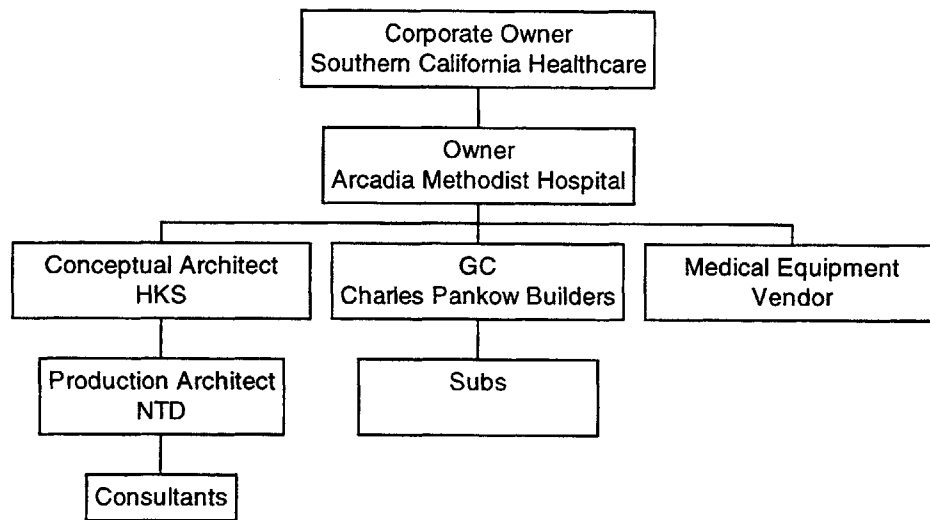


Figure 5.6  
Project 6: Organizational Chart

This \$40 million, 150,000 SF project is a steel structure, 5 levels above grade, one below. The exterior insulation and finish system (EIFS) is made of studs, gypsum, Styrofoam, plaster, and glass. It is a patient wing replacement for an existing hospital with 151 patient rooms. In addition, there was an admissions area, a lobby with a gift shop, an outpatient area for medical exams, and a post-partum area.



Table 5.6  
Complexity and Integration Matrix  
Project 6: Arcadia Methodist Hospital

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High		3	2			1
	Medium						
	Low						
Inter-System Complexity	High	1				1	
	Medium	1			1	1	
	Low	1		1			
Site Complexity	High						
	Medium	2				2	
	Low						
Project Complexity	High	1			1		
	Medium						
	Low	2		2			

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

### INTRA-SYSTEM COMPLEXITY

This project had high levels of intra-system complexity. Medical systems such as equipment, a nurse-paging system, and medical gas lines were challenges, as well as the special moment frame connections that were required in the structure. In all cases in this project, *specialists* in the specific areas were retained.

### INTER-SYSTEM COMPLEXITY

There were also some challenging inter-system interactions on this project. The main interactions occurred at the locations of patient headboards. These interactions between the mechanical, electrical, plumbing, nurse-paging, and medical gas systems were *coordinated* through weekly meetings where Sub-Contractors would provide layouts of their systems and interferences would be resolved. Another interaction was between the installation of mechanical equipment in the basement of the building and the structural steel for the entire building. Access had to be provided so that when equipment arrived on the site, it could be installed after the structural steel was in place. Equipment sizes were *exchanged* and deliveries were *coordinated*.

## SITE COMPLEXITY

The main complexity related to the site was the transportation of the structural steel to the site. The steel was prefabricated in tree-like configurations. These column trees had to be held by jigs at an angle so that they could be transported by truck.

The El Niño storm hit California during the construction of this building. However, the building was enclosed so that the rain did not affect construction. Both site complexities were handled through *coordination*.

## PROJECT COMPLEXITY

The main project complexity was the interaction with the Office of Statewide Health Planning and Development (OSHPD). It brings in a whole other dimension of codes and inspections and usually adds time onto any hospital building project. A high level of *information exchange* between the Constructor and the Inspectors was required, especially in areas such as structure and life safety.

### 5.7 PROJECT 7: METROPOLITAN TRANSIT AUTHORITY HEADQUARTERS

General Project Category: Office Building

Owner: MTA

Architect: McLarand-Vasquez

Constructor: Charles Pankow Builders (GC)

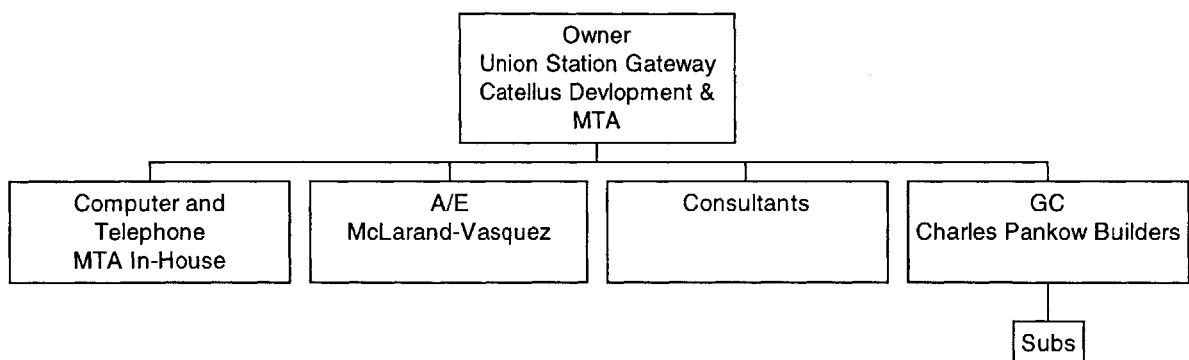


Figure 5.7  
Project 7: Organizational Chart

The MTA Headquarters is a \$70 million, 28-story building, consisting of a steel structure, on top of a portion of a concrete below-grade parking structure. The ornate façade consisted of Minnesota limestone and Italian granite, which were attached in metal tube-framed panels by crane. The lower sections were handset because of the irregular patterns of the façade near the ground.

The primary use of the building was for 628,000 SF of office space. In addition, the ground level consists of a boardroom, a cafeteria, committee rooms, and an ornate lobby.

Table 5.7  
Complexity and Integration Matrix  
Project 7: MTA Headquarters

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High	2	1	1	1		1
	Medium						
	Low						
Inter-System Complexity	High						
	Medium						
	Low	2		2			
Site Complexity	High		1	1			
	Medium						
	Low	1		1			
Project Complexity	High						
	Medium	1				1	
	Low	2		2			

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

### INTRA-SYSTEM COMPLEXITY

The Northridge earthquake hit Southern California just before the erection of steel for this building. Because of this event, the Building Department required (*information exchange*) that more welds be added to the structure.

Because the building had a telephone and data center to respond to customers, this system was very important to the building. A *specialist* was contracted to the Owner to design and install this system.

The finishes were very important to the Owner and a very political topic. There was a lot of *collaboration* of the MTA board members, GC, and the Architect with regard to the choice of the finishes.

#### INTER-SYSTEM COMPLEXITY

There was no special interaction between systems in this building.

#### SITE COMPLEXITY

The site was contaminated. A sub-contractor *specializing* in remediation hauled the contaminated soil off site.

#### PROJECT COMPLEXITY

There was a miscalculation done by the Owner relating to the date they needed to move into the structure. The GC coordinated the final portion of construction to accommodate the move-in needs of the Owner.

## 5.8 PROJECT 8: REFINERY BLENDING AND SHIPPING CONTROL ROOM

General Project Category: Institutional

Owner: Major Refinery

Architect: DMJM

Constructor: DMJM (GC)

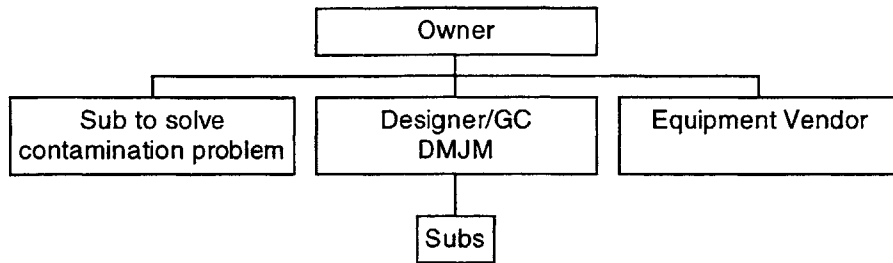


Figure 5.8  
Project 8: Organizational Chart

The \$2.7 million Blending and Shipping control building is on the outskirts of a major refinery in El Segundo, CA. It includes the control room, a laboratory, machine room, a lounge, and offices. It is specifically designed to be an 8,000 SF, 1-story building so that it would not be restricted to a building type by code.

It is type-5 construction (wood, unprotected) upgraded to concrete masonry and steel. The Owner wanted the interior to have a flexible floor layout for future needs. Also, ease of construction was a priority to meet an aggressive schedule. Steel construction was used to meet both of these needs. The building would be operational 24 hours/day and it would have to be self sufficient for 3-5 days just in case there was an emergency at the refinery.

Table 5.8  
Complexity and Integration Matrix  
Project 8: Control Room

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High		2	2			
	Medium	1			1		1
	Low						
Inter-System Complexity	High						
	Medium	1			1	1	
	Low	1		1			
Site Complexity	High						
	Medium	1	1	1		1	
	Low	1		1			
Project Complexity	High						
	Medium	1				1	
	Low	2		2			

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

#### INTRA-SYSTEM COMPLEXITY

The computer which is the control system for equipment in the refinery is the critical system in the building. It was designed by *specialists* and by the Owner's instrumentation division. Also, the interior finishes that were dirt- and damage-resistant were important to the Owner. The finishes were chosen based on previous experience. The Owner and the Designer *exchanged information* and *collaborated* to produce a design, which was suitable for the building.

Also, the HVAC system had special sensors in it that would alert the inhabitants of toxic fumes. A *specialist*, based on previous experience with refinery control rooms, designed this system.

## INTER-SYSTEM COMPLEXITY

The only inter-system relationship was that of the building and the computer. The building had to be designed so that the computer could be replaced in the future. *Information* was given by the computer specialist and the dimensions of the building were *coordinated* to make it work.

## SITE COMPLEXITY

The site was contaminated. The Owner hired a *specialist* to deal with the contamination before the contractors arrived on site.

## PROJECT COMPLEXITY

The duration of the project was really important to the Owner. The adjustments required to change computer control systems had to be implemented on a specific date, which required an aggressive schedule. The Designer/GC met this need by *coordinating* the design and construction to be efficient.

### 5.9 PROJECT 9: ROCKETDYNE HEADQUARTERS RENOVATION

General Project Category: Office Building

Owner: Rocketdyne

Architect: DMJM

Constructor: DMJM (GC)

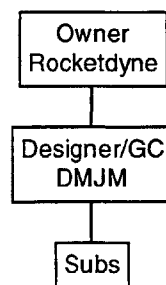


Figure 5.9  
Project 9: Organizational Chart

The \$5.4 million, 40,000 SF Rocketdyne corporate headquarters renovation took place in a 1-story building referred to as Building 001. It was built in the 1920's and had been renovated many times over the years. The facility is divided into sections: the annex (where all of the engineers work), the headquarters, and two factories. The headquarters consists of an executive office area and an administrative office area. The building was a voluntary renovation (for safety reasons), but there was also roof damage due to the Northridge earthquake. Rocketdyne wanted an interior upgrade and a new office plan as well as the structural upgrade. Rocketdyne wanted an aggressive project schedule. The building had to be functional during construction operations.

Special corridors had to be constructed to give the executives access to their conference room without any of the inconveniences or hints of construction. In addition, dust and power outages were not an option because all of the computer equipment had to be operational during construction. Welding was done during the day and demolition was done at night.

Table 5.9  
Complexity and Integration Matrix  
Project 9: Rocketdyne Headquarters

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High						
	Medium						
	Low	1		1			
Inter-System Complexity	High	1			1		1
	Medium						
	Low	1		1			
Site Complexity	High	2			1	1	
	Medium						
	Low						
Project Complexity	High	1				1	
	Medium						
	Low	2		2			

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

## INTRA-SYSTEM COMPLEXITY

There were no special system complexities in this project.



## INTER-SYSTEM COMPLEXITY

The Owner wanted to strengthen the structural system of the building. However, they also wanted to create a more open interior layout. These two objectives conflicted and made it difficult for the Designer. The Designer provided the Owner with *information* on several alternative approaches to solving this problem. From here, the Designer and Owner *collaborated* to come up with a final design.

## SITE COMPLEXITY

The existing documentation for the building was very poor, so the Engineers had to obtain *information* as demolition occurred. Also, the Owner required access to the building during construction. Therefore, the Contractors had to provide dust-free corridors within the construction zone.

## PROJECT COMPLEXITY

The facility had to be on-line during the launching of spacecraft. In order to avoid the risk of a power shutdown, construction was halted for all of the launches. Thus, the schedule had to be *coordinated* with the launch schedule.

### 5.10 PROJECT 10: WARNER BROTHERS SOUND STAGE

General Project Category: Institutional

Owner: Warner Brothers

Architect: HLW International

Constructor: DPR Construction (CM)

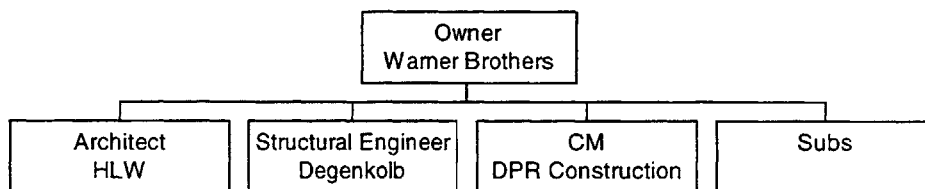


Figure 5.10  
Project 10: Organizational Chart

The \$6 million building is a feature sound stage that is used for the filming of movies. It has 25,600 SF of open space and a 47-foot clearance to the truss. The building is a tilt-up system with cast-in-place concrete columns near the perimeter and steel truss beams. A veneer of plaster was used as the exterior finish.

Table 5.10  
Complexity and Integration Matrix  
Project 10: Warner Brothers Sound Stage

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High						
	Medium						
	Low	1		1			
Inter-System Complexity	High	1					1
	Medium						
	Low	1		1			
Site Complexity	High		1		1	1	1
	Medium	2				2	
	Low						
Project Complexity	High						
	Medium	1				1	
	Low	2		2			

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

#### INTRA-SYSTEM COMPLEXITY

The large column-less environment required for the sound stage made the structural system a little complicated. The Structural Engineer (*specialist*) had to design large truss members to accomplish the desired span.

#### INTER-SYSTEM COMPLEXITY

An interaction between the enclosure and the structure made constructability almost impossible. The reinforcement in the perimeter columns conflicted with the connection with the tilt-up wall. The CM and the Structural Engineer had to *collaborate* over many meetings to come up with a solution to this problem.

## SITE COMPLEXITY

There were three issues, which contributed to the complexity of this project. First, the steel trusses were difficult to transport to the site. *Coordination* was necessary to solve this problem. Second, the construction had to be halted when movie taping was in progress in one of the other studios nearby. The CM had to *coordinate* the work so that the stoppages could occur.

The last issue dealt with an old sewage outfall pipe that was located under the site. The city was afraid that the construction would cause this pipe to break. First, the Structural Engineer (*specialist*) was called in to make sure that the loads were not too high. Second, crane paths were determined to avoid overloading the pipe (*coordination and collaboration*). Third, a camera was placed in the pipe to monitor the condition of the pipe for the city (*information exchange*).

## PROJECT COMPLEXITY

The Owner held all of the contracts. The CM *coordinated* the parties for the Owner.

### 5.11 PROJECT 11: KAISER MEDICAL FACILITY

General Project Category: Medical/Laboratory

Owner: Kaiser

Architect: The Stichler Group

Constructor: DPR Construction (GC)

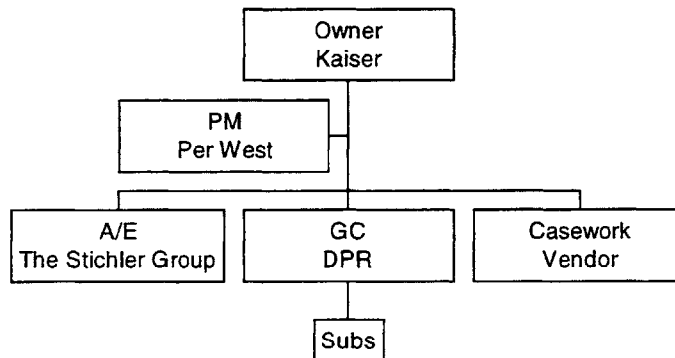


Figure 5.11  
Project 11: Organizational Chart

This \$31 million building is a Kaiser medical facility called a “bedless” hospital. It was designed as such to avoid involvement of the OSHPD, which saved time and money. The region of San Diego lacked adequate Kaiser facilities, so Kaiser promised to start seeing patients on August 31, 1998. This deadline created the challenge of building the project in a way faster than Kaiser had ever experienced.

The facility was constructed in three phases with a total contract of \$54 million. Phase 1 was 180,000 SF and Phases 2 and 3 were 39,000 SF. The buildings are constructed of structural steel with an exterior insulation and finish system (EIFS).

The project was such a success that DPR and Kaiser are doing several additional projects together using the same collaborative working style. Also, they are forming a local chapter of the Collaborative Process Institute.

Table 5.11  
Complexity and Integration Matrix  
Project 11: Kaiser Medical Facility

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High		1				1
	Medium						
	Low						
Inter-System Complexity	High	1				1	1
	Medium						
	Low	1		1			
Site Complexity	High	1				1	
	Medium	1	1	1		1	
	Low						
Project Complexity	High	1				1	1
	Medium	1			1		1
	Low	1		1			

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

## INTRA-SYSTEM COMPLEXITY

The biggest system challenge on this project was the use of a new moment frame connection. The Owner chose to use the “Side Plate” connection, which is a very labor-intensive design. A lot of special supervision and quality control was required from the makers of the connection (*specialists*). The Steel Fabricator worked with the Inspectors to produce a system that was consistent with the requirement (*collaboration*).

## INTER-SYSTEM COMPLEXITY

The MEP interaction was very complex in the building. There were several *collaborative* meetings amongst the Designers and the Sub-Contractors to physically *coordinate* the systems.

## SITE COMPLEXITY

There were three challenges related to the construction site. The first challenge was a mountain of dirt that had to be removed so that the building could be accessible to the public. The removal was done by a hauling company (*specialist*). The second challenge was the El Niño storm. A road made from gravel had to be constructed so that the trucks could drive to the site. In addition, *coordination* amongst the trades had to be accomplished in order to finish the work according to the aggressive schedule. The last challenge was the fact that the second and third phases had to be done while the first phase of the building was in operation. Construction had to be *coordinated* so that it did not disturb the operations of the building and also so that construction was efficient.

## PROJECT COMPLEXITY

The main project objective was to complete the facility in a short period of time. The schedule was accomplished through *collaboration* between the Owner and the GC and *coordination* of the Sub-Contractors by the GC.

One inhibitor to this process was an initial problem with trust within the project team. Distrust caused an extra amount of unnecessary paperwork (*information exchange*) and required extra meetings to *collaborate* on issues such as objectives. The team worked through the distrust and ended with a very strong team that is now working on future projects together.

**5.12 PROJECT 12: CASA SAN JUAN**

General Project Category: Other  
 Owner: Mercy Charity Housing of California  
 Architect: Laufebach Associates  
 Constructor: Benchmark Construction (GC)

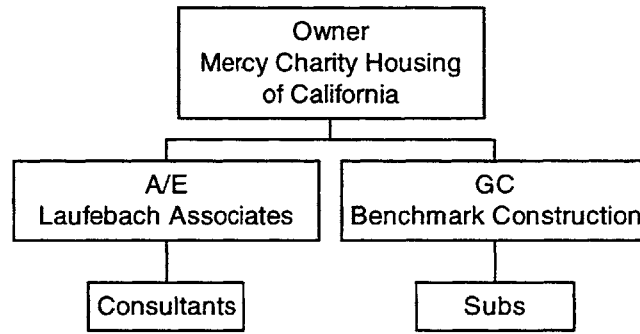


Figure 5.12  
 Project 12: Organizational Chart

Casa San Juan is a Mercy Charity multi-family living community. There are a total of nine 2-story wood-frame buildings for a total contract of \$5.5 million. There are 7 units in most buildings, with a total of 64 units. In addition, there is a manager’s office and a playground. This community is designed to teach low-income families how to respect their community.

Benchmark is the non-union arm of Morley Builders. They do many multi-family residential complexes and other wood-framed structures. They do concrete and some carpentry themselves. It was one of Benchmark’s goals to be Mercy Charity’s contractor of choice in the Los Angeles area. They later received a senior housing project from MC in the same area.

Table 5.12  
Complexity and Integration Matrix  
Project 12: Casa San Juan

Complexity Levels		Integration Mechanisms				
		No Specialist	Specialist	Interaction Level		
				No Interaction	Information Exchange	Coordination
Intra-System Complexity	High					
	Medium					
	Low	1		1		
Inter-System Complexity	High					
	Medium					
	Low	2		2		
Site Complexity	High					
	Medium					
	Low	2		2		
Project Complexity	High					
	Medium					
	Low	3		3		

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

Casa San Juan was a very straight-forward residential project. The GC was familiar with the construction type, and the Owner knew the product that they wanted. The site was a large spread of good land so there was no evidence of contamination and logistics were not a problem. The team worked well together and this project resulted in repeat work for the Architect and GC.

### 5.13 PROJECT 13: 77<sup>TH</sup> STREET POLICE STATION

General Project Category: Institutional  
 Owner: LA Department of Public Works  
 Architect: Kennard  
 Constructor: Morley Construction (GC)

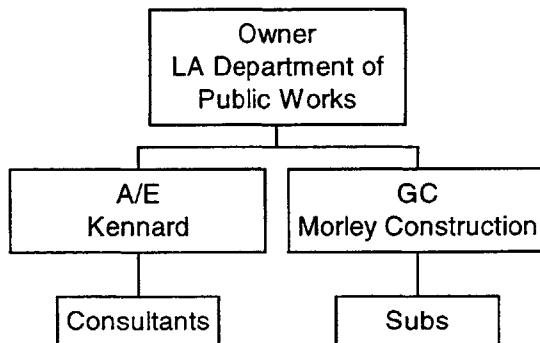


Figure 5.13  
Project 13: Organizational Chart

The 77<sup>th</sup> Street Police Station is a \$26 million, 130,000 SF complex that consists of administration buildings, a short-term detention center, community centers, a parking garage, a police car servicing center, and a helipad. This building was to be a building that could be used by the community, not just a jail. There are two 2-story steel-framed administration towers. In between these two towers is an entrance lobby with an atrium and a bridge to the second level of the towers. The exterior system is pre-cast concrete panels. The jail is a reinforced concrete building with pre-cast concrete panels applied to it. There are basements in many of the buildings and the garage has four levels, with one level that runs under the courtyard. The owner is very happy with the final project and it is a substantial landmark project.

Morley Construction is the union arm of Morley Builders. It did all of the concrete work for this job. This job was bid during a time that the construction market was slow. Even though Morley did not have any experience in building detention centers, the company needed the work. It tried to gain experience by associating with Subs-Contractors that specialize in this type of work. Through this job, Morley gained experience in detention facilities and won two subcontracts due to this job.

Table 5.13  
Complexity and Integration Matrix  
Project 13: 77<sup>th</sup> Street Police Station

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High		1			1	
	Medium						
	Low						
Inter-System Complexity	High						
	Medium						
	Low	2		2			
Site Complexity	High	1	1			2	
	Medium						
	Low						
Project Complexity	High	6			5	1	
	Medium						
	Low						

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.



## INTRA-SYSTEM COMPLEXITY

The detention hardware was a complicated system and the GC did not have any previous experience with building jails. As a solution, the GC hired a Sub-Contractor that *specialized* in detention hardware to *coordinate* all of the trades related to the hardware. Unfortunately, this Sub-Contractor went out of business during the project. The GC then hired and *coordinated* the trades themselves.

## INTER-SYSTEM COMPLEXITY

There were no special complex interactions between the systems.

## SITE COMPLEXITY

The site was contaminated in many places. A *special* Sub-Contractor was brought in by the Owner to deal with the contamination at the beginning of the project. When contamination was later found again, the GC had to *coordinate* the work around it and hired another Sub-Contractor to clean it up.

A school shared one of the adjacent streets with the site so staging could not be done on this street. The GC had to *coordinate* work so that a crane could be supported on top of a below-grade structure on site.

## PROJECT COMPLEXITY

This project was riddled with many project-related problems. Because this project was a public job, much of the interaction was based on *information exchange*. Not only was the Owner a public agency, but it worried that it had to protect itself from the bad contractors. On numerous occasions, this negative attitude resulted in the slowing of work because of the amount of paperwork and *information exchange* required.

Because construction was very slow at the time of the awarding of the project, many of the Sub-Contractors bid the job at a very low price. However, during the construction of this project, the market picked up and many of the Subs replaced their “A” quality teams with lower quality teams.

Lastly, because of a delay in the project, the electrical Sub-Contractor claimed that the costs of materials had risen significantly. In addition, this Sub-Contractor finished work late on the project, which has a liquidated damages clause. The Owner, the Sub-Contractor and the GC are all in the middle of negotiating to avoid a lawsuit because of this matter.

**5.14 PROJECT 14: PARCEL 1, CERRITOS OFFICE BUILDING**

General Project Category: Office Building  
Owner: Transpacific Development Company (TDC)  
Architect: Archisystems  
Constructor: Benchmark Construction (GC)

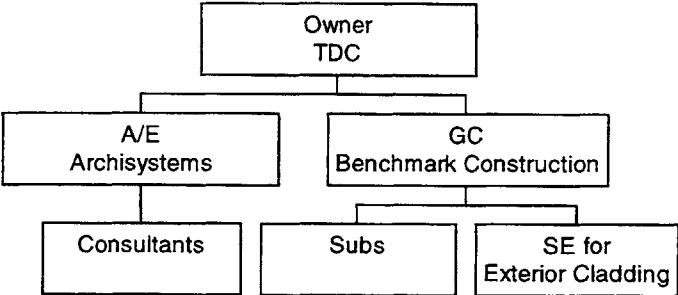


Figure 5.14  
Project 14: Organizational Chart

The building called was called Parcel 1 because it was a speculative office building that did not have a tenant during construction. It is a \$3.2 million, 2-story, 50,000 SF shell of a building, made of the materials that were common to the business park. It is a steel frame building with wood truss joists, plywood floors, and a stone exterior. The material choices were made to minimize material costs. It was a normal office building, but it had some unusual geometry, which caused trouble in the structural design. Once the job was obtained, the Northridge Earthquake hit the area and construction prices went up significantly.

Table 5.14  
Complexity and Integration Matrix  
Project 14: Parcel 1

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High						
	Medium						
	Low	1		1			
Inter-System Complexity	High		1			1	
	Medium						
	Low	1		1			
Site Complexity	High						
	Medium	1			1		
	Low	1		1			
Project Complexity	High	2			1	1	
	Medium						
	Low	1		1			

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

#### INTRA-SYSTEM COMPLEXITY

There were no special intra-system complexities on this project.

#### INTER-SYSTEM COMPLEXITY

The exterior cladding was contracted as design-build to the GC. The preliminary design given by the Architect was not useable because of the building's materials and unusual geometry. Also, the structural system was not suitable to carry the load of the exterior cladding. The GC had to hire a Structural Engineer (*specialist*) to assist in designing a system to support the exterior cladding and to strengthen the main building structure. The GC and this Structural Engineer *collaborated* to design a system that was suitable for both the structure and for construction.

#### SITE COMPLEXITY

The El Niño storm had an effect on construction and the schedule of the project. *Coordination* was necessary to get back on schedule.

## PROJECT COMPLEXITY

A major challenge in this project was the cost. Costs increased significantly between the conceptual design phase and the final design due to the state of the market. There was *collaboration* among the parties in the project to decrease the cost of the project. Contributions toward the solution included the GC's cut in fee and use of different materials.

There were many changes in staff as well as a change in the Owner over the duration of the project. The changes caused many problems with decision-making because verbal agreements were no longer valid. Formal *information exchange* then became necessary.

### 5.15 PROJECT 15: DELTA DENTAL OFFICE EXPANSION

General Project Category: Office Building

Owner: Delta Dental

Architect: Archisystems

Constructor: Morley Construction (GC)

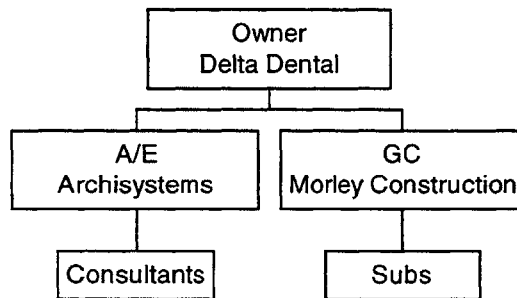


Figure 5.15  
Project 15: Organizational Chart

The Delta Dental office building is a \$2 million, 30,000 SF addition to the existing building. It is located in a business park in Cerritos, CA and is made of materials common to the rest of the business park. It is a steel frame building with wood truss joists, plywood floors, and a stone exterior. These materials were chosen for reason of cost. The building is a normal, rectangular office building that did not provide any big challenges.

Table 5.15  
Complexity and Integration Matrix  
Project 15: Delta Dental Office Building

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High						
	Medium						
	Low	1		1			
Inter-System Complexity	High						
	Medium						
	Low	2		2			
Site Complexity	High						
	Medium	1				1	
	Low	1		1			
Project Complexity	High	2			1		1
	Medium						
	Low	1		1			

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

#### INTRA-SYSTEM COMPLEXITY

There were no special intra-system complexities on this project.

#### INTER-SYSTEM COMPLEXITY

The building was a simple rectangular office building. It is in the same business park as “Parcel 1” (the previous project), so it is made of the same materials. However, since the geometry was simple, it did not have the cladding support problem found in the previous project.

#### SITE COMPLEXITY

The El Niño storm had an effect on construction and the schedule of the project. *Coordination* was necessary to get back on schedule.

## PROJECT COMPLEXITY

A major challenge in this project was the cost. Costs increased significantly between the conceptual design phase and the final design due to the state of the market. There was *collaboration* among the parties in the project to decrease the cost of the project. Contributions toward the solution included the GC's cut in fee and use of different materials.

There were many changes in staff over the duration of the project. Verbal agreements were not enough and formal *information exchange* was necessary.

### 5.16 PROJECT 16: CITY OF HOPE DIABETES RESEARCH CENTER

General Project Category: Medical/Laboratory

Owner: City of Hope

Architect: Anshen & Allen

Constructor: Orla Jensen (CM), Morley Construction (GC)

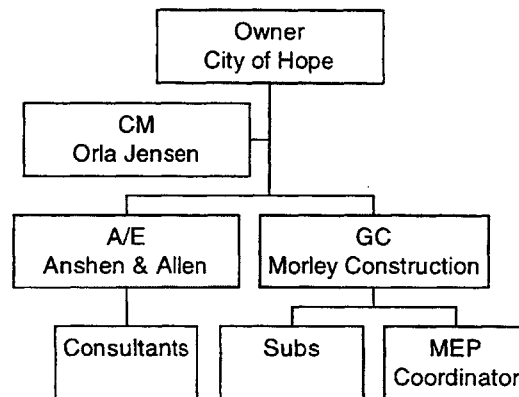


Figure 5.16  
Project 16: Organizational Chart

The City of Hope Diabetes Research Center is a \$10.5 million building with a program of 75% lab space devoted to diabetes research. It is located in the campus of the City of Hope and, therefore, had to be coordinated with the facilities that exist or will exist there.

At the time of the award of the project, the construction business was slow, so Morley decided to take this job even though they did not have the experience. From this experience, they later won a construction management job for a larger hospital.

Table 5.16  
Complexity and Integration Matrix  
Project 16: City of Hope Diabetes Research Center

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High		3	3			
	Medium						
	Low						
Inter-System Complexity	High	1				1	
	Medium						
	Low	1		1			
Site Complexity	High						
	Medium						
	Low	2		2			
Project Complexity	High	2			1	1	
	Medium	5			2	2	2
	Low						

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

### INTRA-SYSTEM COMPLEXITY

Because this building is a medical research facility, there were many challenging systems, including the medical gas system, special structural requirements, and lab equipment. *Specialists* were called into the project to take care of these matters.

### INTER-SYSTEM COMPLEXITY

The building was very heavy with MEP systems. A MEP Coordinator was hired to make sure that the systems would be *coordinated* in the space allocated.

## SITE COMPLEXITY

Other than a little difficulty encountered when excavating through tough soil, the site posed no problems for construction.

## PROJECT COMPLEXITY

Schedule was really important to the Owner because they had researchers already lined up for the lab space. Therefore, the construction had to be carefully *coordinated* to accommodate the short schedule. The steel contract was bid separately from the GC's contract to expedite the ordering of steel. However, the steel ran late because of a dispute about the shop drawings between the Structural Engineer and the Steel Fabricator. The GC made up the time lost by *coordinating* its trades.

The project design was slightly above the budget. To reduce costs, the Architect and GC *collaborated* to come up with value engineering solutions.

Because the project was being built on the City of Hope campus, there were many issues that needed to be addressed. OSHPD was involved with inspections, and the addition of this outside agency required extra *information exchange* on the part of the GC. Since the campus was also building a new central plant, the diabetes research facility had to be designed for the future. There were several meetings where *information was exchanged* and parties *collaborated* to make sure the necessary steps were taken to make the building compatible to the campus. Also, the building's energization had to be *coordinated* with that of a nearby building. Lastly, a no smoking policy was required. The GC had to *send out information* to all of its trades to inform them of this policy.



## 5.17 PROJECT 17: OUR LADY OF THE ANGELS CATHEDRAL

General Project Category: Institutional

Owner: Archdiocese of Los Angeles

Architect: Rafael Moneo (Design), Leo Daly (Executive)

Constructor: Morley Construction (CM/GC)

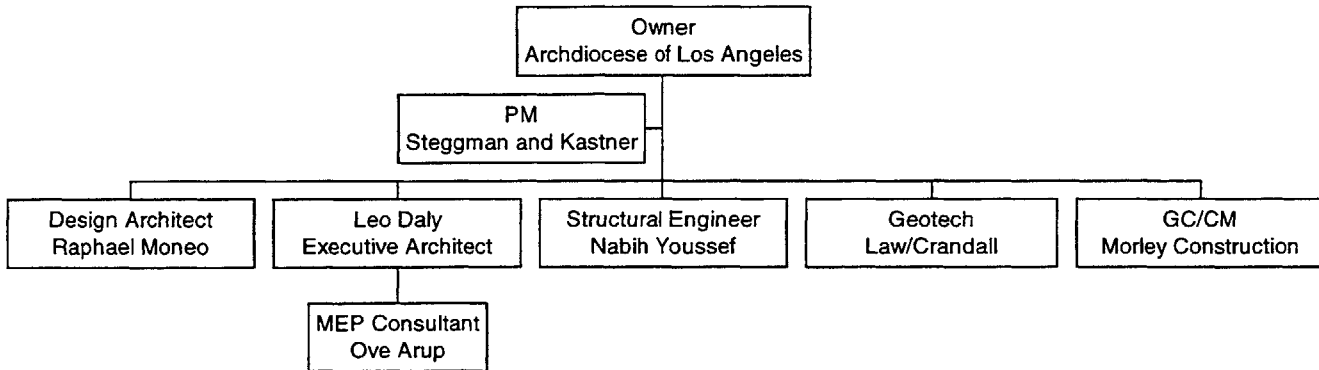


Figure 5.17  
Project 17: Organizational Chart

Our Lady of the Angels Cathedral will be the seat of the Archdiocese of Los Angeles. It is being designed by an architect in Spain to be an approximately \$170 million monument that has a 500 year life. Because of these high design expectations, the design and the choice and quality of materials are crucial. It is the last part of a project that also consists of a cathedral residence, a community center, and an underground parking structure. Currently, it is in the late stages of design and the beginning stages of construction. Because of a delay in the design, the project is now on a fast track schedule.

Table 5.17  
Complexity and Integration Matrix  
Project 17: Our Lady of the Angels Cathedral

Complexity Levels		Integration Mechanisms					
		No Specialist	Specialist	Interaction Level			
				No Interaction	Information Exchange	Coordination	Collaboration
Intra-System Complexity	High		3		2		2
	Medium						
	Low						
Inter-System Complexity	High	1	1		2		2
	Medium						
	Low	1		1			
Site Complexity	High						
	Medium	1			1	1	
	Low	1		1			
Project Complexity	High	6			3	2	1
	Medium						
	Low						

Note: Numbers in each cell represent the number of discrete occurrences of each integration mechanism.

#### INTRA-SYSTEM COMPLEXITY

The Cathedral was designed for a 500-year life, so the façade was very important. Systems such as the exposed structural concrete, the alabaster windows, and the base-isolation system were extremely complex. *Specialists* were used for all of these items. The GC, Structural Engineer and Architects *collaborated* to produce a concrete system that meets all of the needs of the building. The design of the windows required *collaboration* and a lot of *information exchange* between the Architect, the GC, and the Engineers. The base-isolation system required a lot of *information exchange* because it had a long lead time and functionally interacts with many systems.

#### INTER-SYSTEM COMPLEXITY

*Collaboration* and *information exchange* was necessary between the Architects, the GC, and the Structural Engineer in order to meet two challenges of the interaction of systems. The acoustics of the building also involved a *specialist* who did tests on the interior of the building based on the materials and geometry of the interior. The other challenge was the unification of the

structure with the architecture. The color, shape, and quality of the concrete were critical and many meetings were conducted to solve these design issues.

## SITE COMPLEXITY

The site is located in Downtown Los Angeles. Because of the congestion of the area, there had to be a lot of *coordination* and *information exchange* between the GC and the Department of Transportation.

## PROJECT COMPLEXITY

The project had a complicated project team. The Design Architect was located in a different country, so there was a lot of long distance *information exchange*. Also, the Owner held several of the design contracts separately. This form of management caused trouble because the design decisions were behind schedule. Many *requests for information* were filed because of the design deficiencies.

The project was both over budget and behind schedule. The Owner, Architect, and GC were *collaborating* to bring the project closer to budget and the GC was *coordinating* the other team members so that information arrived on time to restore the schedule.

Lastly, there were people protesting the building of the Cathedral. They wanted the money to go toward the poor instead of a building. The Owner had to convince these people through the media (*information exchange*) that this Cathedral will be important to Los Angeles.



## CHAPTER 6: RESULTS

The trends that develop when combining the information from all of the projects are analyzed in this chapter. It is easier to see the trends that exist in the data when all of the information is compiled. The beginning of this chapter outlines the data that was presented in the last chapter. Then, each complexity is analyzed separately so that the reasoning for integration is understood and compared to the expectations outlined in the previous chapters. For each type of complexity, the relationship between building type and complexity is explored. Also, the relationship between project complexity and integration mechanisms is analyzed, where each data point represents the presence (or lack of) a complexity and the integration mechanism (or no mechanism) used as a response.

### 6.1 SUMMARY OF DATA

#### 6.1.1 BUILDING TYPES

The projects used as detailed case studies can be divided into four categories of building type, as outlined in Chapter 4 (Methodology). Table 6.1 shows a breakdown of the projects.

Table 6.1  
Summary of Building Types Evaluated  
In Detailed Case Studies

Building Type	Number of Case Studies
Medical/ Laboratory	4 (24%)
Office Building	6 (35%)
Institutional	5 (29%)
Other	2 (12%)
Total	17

The three main categories are well represented and cover a variety of projects in the Southern California area (Table 6.1). The first type of building includes medical/ laboratory facilities, which covers labs, hospitals, and clinics. The second type is institutional facilities, which are miscellaneous facilities used by institutions such as corporations, schools, and other social groups. Office buildings serve as administration centers for companies and organizations. The

projects in the “Other” category are a small sample of projects with lower levels of complexity, such as a parking structure and a low-rise residential structure. These projects were included to present a broader range of complexity in the research.

### 6.1.2 TYPES OF COMPLEXITY

Areas of complexity were identified within each detailed case study. A full profile of the information gathered on each project is located in Appendix 2. The summary of the areas complexity for each case study is shown in Tables 6.2-6.8.

Table 6.2  
Intra-System Complexity  
Versus Building Type

Building Type	Number of Projects with No Complexity	Number of Projects with Some Complexity
Medical/Laboratory	0 (0%)	4 (100%)
Institutional	1 (20%)	4 (80%)
Office Building	3 (50%)	3 (50%)
Other	2 (100%)	0 (0%)
Total	6 (35%)	11 (65%)

Table 6.2 shows that most of the buildings (65%) showed some evidence of intra-system complexity. All of the medical/ laboratory buildings and 80% of the institutional buildings had intra-system complexity because of the high performance expectations for the buildings. The office buildings are equally split, some with complexity and others without. The other buildings did not have any intra-system complexity.

Table 6.3  
Inter-System Complexity  
Versus Building Type

Building Type	Number of Projects with No Complexity	Number of Projects with Some Complexity
Medical/Laboratory	0 (0%)	4 (100%)
Institutional	1 (20%)	4 (80%)
Office Building	3 (50%)	3 (50%)
Other	2 (100%)	0 (0%)
Total	6 (35%)	11 (65%)

The results in Tables 6.2 and 6.3 look identical. However, these results are not identical. The one institutional building that does not have intra-system complexity is Project 10 (Foran, 1999), a sound stage, whereas the institutional building that does not have inter-system complexity is Project 13 (Howard, 1999), a jail facility. Also, Projects 9, 14, and 15 (Hron, 1998; Morrison, 1999) were office buildings that lacked intra-system complexity, whereas Projects 2, 7, and 15 (Polizzotto, 1999; Sanders, 1999; Morrison, 1999) were buildings of the same category that lacked inter-system complexity. Overall, inter-system complexity was found in 65% of the case studies. All of the medical/ laboratory buildings and 80% of the institutional buildings have some sort of inter-system complexity. This high level of complexity is to be expected because of the heavy reliance on services within the buildings. Office buildings showed evidence of this type of complexity, but not in all cases. The other projects did not have inter-system complexity.

Table 6.4  
 Site Logistics Complexity  
 Versus Building Type

Building Type	Number of Projects with No Complexity	Number of Projects with Some Complexity
Medical/Laboratory	1 (25%)	3 (75%)
Institutional	2 (40%)	3 (60%)
Office Building	4 (67%)	2 (33%)
Other	2 (100%)	0 (0%)
Total	9 (53%)	8 (47%)

Site conditions are independent of building design. However, there were some trends in the data collected that are interesting to note (Table 6.4). Around half (47%) of the projects had some sort of logistical complexity. Medical/ laboratory buildings tended to have a greater amount of logistical complexity (75%), possibly because there are many inter-related systems and large equipment within this type of building, and the construction process necessary to install these systems may have special needs. Institutional buildings tended to have some evidence of logistical problems (60%), but not enough to draw any conclusions. Office buildings and other projects had fewer instances of logistical complexity.

Table 6.5  
Site Special Conditions Complexity  
Versus Building Type

Building Type	Number of Projects with No Complexity	Number of Projects with Some Complexity
Medical/Laboratory	1 (25%)	3 (75%)
Institutional	1 (20%)	4 (80%)
Office Building	0 (0%)	6 (100%)
Other	1 (50%)	1 (50%)
Total	3 (18%)	14 (82%)

Overall, 82% of the projects had instances of complexity with respect to special site conditions, such as unforeseen site conditions and weather problems (Table 6.5). One must note that many of the projects chosen for the case studies were under construction during the year of the El Niño storm (1998). Because of El Niño, the numbers for this type of complexity were quite high. Almost half (47%) of the 17 projects were affected by this stormy season (see Table 6.15).

Table 6.6  
Project Contract Management Complexity  
Versus Building Type

Building Type	Number of Projects with No Complexity	Number of Projects with Some Complexity
Medical/Laboratory	1 (25%)	3 (75%)
Institutional	2 (40%)	3 (60%)
Office Building	3 (50%)	3 (50%)
Other	2 (100%)	0 (0%)
Total	8 (47%)	9 (53%)

Half of the projects (53%) had some complexity with respect to contract management (Table 6.6). Most (75%) of the medical/ laboratory projects showed evidence of this complexity. The institutional buildings and office buildings showed mixed results in this category. The other projects showed no problems with contract management.



Table 6.7  
Project Objectives Complexity  
Versus Building Type

Building Type	Number of Projects with No Complexity	Number of Projects with Some Complexity
Medical/Laboratory	1 (25%)	3 (75%)
Institutional	1 (20%)	4 (80%)
Office Building	0 (0%)	6 (100%)
Other	2 (100%)	0 (0%)
Total	4 (24%)	13 (76%)

Project objectives, such as schedule or budget, posed a challenge to 76% of the projects, regardless of building type (Table 6.7). Only the simpler projects in the “Other” category showed an absence in this category.

Table 6.8  
Project Social Issues Complexity  
Versus Building Type

Building Type	Number of Projects with No Complexity	Number of Projects with Some Complexity
Medical/Laboratory	1 (25%)	3 (75%)
Institutional	2 (40%)	3 (60%)
Office Building	4 (67%)	2 (33%)
Other	2 (100%)	0 (0%)
Total	9 (53%)	8 (47%)

Social issues posed a problem on close to half (47%) of the projects. High instances of social issues complexity were found in medical/ laboratory buildings because of the number of regulations that had to be adhered to. Institutional buildings also showed evidence of complexity with social issues because many of them were owned by public entities, which must answer to the community. Only two of the office buildings, Projects 4 and 7 (Sanders, 1999), involved social issues, and these buildings were also publicly owned. The rest of the office buildings and the other projects did not have social issues.

### 6.1.3 INTEGRATION MECHANISMS

Many of the project teams used integration mechanisms, in reaction to the complexities and complications related to the construction projects. The following table shows the two main categories of integration mechanisms found in the case studies. The use of specialists is a mechanism in which the project team delegates the solution of the problem to parties that have special capabilities related to the complexity. The other main category is formal and informal interactions. In these cases, there has to be some sort of exchange between two or more parties as a reaction to the complexity. This exchange ranges from simple information exchange, to coordination of the parties, to collaboration amongst many parties.

Table 6.9  
Integration Mechanisms Versus Building Type

Building Type	Projects with Use of Specialist		Projects with Interaction	
	None	Some	None	Some
Medical/ Laboratory	0 (0%)	4 (100%)	0 (0%)	4 (100%)
Institutional	0 (0%)	5 (100%)	0 (0%)	5 (100%)
Office Building	2 (33%)	4 (67%)	0 (0%)	6 (100%)
Other	1 (50%)	1 (50%)	2 (100%)	0 (0%)
Total	3 (18%)	14 (82%)	2 (12%)	15 (88%)

Table 6.9 shows that the use of specialists and interaction are common mechanisms used to handle complex situations. Over 80% of the projects used specialists and close to 90% used some sort of interaction. All of the medical/ laboratory and institutional projects used at least one specialist, as well as 67% of the office buildings. All of the medical/ laboratory, institutional, and office buildings used some form of interaction.

## 6.2 INTRA-SYSTEM COMPLEXITY

Intra-system complexities encountered on a construction project are expected to map to the type of building that is being constructed. Figure 6.1 shows the types of intra-system complexities found in the case studies.

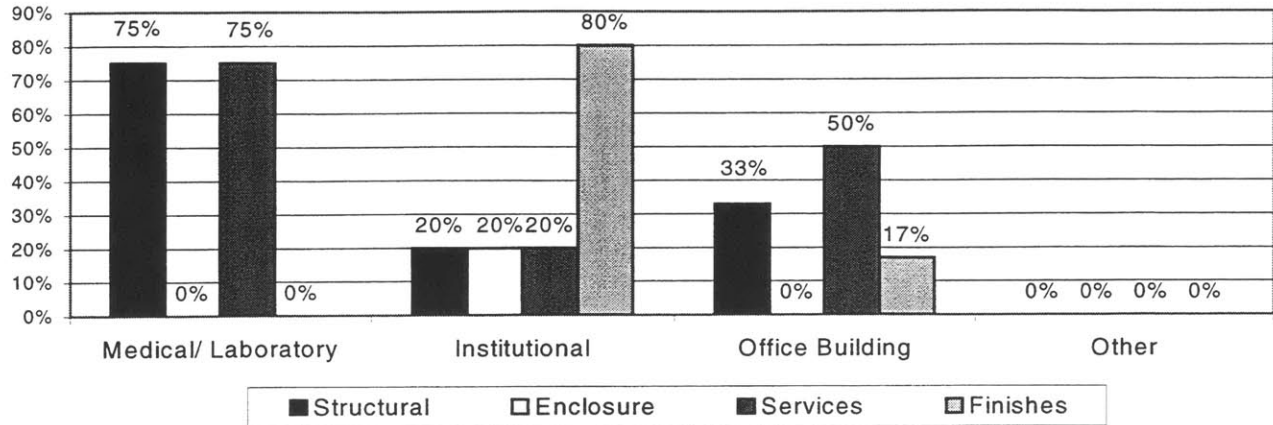


Figure 6.1  
Breakdown of Intra-System Complexity by Project

Figure 6.1 shows that most of the medical/ laboratory buildings had complexities with respect to the structural system and the services. For these buildings, building integrity is important, and the services provide the main function for the buildings. For the institutional buildings, finishes were quite important because the finishes reflect the functions of the buildings. For instance, the acoustics in Project 3, the Mt. SAC Performing Arts Center (Cowin, 1999; Hartman, 1999), is central to the operations of the building.

It must be noted that on several projects there are multiple instances of intra-system complexity, as well as multiple instances of the other types of complexity. Multiple mechanisms were sometimes necessary to deal with these complexities. Table 6.10 shows that some projects had evidence of up to three specialists that were used to work on complex systems. The total number of specialists coincides with the number of complex systems found in the case studies.

Table 6.10  
Instances of Multiple Specialists Used on a Project

Number of Specialists	Number of Projects
0	6 (35%)
1	5 (29%)
2	3 (18%)
3	3 (18%)

Even though the use of specialists is not a mechanism for integration, the division of a complex system into sub-systems that can be dealt with by specialists is a common mechanism used to deal with the complexity, as discussed in the background literature in Chapter 2. Table 6.11 shows the compilation of intra-system complexity data obtained from the detailed case studies. Figure 6.2 is a graphic representation of the project team interactions observed when Medium to High level complexities were encountered.

Table 6.11  
Intra-System Complexity  
By Occurrence of Integration Mechanisms

Level of Complexity	No Specialists	Use of Specialists	No Interaction	Information Exchange	Coordination	Collaboration
High	2	19	10	5	1	8
Medium	1	1	1	1	0	1
Low	6	0	6	0	0	0

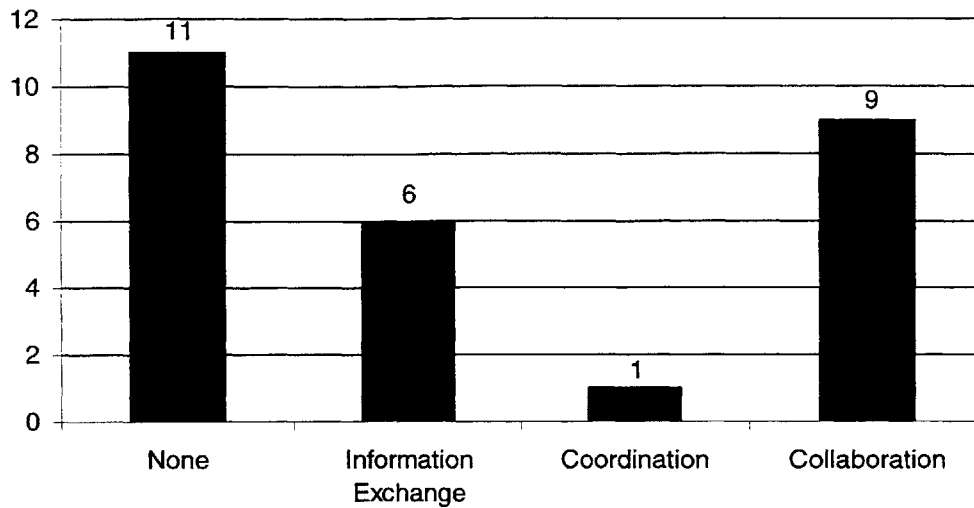


Figure 6.2  
Interactions Used For Intra-System Complexity

Figure 6.2 shows that there were 11 instances where complexities were identified (Medium and High) and no interaction occurred. This lack of integration could be due to the fact that specialists were used on all of the projects from which these data points came (Figure 6.3). The specialists had recognized capabilities to deal with the specific systems that were complex. Therefore, integration of the team was not necessary because of the sense of trust within the team. However, almost half of the time (45%), specialists and interaction were used in combination. There was never an instance when neither a specialist nor interaction was used when complexities existed. When there was no or low complexity, no specialists and no interaction were observed.

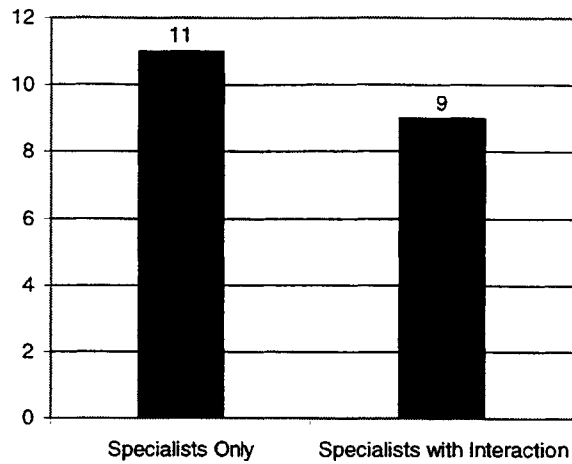


Figure 6.3  
Use of Specialists For Intra-System Complexity

Figures 6.2 and 6.3 show that in addition to the use of specialists, collaboration and information exchange were the mechanisms that were used most to manage intra-system complexity. When there is an intra-system complexity, the availability and mutual understanding of engineering information are crucial to the success of the system. Both collaboration and information exchange provide a means to provide this conceptual integration. Many times, specifications have to be given from Specialist to the Contractors or from the Owner to the Specialist in order for the system to fulfill the needs of the Owner. Project 7, the MTA building (Sanders, 1999) and Project 1, the Amgen building (Foran, 1999) are good examples of projects where specifications were important. Also, on projects where systems are new or complicated, the parties in construction feel more comfortable recording the decisions made and the justification for these decisions for future reference. Project managers for Project 4, the MWD building (Sanders, 1999) and Project 8, the Refinery project (Hron, 1998), both expressed the importance of information exchange on their projects.

### 6.3 INTER-SYSTEM COMPLEXITY

According to Table 6.12, the three most frequently encountered system relationships in this research were Structure and Enclosure, Services and Finishes, and between Services. Structure and Enclosure interactions were present in the office and institutional buildings and Services and Finishes interactions occurred in the medical/ laboratory and institutional buildings. All of the buildings with interactions between the Services were medical/ laboratory buildings. Four of the projects had more than one inter-system complexity (Appendix 4).

Table 6.12  
Inter-System Relationships by Project

Finishes				1
Services			4	3
Enclosure		0	2	0
Structure	0	4	1	1
	Structure	Enclosure	Services	Finishes

Table 6.13 shows the functional and spatial complexities found in the detailed case studies. Functional relationships were found in 41% of the buildings, with the most occurrences in institutional buildings (60%). All of the medical/ laboratory projects had spatial relationships between systems.

Table 6.13  
Inter-System Complexity by Project

Building Type	Functional		Spatial	
	No	Yes	No	Yes
Medical/ Laboratory	3 (75%)	1 (25%)	0 (0%)	4 (100%)
Institutional	2 (40%)	3 (60%)	3 (60%)	2 (40%)
Office Building	3 (50%)	3 (50%)	6 (100%)	0 (0%)
Other	2 (100%)	0 (0%)	2 (100%)	0 (0%)
Total	10 (59%)	7 (41%)	11 (65%)	6 (35%)

Table 6.14 displays the data obtained from the detailed case studies. Figure 6.4 displays the overall inter-system complexity encountered (Medium to High level) in addition to functional and spatial complexities individually. This breakdown of inter-system complexities shows a clearer view of why each of the integration mechanisms was used.

Table 6.14  
Inter-System Complexity  
By Occurrence of Integration Mechanisms

Level of Complexity	No Specialists	Use of Specialists	No Interaction	Information Exchange	Coordination	Collaboration
High	9	2	0	4	5	8
Medium	4	0	0	2	4	1
Low	21	0	20	0	1	0

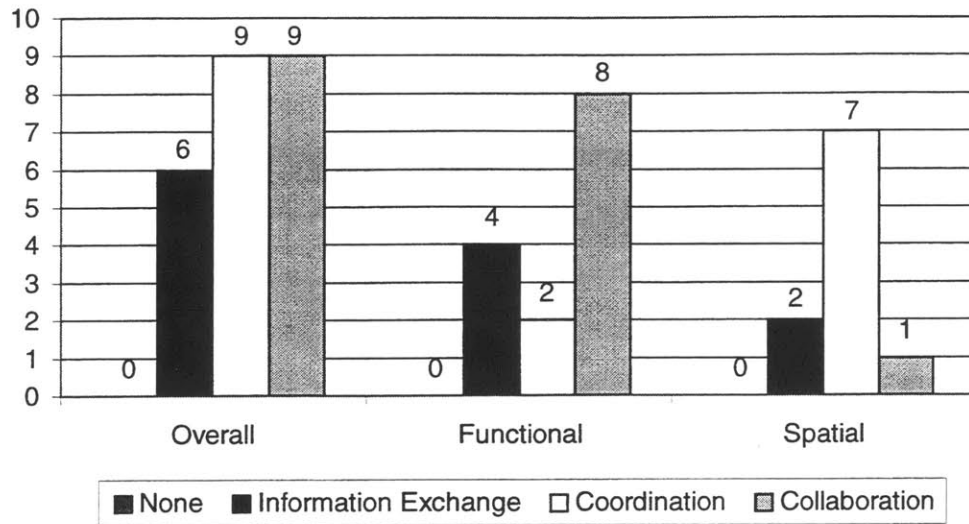


Figure 6.4  
Interactions Used For Inter-System Complexity

Figure 6.4 shows that overall, coordination and collaboration were common, in order to avoid interference and incompatibilities between systems. Lower levels of integration such as information exchange were also observed. When functional interrelationships were involved, 8 instances of collaboration were used on 8 projects, including Project 4 (Sanders, 1999) and Project 10 (Foran, 1999). Information exchange was used 4 times in 3 projects, including Project 9 (Hron, 1998) and Project 17 (Dooley et al., 1999). Coordination was used 2 times in 2 projects, Project 1 (Foran, 1999) and Project 16 (Dooley et al., 1999). Because the interaction needed is cross-disciplinary, it is usually done amongst peers or groups at the same hierarchical level.



When physical or spatial interference occurred, coordination was the most commonly used mechanism at 7 times on 6 projects, including Project 1 (Foran, 1999) and Project 3 (Cowin, 1999; Hartman, 1999). Information exchange was used 2 times in 2 projects, including Project 6 (Firebaugh, 1999) and Project 8 (Hron, 1998; Degnan, 1999), and collaboration was only used once in Project 11 (Leopold, 1999). Decisions were normally made centrally and filtered down the hierarchy.

In only one instance was interaction observed when there was no or low complexity. This was on the Project 2, the Princess Cruises building (Polizzotto, 1999). The Construction Manager on the job is well-known for a teamwork approach to construction and was living up to this reputation by holding weekly meetings with the sub-contractors. This extra coordination resulted in the observation of coordination in the absence of complexity.

#### 6.4 SITE COMPLEXITY

Site complexities are location, not design specific. There are two main types of site complexities observed in the data: site logistics and site special conditions. The site logistics category was divided into three sub-categories: access, transportation, and construction during operations, to make the data clearer. Table 6.15 shows the evidence of logistical complexity in the sample. Since site logistics are not related to building design, there is no correlation between building type and complexity. Logistical complexity appears to have played only a small role in the projects that were evaluated.

Table 6.15  
Site Logistics Complexity By Project

Building Type	Access		Transportation		Construction During Operations	
	No	Yes	No	Yes	No	Yes
Medical/ Laboratory	3 (75%)	1 (25%)	3 (75%)	1 (25%)	3 (75%)	1 (25%)
Institutional	3 (60%)	2 (40%)	4 (80%)	1 (20%)	4 (80%)	1 (20%)
Office Building	5 (83%)	1 (17%)	6 (100%)	0 (0%)	5 (83%)	1 (17%)
Other	2 (100%)	0 (0%)	2 (100%)	0 (0%)	2 (100%)	0 (0%)
Total	13 (76%)	4 (24%)	15 (88%)	2 (12%)	14 (82%)	3 (18%)

Table 6.16 shows the type of special conditions complexities found in the data. This category is divided into unknown conditions (such as contamination) and El Niño, a storm that affected

many of the projects. Overall, almost half (47%) of the projects had some sort of unknown conditions, including Project 9 (Hron, 1998) and Project 13 (Howard, 1999). The unknown conditions did not correlate to the building type, but this type of complexity was common enough to take notice. The El Niño occurrences were separated from the other data because this was a phenomenon that occurred in a single year.

Table 6.16  
Site Special Conditions Complexity By Project

Building Type	Unknown Conditions		El Niño	
	No	Yes	No	Yes
Medical/ Laboratory	3 (75%)	1 (25%)	1 (25%)	3 (75%)
Institutional	2 (40%)	3 (60%)	3 (60%)	2 (40%)
Office Building	3 (50%)	3 (50%)	3 (50%)	3 (50%)
Other	1 (50%)	1 (50%)	2 (100%)	0 (0%)
Total	9 (53%)	8 (47%)	9 (53%)	8 (47%)

Table 6.17 shows the data obtained from the detailed case studies. Challenges with the site are almost always physical ones. Therefore, coordination was the most common integration mechanism, as shown in Table 6.17 and Figure 6.5. Some information exchange was also observed. The decisions about actions to take were made high in the hierarchy so collaboration was not common. In this sample, 4 data points showed that interaction did not occur when there was a site special condition complexity, including Project 5 (Lucas, 1999) and Project 10 (Foran, 1999). In all of these cases, specialists were used to deal with the complexity.

Table 6.17  
Site Complexity  
By Occurrence of Integration Mechanisms

Level of Complexity	No Specialists	Use of Specialists	No Interaction	Information Exchange	Coordination	Collaboration
High	5	4	2	2	6	1
Medium	14	2	2	2	13	0
Low	12	0	12	0	0	0

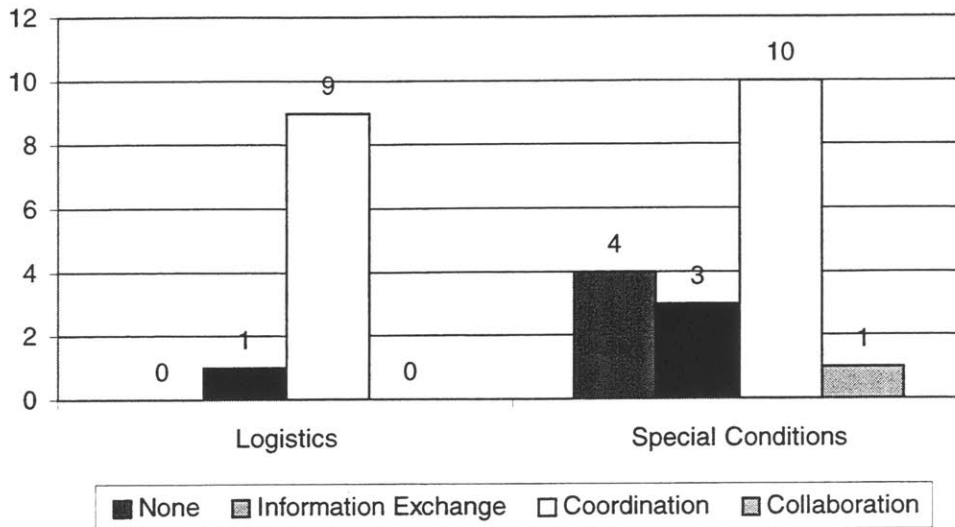


Figure 6.5  
Interactions Used For Site Complexity

## 6.5 PROJECT COMPLEXITY

Project complexities are Owner and project team specific, not design specific. However, many facilities of the same type or Owner have similar objectives, such as schedule and cost. Therefore, it may be helpful to see how specific project complexities map to building types. Overall, the mapping of project complexity to building type may assist construction project teams in establishing organizational practices during the planning phase of the project

Project complexity is divided into three main categories: contract management, project objectives, and social issues. Table 6.18 shows that contract management can be divided into contract hierarchy complexity and team-related problems. Contract hierarchy complexity was usually due to hierarchies of high breadth as in Project 17 (Dooley et al., 1999). Team-related problems often resulted from disputes, as was seen in Project 13 (Howard, 1999). Only a few projects (24%) had complexity from contract hierarchy and 35% had team-related problems.

Table 6.18  
Project Contract Management Complexity by Project

Building Type	Contract Hierarchy		Team-Related Problems	
	No	Yes	No	Yes
Medical/ Laboratory	3 (75%)	1 (25%)	2 (50%)	2 (50%)
Institutional	3 (60%)	2 (40%)	3 (60%)	2 (40%)
Office Building	5 (83%)	1 (17%)	4 (67%)	2 (33%)
Other	2 (100%)	0 (0%)	2 (100%)	0 (0%)
Total	13 (76%)	4 (24%)	11 (65%)	6 (35%)

Table 6.19 shows the complexities related to project objectives: schedule, budget, and other objectives. Schedules were an important factor in 53% of the case studies, especially the medical/ laboratory projects, where 75% of the projects were time sensitive. Project 1 (Foran, 1999) and Project 11 (Leopold, 1999), both medical/ laboratory facilities, were significantly driven by their aggressive schedules. Budgetary constraints added complexity to 35% of the projects. The Owner of Project 4 (Sanders, 1999), was highly concerned with minimizing costs.

Table 6.19  
Project Objectives Complexity by Project

Building Type	Schedule		Budget		Other	
	No	Yes	No	Yes	No	Yes
Medical/ Laboratory	1 (25%)	3 (75%)	3 (75%)	1 (25%)	4 (100%)	0
Institutional	2 (40%)	3 (60%)	3 (60%)	2 (40%)	4 (80%)	1 (20%)
Office Building	3 (50%)	3 (50%)	3 (50%)	3 (50%)	5 (83%)	1 (17%)
Other	2 (100%)	0 (0%)	2 (100%)	0 (0%)	2 (100%)	0 (0%)
Total	8 (47%)	9 (53%)	11 (65%)	6 (35%)	15 (88%)	2 (12%)

Table 6.20 shows the social issues involved in the projects. Complications with respect to regulations were seen in 75% of the medical/ laboratory buildings, but less often in other building types. Project 6 (Firebaugh, 1999) and Project 16 (Didone, 1999) were two examples of projects that had to work with the OSHPD, the Office of Statewide Health Planning and Development. Community issues affected 40% of the institutional buildings, more than other building types. Project 13 (Howard, 1999) dealt with several community issues (Appendix 2).

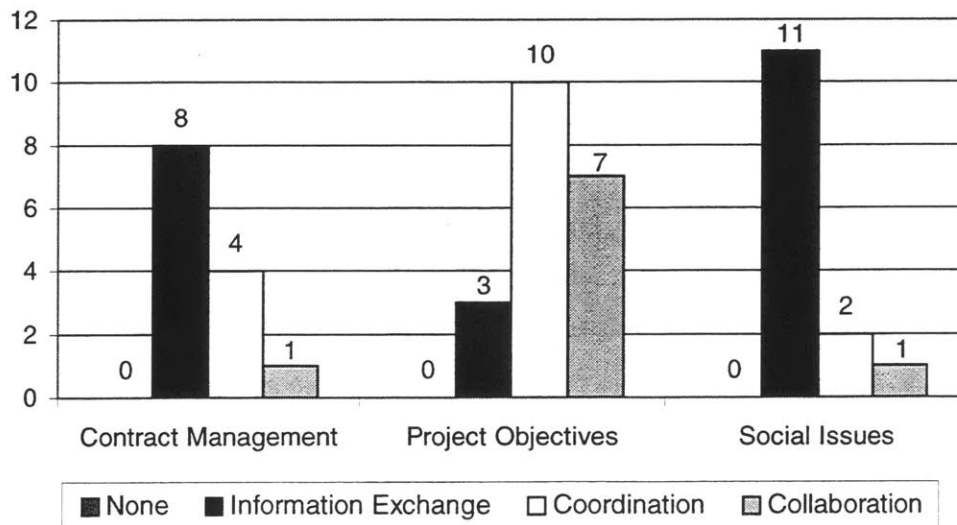
**Table 6.20**  
Project Social Issues Complexity by Project

Building Type	Regulations		Community Relations	
	No	Yes	No	Yes
Medical/ Laboratory	1 (25%)	3 (75%)	3 (75%)	1 (25%)
Institutional	4 (80%)	1 (20%)	3 (60%)	2 (40%)
Office Building	5 (83%)	1 (17%)	5 (83%)	1 (17%)
Other	2 (100%)	0 (0%)	2 (100%)	0 (0%)
<b>Total</b>	<b>12 (71%)</b>	<b>5 (29%)</b>	<b>13 (76%)</b>	<b>4 (24%)</b>

Table 6.21 shows the project complexity data collected from the detailed case studies. Figure 6.6 shows a graphical representation of the data related to instances of Medium and High complexity.

**Table 6.21**  
Project Complexity  
By Occurrences of Integration Mechanisms

Level of Complexity	No Specialists	Use of Specialists	No Interaction	Information Exchange	Coordination	Collaboration
High	32	0	0	19	11	6
Medium	9	0	0	3	5	3
Low	21	0	21	0	0	0



**Figure 6.6**  
Interaction Used For Project Complexity

Contract management usually involved the exchange of information and coordination between parties so that they all knew their roles in the project.

Project objectives usually involved special needs of the Owner, which had to be met in order to satisfy them. Two mechanisms used here are coordination and collaboration. Coordination is used when executive decisions are made which lower tiers of a hierarchical organization must follow. Figure 6.7 shows that when schedules were driving the project, coordination was often used. Collaboration is necessary when the needs of the Owner create a challenge shared by several parties and a common solution must be found. For example, when budgets were exceeded, value engineering and collaboration were common (Figure 6.7).

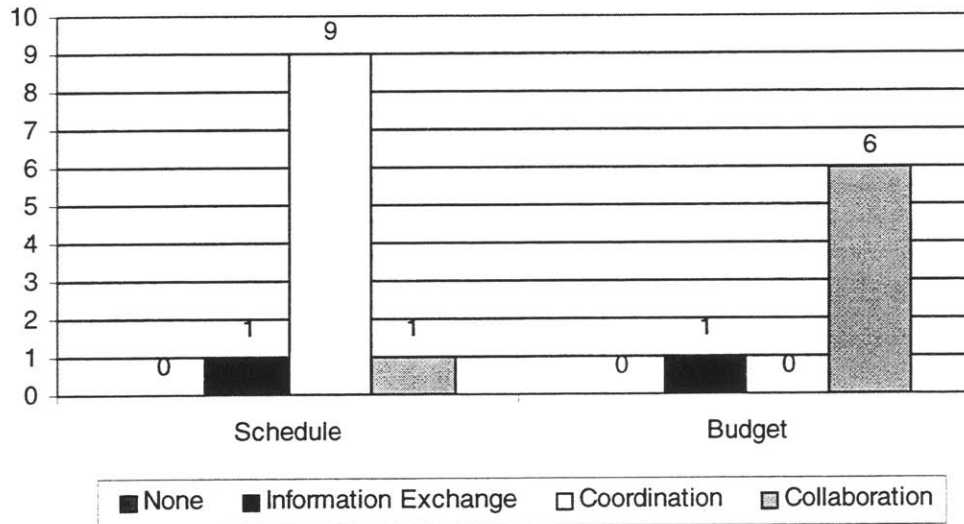


Figure 6.7  
Interaction Used For Project Objectives:  
Schedule and Budget

Interactions with the community normally deal with differences in opinion or misunderstandings. Information exchange is most useful to solve these two problems because it ensures that all parties have and understand the same information. Interactions are between leaders of groups and not delegated down the hierarchy.

## 6.6 SUMMARY OF RESULTS

To test the representativeness of the data collected in the detailed case studies, data from 25 journal articles featuring building projects was compiled. These building projects were located throughout the United States. Because the source for this data was not interviews, the data is not as rich as that of the detailed case studies.

Table 6.22  
Summary of General Case Studies

Building Type		Number of Case Studies
Medical/ Laboratory		2 (8%)
Institutional	Performance	3 (12%)
	Government	5 (20%)
	Museum	4 (16%)
	Convention	2 (8%)
	Retail	1 (4%)
	Stadium	2 (8%)
	Airport	1 (4%)
Office		2 (8%)
Hotel		3 (12%)
Total		25

Table 6.22 shows the breakdown of the projects used as general case studies. Simpler projects tended not to be in journal articles.

This section of the research will summarize the analysis just completed and compare it to the results obtained from the general case studies from the journal articles.

### 6.6.1 INTRA-SYSTEM COMPLEXITY

Intra-system complexity was directly linked to the function of the buildings. The structure and services of the medical/ laboratory building was critical, while the finishes were important for the institutional buildings. When there was intra-system complexity in the detailed case studies,

the most common mechanism was the use of specialists. Collaboration was also used frequently, but it was the faith in the capabilities of the specialists that guided the decisions made by the project team. Figure 6.8 shows that the results from the general case studies support this analysis.

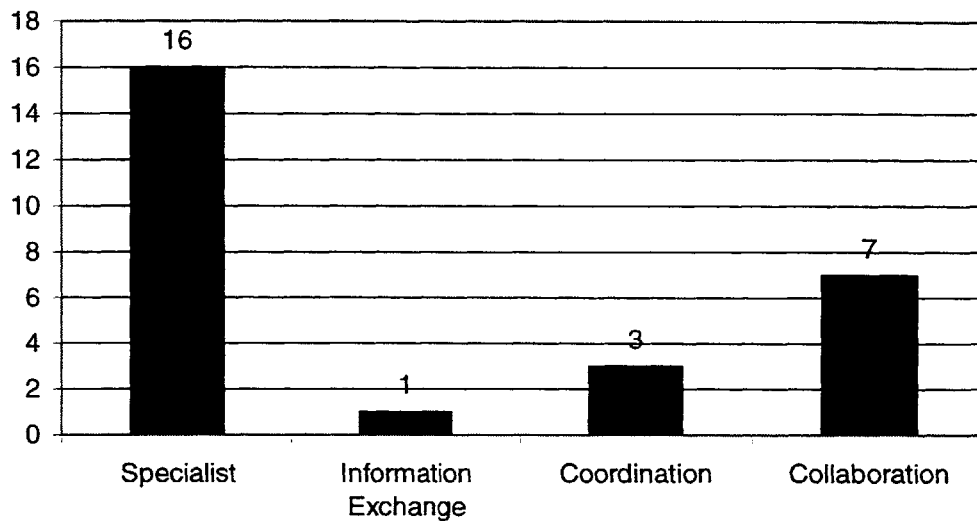


Figure 6.8  
Intra-System Complexity: General Case Studies

### 6.6.2 INTER-SYSTEM COMPLEXITY

Inter-system complexity also mapped to the buildings types. The most direct relationship was of the inter-system complexity of the services with medical/ laboratory buildings. There were two main types of inter-system complexities: spatial and functional. Spatial complexities involved the physical relationship between the systems. In the detailed case studies, coordination was the most frequently used mechanism. Functional complexities involved relationships between how the systems interacted functionally. For functional complexities, collaboration was more commonly used than coordination in the detailed case studies by a ratio of 7:2 (Figure 6.4). The general case studies in Figure 6.9, however, show that even though half of the examples of inter-system complexity were functional, coordination was used significantly more than collaboration. This discrepancy could be due to the type of contractors chosen for the detailed case studies.



Because these contractors were willing to cooperate with this research project, it could be true that they may be more likely to collaborate than the average contractor.

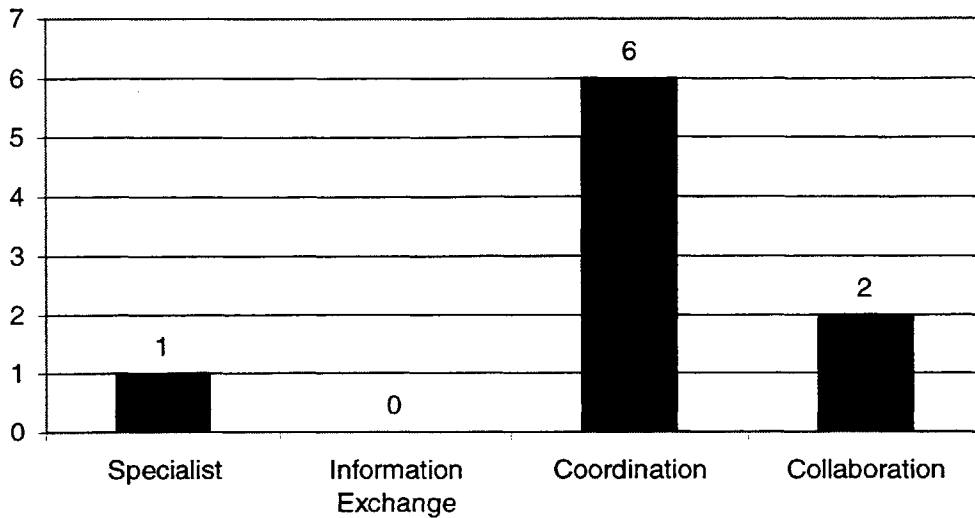


Figure 6.9  
Inter-System Complexity: General Case Studies

### 6.6.3 SITE COMPLEXITY

Site complexities were not specific to building type. Most of them were physical challenges, so the common mechanism used was coordination. However, when there were special conditions complexities, specialists were occasionally used. Figure 6.10 shows the results from the general case studies. They support that coordination is common for site-related complexity.

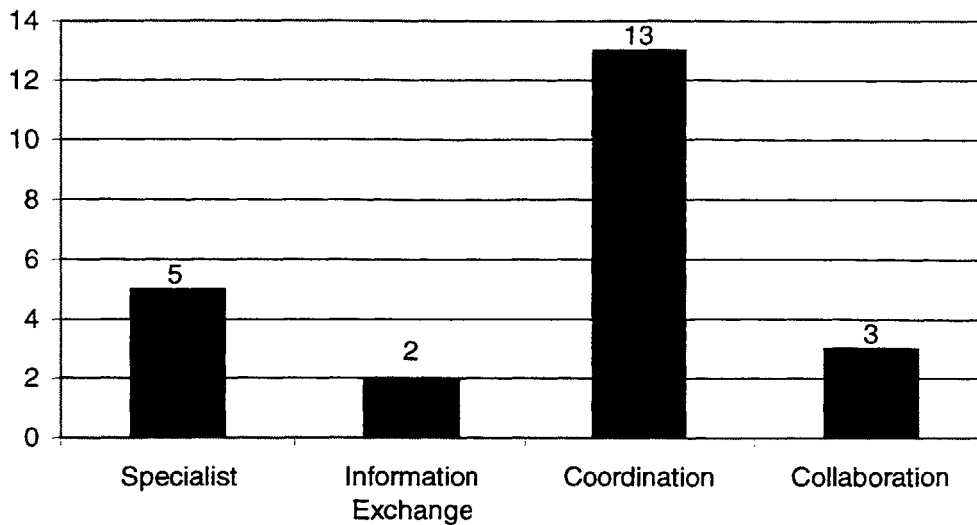


Figure 6.10  
Site Complexity: General Case Studies

#### 6.6.4 PROJECT COMPLEXITY

Project complexity was divided into contract management, project objectives, and social issues. Contract management was addressed through the use of information exchange. Project objectives used a great amount of both coordination and collaboration. Coordination was common with scheduling complications, whereas collaboration was used for budgetary issues. Schedules were crucial for most of the projects, but project objectives as a whole were most emphasized on the medical/ laboratory projects. Social issues necessitated primarily information. Regulatory issues were encountered most often on the medical/ laboratory projects, and community issues were common on institutional projects.

The general case studies in Figure 6.11 show evidence of both coordination and collaboration. However, there was only one instances of information exchange because all of the project-related complexities found in the general case studies were related to project objectives, with few contract management problems and no social issues mentioned in the articles.

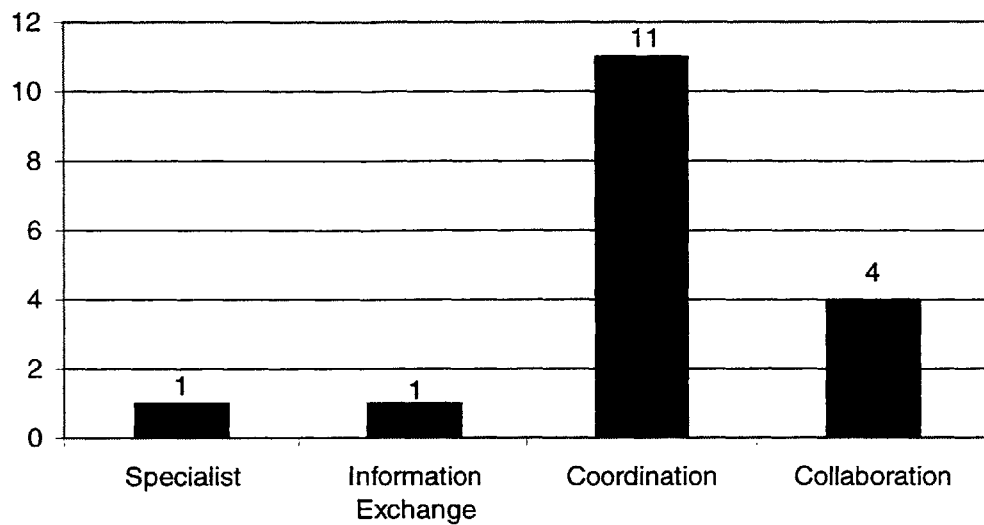


Figure 6.11  
Project Complexity: General Case Studies

Overall the detailed case studies produced the same results as the general case studies. This shows that the sample, as recorded in Chapter 5 (Detailed Case Studies), is representative of building projects throughout the United States.



## CHAPTER 7: CONCLUSION

This research analyzes the relationship between complexity and interactions within project organizations. The purpose is to show that project teams work most effectively if the complexities of a project are identified and an appropriate level of integration is implemented.

This study began with the definition of specific dimensions of complexity and mechanisms to achieve integration, based upon current theory. It was expected that high complexity requires high levels of integration, except when familiarity and trust exist within the project team. Low levels of complexity do not require integration.

This theory was tested through the in-depth study of seventeen building projects, based in Southern California. System, site, and project complexities were identified and the corresponding project team strategies, such as the use of specialists, information exchange, coordination, and collaboration, were recorded. The absence of complexity and the team strategies was also noted. This data was compiled and compared to another set of data collected from a general study of projects in other areas to use as a comparison.

Both sets of data showed four main trends. The first is that the function and purpose of a building determines the systems that will be critical to the project. Obtaining this information is important because it is crucial to identify the problem before trying to come up with a solution. The second conclusion is that a team's faith in the capabilities of specialists can reduce the level of formal interaction needed to successfully complete the project. The third trend shows that complexities related to the physical aspects of design and construction are best solved through coordination. For instance, issues related to spatial conflicts, site logistics and scheduling were frequently resolved through the coordination of the relevant parties. The fourth trend shows that complexities related to the conceptual aspects of design and construction are best solved through collaboration. For instance, functional incompatibilities of systems and cost-control issues require collaboration to arrive at a solution that satisfies all parties involved.

These results can be applied to the construction industry as well as many other industries. A problem frequently encountered in all industries is when integration is used when it is not appropriate. When integration is used in the wrong way, many times the problem is not solved efficiently and people think that integration is useless, therefore not using it when they truly need it. However, the proper use of integration is a powerful tool when dealing with high levels of complexity.

In order to determine the correct way of using integration, the type of complexity must be identified and the appropriate mechanisms to achieve integration must be implemented. Capabilities amongst project team participants must also be recognized and utilized. The combination of these three actions can produce an efficient strategy to attack complex problems.

This study provides the introductory groundwork for many other topics of future research. Studies could be done on other building types to identify their critical systems and the corresponding integration mechanisms. In addition, the category of institutional buildings can be divided according to the specific building usage type. Furthermore, the effect of owner type can provide insight on the difference in needs between private, public, and publicly-overseen projects. Some effort was put into this last topic in this research, but the data were inconclusive. Another interesting topic would be the relationship between integration and organization structures.

Another topic that was touched upon was the effect recognized capability has on the need for integration. Future research could identify the ways in which specialists can enhance the recognition of their capabilities, and the most effective means to fit specialists into teams.

Company business strategies appear to influence project team integration. Companies tend to take projects to position themselves in market segments and with clients. The importance of these projects give the companies greater incentives to integrate, whether they need to or not. Lastly, a fascinating topic of study would be the effect of inter-organizational learning over time about appropriate project integration.

The more that is understood about project organizations and the interactions of parties within the organizations, the fewer mistakes will occur when project decisions are made and tasks are delegated within the team. These mistakes can hamper a project team's ability to implement a successful project. This research was pursued to identify the most effective mechanisms to use to cope with complexity and to enhance the way that business is done in the construction industry.





# APPENDIX 1: SAMPLE INTERVIEW DATA SHEET

## Phone Interview Reference Sheet

The following is a summary of the topics to be discussed during our telephone interview. Please use it to jot some notes, for your reference. I would greatly appreciate a copy of your notes to supplement my interview.

### Company Data

1. Review of the Past Few Years of the Company
2. Overview of Goals and Strategy, especially if there are any particular to this project.
3. Characterization in Industry (Market Niche)

### Basic Project Data

1. Start and Completion Dates, Duration of the Project
2. Scope of Project
3. Basic Usage (Long-Term, Type of Building)
4. Location, SF, Height, Etc.
5. Identify Parties Involved in the Project (Owner, A/E, GC/CM, Other)
6. Objectives – Schedule, Cost, Ease of Construction, Long-Term Quality, Operations/ Maintenance, Aesthetics, Reputation/ Strategy, Environmental, Etc.
  - Of Owner
  - Of Architect
  - Of Constructor
7. Delivery System Used (Traditional, Design/Build)
8. Contract (Negotiated, Lump Sum)
9. Drivers of the Project – Special or Critical Systems
10. Milestones, timeline of the project
11. Any Special Conditions & Difficulties Associated with:
  - Site
  - Financing
    - Regulations
    - Materials
    - Equipment
    - Labor
    - Construction Methods
12. Design Changes?
13. Other Problems/ Issues
14. Fortuitous Occurrences

### Organization Data

1. Description of Project Parties, Internal Capabilities, Experience, Resources
  - Owner
  - Architect
  - Constructor
  - Other Critical Parties (Regulators, Specialty Subs, Suppliers)
2. Degree of Previous Working Relationships
3. Flow of Information Throughout Project



# APPENDIX 2: DETAILED CASE STUDY DATA SHEETS

## Amgen Cell Culture Building

### Contact Information and Project Summary

- I. Name of Contact      John Foran, DPR Construction (formerly of ARB Construction)

The project is a 2-story 6000 SF building addition. The project was quite expensive, but timing was the key objective, not price. This building was to house a cell culture growing process and is best described as consisting of cleanroom manufacturing labs. It was highly process-oriented. The structural steel building has an exterior insulation and finish system that matches the existing buildings.

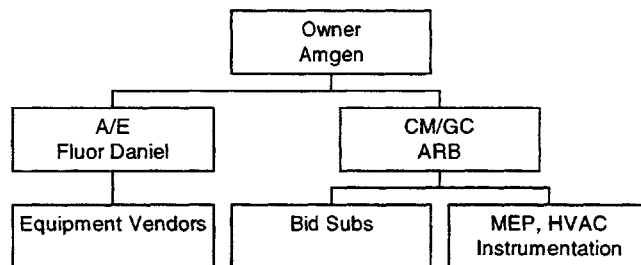
At the time, ARB was already doing a project at the Amgen campus and was approached by Amgen to see if they could do the project in 6 months. They were given 2-8-1/2" x 11" sketches. ARB did the preliminary schedule given certain assumptions, one of which being no budget constraints. Amgen was about to get a 10-year permit for a product and wanted to be sure that production could start as soon as possible. The building was to produce trial batches. The time frame that Amgen wanted was unheard of for this type of project. Normally it would take 18-20 months for the design, construction and validation. They wanted it to be done in 10-12 months.

### Basic Project Data

1. Location      Thousand Oaks, CA (NW of LA)
2. Project Timeline      Start: 5/97    Completion: 12/97  
Total: 7 months  
For the first 3 months, there was intense design to get the general routing and process done. In total, there was a total of 6-8 months of design time.  
  
Construction began after the first three months of design. They were in validation until February and closeout was in March.
3. Delivery System      Design-Build (not in contract, but in management responsibilities)
4. Contract      \$9.6 million. The contract was basically cost-plus for the important systems and the lesser trades were bid out. General conditions was a lump sum paid monthly.
5. Critical Systems      There were 1300 instruments that had to be accounted for. There were warmrooms, tanks, and a bioreactor that were procured by the designer. Since there were so many instruments, teams were formed to divide up the systems.
6. Site-Specific Conditions      There was not a lot of room for laydown at the construction site. The CM/GC was given access to a warehouse across the street for storage.  
  
There were weekly meetings, facilitated by the Owner, with the other contractors on site (lots of construction going on at same time) to coordinate deliveries.  
  
The El Niño storm affected construction, but effort was made to put the roof on the structure as soon as possible.

- 7. **Financing Issues**      The budget was based on the subs' best guess. This was done on an as-needed basis so that funding could be approved. The initial estimate was \$8.6 million, which was pretty close to the final cost. There were approval letters sent to Amgen so that they could set aside money.
- 8. **Regulations Issues**      The validation process, which involves equipment lists, inspections, and tests was started during construction to save time. This is usually done after construction.
- 9. **Materials & Equipment Issues (Lead-Items)**      The equipment came from many foreign countries so its delivery caused lots of out of sequence work, which was costly. This was inefficient, but necessary.
- 10. **Labor Issues**
- 11. **Problems**      The electrical sub messed up their estimate and the price was double what they projected.
- 12. **Fortuitous Occurrences**

**Organization Data**



- 1. **Owner**      Amgen, a biopharmaceuticals company. They are known for their collaborative style of teamwork. Amgen has its own validation staff. Also, their mechanical engineers contributed to the design of the instrumentation.
- 2. **A/E**      Fluor Daniel, Greenville, SC. They played roles in equipment design and procurement
- 3. **Consultants**      None noted.
- 4. **GC or CM**      ARB (CM/GC), a local company that specializes in technical building projects. They were to manage the architect and designers so that information would be available for timely construction. Their contributions dealt with money, time, and constructability issues. They had a large staff because they were the focal point for information and document control. They also did the structural steel on this job.
- 5. **Others**      Mechanical/Piping/Plumbing sub: Murray Company  
 Electrical sub: Sasko  
 HVAC: Cabrillo  
 Fire Protection: Costco  
 Process Instrumentation: Western Aire

6. Information Flow within the Project
- There were many meetings, almost to the point of meeting paralysis. The CM/GC managed this by only allowing necessary staff to attend the meetings.
- The CM/GC pushed the designer as design packages were required, according to their schedule. The designer did the general routing and process engineering. From here, the MEP subs did all of the detailed design.
- The Owner, the subs, and the CM/GC checked the systems point to point during construction. The Instrumentation sub was given information about the process. The designer and the Owner's mechanical engineers decided on the instrumentation type and interaction. The CM/GC was given information so they could stub out the building.
- The GC created a database system to log in all of the instruments and equipment, their delivery times, and their functional interactions.
- The instrumentation and process control sub had to interact with the electrician and plumbers to work out the interface between these systems. Functional relationships between the systems were engineered by the GC, Engineer, and the Sub. Also, the Sub had to work with the validation teams.
7. Previous Working Relationship
- The CM/GC had worked with all of the critical subcontractors before. The HVAC sub had done work for the Owner previously.
- The Owner and the Engineer knew the equipment vendors from previous work.

## Princess Cruises Office Tenant Improvements

### Contact Information and Project Summary

1. Name of Contact Gino Polizzotto, Project Manager, Bovis Construction Corporation

The Princess Cruises office project consists of a shell and core constructed for the Newhall Land and Farm development company and the tenant improvements contracted by Princess Cruises. The 130,000 SF building is 6-stories (85 feet) tall. The work done by Bovis, as Construction Manager, was all interior tenant improvements and the shell and core was another contract. The office building consists of a data center (computers), a reservations agent call center, managerial support, and services. The objectives of Princess Cruises were to construct a building that would stay operational and connected to all of its ships 24-hours a day, to be at the forefront of technology in its industry, and to serve its employees well. They knew exactly what they wanted in the building so they determined the technology systems for the project.

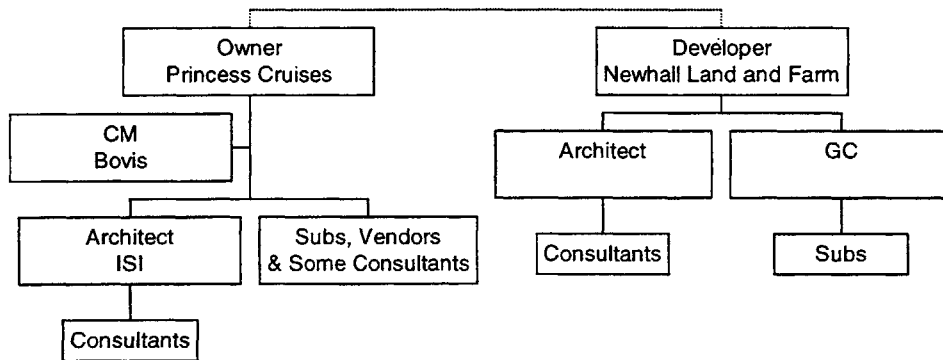
Bovis North America is a large, international company that specializes in general contracting and construction management, with an emphasis on teamwork. They do projects from \$150,000 to \$2 billion and have lots of experience in managing large, complex projects. The same parent company, Peninsular and Oriental Steam Navigation Company (P&O) owns Bovis and Princess Cruises (the Owner in this project). In the past, P&O and Bovis had not had the best working relationship and Bovis made it an objective to meet and surpass the needs of Princess Cruises on this project.

### Basic Project Data

1. Location Valencia, CA (NW of Los Angeles)
2. Project Start: 06/10/98 Completion: 11/30/98  
Timeline Total: 5-mo,3-wk.  
(Note: shell/core constr. 11/97-11/98 (9 wk late))  
  
The building had to operate on 12/15/98 because Princess is a seasonal business. If it wasn't ready, construction had to stop until 04/15/99.
3. Delivery System The CM Agent pulled all of the permits. The Owner held all of the contracts.
4. Contract \$15 million in tenant improvements and \$9-10 million shell/core. The CM had an exclusive contract with the Owner. Their scope included pre-construction services and management of construction and the move from Century City.
5. Critical Systems The data system consisted of two systems. The first is a system where every workstation is wired to a fiberoptic backbone. The second is a backup system with a data line for the future. The data system had its own CPM schedule.
6. Site-Specific Conditions The site was previously a riverbed so the building needed piles. They ran into a rock shelf that resulted in trouble with "zeroing" the piles.
7. Financing Issues None
8. Regulations Issues There were unusual regulations because Valencia was an incorporated city. The inspector made them do a lot of redundant work. The CM fought many of the redundancies, but the ones that they couldn't win were agreed to by the Owner.

- 9. **Materials & Equipment Issues**      None other than the data system.
- 10. **Labor Issues**      None
- 11. **Problems**      There were two owners and two constructors involved in the project and this made it complicated. The base building (shell/core) GC missed all of its deadlines so the interior construction had to compact its schedule. 85% of the interior construction was in recovery/compaction mode. The CM, which does not have much experience designing security systems, had a little trouble with the one it designed
- 12. **Fortuitous Occurrences**      None noted.

**Organization Data**



- 1. **Owner**      Princess Cruises, a private Owner. It involved senior management in the project so that decisions could be made quickly. They had a great understanding of the needs for their building, based on previous experience.
- 2. **A/E**      Interior Space International (ISI), a firm known for planning and interior architecture.
- 3. **Consultants**      Food consultant: Arthur Manask (hired by Owner)  
Datacenter infrastructure consultant: Datasphere (hired by Owner)  
Network Contractor: Orblom (hired by Owner)
- 4. **GC or CM**      Bovis (CM Agent Started Project 1996), has a lot of experience with construction management. Some of the duties they performed were estimating, budgeting, site location, monitoring construction, and scheduling. They were understaffed for this project, but managed to make it work.
- 5. **Others**      Developer (owner of building): Newhall Land and Farm  
MEP: Syska & Hennesey (hired by architect)

6. Information Flow within the Project The CM was instrumental in monitoring the progress of the shell/core construction. The shell/core GC did not use a schedule so the CM set milestones for them in weekly meetings. The CM used a proprietary project quality planning methods that promote continuous improvement through feedback.

The CM tried to communicate as little on paper as possible, just enough to track the progress. The CM required all subs to attend a weekly meeting if they had any work in place in the next two weeks. This meant that they had to attend two meetings before they even did any work. The subs didn't like to do this because they thought it was unproductive time, but they had to do it because it was in the contract.

Overall the CM was in charge of the information flow and passed questions to the relevant parties.

The CM used a program called Prolog, an integrated project management program to integrate the information: financial, RFI's, change orders, bulletins, schedule, transmittals. There was great communication throughout the project. The architect did not participate much in this, but they did not take on a management role from the beginning.

7. Previous Working Relationship The CM and the Owner are held by the same parent company, Peninsular and Oriental Steam Navigation Company (P&O) of London. It did not make sense to put the CM at risk because of this relationship. However, P&O had some bad previous experiences with the CM. The Project Manager convinced the Owner to do this project with the CM and made it his personal cause to do a great job for them.

The A/E recommended the MEP. The CM will be working on a future building with the A/E.

The Architect wanted to do future work for the Owner so they were very cost efficient.



## Mt. San Antonio College Performing Arts Center

### Contact Information and Project Summary

1. Name of Contact Caryn Cowin, (former employee of Architect), Bovis Construction  
Randy Hartman, Project Manager, Bovis Construction

The Mt. SAC Performing Arts Center is located on the Mt. San Antonio College campus. It is a 2-building 65,000 SF complex consisting of a large theater (5500SF and 410 seats) and a smaller recital hall (2500SF). Other components include a dance studio, band room, rehearsal room, and offices. It is constructed of structural steel with a brick façade and its highest point rises 73 feet high. The walls have interior angles for sound reasons.

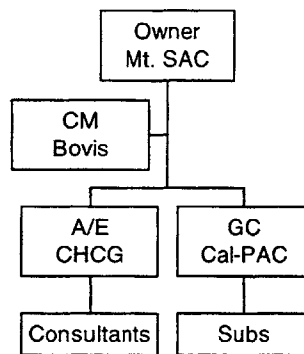
Bovis, a large international company, specializing in construction management and general contracting, has a long-standing relationship with Mt. SAC and wishes to continue doing work for them.

### Basic Project Data

1. Location Walnut, CA (E of Los Angeles)
2. Project Start: 07/94 Completion: 09/17/96  
Timeline Total: 2-yr., 2-mo. (only 31 days extended due to rain delays)
3. Delivery System Design-Bid-Build with Construction Management Agency
4. Contract \$16 million total. Bovis had a contract providing for a flat fee plus reimbursables. Cal-PAC received a lump-sum contract, based on low-bid.
5. Critical Systems Lighting, electrical, sound systems, theatrical equipment.  
  
The acoustical engineer was concerned with sound coming from the electrical and HVAC equipment. He made sure that these systems were designed so that they were acoustically acceptable.
6. Site-Specific Conditions There were no problems with the site.
7. Financing Issues The budget was constrained because it was funded by the state. When the job was estimated, California was in a recession and all of the prices were low. After the estimates were made, the Northridge earthquake hit and all of the prices went up. The costs were brought down by value engineering done by Bovis. Through value engineering, the intent was the same, but many architectural deletions were made and this was a sore spot for the architect. Other areas affected were mechanical and electrical systems. It is also noted, that many deletions were reinstated later in the project.
8. Regulations Issues All decisions had to be approved by the State Architect's office, which regulates all schools. They focussed on reviewing building access, fire and life safety, and structure. They did the bid plancheck and have to approve changes. One needs to be on top of knowing what the state requires before submitting requests.

- 9. Materials & Equipment Issues (Lead-Items) None noted.
- 10. Labor Issues None noted.
- 11. Problems They had problems with the installation of the HVAC system. Not enough space was allocated for it.
- 12. Fortuitous Occurrences None noted

**Organization Data**



- 1. Owner Mt. San Antonio College, a state-owned agency. They have their own facilities staff that is supplemented by Bovis on a long-term maintenance contract.
- 2. A/E CHCG Architects. They have a lot of school experience, including some with Mt. SAC. They have also done 2-3 theaters.
- 3. Consultants SE: Wheeler and Grey (Hired by A/E)  
ME: Syska and Hennessey (Hired by A/E)  
EE: CalPec. (Hired by A/E)
- 4. GC or CM Cal-PAC
- 5. Others Bovis was the CM (Hired by Owner). At Mt. SAC, they have a staff of 5 people devoted to construction management.
- 6. Information Flow within the Project There were 29 change orders. The owner was a state entity so, many times, change orders were used as a way of conveying what items were complete. This was a misuse of change orders. There were many other problems with excessive paperwork.

The approval process provided a logistical problem because quick decisions could not be made. Paperwork had to be done and information had to be gathered two weeks prior to going to the board of directors of the college for approval. After approval, the item would become a change order and would have to go to the state to approve. The state may require changes and the issue may take months to resolve.

There was lots of interaction between the MEP and acoustical people. The GC did most of this coordination.

7. Previous Working Relationship For the past 4-5 years, Bovis has been acting as the Program Manager and Construction Manager for the capital programs at Mt. SAC. Much of their work is deferred maintenance, large and small. They also have other contracts with Mt. SAC for large renovations and new construction.

Mt. SAC facilities management was very particular about its staff. Many people were let go because they did not fit the needs of facilities management so there were many staffing changes throughout the project.

Cal-PAC had never worked for Mt. SAC before (or any of the other parties).

There was a sense of tension from the architect's office, but things seemed to work out well.

The Architect's consultants all have long-standing relationships with the Architect.

## Metropolitan Water District of Southern California Headquarters

### Contact Information and Project Summary

1. Name of Contact Joe Sanders, Charles Pankow Builders  
Rosenbaum, David B. "Cladding Serves as Formwork to Help Water Agency Save Face." Engineering News Record, January 11, 1999. 19.

The Metropolitan Water District of Southern California (MWD) Headquarters is an administration office building for a large public agency. The 12-story 536,000 SF structure is a conventional cast-in-place ductile concrete frame with pre-cast pre-tensioned beams and mildly reinforced concrete slabs. Pre-cast concrete is used for the exterior. It also includes 2 levels, or 370,000 SF, of below-grade parking. Structural design of the building was very important because the Owner considered the building to be of essential status. This was reflected in the budget that was allotted for it.

Another main objective was that the building be efficient. This was accomplished through careful consideration of layout, systems, and finishes. The ground floor of the building also includes a boardroom, cafeteria, committee rooms, and an art gallery.

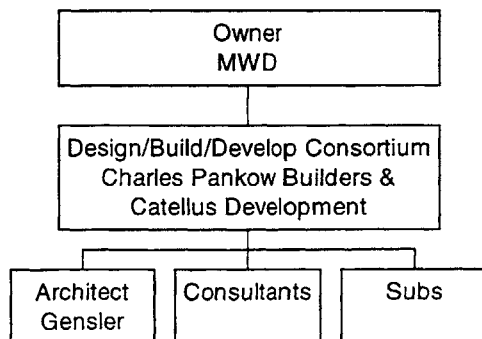
Pankow does all of the concrete work for their projects, including this one. They are well-known for their desire to be innovative in concrete construction.

### Basic Project Data

1. Location Downtown, Los Angeles, CA
2. Project Start: 5/96 Completion: 9/98  
Timeline Total: 2-yr, 3-mo. (3 mo. Ahead of schedule)  
There was a 8-9 month design process which involved permitting and property dealings. Move-in day was designated as 12/1/98 so that they can move out of their old building by 3/1/99. Pankow felt that they set a realistic schedule and they beat it. They could have done it faster, but they knew that they had to deal with a public entity and that this process was slower.
3. Delivery Design-Build partnership between Pankow and Catellus Development called Union System Partners. Catellus brought the land and Pankow brought the construction expertise. Together they came up with a proposal to construct the new building on land that Catellus owned. This was the first design-build contract in MWD's recent history.
4. Contract \$135 million negotiated.
5. Critical Structural concrete frame.  
Systems Software controlled building management systems and a data distribution network. It was very difficult to obtain the expectations of the Owner with regard to these systems.

- 6. Site-Specific Conditions  
 There was an archeological excavation because they were building on the site where Chinatown was previously located. There was a lot of hand-excavation of artifacts and old building foundations. The most interesting find was the 17 bodies of Native Americans that were 1000 years old. The downtown area has many areas where there are Native American burial grounds. The bodies were stored off-site while there were negotiations with the local representative of the tribe. It took a month to resolve the problem. The bodies were reburied with a ceremony at the bottom of the excavation beneath the garage. Not much work could be done at that time because they could only work on one side of the site while the archeologists did their work.  
  
 El Nino hurt the project because it rained from 10/97-5/98 when the interior finish was exposed.  
  
 Site accessibility was worked out with Union Station and access was from the back of the station. Pankow rented land from Catellus to construction the pre-cast members.
- 7. Financing Issues  
 MWD has always been criticized in the past about spending. The cost of this project was a very important PR issue.
- 8. Regulations Issues  
 The Owner and the GC had weekly meetings with the inspectors. The Owner wanted the inspectors to have higher expectations for this project. The building department was kept involved in the process so permits and certificates were easier to obtain.
- 9. Materials & Equipment Issues  
 (Lead-Items)  
 The GC was trying a new splicing technique for the pre-cast members. They had to get the Owner comfortable with it so they did a mock-up to show that there were no voids in the grout.  
  
 The construction scheme that they used was to build the structure and add the exterior panels at the same time, doing cast-in-place during the day and pre-cast at night. This was to save money on the crane. This was a little difficult because the goal was to hang the panels from the top of the building so that they could be isolated from the structure. This was accomplished by temporarily supporting them at the ground. Also, the exterior panels were used as formwork for the cast-in-place columns and beams.
- 10. Labor Issues  
 None noted.
- 11. Problems  
 The crane malfunctioned and needed a new part. Because the part had to be special ordered from Germany, this took 10 days.
- 12. Fortuitous Occurrences  
 None noted.

**Organization Data**



8. Owner Metropolitan Water District, a public agency. They are in charge of a lot of public works construction, but do not have experience with commercial construction. They laid out the design, building type, quality, goals, budget, and schedule in the RFP. They also had a person in charge of the interior design, who was very disciplined in avoiding changes.
9. A/E Gensler and Associates (Hired by GC). The architect had a large staff and a lot of creativity. They specialize in entertainment and tenant improvement architecture.
10. Consultants GC held all contracts with consulting engineers.  
SE: Martin & Huang International Inc.
11. GC or CM GC: Pankow. They did all of the concrete on this job. They have used the pre-cast panels as formwork in previous jobs, but not on such a large scale.
12. Others Some of the subs were more active in design than others. They had to hire some minority subs because of political pressures.
13. Information Flow within the Project All information flowed through the GC and the Owner.
- Through contracting directly with the consultants, the GC created a flat organization so that the consultants would take more responsibility for their function and their interactions with other functions. Everyone was brought together for the design meetings so there was a lot of front-end consulting.
- The Owner had 10-12 representatives at all of the meetings so the meetings were a little cumbersome. Everything had to be put on paper and numerous alternatives had to be examined for every system for approval of their 51-member board of directors.
- The Owner wanted to be in the middle of everything and to be educated about how things happen on a construction project. There had to be documentation for every trade, which was good to control quality. After this was done, the GC and the Owner held meetings with every sub to go over the documentation.
- There was a full-time staff devoted to doing walk-throughs of the project. This was time-consuming, but it meant that the owner had an intimate knowledge of the building.
- The GC had meetings with the Owner and the building control systems designers. The capabilities of the systems were introduced and the Owner's needs were assessed.
- There were 40 consultants on this job that were contracted to the GC. This high number resulted from the Owner's desire to obtain an expert second opinion about every system and a lack of trust of the GC.
14. Previous Working Relationship Creative nature of A/E fit with the culture of GC. There was a culture clash between the Owner and the GC because the Owner wanted everything to go through them. Catellus came to the GC for this project and a previous project for the Metropolitan Transportation Authority.

## Carbarn

### Contact Information and Project Summary

1. Name of Contact Jeff Lucas, Charles Pankow Builders

The Carbarn is a typical 540,000 SF parking structure with over 1000 parking spaces, 1 level below ground and 3 suspended decks. 1/16 of the parking is valet and this includes the drop-off space. Also, there is a 1000SF office/lobby for the valet service. A carwash will be added in the near future. It is expected that the need for parking near LAX will exist for a long period of time and that this garage may change owners, but will have the same function. The beams, columns, and spandrel panels (structural by LAUBC standards) are pre-cast. The slabs and ramps were cast-in-place. The exterior stairs were located at the corners of the garage and they had structural steel canopies.

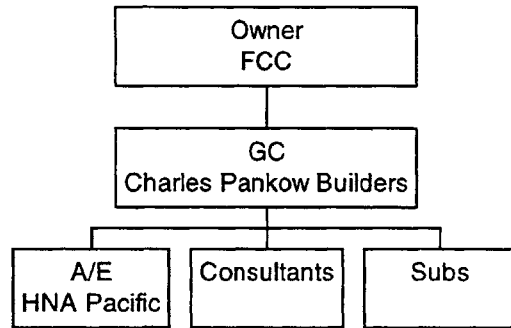
Pankow does all of the concrete work for their projects.

### Basic Project Data

1. Location Across street from LAX in Los Angeles, CA. Bounded by: Century Blvd., 98<sup>th</sup> St., Balanca St, LAX Hilton. (W of LA)
2. Project Start: 03/19/98 Completion: 10/27/98  
Timeline Total: 7-mo., 1-wk. (1-1/2 wk. early)  
Design: 3-1/2 mo.  
Lease for old valet service lobby was to end on 10/31/98 so Owner originally wanted to move into the facility before this date.
3. Delivery Design-Build. Proposal was made with the A/E involved.  
System
4. Contract \$12 million. Lump-Sum. Pankow held all of the contracts.
5. Critical Two types of foundations, conventional footings and friction piles, had to be used in  
Systems the project because of the differing soil conditions at different points in the site.  
Two types of retaining walls, one a strengthening measure and the other a shotcrete wall, had to be used depending on the adjacent circumstances.  
  
On this project the GC improved upon the method of constructing the suspended ramps by adding columns and putting expansion board around the columns. Otherwise, all details are old. The GC had to deal with congested rebar problems and the pin connections required care because they had small tolerances.
6. Site-Specific Uncertified fill covered a significant portion of the site and had to be removed to  
Conditions obtain the desired bearing capacity.
7. Financing None noted.  
Issues
8. Regulations The building inspector was very helpful because he was very knowledgeable about  
Issues construction. Also, he was not overly picky about little administrative items.
9. Materials & None noted.  
Equipment  
Issues

- 10. Labor Issues     There was a shortage of rod-busters. Pankow is signatory to a union.
- 11. Problems         There were many changes in the finishes for the valet area and in the exterior lighting system, but they were all treated as changes made by the owner. The lighting scheme required many iterations in the design because the systems were all too expensive
- 12. Fortuitous Occurrences     Pankow had a great relationship with the neighboring hotel and they had a give-and-take relationship.

**Organization Data**



- 1. Owner             First Commercial Corporation (FCC). This is a private Owner who is not usually involved in development, usually they are in business to sell property. They had a construction staff of 25-30 people. They had a good construction representative working for them.
- 2. A/E                HNA Pacific (Hired by GC). They have done several parking garages in the past.
- 3. Consultants      SE: Robert Englekirk (Hired by GC)  
CE: KPFF (Hired by GC)  
EE: Sasel Electric (Hired by GC)  
ME: Key Air (Hired by GC)  
Plumbing: Deel Mechanical (Hired by GC)
- 4. GC or CM         Charles Pankow Builders (GC). Pankow was able to give information on alternatives and planning options for the Owner. Pankow does their own concrete work and has a storage yard in Fontana, CA for equipment
- 5. Others            None noted.
- 6. Information Flow within the Project     GC held all of the contracts.
- 7. Previous Working Relationship         Owner was a new client to the GC that was made by referral from previous clients. The Architect, Engineers, and GC have worked together on several parking structures in the past and enjoy working together.



## Arcadia Methodist Hospital Patient Wing Replacement

### Contact Information and Project Summary

1. Name of Contact Brett Firebaugh, Charles Pankow Builders

This was the largest medical project that Pankow had done up to that date. Most of their medical facilities projects were under \$5 million and undertaken by their Special Projects Division. This 150,000 SF project is a steel structure, 5 levels above grade, one below. It is a patient wing replacement for an existing hospital with 151 patient rooms. In addition, there was an admissions area, a lobby with a gift shop, an outpatient area for medical exams, and a post-pardem area. The exterior insulation and finish system (EIFS) is made of studs, gypsum, Styrofoam, plaster, and glass.

### Basic Project Data

1. Location Arcadia, CA (E of Los Angeles)
2. Project Start: 8/96 Completion: 10/98  
Timeline Total: 2-yr, 2-mo  
There were two phases: 1) the top 3 levels, completed in July of 1998 and 2) the lower levels, completed in August of 1998. The schedule was made flexible for weather. The schedule was extended for expansion of scope and project was finished on-time. The schedule was important because they wanted to move patients in ASAP.
3. Delivery System Design-Bid-Build
4. Contract Negotiated to \$40 million. The original scope only had the top 3 floors built-out, but later they made a change to build-out floors 1-2. This increased the contract by \$7 million. There were more add-ons including redesigning the patient rooms by changing the wall configuration to make them more efficient. This involved another permitting process.  
  
MEP subs were bid out, but performance was also an issue upon selection.

5. Critical Systems
 

The systems that led the project were the med gas systems, life safety, the nurse call system (it was a very new and advanced system), a master antennae system for all of the TV's, a special HVAC system for constant volume because there is a lot of congestion in the systems, and a paging system. The med gas system was above the patient's heads in the head wall unit. In the nurse call system, there were lots of cables. The manufacturer did the start-up. Pankow had to make sure that everything was on schedule because there was a lot of work in the headwall including the studs, electrical, plumbing, nurse call, and gases. Pankow did the supporting systems for the telemetry and pneumatic tube systems. There was a vacuum and oxygen system where the pipe placement had to line up.

There was a special moment frame connection, the first OSHPD-approved connection for a hospital after the Northridge earthquake. They had to redesign the building because of the earthquake and to provide proof that it worked. They used a connection called the "Side Plate" connections. It was tough to put together because it was a new process.

There had to be coordination between the steel erection and the delivery of equipment for the basement. There was an opening created so that the equipment would fit.
6. Site-Specific Conditions
 

El Niño hit when a majority of the exterior was already in place so it did not affect the construction by too much. The site had good soil and it was sandy so when it rained, they did not have to wait long for it to dry. The system that was most affected by the rains was the EIFS.
7. Financing Issues
 

None noted.
8. Regulations Issues
 

Pankow had to deal with OSHPD, which is the Office of Statewide Health Planning and Development. They are the governing authority of hospitals in California. The inspector of record was full-time and advised the city inspectors. OSHPD is more detailed than any city inspector so they were more helpful in identifying problems. The GC had to work closely with the inspectors. The sign-off process was different because OSHPD had to do the sign-off. This process takes between 2-6 months and includes the Fire Marshall for OSHPD, Area Compliance Officer (architectural inspector for OSHPD), Beneficial Occupancy (to allow staff and equipment into the building), and the Department of Health Services (to allow patients to occupy the building). For this project, the process took 3 months.
9. Materials & Equipment Issues (Lead-Items)
 

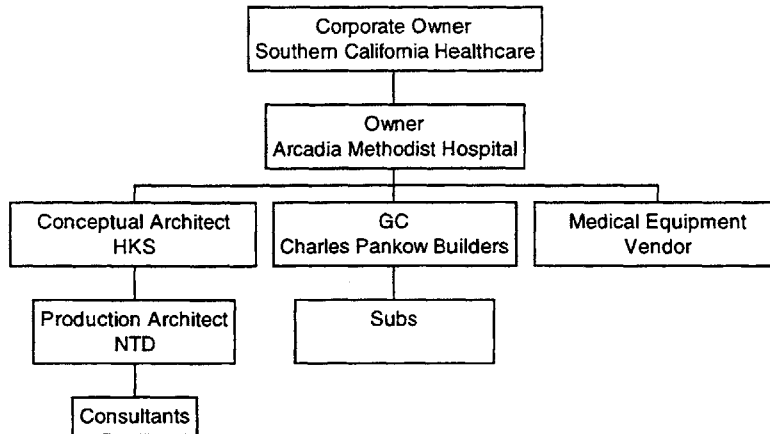
The structural steel was from Salt Lake City and was pre-assembled in a tree-like configuration. The trucks had to have a special way to carry them. Inspectors in the shop and on site were in charge of quality control, looking for material defects. Some steel had lamination problems and they had to be replaced. Lead time for some of the materials was due to the time needed for shop drawings, inspectors, quality control, and transportation. The size of members did not allow too many on each truck and there was lots of shipping charges.
10. Labor Issues
 

None noted.
11. Problems
 

The redesign of the building was done when Pankow was already on the project and delayed the project by a year. This affected the structural and architectural systems.
12. Fortuitous Occurrences
 

None noted.

## Organization Data



1. Owner      Arcadia Methodist Hospital.  
Above the Methodist Hospital was the Corporate owner, which was Southern California Healthcare (there were representatives for this Private entity).
2. A/E        HKS did the initial conceptual design and NTD was the production architect, hired by HKS. NTD has a lot of experience in doing hospital design.
3. Consultants    Plumbing & HVAC: Hillman and Lober (Hired by NTD)  
SE: Taylor and Gaines (Hired by NTD)  
EE: Norman Cohen and Associates (Hired by NTD)  
Nurse Paging System: Hill-Rom (Hired by GC)
4. GC or CM    Charles Pankow Builders (GC)
5. Others        HP: Vendor hired by Owner (telemetry system)  
Translogic: Vendor hired by Owner (pneumatic tube system)
6. Information Flow within the Project    There was a lot of upfront coordination. They got everyone together and established the general process that had to happen sequentially. There were lots of departments to be coordinated including nursing, housekeeping, etc.  
  
There were meetings between the Owner, GC, and the system vendors to determine the needs of the hospital and how the systems could respond to them.  
  
There were coordination meetings between MEP subs and their drawing were overlaid so that installation could be planned ahead of time.
7. Previous Working Relationship    Pankow worked well with the designers even though they had never done previous work with them.

## Metropolitan Transit Authority Headquarters

### Contact Information and Project Summary

1. Name of Contact Joe Sanders, Charles Pankow Builders

The MTA Headquarters is a 28-story building, consisting of a steel structure, on top of a portion of concrete below-grade parking structure. The ornate façade consists of Minnesota limestone and Italian granite, which was attached in metal tube-framed panels by crane. The lower sections were hand-set because of the irregular patterns of the façade near the ground.

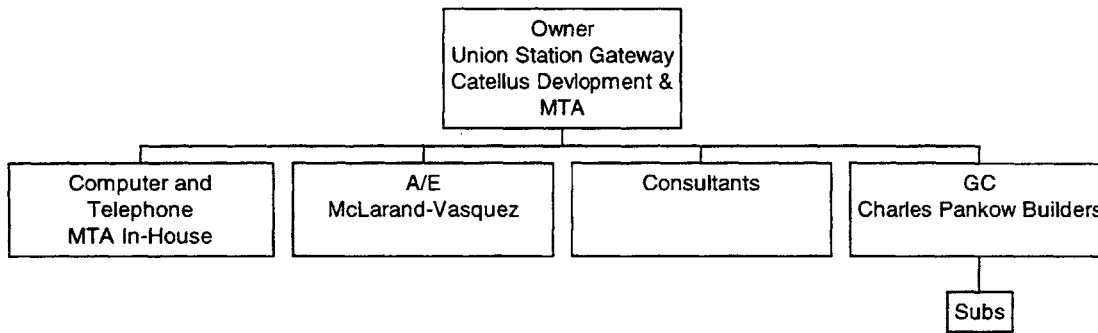
The primary use of the building was for 628,000 SF of office space. In addition, the ground level consists of a boardroom, a cafeteria, committee rooms, and an ornate lobby.

### Basic Project Data

1. Location Downtown LA
2. Project Start: 2/93 Completion: 9/95  
Timeline Total: 2 yr. 7 mo.  
The September deadline was required because the Owner's lease was to end 9/30/95. The contract with the GC had an end date of 9/30/95. Since the Owner forgot to account for time to move into the building, the GC had to allow the Owner into the building early and coordinate move-in with the punchlist.
3. Delivery System Design-Bid-Build
4. Contract The total cost of the project was \$70 million plus design fees. The GC had a negotiated contract.
5. Critical Systems The steel structure was about to be put in place when the Northridge earthquake hit California in January 1994. Because of steel structure failures during this event, the LA City Building Department required that the GC go back and do more welding to stiffen the structure.  
  
The data center and the telephone distribution center posed difficulties for construction.  
  
The lobby was a battle between the Architect and the Owner. It was a very political matter that had to be addressed. Many changes were made and this had an impact on the construction schedule.
6. Site-Specific Conditions In two areas of the site, soil had to be hauled off and remediated. This required a hazardous waste inspector and took some time.
7. Financing Issues None noted.
8. Regulations Issues None noted.

- 9. Materials & Equipment Issues None noted.
- 10. Labor Issues None noted.
- 11. Problems None noted.
- 12. Fortuitous Occurrences None noted.

**Organization Data**



- 1. Owner Metropolitan Transportation Authority
- 2. A/E McLarand-Vasquez. Their specialty is residential building and track housing. They also do small office buildings.
- 3. Consultants None noted.
- 4. GC or CM GC: Charles Pankow Builders  
CM: Catellus Development
- 5. Others None noted.
- 6. Information Flow within the Project Even though this was a public agency, they were relatively easy to work for. They had a great deal of trust of the contractor. The only conflicts deal with changes in the finish in the lobby.
- 7. Previous Working Relationship The GC had worked on previous jobs with the structural engineer and the mechanical engineer.

## Major Refinery Blending and Shipping Control Building

### Contact Information and Project Summary

1. Name of Contact    Magdalen Hron, PM, DMJM  
                              Bob Degnan, Facilities Management, Owner

The Blending and Shipping control building is on the outskirts of a refinery in El Segundo, CA. It includes the control room, a laboratory, machine room, a lounge, and offices. It is an 8,000 SF, 1-story building so that it would not be restricted to a building type by code.

It is type 5 construction (wood, unprotected) upgraded to concrete masonry and steel. The Owner wanted the interior to have a flexible floor layout for future needs. Also, ease of construction was a priority to meet an aggressive schedule. Steel construction was used to meet both of these needs. The building would be operational 24 hours/day and it would have to be self sufficient for 3-5 days just in case there was an emergency at the refinery.

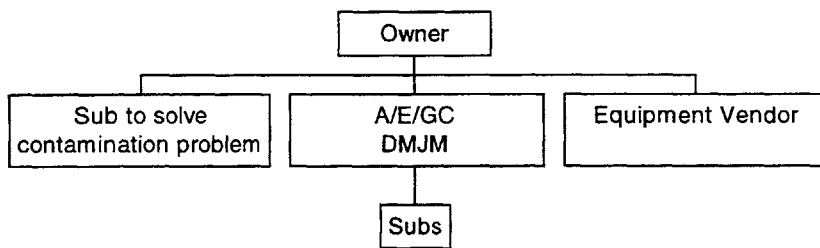
DMJM, a large international architectural, engineering, and construction firm, sees design-build as a method to allow them to have better control over the construction process. It is a more fluid process because it tackles both design and construction.

### Basic Project Data

1. Location            El Segundo, CA
2. Project            Start: 6/94    Completion: 6/95  
   Timeline            Total: 1 year (2-1/2 months of design)  
                              The date of transfer of old control systems to new ones was a milestone. The computer room had to be completed earlier than the rest of the building so that the installation of the systems could take place.
3. Delivery System    Design-Build. Using this system, the Builder views the client as partner.
4. Contract            The contract was for a \$2.7 million GMP. The Owner would pay if changes were within 10% of price. Anything over that would be shared by the Builder and the Owner. Anything under the price would also be shared.
5. Critical Systems    The Owner ordered the equipment for the control room. The Builder had to provide the feeds and cabinetry for the equipment. Also, larger doors and removable ceiling panels were necessary to account for the equipment.  
  
                              There was a special HVAC system because of the concern for toxic fumes. The intake had to be a certain height in the air for the same reasons. There was a sensor system in the ducts for alarms to detect toxins.  
  
                              Equipment A/C was important and so was a raised interior floor.
6. Site-Specific Conditions    From December until February, it was pouring rain.  
                              The site was contaminated because it was previously the site of an old fuel tank. It just required replacement of topsoil and grading. The Owner hired a sub to dispose of the contamination.
7. Financing Issues    Financing for capital programs is usually at the end of the year. Because of this, construction had to begin during the rainy season.

- 8. Regulations Issues
- 9. Materials & Equipment Issues (Lead-Items) The vendor was on the project before DMJM because of the long lead-time of the equipment.
- 10. Labor Issues
- 11. Problems
- 12. Fortuitous Occurrences

**Organization Data**



- 1. Owner Major Refinery. It had a Construction Management staff which provided value engineering and had many interfaces with DMJM.
- 2. A/E DMJM
- 3. Consultants
- 4. GC or CM DMJM. Large multi-disciplinary company Has done 2 control rooms for this Owner before in addition to the preliminary design for another one.
- 5. Others Equipment vendor was contracted to Owner.
- 6. Information Flow within the Project Information was distributed via phone, meetings (daily between CM/PM and every other day PM/Owner. Every decision (and reasoning behind) were documented so that the decisions could be explained at a later date.
- 7. Previous Working Relationship The Builder has done many projects with the Owner and has a good relationship with them. Both parties have expressed a good experience.

# Rocketdyne Corporate Headquarters Renovation

## Contact Information and Project Summary

1. Name of Contact   Magdalen Hron, Project Manager, DMJM

The 40,000 SF Rocketdyne corporate headquarters renovation took place in a building referred to Building 001. It was a 1-story building built in the 1920's and had been renovated many times over the years. The facility is divided into sections: the annex (where all of the engineers work), the headquarters, and two factories. The headquarters consists of an executive office area and an administrative office area. The building was a voluntary renovation (for safety reasons). There was roof damage due to the Northridge earthquake. Rocketdyne wanted an interior upgrade and a new office plan as well as the structural upgrade. Very little was done to the exterior. Rocketdyne wanted an aggressive project schedule. Construction had to be done during business hours.

Construction, including mechanical and electrical systems, began during the company holiday shutdown. Special corridors had to be constructed to give the executives access to their conference room without any of the inconveniences/hints of construction. In addition, dust and power outages were not an option because of all of the computer equipment that had to be operational during construction. Welding was done during the day and demo was done at night.

## Basic Project Data

1. Location           Canoga Park, CA (NW of Los Angeles)
2. Project            Start: 9/96   Completion: 7/97  
   Timeline           Total: 10 months (2 months of design)
3. Delivery           Design-Build. The project was originally traditional, but DMJM proposed a design-build process to fulfill the schedule desires of Rocketdyne.  
   System
4. Contract           \$5.4 million GMP.
5. Critical  
   Systems
6. Site-Specific      The previous renovations were done by internal Rocketdyne staff. Some of these were  
   Conditions         documented and some were not. The lack of documentation was a big frustration for  
                          the designers.

The circulation of the building was awful and needed to be sorted out.

Executives wanted access to the middle of the construction site because the executive conference room was in the middle of the work.

There was asbestos abatement required.

7. Financing  
   Issues
8. Regulations  
   Issues



9. Materials & Equipment Issues (Lead-Items)

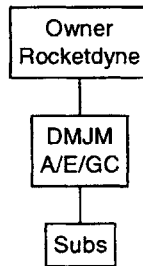
10. Labor Issues

11. Problems      The objective of opening up the building plan conflicted with the desire to beef-up the structure.

The building housed a computer system which was the hub of the Rockwell telecommunications and tracking of NASA rocket launching. The construction schedule had to work around the spacecraft-launching schedule because Rocketdyne did not want to risk any interruption during this time. If the launches were delayed, construction had to be pushed back in response.

12. Fortuitous Occurrences

### Organization Data



1. Owner      Rocketdyne, a private technical organization, has many engineers on staff. Over the years, they had done several renovations to the building with their own staff.

2. A/E      DMJM. They gave design alternatives to the owner.

3. Consultants

4. GC or CM      DMJM

5. Others

6. Information Flow within the Project

7. Previous Working Relationship      The relationship between Rocketdyne and DMJM was good because it had to be. DMJM appreciated the owner's construction manager on site. DMJM had done previous work for Rocketdyne as a designer.

## Warner Brothers Sound Stage

### Contact Information and Project Summary

1. Name of Contact John Foran, DPR Construction

The building is a feature sound stage that is used for the filming of movies. It had 25600 SF of open space and a 47 foot clearance to the truss. The building is a tilt-up system with cast-in-place concrete columns near the perimeter and steel truss beams. A veneer of plaster was used as the exterior finish.

### Basic Project Data

1. Location Burbank, CA (N of LA)
2. Project Start: 4/20/98 Completion: 3/26/99  
Timeline Total: 11 months  
The project experienced delays due to permitting, but finished only 3 weeks late. April 1, the building has to be turned over to a production company.
3. Delivery System Design-Bid-Build with CM Agent
4. Contract \$6 million. The general conditions were billed monthly on a GMP.
5. Critical Systems The concrete tilt-up panels were 50 feet high, 9 inches thick, and 20 feet wide. The panels were used for mass (sound deadening) and not for bearing. This is pretty big for a tilt-up. The span inside of the building was 140 feet and the height was 19 feet. The roof was made of bow string trusses that look like a half barrel. They were assembled on site from 4-5 pieces. The chord was 126-feet long. They were made in northern California and had to be shipped at night.

There were no internal columns, they were all on the inside perimeter of the walls. This was a complicated system. The columns by the walls were poured in place. There was a bearing plate assembly and a thick rebar cage. The design looked good on paper but was not constructable. The interaction between the anchor bolts, shear plate, bearing plate and rebar conflicted. The designer and the GC had a dispute over this.

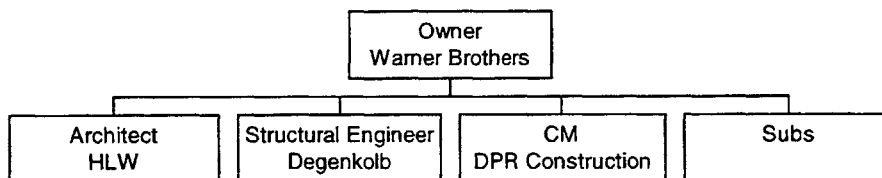
There was a lot of detailing done for absorbing of sound such as caulking, insul-quilt (insulation blankets that were anchored to the walls). The blankets were a pain to attach, because they had to put it on large stick pins with a large head attached to the wall and the blanket pushed into the other end. Sound penetration was avoided through the use of mass. The roof had layers of drywall.

There were also two 20' x25' holes in the walls to bring in large equipment. These had large sliding doors were very heavy.

They used a 300 ton crane for construction. This caused structural concerns for the slab and for the sewage outfall under the site. This caused a delay of 22 days for the permitting process. To resolve this, a camera had to be put in the sewer so that the CM could make sure there was no damage throughout the construction project.

- |                                 |   |
|---------------------------------|---|
| 6. Site-Specific Conditions     | <p>There was a sewage outfall that ran right under the building. The site was horrible because it was 15-20 feet of trash, debris, and fill. They could not take out the fill because it was too expensive so they had 140-50 foot deep caissons and a 12 inch slab on grade. Normal tilt-up construction has a 6 inch slab. The building was not supported on grade so the slab was structural.</p> <p>There were other site constraints due to the other sounds stages around. They were filming so when the red light turned on, there couldn't be any background noise. There was \$15,000 in lost time cost that the owner had to pay.</p> |
| 7. Financing Issues             | None noted.   |
| 8. Regulations Issues           | None noted.   |
| 9. Materials & Equipment Issues | The large sliding doors had a 6-week lead time.   |
| 10. Labor Issues                | None noted.   |
| 11. Problems                    | None noted.   |
| 12. Fortuitous Occurrences      | None noted.   |

### Organization Data



- |  |   |
|--|---|
| 1. Owner                               | Warner Brothers. They held the sub-contracts.   |
| 2. A/E                                 | HLW International. They were brought on to organize the drawings.   |
| 3. Consultants                         | SE: Degenkolb. Lead designer on the project. This was their first tilt-up building  |
| 4. GC or CM                            | CM: DPR Construction. Their duties included pre-construction services, bidding the job, assistance in developing sub-contract scopes, budgeting, arranging change orders, running meetings. |
| 5. Others                              | None noted.   |
| 6. Information Flow within the Project | None noted.   |
| 7. Previous Working Relationship       | The SE and the A/E had a good working relationship.   |

## Kaiser Medical Facility

### Contact Information and Project Summary

1. Name of Contact Jay Leopold, DPR Construction  
Davis, Bill. "Bedless Hospital Built on Trust." California Construction Links,  
February 1999. 18-20.

This building is a Kaiser medical facility called a bedless hospital. It was designed as such to avoid involvement of the OSHPD, which saved time and money. The region of San Diego lacked adequate Kaiser facilities, so Kaiser promised to start seeing patients on 8/31/98. This created the challenge of building the project in a way faster than Kaiser has ever experienced.

The facility is constructed in three phases. Phase 1 is 180,000 SF and Phases 2 and 3 are 39,000 SF. The buildings are constructed of structural steel with an exterior installed finish system.

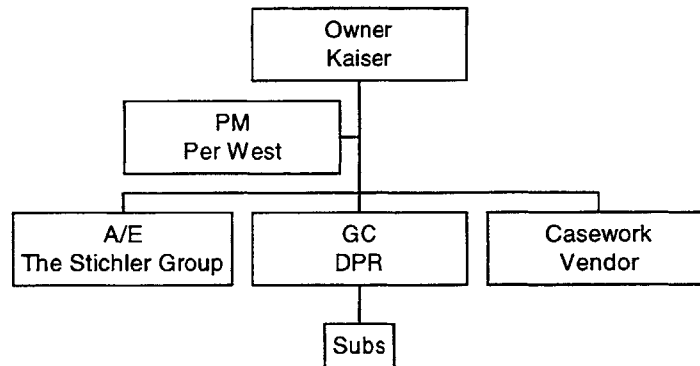
The project was such a success that DPR and Kaiser are doing several additional projects together using the same collaborative working style. Also, they are forming a local chapter of the Collaborative Process Institute.

### Basic Project Data

1. Location Otay Mesa, CA (S of LA)
2. Project Timeline Phase 1: Start: 8/28/97 Completion: 8/28/98  
Total: 1 year  
Other phases are to be finished in June 1999.  
  
Aug 1997 closed Escrow. Needed to see patients 8/31/98. Very compressed schedule. Design and construction were going in parallel. The scheduled finish was 7/31, but there were 54 rain days.
3. Delivery System Design-Assist GC was on at the very beginning.
4. Contract \$31 Million: 1<sup>st</sup> phase of a 250,000SF total campus. The total contract is \$54 million for all three phases.  
  
Contracts were negotiated for steel, MEP. This was because of the leadtime issues of these trades. They interviewed and hand-picked these trades. Everything else was bid. \$1 million in changes from owner were absorbed into the GMP. GC was hired without a contract and made a GMP half-way into job. The GC was on a fixed fee.
5. Critical Systems Structural steel was on the critical path. Its leadtime is usually 18-20 months. They bought the steel very early in the design, after establishing footprint, ceiling heights, and loads. Also, a "Side Plate" moment frame design was chosen as the structural system. This required rigorous QC and full-time inspection from the "Side Plate" people. It is a patented system, so there was no problem with the building department.  
  
The EIFS skin system was chosen to have the look of plaster but using an easier construction method.

- 6. **Site-Specific Conditions** A 30 foot mountain of dirt (280,000 CY) had to be moved to create accessibility to the building.  
  
El Niño made it necessary to build a gravel road to the site so that construction could continue during the rain.
- 7. **Financing Issues** None noted.
- 8. **Regulations Issues** OSHPD was avoided because the hospital was “bedless”.
- 9. **Materials & Equipment Issues (Lead-Items)** None noted.
- 10. **Labor Issues** None noted.
- 11. **Problems** After the first phase was completed and patients were being treated in the new facility, the construction of the other two phases began. This was a challenge because the first phase of the project had to be operational during this construction. This required a lot of planning and coordination beforehand. One example of this included not building walls in Phase 1 that would have to be torn down in Phases 2 and 3.
- 12. **Fortuitous Occurrences** None noted.

**Organization Data**



- 1. **Owner** Kaiser
- 2. **A/E** The Stichler Group, a San Diego-based company. They had the MEP and Structural trades in-house.
- 3. **Consultants** PM: Per West (by Owner)
- 4. **GC or CM** DPR (GC)
- 5. **Others** MEP subs were brought in early to help bring a cost-effective mindset to the design.

6. Information Flow within the Project Kaiser was not used to the collaborative fashion of work done on this project. At the time of the project, they did not have the staff to do the project so they hired an outside consultant that was not trusted by the GC. The PM consultant was very effective in planning the design and construction, but during construction became an unnecessary watchdog for the Owner. They created a sense of distrust and lots of paperwork. After a while, the consulting PM position was eliminated and they hired an internal PM, which improved efficiency because he had a stake in the results. After this move, the project became highly collaborative.

The project began with a session of ten people who didn't leave the room until the objectives for the project were agreed upon. These goals were communicated to the crafts. Many mechanisms were used to create an open channel of communications: shared trailers, internal surveys, QC teams.

7. Previous Working Relationship This was the first project between the A/E and GC, but they went on to do other projects together. DPR had not worked with MEP subs before. Kaiser owned a casework vendor so this work was directly contracted to Kaiser instead of through the GC.

## Casa San Juan

### Contact Information and Project Summary

1. Name of Contact    Jeremy Dominik, Benchmark Construction

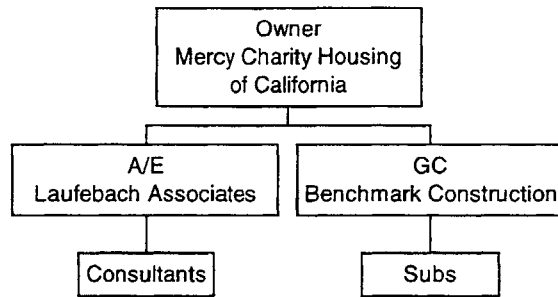
Casa San Juan is a Mercy Charity multi-family living community. There are a total of 9-2 story wood-frame buildings. There are 7 units in most building coming to a total of 64 units. In addition, there is a manager's office and a playground. This community is designed to teach low-income families how to respect their community.

Benchmark is the non-union arm of Morley Builders. They do many multi-family residential complexes and other wood-framed structures. They do concrete and some carpentry themselves. It is Benchmark's goal to be Mercy Charity's contractor of choice in LA. They received a senior housing project from MC in the same area.

### Basic Project Data

1. Location            Oxnard, CA (NW of Los Angeles)
2. Project            Start: 05/95    Completion: 03/96  
Timeline            Total: 8-1/2 mo. (2 mo. Early and on budget)
3. Delivery System    Design-Bid-Build with pre-construction services.
4. Contract            The GC was chosen after interviewed. Estimates were given at 30, 60 and 90% design completion. There was a \$5.5 million GMP.
5. Critical Systems    None noted.
6. Site-Specific Conditions    The site was a clean 3-acre piece of land. There were no problems with the site.
7. Financing Issues    The project was financed by Allied Irish Bank.
8. Regulations Issues    The inspector took his time with the project and was very picky about many items. This meant that the quality of work was very high.
9. Materials & Equipment Issues (Lead-Items)    None noted.
10. Labor Issues      None noted.
11. Problems          None noted.
12. Fortuitous Occurrences    None noted.

## Organization Data



1. **Owner**      Mercy Charity Housing of California, a non-profit developer, based in San Francisco. The main office is in Denver, CO. They build low-income housing and provide a learning community atmosphere. They hired an Owner's representative to help them to manage the project. This representative approved money issues and attended meetings.
  
2. **A/E**      Laufebach Associates. They hired all of the engineers. It was hired based on recommendation.
  
3. **Consultants**      None noted.
  
4. **GC or CM**      Benchmark (hired really early to provide pre-construction services.) The project manager did some value engineering to bring the design within budget. The project manager and project executive pursued the project and did the estimates. The project was run by the project engineer. The project manager had run several projects like this one before. He knew all of the up-front details and how to deal with the money and material issues. The Superintendent was a local resident so he was the liaison with the area and the people there.
  
5. **Others**      None noted.
  
6. **Information Flow within the Project**      None noted.
  
7. **Previous Working Relationship**      None noted.



## 77<sup>th</sup> Street Police Station

### Contact Information and Project Summary

1. Name of Contact    Tod Howard, Morley Construction

The 77<sup>th</sup> Street Police Station is a 130,000 SF complex that consists of administration buildings, a short-term detention center, community centers, a parking garage, a police car servicing center and a helipad. This building was to be a building that could be used by the community, not just a jail. The main entrance to the complex is on Broadway Street. There are two 2-story steel-framed administration towers. In between these two towers is an entrance lobby with an atrium and a bridge to the second level of the towers. The exterior system is pre-cast concrete. The jail is cast-in-place concrete with pre-cast concrete applied to it. There are basements in many of the buildings and the garage has 4 levels, with one level that runs under the courtyard. The owner is very happy with the final project and it is a substantial landmark project.

Morley Construction is the union arm of Morley Builders. They did all of the concrete work for this job. This job was bid during a time that the construction market was slow. Even though Morley did not have any experience in building detention centers, they needed the work. They tried to gain experience by associating with subs that specialize in this type of work. Through this job, Morley gained experience in detention facilities and won two subcontracts due to this job.

### Basic Project Data

1. Location            Watts: Downtown, LA
2. Project            Start: 3/96    Completion: 4/18/97  
  Timeline            Total: Supposed to be 700 days. The electrical sub did not finish until 8/97.
3. Delivery            Design-Bid-Build  
  System
4. Contract            The GC's bid was \$26 million and was very close to the next lowest bidder.
5. Critical            There was a specialty security system and detention hardware (doors and locks).  
  Systems
6. Site-Specific        The site was the size of 3 city blocks.  
  Conditions

Along Broadway Street, there was a gas station, so there was contamination of the soil. The city delayed the project by 3 months because they were in charge of cleaning the site. Under the old police station, there was a tank. The GC took this clean-up as a change order. Also, there was more contamination that had to be capped because it was too deep in the soil. A passive venting system had to be incorporated into the administration building.

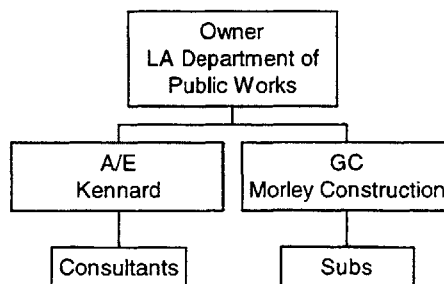
The buildings were built simultaneously. When they came across contamination, they moved the crews around so that they could continue working on other portions of the project. The time wasted in doing this was costly.

Staging had to be done on site because they couldn't do it on the street. They had to brace the structure to hold the crane.

7. Financing            Money was raised through a Public Bond Issue to redo the police stations. Restrictions  
  Issues                were that there would be a 700-day limit from start to finish and that any delays would  
                              result in a \$3500/day liquidated damages.

8. Regulations Issues The inspectors ordered the GC around and tried to direct the work for them.
9. Materials & Equipment Issues (Lead-Items) The GC ran into many problems with materials issues. The city was very strict with the specifications and there were many arguments about the suitability of the materials being used.  
The detention doorframes were a long lead-item, especially because the supplier went bankrupt.
10. Labor Issues The bid of the project was done during a time that was slow in the construction industry. All of the contractors bid the project aggressively. Once construction began, the market improved and the subs were receiving other jobs. The subs took their "A" teams off of the job and put in their "B,C" teams in. This affected the quality of work.  
This was a prevailing wage job and some of the subcontractors tried to get around this and the GC had to withhold payments and penalize them for this.
11. Problems During the 3-month delay of the project, the electrical sub claimed that the price of copper went up \$150,000. The sub is threatening to sue the city for this. The city, in return, is threatening to collect liquidated damages form the GC because the electrical sub didn't finish work on time.  
There were 1200 RFI's (large number for a project that size) and many of them had to do with security issues that weren't planned enough.  
Dealing with the city was hard because of internal audits and the mindset that they have had too many bad experiences with contractors in the past and they were not going to take it this time. To make things worse, there were many change orders because the design was not complete. The owner rejected many of these change orders, but gave-in in the end.  
The GC made some internal mistakes, including omitting the helipad in the estimate.  
The glass frames were painted incorrectly so they had to be replaced or sandblasted or repainted in place. This prevented any other work from being done at that time.
12. Fortuitous Occurrences Many police officers had emotional ties to the old police station so they monitored the site and wanted souvenirs of the building. This reduced the need to provide security during the day. Originally, the GC planned to have 24-hour security because the site was located in a bad neighborhood.

## Organization Data



1. Owner LA Department of Public Works, but the user is the LAPD. The LAPD had not built a station in a long time so they did not know exactly what was needed in the program.
2. A/E Kennard, a local minority-owned architectural firm. They did not have any experience in building jails, but they won the design competition.
3. Consultants LA Building Department: contract administration, inspection.  
SE: Benito Saint Claire (hired by A/E)  
PL/ME: Ezer (hired by A/E)  
EE: Cohen and Kanwar (hired by A/E)  
Detention systems sub (hired by GC): went out of business
4. GC or CM Morley Construction . They had never built a jail before so they hired a detention hardware sub-contractor. Unfortunately, the sub-contractor went out of business.
5. Others None noted.
6. Information Flow within the Project GC had very little interaction with the engineers. At the beginning of the project, there was a partnering meeting, but the city counteracted it with its suspicions of the GC.
7. Previous Working Relationship
 

The City of LA had had horrible working experiences with general contractors in the past and they resolved that they were not going to be taken advantage of on this project.

The GC had to hire subs from the community and minority-owned businesses.

GC had never done work with the Architect before, but they did work on a project together afterward.

Morley has a very good relationship with the community there.

There was a lot of labor turnover within the project.

## Parcel 1, Cerritos Office Building

### Contact Information and Project Summary

1. Name of Contact Bob Morrison, Benchmark Construction

The building called was called Parcel 1 because it was a spec office building that did not have a tenant during construction. It is a 2-story, 50,000 SF shell of a building, made of the materials that were common to the business park. It is a steel frame building with wood truss joists, plywood floors, and stone exterior. The material choices were made to minimize material costs. It was a normal office building, but it had some unusual geometry, which caused trouble in the structural design.

At the time of the project, the construction market was slow so it was important for Benchmark to get the job. However, once the job was obtained, the Northridge Earthquake hit the area and construction prices went up significantly.

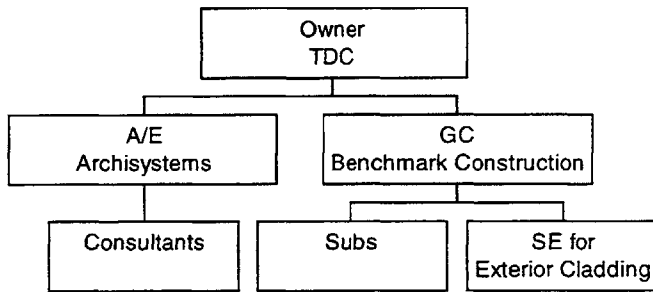
Benchmark Construction is the non-union arm of Morley Builders, a local GC well-known for its initiative and problem-solving skills.

### Basic Project Data

1. Location Cerritos, CA
2. Project Start: 10/97 Completion:  
Timeline Total:  
The Parcel 1 schedule was condensed to save money, but it turned out to be 4-5 months late
3. Delivery System Design-Bid-Build, except for cladding support system, which was Design-Build.
4. Contract Negotiated to a GMP of \$3.2 million.
5. Critical Systems The support system for the stone façade was design-build. In hindsight, the GC would have never agreed to this. The design in the conceptual drawings was not close to what they had to do. The odd shape of the building, along with the plywood floors required that a special support system be used and the building's structure be beefed-up to support this system. The GC had to hire a structural engineer to design this system.
6. Site-Specific Conditions El Nino rains occurred during excavation and concrete slab pours.
7. Financing Issues Parcel 1 had a tight budget because of the costs involved in dealing with the geometrical complexities. The conceptual estimate was significantly lower than the complete design estimate because of cost escalation after the Northridge earthquake. Lots of value engineering took out \$200,000 and Morley cut their fee. Value engineering involved using different mechanical equipment and plywood and the deferment of work.
8. Regulations Issues

- 9. Materials & Equipment Issues (Lead-Items)      The lead time was not considered for the stone for the exterior finish, which was imported.
- 10. Labor Issues      Parcel 1 was a Benchmark job because it did not require union labor.
- 11. Problems      The GC had trouble with the punch-list because TDC wouldn't sign off on things. They wanted Spieker to sign-off and they were picky and wanted to add things to the building.
- 12. Fortuitous Occurrences      None noted.

**Organization Data**



- 1. Owner      Transpacific Development Company (TDC), but sold it to Spieker Development during the construction. They are developers that own a lot of office space in Southern California.
- 2. A/E      Archisystems
- 3. Consultants      SE for exterior cladding system (by GC)
- 4. GC or CM      Benchmark Construction. The Project Manager for the GC was always running two jobs at once from the main office and there was a full-time project engineer working on two office at the business park. They were understaffed. Morley had done several office buildings in the 80's but this was the first spec office building in the LA area in the past 5 years.
- 5. Others      None noted.
- 6. Information Flow within the Project      TDC relied heavily on the A/E for advice and the GC was very proactive in solving problems.  
  
The architect was extremely hard to work with because he was trying to avoid liability. He never gave straight answers on the RFI's, fought value engineering, and was not a team player. He produced a beautiful design and the drawings were decently complete, but he was very defensive about the design.

7. Previous Working Relationship  
TDC owned the buildings that the GC and A/E occupy and the GC has been trying to get work from TDC for a long time. Also, the CEO of the GC knew the CEO of TDC. TDC had been having trouble with contractors recently (with respect to lawsuits and bankruptcies) so they needed a change. There will be another building in that park in the next 10 years and the GC hopes to get it.

The architect did the design for all of the Cerritos Business Park.

The owner had three different project managers working for them and this made dealing with the owner a little difficult because they had to be brought up to speed and verbal agreements were worthless.

## Delta Dental Office Building

### Contact Information and Project Summary

1. Name of Contact Bob Morrison, Morley Construction

The Delta Dental office building is a 30,000 SF addition to the existing building. It is located in a business park in Cerritos, CA and is made of materials common to the rest of the business park. It is a steel frame building with wood truss joists, plywood floors, and a stone exterior. These materials were chosen for reason of price. The building is just a normal, rectangular office building that did not provide any big challenges.

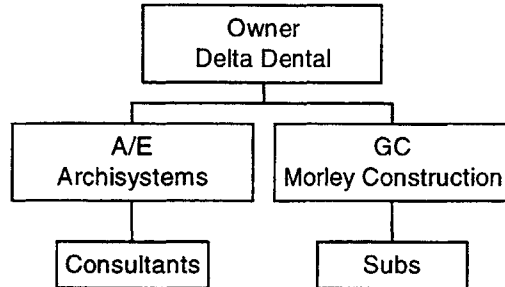
At the time of the project, the construction market was slow so it was important for Morley to get the job. Morley Construction is the union arm of Morley Builders, a local GC that is well-known for its initiative and problem-solving skills.

### Basic Project Data

1. Location Cerritos, CA
2. Project Start: 10/97 Completion:  
Timeline Total:
3. Delivery System Design-Bid-Build
4. Contract Negotiated to a GMP of \$2 million.
5. Critical Systems None noted.
6. Site-Specific Conditions El Niño rains occurred during excavation and concrete slab pours.
7. Financing Issues The conceptual estimate was significantly lower than the complete design estimate. There was lots of value engineering and Morley cut their fee. Value engineering involved using different mechanical equipment and plywood and the deferment of work.
8. Regulations Issues None noted.
9. Materials & Equipment Issues (Lead-Items) The lead time was not considered for the stone for the exterior finish, which was imported.
10. Labor Issues Delta Dental had to be 100% union labor because it had financing from the AFLCIO.
11. Problems The GC had trouble with the punch-list because TDC wouldn't sign off on things. They wanted Spieker to sign-off and they were picky and wanted to add things to the building.

12. Fortuitous Occurrences      None noted

## Organization Data



1. Owner      Transpacific Development Company (TDC), but sold it to Spieker Development during the construction. They are developers that own a lot of office space in Southern California. Delta Dental was the occupant of the building.
2. A/E      Archisystems
3. Consultants      None noted.
4. GC or CM      Morley Construction. The Project Manager from the GC was always running two jobs at once from the main office and there was a full-time project engineer working on two offices at the site. They were understaffed for the job. Morley had done several office buildings in the 80's but this was the first spec office building in the LA area in the past 5 years.
5. Others      None noted.
6. Information Flow within the Project      TDC relied heavily on the A/E for advice and the GC was very proactive in solving problems.  
  
The architect was extremely hard to work with because he was trying to avoid liability. He never gave straight answers on the RFI's, fought value engineering, and was not a team player. He produced a beautiful design and the drawings were decently complete, but he was very defensive about the design.
7. Previous Working Relationship      TDC owned the buildings that the GC and A/E occupy and the GC has been trying to get work from TDC for a long time. Also, the CEO of the GC knew the CEO of TDC. TDC had been having trouble with contractors recently (with respect to lawsuits and bankruptcies) so they needed a change. There will be another building in that park in the next 10 years and the GC hopes to get it.  
  
The architect did the design for all of the Cerritos Business Park.  
  
The owner had three different project managers working for them and this made dealing with the owner a little difficult because they had to be brought up to speed and verbal agreements were worthless



## City of Hope Diabetes Research Center

### Contact Information and Project Summary

1. Name of Contact Joe Didone, Morley Construction

The City of Hope Diabetes Research Center is a building with a program of 75% lab space devoted to diabetes research. It is located in the campus of the City of Hope and, therefore, had to be coordinated with the facilities that exist/ will exist there.

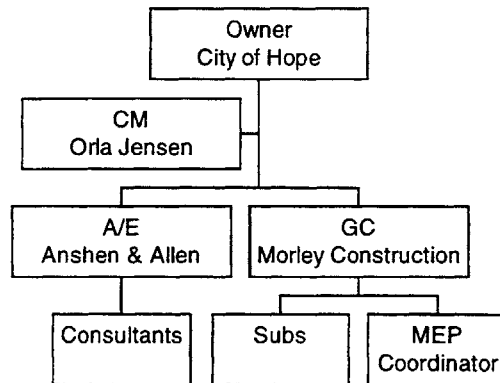
At the time of the award of the project, the construction business was slow so Morley decided to take this job even though they did not have the experience. They lost a little money on this project but they later won a CM job for a larger hospital job because of the experience they gained on this job. Morley, is a well-known local GC that does institutional work. Also, it does all of its own concrete and some carpentry.

### Basic Project Data

1. Location Duarte, CA (E of Los Angeles)
2. Project Start: 4/96 Completion: 5/97  
Timeline Total: 14 months.  
The GC had to expedite the schedule by 1 month to meet the deadline. Researchers were already booked into the labs so the construction could not be late.
3. Delivery Design-Bid-Build with separate contracts (listed below). The GC was still in charge of System coordinating the extra disciplines.
4. Contract Low-Bid. \$8.5 million for GC, \$10.5 million total including structural steel, excavation, and metal decking, which were bid separately to expedite construction. The PM felt that it would have been better if the contract was negotiated to improve the quality of the project.
5. Critical The building was heavy in MEP systems so there were many coordination meetings Systems with the MEP engineer held by a person hired specifically to do this coordination. Also, there were coordination meetings for the trades so that they knew where to place their work. The Owner did the security system themselves, but the GC had to provide the conduit for the system.
6. Site-Specific Excavation was a little difficult because Duarte is in a rock-query-like area. Conditions
7. Financing The money was (\$10-12 million) donated for a diabetes research center. The first Issues design was too expensive so a lot of value engineering had to be done to bring it within budget.
8. Regulations City of Hope is a campus-like setting and their strictest rule was that no smoking was Issues to occur on the site.

- 9. **Materials & Equipment Issues (Lead-Items)** Steel ran late because there was a conflict between the engineer and the steel sub. Equipment had long lead-times and the owner couldn't afford the equipment at the time of construction. The GC had to provide the electrical and hook-ups for this equipment so they had to push the Owner to think ahead about what equipment they would want in the future. Modifications were made in the future when the equipment was obtained.
- 10. **Labor Issues** None noted.
- 11. **Problems** None noted.
- 12. **Fortuitous Occurrences** None noted.

**Organization Data**



- 1. **Owner** City of Hope, a private organization. They produce their own schematic design with their own architect.
- 2. **A/E** Anshen & Allen. They are well-known for research and medical facilities.
- 3. **Consultants** MEP coordinator (Hired by GC)  
SMEP engineers: Ove Arup (Hired by A/E)
- 4. **GC or CM** Morley (GC). This was the GC's first lab job. They had done retirement homes, which require special gas systems, but this was a learning job.
- 5. **Others** Orla Jensen (CM, advisor to the owner). The CM was extremely helpful and were the eyes and ears of the owner during the project
- 6. **Information Flow within the Project** None noted.

7. Previous Working Relationship
- The GC had never worked in Duarte before, but when they enter a new city, they have the project executive, the project manager, and the superintendent visit the Fire, Police, and Building Departments to introduce themselves. The GC had a good relationship with the campus because they held monthly meetings to update the community.

The Owner likes to give their work to different architects.

The GC has worked with the Architect before and the Architect actually recommended the GC to the job. The GC has also worked with the SMEP on other projects.

# Our Lady of the Angels Cathedral

## Contact Information and Project Summary

1. Name of Contact Various Members of the Project Team, including Morley Builders, Raphael Moneo Architects, Leo Daly Architects, Bovis Construction, Archdiocese of Los Angeles

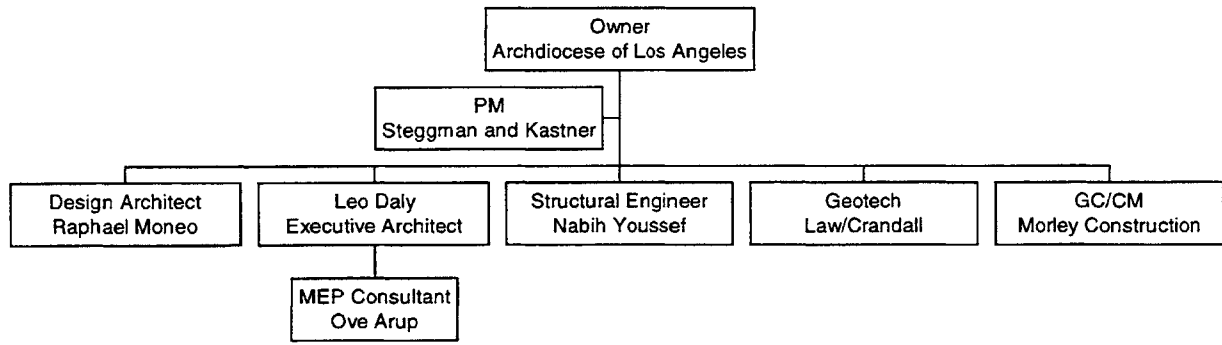
Our Lady of the Angels Cathedral will be the seat of the Archdiocese of Los Angeles. It is being designed by an architect in Spain to be a monument that has a 500 year life. Because of this, the design and the choice/quality of materials are crucial. It is the last part of a project that also consists of a cathedral residence, a community center, and an underground parking structure. Currently, it is in the late stages of design and the beginning stages of construction. Because of a delay in the design, the project is now on a fast track schedule.

## Basic Project Data

1. Location Downtown, Los Angeles, CA
2. Project Start: ? Completion: 12/00 (expected)  
Timeline Total: Not known.
3. Delivery Design-Bid-Build with Construction Management Agency and preconstruction  
System services.
4. Contract \$170 million (estimated)
5. Critical The structural system is the most important of the building because of the expected life  
Systems of the building. It is a seismically-isolated concrete structure.  
  
The concrete is exposed so it is also the interior and exterior facades.  
  
Alabaster will be used for the windows and this material has caused some problems because of its sensitivity to heat.  
  
The finishes are extremely important because of the high profile of this project.
6. Site-Specific The site was announced to be an ancient American Indian burial ground so special  
Conditions permission had to be obtained in order to construct on it.  
  
Also, there are utilities that run through the southwest corner of the site. This resulted in the need for pile foundations under a small portion of the parking garage (didn't affect the cathedral).  
  
The access to the site is difficult because it is located in the downtown area of one of the largest cities in the US. The GC interacted with the department of transportation to make preparations for the construction. Also, parking for the staff had to be obtained.
7. Financing The Cathedral is financed through donations to the Archdiocese. Many people  
Issues protested the use of this money on a building, and not the poor.  
  
The design is overbudget and the Owner has vowed not to go over budget.
8. Regulations Because the owner wished construction to begin before design was complete, the  
Issues permits had to be obtained in parts.

- 9. **Materials & Equipment Issues (Lead-Items)**      There was a lead time for the seismic isolators so these were designed and ordered early in the design process.  
The alabaster was also a lead item.
- 10. **Labor Issues**      None noted.
- 11. **Problems**      The Owner holds contracts with the GC, SE and Architects separately. This has caused a little trouble with the chain of command. Deadlines have been missed and pushed back repeatedly.
- 12. **Fortuitous Occurrences**      None noted.

**Organization Data**



- 1. **Owner**      Archdiocese of Los Angeles. They have an internal construction department that deals with a significant amount of construction throughout the archdiocese. However, they do not have the resources for a project of this size.
- 2. **A/E**      Raphael Moneo, Design Architect  
Leo Daly, Executive Architect
- 3. **Consultants**      Steggman and Kastner, PM (hired by Owner)
- 4. **GC or CM**      Morley Construction, GC
- 5. **Others**      None noted.
- 6. **Information Flow within the Project**      There are weekly meetings with the Owner, Designer, and Constructor. Also, there are monthly meetings with all of the parties.
- 7. **Previous Working Relationship**      None noted.



## APPENDIX 3: GENERAL CASE STUDY DATA SHEETS

### U.S. Army Research Laboratory at Aberdeen Proving Ground (Laboratory)

#### Contact Information and Project Summary

1. Name of Source "Clean Rooms to Explosion-Proof Testing Labs, Army Gets High-Tech Facility." ENR Magazine, December 21, 1998. Pg. B-101.

The \$63 million building is designed to serve some of the leading researchers in the military. It replaced the Materials Technology Laboratory, which developed major military products. The facility has 185 different laboratories ranging in size and application. Some were clean rooms and others were explosion proof. Nearly 50% of the project is mechanical, electrical, and specialty construction. Partnering was very important on this project.

The building is 292,000 SF. There is an administrative wing, science and engineering offices, a library, and laboratories. The labs have clear story heights of 8-20 feet to accommodate any size research project. There is a glass atrium that is a major design feature. There are large louvers to shade the large windows into the administrative offices. The building has an exposed steel frame that is non-combustible and 100% protected by a wet pipe automatic fire protection system. The lab space has an exterior closure of precast concrete inlaid with ceramic tile. The exterior glazing is double-paned and thermally insulated with thermally broken aluminum frames. Special coatings provided shading. The building is constructed with future needs in mind. Utilities were distributed along primary lines and labs had secondary lines.

#### Basic Project Data

1. Location Aberdeen Proving Ground, Maryland
2. Critical Systems MEP, specialty construction, special materials
3. Site-Specific Conditions The facility is located on an 80-acre site, on the crest of a hill.
4. Problems

#### Organization Data

1. Owner U.S. Army
2. A/E Benham Group, Oklahoma City, OK
3. Consultants Baltimore District Corps of Engineers, very active
4. GC or CM The Morganti Group, Danbury, CT.
5. Others

## Nancy Lee and Perry R. Bass Performance Hall (Performance)

### Contact Information and Project Summary

1. Name of Source "A Monument of World-Class Performance." ENR, December 21, 1998. B-48.

The Nancy Lee and Perry R. Bass Performance Hall is a \$65 million 10-story facility that is the home for the Fort Worth Symphony, opera, ballet, Van Cliburn Piano Competition. The funds for the building were all donations from the community. It was completed within budget and on schedule.

### Basic Project Data

1. Location Fort Worth, TX
2. Critical Systems Acoustical: finishes (ceiling), ductwork design and placement
3. Site-Specific Conditions
4. Problems

### Organization Data

1. Owner Sundance Square Management  
Edward Bass: Chairman for Board of Performing Arts, Fort Worth.
2. A/E David M. Schwartz/ Architectural Services, Inc: design architect  
HKS: Architect of Record  
Calloway Johnson Moore, PA: Program Architect
3. Consultants Theater: Fisher-Dachs Associates
4. GC or CM Linbeck Construction Corporation  
They provided initial cost and constructability analyses and construction management
5. Others Sculptor of statues: Marton Varo  
Murals: Scott and Stuart Gentling  
Acoustic: Jaffe Hold Scarbrough Acoustics, Inc.



## Bellagio Hotel (Hotel)

### Contact Information and Project Summary

1. Name of Source "Bellagio: The World's Most Expensive Hotel." ENR, December 21, 1998. B-82.

Bellagio Hotel is a \$1.6 billion 35-story hotel and casino with 2600 rooms and 400 suites. It also has convention space and retail space. The service systems were provided by EMCOR, the parent company of Hansen Mechanical. They have a significant amount of experience in building casinos within the Las Vegas area.

### Basic Project Data

1. Location Las Vegas, NV
2. Critical Systems Air handling system to simulate a smoke-free atmosphere and have the highest performance and installation.  
Roof to withstand wind loads.  
Man-made lake designed for water shows.
3. Site-Specific Conditions
4. Problems

### Organization Data

1. Owner Bear, Stearns & Co.
2. A/E Marnell Corrao Associates and Atlandia Desgin
3. Consultants
4. GC or CM Marnell Corrao (GC)
5. Others EMCOR  
ME Contractor: Hansen Mechanical Contractors, Inc.  
Roof supplier: Custom Panel Industries, Rancho Cucamonga, CA

## Robert C. Byrd U.S. Courthouse (Government)

### Contact Information and Project Summary

1. Name of Source "Courthouse Construction Earns High Accolades from Federal and Local Organizations." ENR Magazine, December 21, 1998. Pg. B-90.

The \$60 million 8-story, 425,000 SF structural steel building occupies an entire city block. It includes a multi-level underground parking garage, modern courtrooms, a pistol range, conference rooms, a law library and offices. The exterior consists of pre-cast concrete and custom windows. All parties participated in formal partnering sessions to establish a team purpose and goals. Alternatives were introduced.

### Basic Project Data

1. Location Charleston, WV
2. Critical Systems Architectural ornate aluminum cornice. Special scaffolding had to be hung because it was so high that ground scaffolding was not reasonable.
3. Site-Specific Conditions It was located in a downtown area and occupies over 90% of the site area. Two tower cranes were used simultaneously in order to avoid laydown. The exterior panels went up closely behind. This was a coordination challenge.
4. Problems

### Organization Data

1. Owner General Services Administration, housing the U.S. District Court and the Southern District of West Virginia.
2. A/E Skidmore, Owings & Merrill (NYC)
3. Consultants
4. GC or CM GC: Dick Corporation, (Pittsburgh, PA)  
CM: Day & Zimmerman (Philadelphia, PA)
5. Others

## Rough Creek Executive Retreat and Resort (Hotel)

### Contact Information and Project Summary

1. Name of Source "Five-Star Resort in the Lone Star State." ENR Magazine, December 21, 1998. Pg. B-102

The project was to build a five-star resort/conference center/retreat and no expense was spared. Exceptional architectural design and high quality construction was required. The original construction budget was determined by the architect to be \$3.5 million. The owner added scope and the budget grew to \$10.9 million. The GC had to be flexible to incorporate new scope into construction.

### Basic Project Data

1. Location Glen Rose, Texas
2. Critical Systems The ceiling plenum varied from 10-18 inches, which provided a challenge to coordinate ductwork, electrical, plumbing, and lighting systems. The mechanical sub developed a detailed set of HVAC ductwork shop drawings that included an overlay of many of the other systems. The design complexity required a high degree of precision and craftsmanship. This was a common goal of all parties. There were regularly scheduled job meetings, prompt and thorough shop drawing submittals, regular site visits by the architect, and daily involvement of the owner.
3. Site-Specific Conditions Site was a 5000-acre ranch. Rock excavation was necessary to install underground piping and an aerobic septic system. The piping systems were tiered within the trenches to minimize the lineal footage of excavation needed. A subsurface drainage system was necessary to control the runoff of the nearby hills.
4. Problems North Texas had a record amount of rain in the early stages of the project, delaying foundation and structural work. Also, they had to work during times of record heat.

### Organization Data

1. Owner John Adams, a private party.
2. A/E Lawrence Speck, Austin, TX
3. Consultants
4. GC or CM Thos. S. Byrne
5. Others

## **Boston Federal Courthouse (Government)**

### **Contact Information and Project Summary**

1. Name of Source "Sweeping Finish: Federal Courthouse Opens Within Budget." ENR Magazine, October 5, 1998. Page 7.

The \$219 million courthouse is 765,000 SF and has a complicated aluminum and glass curtainwall.

### **Basic Project Data**

1. Location Boston, MA
2. Critical Systems Glass Wall
3. Site-Specific Conditions
4. Problems

### **Organization Data**

1. Owner U.S. General Services Administration
2. A/E Pei Cobb Freed & Partners, NYC
3. Consultants SE: LeMessurier Consultants
4. GC or CM Clark Construction
5. Others Contractors for glass wall: Advanced Structures Inc., M&J Materials Inc., McGuire Steel Erection Inc., and Salem Glass Co.

## Thomas F. Eagleton Federal Courthouse (Government)

### Contact Information and Project Summary

1. Name of Source           Roosa, Jim and Paul Laskowske. "Holding Court." Civil Engineering Magazine, February 1999. Pages 62-64.

This \$186 million 29-story building was constructed using concrete-filled perimeter columns as a prime structural element. It is the largest federal courthouse in the U.S. at over 1 million SF. It will house 25 federal courts and offices for the FBI, U.S. Marshall Service and Members of Congress. It has seven different elevator systems dedicated to different uses.

### Basic Project Data

1. Location                    St. Louis, MO
2. Critical Systems
3. Site-Specific Conditions       Installation of columns and concrete pours at high elevations posed a challenge
4. Problems                    Temperature swings, deformed pipes

### Organization Data

1. Owner                        U.S. General Services Administration
2. A/E                          Hellmuth Obata and Kassabaum (HOK), St. Louis
3. Consultants
4. GC or CM                    Construction Team: Morse Diesel International, Chicago;  
CMR Construction Inc., St. Louis
5. Others                        Midwest Steel Erectors, Toronto  
Hammerts Iron Works Inc., St. Louis (steel fabricators)  
Stupp Brothers Bridge & Iron Co, St. Louis

## Center for Jewish History (Museum)

### Contact Information and Project Summary

1. Name of Source                      Tirnakli, Sukru and Ramon Gilsanz. "Structural Surgery." Civil Engineering Magazine, February 1999. Pages 56-59.

Four non-profit groups wished to combine four existing buildings into one headquarters. They were buildings of varying heights and shapes. The one building will consist of an auditorium, exhibit galleries, reading rooms, reception rooms, classrooms, offices, workrooms, book storage, archives, and a loading dock.

### Basic Project Data

1. Location                                New York, NY
2. Critical Systems                      The structural tying together of the four buildings so that it is architecturally attractive.
3. Site-Specific Conditions            Very constrained site in a landmark district.
4. Problems

### Organization Data

1. Owner                                    American Jewish Historical Society, Leo Baeck Institute, YIVO Research Institute, Yeshiva University Museum
2. A/E                                        Beyer Blinder Belle
3. Consultants                              SE: Gilsanz, Murray and Stepicek, NY
4. GC or CM                                Lehrer McGovern Bovis
5. Others

## Seaport Hotel (Hotel)

### Contact Information and Project Summary

1. Name of Source Angelo, William J. "Making a Sound Barrier Under Flight Path of Boston Airport." ENR Magazine, May 25, 1998. Pages 123-124.

This \$85 million 18-story hotel sits under the flight path of Logan International Airport. A great concern for the Owner was that the noise be eliminated in the interior of the building.

### Basic Project Data

1. Location Boston, MA
2. Critical Systems The soundproofing of the building was very important. Walls, windows, and crevices were accounted for.
3. Site-Specific Conditions
4. Problems

### Organization Data

1. Owner Commonwealth Flats Development
2. A/E The Stubbins Associates, Cambridge, MA
3. Consultants Acoustical Engineer: Cerami & Associates, NYC
4. GC or CM CM: Morse Diesel International
5. Others Glass Installation: Salem Glass Co.

## Santa Fe Opera House (Performance)

### Contact Information and Project Summary

1. Name of Source Fairweather, Virginia. "Santa Fe Sensation." Civil Engineering Magazine, May 1998. Pages 36-39.

This is a \$18 million renovation of an outdoor opera theater. It has exterior adobe walls, a fabric roof, and white steel masts and rods. Costs were a big issue because the facility had to be self-sufficient and performances could only be held seasonally. Structural members were reused to cut costs. Also, construction of different phases were done simultaneously to save money on equipment. Value engineering was also done on the steel to save costs in fabrication.

### Basic Project Data

1. Location Santa Fe, NM
2. Critical Systems The Owner wanted to retain the ambience of the outdoors without sacrificing acoustics. The engineers had to work together to create the shape of the fabric structure so that acoustics would be accounted for as well as the profile of the structure. Wind and snow loads made the design of the fabric structure difficult. Also, construction loads required a special erection sequence.
3. Site-Specific Conditions
4. Problems

### Organization Data

1. Owner Santa Fe Opera
2. A/E Polshek and Partners Architects, NYC
3. Consultants Ove Arup & Partners, NYC  
Acoustics: Purcell & Noppe, CA
4. GC or CM Manhattan Construction, Dallas
5. Others Steel Erector: Derr Construction Co., Dallas



## Wachovia Bank Headquarters (Office)

### Contact Information and Project Summary

1. Name of Source Sawyer, Tom. "Big-League 'Bench Pressing' Lifts Factory's 1,500-Ton Second Story." ENR Magazine, January 19, 1998. Pages 47-48.

Owner found out that lifting a 37,000 SF floor up and building one more floor would be more economical than demolishing one floor and building two. The floor was separated from the columns and lifted 8.5 feet. Then the floor was reattached to the columns at the higher elevation. This also saved time so that the Owner could occupy the building earlier.

### Basic Project Data

1. Location Winston-Salem, NC
2. Critical Systems The lifting process was critical
3. Site-Specific Conditions
4. Problems

### Organization Data

1. Owner Wachovia Bank
2. A/E Walter, Robbs Callahan & Pierce Architects, Winston-Salem
3. Consultants SE: Phil Levine, Cummings, GA
4. GC or CM GC: Frank L. Blum Construction Co.
5. Others Liftplate International Inc., Miami

## Midwest Express Center (Convention)

### Contact Information and Project Summary

1. Name of Source            Kissinger, John H. "Express Design." Civil Engineering Magazine, August 1998. Pages 40-43.

This \$170 million 670,000 SF convention center was built in two phases. The first phase was to be in July 1998 in time for the city to host the National Conference of Governors. A design-build team called the Cream City Associates competed for and won the project.

All together, the facility includes 218,000 SF of exhibition space, a 30,000 SF ballroom, two upper decks, 2,800 SF of meeting rooms, kitchen facilities, atrium areas, and a loading dock.

### Basic Project Data

1. Location                    Milwaukee, WI
2. Critical Systems            Supplying power to the exhibition space required close coordination with the other systems. The engineers worked with the manufacturer to design a partitioned floor box that contained electrical, voice, data, water, and compressed air.
3. Site-Specific Conditions    The site had to be cleared of several major structures and the Owner had to complete environmental remediation. There were lots of utilities located under a street down the middle of the site. This was left alone. The swampy site required piles.
4. Problems

### Organization Data

1. Owner                      Wisconsin Center District
2. A/E                         Managing Architect: Engberg Anderson Design Partnership, Milwaukee  
Design Architect: Thompson, Ventulett, Stainback & Associates, Atlanta
3. Consultants                SE: Graef, Anhalt, Schloemer & Associates  
MEP: Affiliated Engineers Inc., Madison, WI
4. GC or CM                  Clark Construction Group, MD  
Hunzinger Construction, Milwaukee
5. Others

## Huntington Memorial Hospital (Medical)

### Contact Information and Project Summary

1. Name of Source Rosta, Paul. "Planning Ahead Eases Pain." ENR Magazine, December 14, 1998. Page 23

This was a \$28 million addition to the hospital. This addition was planned as a second phase so a footing was built under the hospital for use by the crane when construction would begin at a later date. This foresight prevented a logistical nightmare. The construction was phased for financial reasons.

### Basic Project Data

1. Location Pasadena, CA
2. Critical Systems
3. Site-Specific Conditions Construction was taking place over 18 functional operating rooms so the most disruptive work was scheduled at night.
4. Problems OSHPD required that a retrofit be done on the existing structure before the addition could begin.

### Organization Data

1. Owner Huntington Memorial Hospital
2. A/E HDR Architecture Inc., Omaha, NE
3. Consultants
4. GC or CM GC: McCarthy
5. Others

## Electronic Arts Headquarters (Office)

### Contact Information and Project Summary

1. Name of Source "A New State-of-the-Technology Campus for Electronic Arts." ENR, December 21, 1998. Page B-77.

The Owner had to move in on September 1, 1998. Therefore, the first phase of the new \$76 million campus had to be completed. This phase was an 8-story 210,000 SF office building, a 6-story 150,000 SF office building, a 50,000 SF commons, and a 208,000 SF 4-story parking garage. Early in the project a strong team was formed to identify cost-saving elements. New materials and construction techniques were identified and used. Steel-framed buildings were chosen. An extremely detailed schedule was made so that work could be planned and labor acquired.

### Basic Project Data

1. Location Redwood City, CA
2. Critical Systems
3. Site-Specific Conditions
4. Problems

### Organization Data

1. Owner Electronic Arts
2. A/E
3. Consultants
4. GC or CM CM/GC: Webcor Builders
5. Others

## San Francisco U.S. Customs House (Government)

### Contact Information and Project Summary

1. Name of Source "Seismic Overhaul Preserves Historic Customhouse." Civil Engineering Magazine, February 1998. Page 14.

The \$17 million seismic retrofit of the custom house replaced walls but preserved the building's historical appearance.

### Basic Project Data

1. Location San Francisco, CA
2. Critical Systems The finishes and cladding were essential to this project. They were removed and cataloged so that they could be replaced. Also, 70-foot piles had to be driven through the lobby floor. When completed, the finishes and cladding were replaced and any damage was repaired so that construction was not detectable.
3. Site-Specific Conditions The pile driver had to be brought into the building, the area cleared and secured, and the piles driven in sections and then welded together.
4. Problems

### Organization Data

1. Owner
2. A/E
3. Consultants SE: URS Greiner, San Francisco
4. GC or CM GC: Morse Diesel International, Chicago
5. Others

## Roanoke Island Festival Park Center (Museum)

### Contact Information and Project Summary

1. Name of Source "Timber Trusses Span Cultural Center." Civil Engineering Magazine, February 1998, Page 20.

The greatest concern for this \$6 million museum was that it be strong enough to resist hurricane-force winds. The building had to have a large span for large exhibits like lighthouses and boats. Also, the 37,000 SF center includes exhibit space, a 250-seat theater, meeting rooms, and office space.

### Basic Project Data

1. Location Manteo, NC
2. Critical Systems Massive glulam trusses were part of the structural system used to resist hurricane-force winds.
3. Site-Specific Conditions The building was in a hurricane zone.
4. Problems

### Organization Data

1. Owner North Carolina Cultural Resources Department
2. A/E Dove & Knight Architects, Rocky Mount, NC
3. Consultants SE: Stewart Engineering, Research Triangle Park, NC
4. GC or CM
5. Others

## Baltimore/ Washington International Airport Expansion (Airport)

### Contact Information and Project Summary

1. Name of Source Mukhopadhyay, Chirantan and Emory W. Carrigan. "Scheduled Departure." Civil Engineering Magazine, April 1998. Pages 48-50.

The \$125 million expansion included a new international wing with a light-rail connection to Baltimore, expanding the garage, and expanding the departure road. Work had to be done on both sides of the airport road without disrupting airport operations. Even though there were different contracts, the contractors were coordinated so that work could proceed on an aggressive schedule to avoid construction during holiday seasons.

### Basic Project Data

1. Location Outside Baltimore, MD
2. Critical Systems Utility relocation was a really important portion of the roadway part of the project. Test pits were dug to locate the utilities.
3. Site-Specific Conditions Construction had to be worked out so that the contractors would have enough room to do the work in a congested area. Holes were cut into the parking garage slabs in order for a tower crane to fit in the area. This saved some space and time on the schedule.
4. Problems

### Organization Data

1. Owner Maryland Aviation Administration
2. A/E Joint Venture: STV Group and William Nicholas Bodouva & Associates (Roadway and International Terminal)  
URS Greiner, Timonium, MD (Parking Garage)
3. Consultants
4. GC or CM CM: Parsons Infrastructure & Technology Group, Pasadena, CA  
GC: IA Construction Corp, Concordville, PA (Roadway)  
GC: Clark Construction Group, Bethesda, MD (International Terminal and Parking Garage)
5. Others

## Discovery Center (Museum)

### Contact Information and Project Summary

1. Name of Source            Rosenbaum, David B. "Angles Jab at Constructibility." ENR Magazine, January 26, 1998. Pages 24-26.

This \$5.5 million single story building has a very complicated geometry, making it difficult to represent on paper and to construct.

### Basic Project Data

1. Location                    Kartchner Caverns State Park, AZ
2. Critical Systems            The geometry of the building was difficult to recreate. Several different coordinate systems had to be used and different building trades had to coordinate in order for the building to come together.
3. Site-Specific  
Conditions
4. Problems

### Organization Data

1. Owner                        Kartchner Caverns State Park
2. A/E                            Vernon Swaback Associates, Scottsdale, AZ
3. Consultants
4. GC or CM                    GC: Diversified Design & Construction Inc.
5. Others



## Bank One Ball Park (Stadium)

### Contact Information and Project Summary

1. Name of Source Rosenbaum, David B. "Seeing Red Over Green." ENR Magazine, February 9, 1998. Pages 30-33.

The \$354 million baseball stadium was scheduled on fast track so there were nine phased, overlapping contracts.

### Basic Project Data

1. Location Phoenix, AZ
2. Critical Systems The retractable roof was extremely difficult to analyze because of the several load conditions that had to be considered.
3. Site-Specific Conditions The fluctuating temperatures caused the large trusses to expand and contract, making alignment a big problem.
4. Problems

### Organization Data

1. Owner Bank One, Arizona Diamondbacks, Maricopa County
2. A/E Ellerbe Becket
3. Consultants Air Conditioning: M-E Engineers, Wheat Rdige, CO  
SE: Martin/Martin, Wheat Ridge, CO
4. GC or CM CM: Huber Hunt & Nichols Inc., Indianapolis  
GC: Joint Venture: Perini Corp. and McCarthy (foundation, corner towers, fixed trusses).
5. Others

## Royce Hall Seismic Retrofit (Performance)

### Contact Information and Project Summary

1. Name of Source Rosta, Paul. "College Landmark's Rehab is Lesson in Climbing the Walls." ENR Magazine, April 6, 1998. Pages 20-21.

This \$68.3 million retrofit was an emergency job that was done after the Northridge earthquake. A system of shear walls were installed within existing walls of a building that was very irregular in shape from a seismic strengthening standpoint.

### Basic Project Data

1. Location Westwood, CA
2. Critical Systems The finishes and the enclosure had to be preserved for historical reasons. Items were photographed, recorded, and stored while strengthening was done.
3. Site-Specific Conditions Construction had to occur during the school year so deliveries and operations could not disrupt the student activities.
4. Problems

### Organization Data

1. Owner
2. A/E Executive Architect: Anshen & Allen  
Local Design Architect: Barton Phelps & Associates
3. Consultants SE: John A. Martin & Associates
4. GC or CM Morley Construction Co, Santa Monica
5. Others

## Hawaii Convention Center (Convention)

### Contact Information and Project Summary

1. Name of Source Rosta, Paul and Nadine M. Post. "It Takes Great Panes to Blur the Distinction between Inside and Out." ENR Magazine, April 20, 1998. Pages 98-100.

The \$200 million, 1.1 million SF convention center is characterized by a glass wall and a series of steel "trees", which have skylights and fabric sails.

### Basic Project Data

1. Location Honolulu, HI
2. Critical Systems 540-foot long, 60-foot tall suspended glass wall that zigzags throughout the building.
3. Site-Specific Conditions The limited space and winds made it very difficult to assemble the portions of the glass wall. In order to avoid problems, the assembly was done in the exhibit space of the building.
4. Problems

### Organization Data

1. Owner Hawaii
2. A/E LMN Architects and Wimberly Allison Tong & Goo
3. Consultants SE: Skilling Ward Magnusson Barkshire, Seattle
4. GC or CM Design-build team is a joint venture between PCL Construction Services, Seattle, and Nordic Construction Ltd., Honolulu.
5. Others Apex Curtain Wall Group, Temecula, CA

## North Carolina Museum of Natural Science (Museum)

### Contact Information and Project Summary

1. Name of Source "Ingenuity Conquers Museum's Construction Problems." ENR Magazine, May 18, 1998. Page C-37.

This 147,000 SF museum has 2 floors below grade and 5 above. The total cost of the building was \$30 million.

### Basic Project Data

1. Location Raleigh, NC
2. Critical Systems
3. Site-Specific Conditions The new building was being constructed only 5 feet away from an existing building that did not have a basement. Also, another neighboring building was under construction and had caused the existing building to tilt. The existing building had to be shored using a mini-pile system.
4. Problems

### Organization Data

1. Owner
2. A/E R.W. Carr, Durham, NC  
Verner Johnson And Associates, Boston
3. Consultants Soils: Schnabel Engineering Co., Atlanta  
SE: Gardner & McDaniel, Durham, NC
4. GC or CM GC: Davidson Jones Beers, Atlanta
5. Others

## Providence Place Mall (Retail)

### Contact Information and Project Summary

1. Name of Source Angelo, William J. "Mall Site's Complex Features Require Unusual Underpinning." ENR Magazine, September 7, 1998. Pages 20-21.

This \$455 million project includes 1.5 million SF of retail space and 2.5 million SF of parking.

### Basic Project Data

1. Location Providence, RI
2. Critical Systems Deep foundations were necessary because of the project's location near the Woonasquatucket River and 5 rail tracks. Caissons were new to the area so equipment had to be obtained from Florida and a specialist was brought in from Quincy, MA. Also, pre-cast concrete piles were driven.
3. Site-Specific Conditions The Amtrak rail company required that the construction be done at night. The schedule was coordinated to that construction occurred between train operations.
4. Problems

### Organization Data

1. Owner Commonwealth Development Group LLC
2. A/E
3. Consultants SE: McNamaraa/ Salvia Inc., Boston
4. GC or CM CM: Gilbane (did not finish project)  
GC: Morse Diesel International Inc. (finished the project)
5. Others Steel Sub: American Bridge Co., Pittsburgh  
Caissons: New England Foundation Co. Inc, Quincy, MA

## Los Angeles City Hall Seismic Rehabilitation (Government)

### Contact Information and Project Summary

1. Name of Source Taylor, C. Maria. "The Remaking of L.A. City Hall." F.W. Dodge California Construction Link, November 1998. Pages 4-10.

The building was fitted with seismic isolators at the base of the building and with new sheer walls throughout the building. The rehabilitation and historical preservation project had a total cost of \$112 million.

### Basic Project Data

1. Location Los Angeles, CA
2. Critical Systems The sheer walls had to fit inside of existing walls. There was a lot of rebar that had to fit in the small spaces and it was difficult to get the concrete to flow in between the bars. The installation of isolators and construction of sheer walls had to be coordinated to maintain the structural stability of the building. Access to the bases of the columns was a challenge.
3. Site-Specific Conditions The building is the 911 emergency center for the City of Los Angeles and needed to remain active 24 hours a day. Construction could not disrupt operations.
4. Problems

### Organization Data

1. Owner City of LA
2. A/E Albert C. Martin and Associates
3. Consultants SE: Nabih Youssef and Associates  
Owner's Representative: Lehrer McGovern Bovis, Inc.  
Historical Preservation Architect: Levin and Associates
4. GC or CM GC: Clark Construction Group
5. Others  
Concrete sub: Conco  
Isolator installer: Bigge Crane and Rigging Company

## Safeco Field (Stadium)

### Contact Information and Project Summary

1. Name of Source            Daniels, Stephen H. "Let the Sun Shine In." ENR Magazine, March 8, 1999. Pages 36-40.

This \$498 million ballpark with a retractable roof is the most expensive stadium in U.S. history. The schedule was extremely demanding and made cost overruns occur. The Structural Engineer and the CM/GC collaborated to make changes in the roof and in making the structure more constructable and reduce cost.

### Basic Project Data

1. Location                    Seattle, WA
2. Critical Systems            The retractable roof was designed for moving loads, seismic loads, and snow loads. It also has seismic dampers to reduce the size of the members required for the runway on which the roof moves.
3. Site-Specific Conditions    The workers had to work about a set of train tracks. When the trains came, work had to be stopped for safety reasons. The other three sides of the stadium are constrained by busy city streets.
4. Problems

### Organization Data

1. Owner                      Safeco, Seattle Mariners and the Seattle Public Facilities District
2. A/E                         NBBJ
3. Consultants                SE: Skilling Ward Magnusson Barkshire
4. GC or CM                  CM/GC Joint Venture: Huber, Hunt, Nichols/ Kiewit Construction Co.
5. Others                      The Erection Co.





## APPENDIX 4: COMPLEXITY MATRICES

TABLE A.1: DETAILED CASE STUDIES

Project Name	Complexity Type	Complexity Name	Integration Mechanism
Project 1: Amgen Cell Culture Building Addition in Thousand Oaks, CA	Intra-System: High	Equipment	Specialist, Information Exchange, Collaboration
	Intra-System: High	Process Control System	Specialist
	Functional Inter-System: High	Process Controls with Equipment	Information Exchange, Coordination, Collaboration
	Spatial Inter-System: High	Services, Enclosure, Finish	Coordination
	Logistics on Site: Medium	Lots of Concurrent Construction	Coordination
	Site Special Conditions: Medium	El Nino	Coordination
	Contract Management: High	Owner Holds Contracts	Coordination
	Project Objectives: High	Fast Schedule	Information Exchange, Coordination
Project 2: Princess Cruises Office Tenant Improvements in Valencia, CA	Social Issues: High	Validation	Information Exchange
	Intra-System: High	Data Center	Specialist
	Functional Inter-System: Low	None	No
	Spatial Inter-System: Low	None	Coordination
	Logistics on Site: Low	None	No
	Site Special Conditions: Medium	Trouble with Piles	Information Exchange
	Contract Management: High	Contracts	Coordination
Project 3: Mt. San Antonio College Performing Arts Center in Walnut, CA	Project Objectives: High	Shell Construction Late: Compressed Schedule	Coordination
	Social Issues: High	Inspector	Information Exchange
	Intra-System: Medium	Staging/ Theater	Specialist
	Functional Inter-System: Medium	Acoustics with MEP	Coordination, Collaboration
	Spatial Inter-System: Medium	Not Enough Room for HVAC	Coordination
	Logistics on Site: Low	None	No
	Site Special Conditions: Medium	El Nino	Coordination
Project 4: Metropolitan Water District Headquarters in Los Angeles, CA	Contract Management: Low	None	No
	Project Objectives: High	Cost Escalation	Collaborate
	Social Issues: High	Work with State Architects Office	Information Exchange
	Intra-System: High	Software-Controlled Building Management System	Specialist, Collaboration
	Intra-System: High	Structural Splicing Technique	Specialist, Information Exchange, Collaboration
	Functional Inter-System: High	Construction Methods for Structure and Enclosure	Collaboration
	Spatial Inter-System: Low	None	No
	Logistics on Site: High	Site Access	Coordination
Project 5: Carbam in Los Angeles, CA	Site Special Conditions: Medium	El Nino	Coordination
	Contract Management: Low	None	No
	Project Objectives: High	Cost	Information Exchange, Collaboration
	Project Objectives: High	Documentation Required	Information Exchange
	Social Issues: High	Archeological Find	Information Exchange, Coordination
	Intra-System: Low	None	No
	Functional Inter-System: Low	None	No
	Spatial Inter-System: Low	None	No
Logistics on Site: Low	None	No	
Project 5: Carbam in Los Angeles, CA	Site Special Conditions: High	Uncertified Fill	Specialist
	Contract Management: Low	None	No
	Project Objectives: Low	None	No
	Project Objectives: Low	None	No
	Social Issues: Low	None	No

Project 6: Arcadia Methodist Hospital Patient Wing Replacement in Arcadia, CA	Intra-System: High	Medical Equipment	Specialist	
	Intra-System: High	Special Moment Frame Connection	Specialist	
	Intra-System: High	Nurse Call System	Specialist, Collaboration	
	Functional Inter-System: Low	None	No	
	Spatial Inter-System: Medium	Equipment and Structure	Information Exchange, Coordination	
	Spatial Inter-System: High	Patient Headboard	Coordination	
	Logistics on Site: Medium	Steel Difficult to Transport	Coordination	
	Site Special Conditions: Medium	El Nino	Coordination	
	Contract Management: Low	None	No	
	Project Objectives: Low	None	No	
	Social Issues: High	OSHPD	Information Exchange	
	Intra-System: High	Finishes	Collaboration	
	Project 7: Metropolitan Transit Authority Headquarters in Los Angeles, CA	Intra-System: High	Structural Redesign	Information Exchange
Intra-System: High		Data/ Telephone	Specialist	
Functional Inter-System: Low		None	No	
Spatial Inter-System: Low		None	No	
Logistics on Site: Low		None	No	
Site Special Conditions: High		Contamination	Specialist	
Contract Management: Low		None	No	
Project Objectives: Medium		Scheduling Mistake By Owner	Coordination	
Social Issues: Low		None	No	
Project 8: Chevron Blending and Shipping Control Building in El Segundo, CA		Intra-System: High	Computer System	Specialist
		Intra-System: Medium	Interior Finish	Information Exchange, Collaboration
	Intra-System: High	Sensored HVAC	Specialist	
	Functional Inter-System: Low	None	No	
	Spatial Inter-System: Medium	Computer Must Fit	Information Exchange, Coordination	
	Logistics on Site: Low	None	No	
	Site Special Conditions: Medium	Contamination	Specialist	
	Site Special Conditions: Medium	El Nino	Coordination	
	Contract Management: Low	None	No	
	Project Objectives: Medium	Schedule	Coordination	
	Social Issues: Low	None	No	
Project 9: Rocketdyne Headquarters Renovation in Canoga Park, CA	Intra-System: Low	None	No	
	Functional Inter-System: High	Interior and Structural Objectives Conflict	Information Exchange, Collaboration	
	Spatial Inter-System: Low	None	No	
	Logistics on Site: High	Access and a Dustfree Environment for the Owner	Coordination	
	Site Special Conditions: High	Poor Existing Documentation	Information Exchange	
	Contract Management: Low	None	No	
	Project Objectives: High	Schedule Had to Work Around Launches	Coordination	
	Social Issues: Low	None	No	
Project 10: Warner Brothers Sound Stage in Burbank, CA	Intra-System: Low	None	No	
	Functional Inter-System: High	Construction of Tilt-Up and Columns	Collaboration	
	Spatial Inter-System: Low	None	No	
	Logistics on Site: Medium	Difficult to Transport Trusses	Coordination	
	Logistics on Site: Medium	Stop for Taping	Coordination	
	Site Special Conditions: High	Fill and Sewage Outfall	Specialist, Information Exchange, Coordination, Collaboration	
	Contract Management: Medium	Owner Holds All Contracts	Coordination	
	Project Objectives: Low	None	No	
	Social Issues: Low	None	No	

Project 11: Kaiser Medical Facility in Otay Mesa, CA	Intra-System: High	New Moment Frame Connections	Specialist, Collaboration
	Functional Inter-System: Low	None	No
	Spatial Inter-System: High	MEP	Coordination, Collaboration
	Logistics on Site: Medium	Construction During Operations	Coordination
	Site Special Conditions: High	El Nino	Coordination
	Site Special Conditions: Medium	Move Mountain of Dirt	Specialist
	Contract Management: Medium	Problems with Distrust	Information Exchange, Collaboration
	Project Objectives: High	Schedule	Coordination, Collaboration
Project 12: Casa San Juan in Oxnard, CA	Social Issues: Low	None	No
	Intra-System: Low	None	No
	Functional Inter-System: Low	None	No
	Spatial Inter-System: Low	None	No
	Logistics on Site: Low	None	No
	Site Special Conditions: Low	None	No
	Contract Management: Low	None	No
	Project Objectives: Low	None	No
Project 13: 77 <sup>th</sup> Street Police Station in Watts, CA	Social Issues: Low	None	No
	Intra-System: High	Detention Hardware	Specialist, Coordination
	Functional Inter-System: Low	None	No
	Spatial Inter-System: Low	None	No
	Logistics on Site: High	No Staging Near School	Coordination
	Site Special Conditions: High	Contamination	Specialist, Coordination
	Contract Management: High	Labor Problem	Information Exchange
	Contract Management: High	Owner's Negative Attitude toward Construction	Information Exchange
	Contract Management: High	Electrical Sub's Claims	Information Exchange
	Project Objectives: High	Schedule	Coordination
Project 14: Parcel 1, Cerritos Office Building in Cerritos, CA	Social Issues: High	Bad Neighborhood	Information Exchange
	Social Issues: High	Lots of Community Interest	Information Exchange
	Intra-System: Low	None	No
	Functional Inter-System: High	Cladding with Structure	Specialist, Collaboration
	Spatial Inter-System: Low	None	No
	Logistics on Site: Low	None	No
	Site Special Conditions: Medium	El Nino	Coordination
	Contract Management: High	Many Changes In Staff	Information Exchange
Project 15: Delta Dental Office Expansion in Cerritos, CA	Project Objectives: High	Cost Escalation	Collaboration
	Social Issues: Low	None	No
	Intra-System: Low	None	No
	Functional Inter-System: Low	None	No
	Spatial Inter-System: Low	None	No
	Logistics on Site: Low	None	No
	Site Special Conditions: Medium	El Nino	Coordination
	Contract Management: High	Many Changes In Staff	Information Exchange
Project 16: City of Hope Diabetes Research Center in Duarte, CA	Project Objectives: High	Cost Escalation	Collaboration
	Social Issues: Low	None	No
	Intra-System: High	Medical Gas System	Specialist
	Intra-System: High	Structure	Specialist
	Intra-System: High	Lab Equipment	Specialist
	Functional Inter-System: Low	None	No
	Spatial Inter-System: High	Heavy MEP	Coordination
	Logistics on Site: Low	None	No
	Site Special Conditions: Low	None	No
	Contract Management: Medium	Steel Dispute	Coordination
	Project Objectives: High	Schedule	Coordination
	Project Objectives: Medium	Over Budget	Collaboration
	Social Issues: Medium	Design for Future	Information Exchange, Collaboration
Social Issues: Medium	Co-Energization	Coordination	
Social Issues: High	OSHPD	Information Exchange	
Social Issues: Medium	No Smoking	Information Exchange	

Project 17: Our Lady of the Angels Cathedral in Los Angeles, CA	Intra-System: High	Seismic Isolation	Specialist, Information Exchange
	Intra-System: High	Architecture	Specialist, Collaboration
	Intra-System: High	Windows	Specialist, Information Exchange, Collaboration
	Functional Inter-System: High	Acoustics	Specialist, Information Exchange, Collaboration
	Functional Inter-System: High	Architecture and Structure are Unified	Information Exchange, Collaboration
	Spatial Inter-System: Low	None	No
	Logistics on Site: Medium	Tight Site	Information Exchange, Coordination
	Site Special Conditions: Low	None	No
	Contract Management: High	All Design Contracts Held By Owner	Information Exchange
	Contract Management: High	Foreign Designer	Information Exchange
	Project Objectives: High	Behind Schedule	Coordination
	Project Objectives: High	Over Budget	Collaboration
	Project Objectives: High	Permitting Done in Phases	Coordination
Social Issues: High	Protesters	Information Exchange	

TABLE A.2: GENERAL CASE STUDIES

Project Name	Complexity Type	Complexity Name	Integration Mechanism
1. U.S. Army Research Laboratory at Aberdeen Proving Ground, MD	Intra-System: High	MEP	Collaboration
	Intra-System: High	Specialty construction	Collaboration
	Intra-System: High	Use of special materials	Collaboration
2. Nancy Lee and Perry R. Bass Performance Hall in Fort Worth, TX	Functional Inter-System: High	Acoustics	Specialist, Coordination
3. Bellagio Hotel in Las Vegas, NV	Intra-System: High	Powerful air handling system	Specialist
	Intra-System: High	Structural design	Specialist
	Intra-System: High	Man-made lake for shows	Specialist
4. Robert C. Byrd U.S. Courthouse in Charleston, WV	Logistics on Site: High	Tight site	Collaboration
5. Rough Creek Executive Retreat and Resort in Glen Rose, TX	Spatial Inter-System: High	Not much room in ceiling for services	Coordination
	Site Special Conditions: High	Difficult soil conditions	Coordination
	Project Objectives: High	High quality demands	Coordination
6. Boston Federal Courthouse in Boston, MA	Intra-System: High	Curving Glass Wall	Specialist
7. Thomas F. Eagleton Federal Courthouse in St. Louis, MO	Logistics on Site: High	Massive structural members had to be erected on tall building	Coordination
8. Center for Jewish History, New York, NY	Intra-System: High	Structural Challenges	Specialist, Collaboration
	Spatial Inter-System: High	Architectural and Structural differences between adjacent buildings	Coordination
9. Seaport Hotel in Boston, MA	Intra-System: High	Soundproofing	Specialist
10. Santa Fe Opera House in Santa Fe, NM	Intra-System: High	Design of odd-shaped structure for wind loads	Specialist
	Intra-System: High	Construction of Structural system	Specialist, Coordination, Collaboration
	Functional Inter-System: High	Acoustics and Architectural conflicts	Collaboration
	Project Objectives: High	Budget and the schedule's effect on cost	Coordination, Collaboration
11. Wachovia Bank Headquarters in Winston-Salem, NC	Intra-System: High	Lifting of floor	Specialist
	Project Objectives: High	Budget	Specialist, Coordination

12. Midwest Express Center in Milwaukee, WI	Spatial Inter-System: High	Delivery of services to the large exhibit space	Coordination, Collaboration
	Site Special Conditions: High	Contamination	Specialist
13. Huntington Memorial Hospital in Pasadena, CA	Logistics on Site: High	Construction during the operations of the hospital	Coordination
	Project Objectives: High	Phasing of construction for financial reasons	Coordination
14. Electronic Arts Headquarters in Redwood City, CA	Project Objectives: High	Budget	Collaboration
	Project Objectives: High	Schedule	Coordination
15. San Francisco U.S. Custom House in San Francisco, CA	Logistics on Site: High	Had to drive piles in the lobby	Specialist, Coordination
	Project Objectives: High	Historical preservation	Coordination
16. Roanoke Island Festival Park Center in Manteo, NC	Intra-System: High	Structural design for hurricane-force winds	Specialist
17. Baltimore/Washington International Airport Expansion in Baltimore, MD	Logistics on Site: High	Construction during airport operations	Information Exchange, Coordination, Collaboration
	Site Special Conditions: High	Unmarked utilities under site	Specialist, Information Exchange, Coordination, Collaboration
	Project Objectives: High	Schedule	Coordination
18. Discovery Center at Kartchner Caverns State Park, AZ	Intra-System: High	Building shape was difficult	Information Exchange, Coordination, Collaboration
	Spatial Inter-System: High	Building geometry made it hard to match interior plans	Coordination
19. Bank One Ball Park in Phoenix, AZ	Intra-System: High	Retractable roof	Specialist
	Site Special Conditions: High	Thermal expansion of steel members	Specialist, Coordination
	Contract Management: High	Several separate contracts	Coordination
20. Royce Hall Seismic Retrofit in Westwood, CA	Intra-System: High	Irregular shape meant difficult design	Specialist
	Logistics on Site: High	Tight site located on a college campus	Coordination
	Project Objectives: High	Historical preservation	Information Exchange, Coordination
21. Hawaii Convention Center in Honolulu, HI	Intra-System: High	Glass wall	Specialist, Coordination
	Logistics on Site: High	Needed safe space to assemble glass panes	Coordination
22. North Carolina Museum of Natural Sciences in Raleigh, NC	Site Special Conditions: High	Neighboring building was sinking	Specialist
23. Providence Place Mall in Providence, RI	Intra-System: High	Caissons not usual to the area	Specialist
	Logistics on Site: High	Neighbor required night construction	Coordination
	Contract Management: High	Change in CM	Collaboration
24. Los Angeles City Hall in Los Angeles, CA	Intra-System: High	Congested rebar and no little space for concrete to flow	Specialist
	Functional Inter-System: High	Sequencing requirements for isolators and sheer wall installation to maintain structural integrity	Coordination
	Logistics on Site: High	Access to column base	Coordination
	Logistics on Site: High	Building had to be operational 24-hour per day	Coordination
25. Safeco Field in Seattle, WA	Intra-System: High	Demanding structural design of retractable roof	Specialist
	Intra-System: High	Large trusses would be unstable during construction	Collaboration
	Logistics on Site: High	Work had to be done over train tracks	Coordination
	Project Objectives: High	Schedule was aggressive	Coordination
	Project Objectives: High	Costs were running high and needed to be cut	Coordination, Collaboration



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