ANALYSIS AND OPTIMIZATION OF MEGAPROJECT PERFORMANCE

By

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To my uncle, mom, dad, and all who had faith in me

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LIST OF ABBREVIATIONS

DOT	Department of Transportation
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FTA	Federal Transit Administration
IMEC	International Program in the Management of Engineering and Construction
IPO	Integrated Project Organization
MOT	Management of Traffic
MTA	Massachusetts Turnpike Authority

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Large scale complex projects commonly known as megaprojects suffer from poor managerial performance that results in enormous cost overruns and time extensions. Several researchers of different management fields have attempted to improve megaprojects' time and cost performance. However, the methodologies provided do not constitute tangible solutions that could be used to improve megaprojects' managerial as well as project performance.

The research aims to optimize megaproject project performance by providing work practices that are capable of handling megaprojects' managerial difficulties caused by the dynamic and parallel operation of numerous interrelated workgroups. Two methods are provided to achieve megaproject performance optimization. The first method is a decision model that determines the optimal work practices based on predetermined management objectives. The model was developed from case studies that determined the work practices and a survey that evaluated them. The second method is a planning process for optimizing the management organization. The process was developed from the case studies' lessons learned and conclusions drawn from the survey evaluations. The proposed benefits of using the methods include improved megaproject cost, time,

and quality performance. Benefits also include improved managerial performance through optimal allocation of duties and responsibilities, streamlined management processes, and better integration and coordination. Most important, the methods provide construction practitioners a decision support system to determine the optimal work practices that suit their capabilities and management objectives.

CHAPTER 1
INTRODUCTION

Throughout history, construction projects have had a huge impact on the economy, welfare, and advancement of different civilizations. Enormous landmarks were constructed to signify the wealth and supremacy of many civilizations. Even in the present time, enormous undertakings that have been considered as unattainable marvels are being constructed at an incremental pace. The present-day common knowledge refers to such undertakings as megaprojects. Megaprojects are unique construction projects known for their complexity, vast size, expensive cost, and long time frame compared to conventional construction projects. The size and complexity are reflected by a price tag that exceeds one billion dollar and a time frame that may exceed the five year limit. However, constructing megaprojects is neither simple nor trouble-free. Megaprojects are known for their poor performance in terms of cost and time where the cost overrun could exceed initial project cost and the time extension could extend for years. There are numerous examples of megaprojects that were built and performed poorly. The most famous project is the Channel Tunnel which initially cost 2.6 billion pounds in 1985 and led to 80% cost overrun (Flyvbjerg et al., 2003). Another example is the Boston artery “Big Dig” project, where an elevated highway was replaced with an underground tunnel. The project was estimated in 1985 to cost $2.8 billion but was completed with over $14.6 billion (Reina et al., 2002). The most well-known problematic megaprojects are nuclear power plants where the cost overruns of plants built between years 1966 to 1977 averaged to 200% (Energy Information Administration, 1986).

Problem Definition

Megaprojects' poor performance attracted researchers from different management fields such as public planning, urban decision making, and economic analysis fields. Nevertheless, limited research has been done in the construction industry to analyze megaproject's poor performance. Therefore, there was a need to define and analyze megaprojects from the construction management point of view.

Compared to conventional projects, megaprojects require much more resources, organizations, and workgroups to handle the project's size and complexity. The dynamic and parallel operation of the large number of interrelated workgroups imposes great managerial difficulties that cannot be handled by conventional work practices, leading to poor project performance. Therefore, there was a need to investigate, analyze, and evaluate work practices that were applied on megaprojects to determine their effect on project performance. More importantly, there was a need for a methodology that would provide tangible and empirically tested management solutions which would handle megaprojects' managerial difficulties and optimize project performance.

Solution Overview

The solution proposes a two part methodology that would assist construction professionals in optimizing megaproject performance. The first part consists of a decision model for selecting the optimal work practices based on predetermined performance objectives since there is no optimal solution that is capable of solving all of megaprojects' problems. The second part provides recommendations and guidelines to plan and refine the management organization in the most effective way. Five main steps were performed to analyze megaprojects and develop the solution.

The first step was to clearly define megaprojects and differentiate them from conventional projects. A theoretical definition was devised based on a theoretical size-complexity framework. In addition, an industry definition was devised based on the views and opinions of professionals who have worked on megaprojects.

The second step was to analyze megaprojects' poor performance. The causes of poor performance were determined. In addition, megaproject's main management problems were analyzed.

The third step was to research work practices that are candidates to handle megaprojects' management challenges. The practices researched were management organization, controls and reporting, and communication and coordination. The work practices were retrieved through interviewing project officials who have worked on megaprojects, in addition to reviewing megaproject technical reports, management reports, and construction management literature.

The fourth step was to evaluate megaproject work practices according to the opinions of construction experts and professionals. A survey was conducted in order to rank different management structures, contractual structures, and operation methods according to different performance measures.

The fifth step was to develop a methodology that would optimize megaproject performance. The methodology consists of two parts. The first part is a decision model that would assist construction professionals in selecting the optimal work practices based on predetermined performance goals. The second part is a planning procedure that provides general guidelines for planning the management organization, work division and packaging, controls and reporting, and the design and schedule.

CHAPTER 2
LITERATURE REVIEW

Megaproject Definition

Numerous researchers from different scientific fields have provided several definitions that describe megaprojects broadly. There are three categories of definitions provided in the literature.

The first category provides a general definition that professionals and researchers agree on. It describes a megaproject as a large scale project with a price tag in excess of one billion dollar that frequently leads to cost overruns (Flyvbjerg et al., 2003). For instance, Jargeas (2008) defines megaprojects as being over a billion dollar in total cost, large in size, and characterized by large number of interdependencies, interfaces, complexity, and risk.

The second category places megaprojects not in their construction management context but in a wider public planning and economy context. For instance, Ruuska (2009) defines megaprojects as: “significant undertakings characterized by multi-organizations seeking success on different objectives and subject to the impacts of a wider socio–political environment” (p. 142). Other definitions describe megaprojects as large complex projects that are delivered through public and private partnerships that fail to meet project outcomes and are motivated by interests that operate against the public interest (Marrewijk et al., 2007). Additional public planning definitions describe megaprojects as projects that lead to cost overruns and lower-than-predicted revenues that hinder economic growth instead of advancing it (Flyvbjerg et al., 2003). Fiori (2005) defines megaprojects as: “A construction project or aggregate of such projects characterized by: magnified cost, extreme complexity, increased risk, lofty ideals, and high visibility that represent a significant challenge to stakeholders and a significant impact to the community" (p. 717). The Federal High Way Administration defines megaprojects as: "Major infrastructure projects that cost more than $1 billion, or projects of a significant cost that attract a high level of public attention or political interests because of substantial direct and indirect impacts on the community, environment, and state budgets" (Capka, 2004, p. 2).

The third category places megaprojects in their construction management context that is projects with activities, resources, budgets, and deadlines. Capka (2004) defines megaprojects as expensive projects that require the management of many concurrent and complex activities while maintaining tight budgets and tough schedules. More elaborate definitions describe megaprojects as large scale complex projects that often fail to meet costs estimates, time schedules, and anticipated project objectives. Other definitions describe megaprojects as projects that contain a large element of risky technological innovations (Antikoye et al., 2003), and characterized by conflict and poor cooperation between partners (Marrewijk, 2005).

Construction management definitions describe megaprojects broadly. Nevertheless, these definitions do not distinguish megaprojects from other large or complex projects. In other words, these definitions could apply to any construction project that may lack megaprojects' characteristics. In addition, there is no definite understanding of what characteristics differentiate megaprojects from other projects.

Megaproject Problems and their Causes

The recent decades have seen numerous well-known infrastructure megaprojects that expanded engineering limits and brought economic development and progress worldwide. Nevertheless, these projects were accompanied by overwhelming problems.

Megaprojects throughout the world have had a calamitous history of cost overruns where the difference between the estimated and actual cost was often fifty to a hundred percent (Flyvbjerg et al., 2003). In the United States, large scale projects have had similar problems. According to a study done by the US Department of Transportation that covered ten US rail transit projects, the total cost overrun of these projects was sixty one percent (US Department of Transportation, 1990).

There are numerous reasons provided in the literature that explain megaproject poor performance. Several researchers consider that megaprojects suffer from poor performance due to fact that project costs are undervalued and their outcomes are overvalued. In other words, feasibility studies, project costs, and financial studies are purposely misrepresented so that megaprojects would be approved by public officials (Bruzelius et al., 2002; Flyvbjerg et al., 2002; Pickrell, 1992). According to Flyvbjerg (2003), project promoters violate established principles of transparency and administrative decision making because they either are ignorant or they believe that such practices are counterproductive to start the projects. Flyvbjerg (2003) provided numerous reasons that cause megaprojects' poor performance:

- Lack of realism in initial cost estimates
- Underestimation of the length and cost of delays
- Low contingencies
- Design changes are not adequately taken into account
- Underestimated changes in currencies' exchange rates
- Underestimated geological risk
- Undervalued quantity and price changes
- Underestimated expropriation costs, safety demands, and environmental demands
- High risk of technological innovations that is translated into cost increase

Other than decision making transparency causes, there are managerial and planning causes of poor megaproject performance. The Construction Industry Institute summarizes the general reasons for poor performance in the following areas: Front end planning, design, procurement, startup phase, human resources issues, organization structure, project processes, and project control (Construction Industry Institute, 1987). Throughout the construction management literature, numerous case studies have been conducted to determine the causes of poor performance. The planning phase causes of poor performance are summed up in the following:

- Incomplete project definition (Jergeas et al., 2008)
- Incomplete execution requirements (Jergeas et al., 2008)
- Non-realistic planning in terms of cost and time leading to compressed schedule and low prices (Flyvbjerg, 2002; Jergeas et al., 2008; Assaf et al., 1995; Molenaar, 2005)
- Underestimation of the project's complexity (Jergeas et al., 2008; Capka, 2004)
- Optimism in the ability to manage projects of such size and complexity (Flyvbjerg, 2002; Jergeas et al., 2008)
- Underestimation of the size and material requirements (Jergeas et al., 2008; Flyvbjerg, 2002; Fayek et al., 2006; Assaf et al., 1995)
- Under evaluated risks (Flyvbjerg, 2002; Molenaar, 2005; Dey, 2009; Jergeas et al., 2008; Capka, 2004; Van Marrewijk, 2005)
- Low contingencies for technical, operational, and business risks (Flyvbjerg, 2002; Dey, 2009)
- In-efficient governmental procedures, environmental regulations, and other time consuming effects (Assaf et al., 1995)

The execution phase causes of poor performance are summed up in the following:

- Variations and mistakes due to inadequate planning, incomplete execution requirements, and ambiguous design documents (Assaf et al., 1995; Jergeas et al., 2008)
- Poor project culture leading to productivity loss (Ruuska et al., 2009; Van Marrewijk, 2005)

- Contracting parties' adversarial relationships and disputes (Ruuska et al., 2009; van Marrewijk, 2005)
- Inadequate project organization that is insufficient for the size and complexity of the project (Assaf et al., 1995; Jergeas et al., 2008)
- Inadequate contract strategies driven by time objectives that lead to project cost increase (Assaf et al., 1995; Jergeas et al., 2008)
- In-efficient decision making structure caused by governmental intervention and inadequate public/private partnership (Assaf et al., 1995)
- Poor team work and communication leading to management inefficiencies (Jergeas et al., 2008)
- Poor integration of work crews (Ruuska et al., 2009; Fayek et al., 2006; Van Marrewijk, 2005)
- Inexperienced personnel in critical positions (Ruuska et al., 2009; Fayek et al., 2006; Van Marrewijk, 2005)

Though the reasons presented are sufficient, the literature does not explain why megaprojects suffer from some of the execution phase causes. In other words, the literature does not explain why megaprojects' organizational structure is inadequate nor why integration is poor nor why decision making is inefficient. In addition, the literature does not explain why megaprojects experience more frequent cost overruns and time extensions as compared to conventional projects.

Megaproject Performance Improvement

Several causes of poor performance obtained from the literature – i.e. underestimation of size and complexity, inadequate project organization, inefficient structure, and poor integration – highlight the fact that megaprojects' managerial performance could be improved. Construction management literature has provided several methods to improve performance on large and complex projects.

Critical Success Factors

Critical success factors have been researched thoroughly since they contribute to project performance improvement. The critical success factors are general points of what might contribute to project success. Critical success factors have been studied and modified by different researchers such as Ashley et al. (1987), Pinto and Selvin (1988), Savindo et al. (1992), Cooke-Davies (2002), and Nguyen et al. (2004). According to different studies, the critical success factors may vary in importance and in number. The following is a list of the critical success factors that contribute to the success of large-scale construction projects:

- Clear and detailed written contract
- Clearly defined goals and priorities of all stakeholders
- Competent project manager
- Adequate communication among related parties
- Competent team members
- Knowing what the client really wants
- Responsiveness of client
- Sufficient resources
- Awarding bids to the right designers/contractors
- High quality workmanship
- Regular client consultation Effective project planning and control
- Proven methodology (that includes a vision process) of project management
- Conducting regular reviews to assure and verify progress on project
- Proper dispute resolution clauses incorporated in the contract
- Frequent meetings among various stakeholder to evaluate overall performance
- Fast trouble shooting capabilities in the system
- Adequate work breakdown structure linked with organizational structure
- Clearly designed and coordinated technical tasks
- Absence of bureaucracy from the work place
- Effective change management
- Effective project control mechanics
- Top management sponsorship
- Learning from previous experiences
- Feedback capabilities in the system
- Clearly written lines of responsibility
- Building a balanced and winning team
- Client acceptance of plans

- Reliable estimates by quantity surveyors
- Positive organizational culture for effective project management
- Clear prioritization of project goals by the client
- Requiring the use of data to support actions at all levels of decision-making
- Creating accountabilities, roles, and responsibilities for the organization
- Mutual trust among project stakeholders
- Developing positive friendly relationships with project stakeholders
- Standard software infrastructure and adequate use of IT
- Benchmarking firm's performance against successful projects
- Using up to date technology and automation for construction work
- Strategic alignment of project goals with stakeholders' interests

In addition to the critical success factors, Toor (2007) developed four critical COMs i.e. comprehension, competence, commitment, and communication that can guarantee success in large scale construction projects. Each of the critical COMs consists of several sub factors. The comprehension sub factors are client acceptance of plans, knowing the client's requirements, clear prioritization of project goals by client, and use of facts and data to support actions at all decision making levels. The competence sub factors are having competent team members, competent project manager, and awarding bids to right consultants and contractors. The commitment sub factors are effective project planning, effective control, and clear definition of goals and priorities for all stakeholders. The communication sub factors are regular client consultation and client responsiveness.

Critical success factors provide general guidelines that may be useful for construction professionals and project managers. However, they do not provide a practical work plan to be applied to megaprojects. In other words, they only answer the question of what goals to achieve instead of how to achieve the goals.

Project Governance

In large scale complex projects, project officials are faced with the challenge of governing a chain of multiple projects (Stinchcombe et al., 1985) and a complex network of shareholders (Freeman, 1984; Aaltonen et al., 2009). One of the methods to deal with these challenges is to apply an adequate governance regime. In general, a governance regime is defined as a process that affects how multiple transactions are carried out between multiple actors within the boundaries of a single organization or among multiple organizations (Ruuska et al., 2009). Literature provided three concepts of governance regimes i.e. corporate governance, institutional governance, and project governance.

Corporate governance literature addresses the problem of shareholders' lack of control over firms' operations (La Porta et al., 2000; Shleifer et al., 1997; Letza et al., 2004). Therefore, corporate governance literature provided several structures and hierarchal relationships between a principal and an agent (Williamson, 1996) in order to ensure that shareholders' capital is not wasted on inefficient investments or stolen by the firms' managers (Ruuska et al., 2009).

Institutional governance literature addresses the problem of governmental and institutional control over large scale construction projects. Institutional governance literature provided descriptions of regimes, markets, hierarchies, and regulations (Boyer et al., 1997; North, 1990). For instance, Flyvbjerg (2003) provided that governments and regulatory regimes should enforce arm's length principle and be specific as far as possible. The IMEC program provided that the best institutional governance is to combine a large number of individual strategies in order to manage different stages of the project life cycle (Miller and Lessard, 2000).

Project governance literature discusses governance of different parties in projects. Reve and Levitt (1984) described governance arrangements in large engineering projects that involve clients, consultants, and contractors who have different types of relations. Turner and Simister (2001) presented a framework of four contracting approaches by which risk and uncertainty would determine the type of contract to choose. The Association of Project Management published a comprehensive standard on project governance which provides general guidelines to design project governance regimes (APM Governance SIG, 2004). However, the guide could not be applied to megaprojects since they necessitate dynamic governance regimes that require control, self organizing properties, and the ability to adapt themselves to emerging contexts (Miller et al., 2005).

Miller and Hobbes (2005) provided that the creation and management of adaptive project governance structures is done through institutional learning. They described two examples of institutional learning. In the first example, the Norwegian University of Science and Technology in cooperation with the Norwegian Ministry of Finance developed a framework to scrutinize megaprojects' front end phase which they called Quality at-entry regime. This was done through a five year experimental quality control process by which the cost of different megaprojects was validated by independent consultants. Thanks to the experiment, several modifications were put in place to improve the front end quality at-entry process. In the second example, the Private Finance Initiative in Great Britain recommended several significant changes to its management following a series of interviews conducted with key governmental officials, private officials, and investors. In addition, a task force was formed to centralize and channel learning. The task force also produced policies, tools, guidelines, and standard contracts for use when undertaking large projects. Before the changes, project performance was unsatisfactory and the learning process was expensive, incomplete, and fragmented. After the changes, significant improvement in project performance was reported. Governmental officials claimed that over 75% of the projects were delivered on time, within cost limits, and according to the expectations of public sector managers (HM Treasury, 2003).

Ruuska et al. (2010) considered that the prevalent governance approaches are inadequate. Thus, they presented a novel project governance theory that would improve effectiveness and efficiency of large complex projects. The new approach is based on three concepts. The first concept suggests that the view of project governance should shift from the simple hierarchical approach to a complex approach that emphasizes network relationships and self regulation. Research findings suggest that network level mechanisms such as information sharing and macro-culture play a significant role in forming project governance (Stinchcombe et al., 1985). The second concept suggests that multi-firm projects should be viewed as long term investments which extend beyond the project duration instead of being viewed as temporary endeavors. According to Turnbull (2002), stakeholders' participation in decision making lead to improved management efficiency, management effectiveness, and more accurate decisions. The third idea suggests that the narrow hierarchal organization view should be altered into an open network view where networks are composed of interwoven relations among different actors and environments. Large projects involve thousands of businesses that form a complex network of actors who are connected by different types of relationships. Therefore, the idea of a project being governed by few actors is misleading.

The application of governance regimes could improve megaproject cost and schedule performance. In addition, project governance regimes provide feasible solutions to be used on construction projects. However, the solutions are general and do not offer a tangible work plan for construction professionals. In addition, project governance regimes were not evaluated by a sufficient number of construction professionals to determine their real effect on the project outcome.

Organizational Structures Used in Large Projects

One of the methods to improve cost and time performance on large construction projects is to select a suitable organizational structure. Organizational structures determine several characteristics that impact the ability to manage a project. For example, organizational structures determine how duties are distributed among different departments and management levels. They determine the formal reporting relationships and controls procedures. In addition, they determine the extent of coordination and communication among employees in different departments and management levels. Numerous studies were done to analyze different organizational structures that were used in manufacturing, information technology, management consultancy, design, product development, construction, and other industries. The selection of the suitable organizational structure depends on the nature of works, strategy of the firm, and external effects surrounding the firm and the industry. The five organizational structures presented in the management sciences are vertical functional organization, divisional organization, horizontal matrix organization, team based organization, and virtual network organization (Galbraith, 1977; Gobeli et al., 1987).

Vertical functional organization. The vertical functional organization is where work teams are grouped into same specialization departments. Each department has its own resources, staff, and activities. Examples of different functional units are accounting, finance, marketing, and manufacturing.

Divisional organization. The divisional organization is where work teams are grouped based on organizational outputs. Different divisions of the firm are responsible for managing different programs or producing different products. Each division is composed of different functional units.

Horizontal matrix organization. The horizontal matrix organization combines both characteristics of functional and divisional organizations. The functional hierarchy is formed vertically and the divisional hierarchy is formed horizontally. In matrix organizations, employees report to two managers which are the functional manager and the division manager.

Team based organization. The team organization allocates employees of different specializations to different teams. The decision making authorities are delegated to a team leader which creates a more responsive and flexible organization.

Virtual network organization. The virtual network extends beyond the boundaries of the organization. It allows separate groups to be connected. In other words, it is when different units that belong to different firms work together to produce a certain output. An example of a virtual network is a firm that subcontracts its different functions to separate companies.

Organizational structures applied on construction projects were also researched. Tatum (1986) presented different organizational structures that were applied on large scale projects. In addition, he presented conditions that favor the use of different structures. The organizational alternatives and their corresponding advantages, disadvantages, and favorable conditions are as follows:

Strong functional organization. Strong functional organization allocates duties according to different disciplines such as civil, electrical, and mechanical disciplines where each discipline has its corresponding supervisory and engineering staff. This type of organization has many advantages such as clear definition of authority, clear division of works, simple reporting procedures, and rapid decision making for single trade problems. However, strong functional organizations might not be applicable for projects that involve numerous interfaces between disciplines. In addition, they might not be applicable for large projects where the scope of a single discipline is not manageable by a single work group. There are several conditions that favor this type of organization such as small project size, well defined scope where the need for coordination is minimal, and a project plan that has different functional phases.

Functional organization with area coordination. Functional organization with area coordination has a structure that is different than the functional structure. The organization is headed by a construction manager, field engineering manager, and planning and control manager. The subunits are composed of area coordinators that organize and coordinate the works of different disciplines. This type of organization has several advantages. One of its advantages is its large integration capacity and its greater visibility of different specializations. Another advantage is that it delegates responsibilities to the lowest possible level which leads to rapid decision making. However, this organization has several disadvantages. It adds conflict to area and functional managers' roles. It requires a large number of personnel with multiple-discipline skills. It suffers from ineffectiveness due to the fact that area-oriented staff lack of decision making authority. Projects that favor this structure's use are moderate size projects that have moderate complexity.

Functional organization with area management. Functional organization with area management is a matrix organization that splits management duties between area managers and general superintendants. Area managers are responsible for area activities, cost monitoring, schedule monitoring, coordination of different disciplines, and reporting of any problems. General superintendants are responsible for the construction organization, work direction, and craft performance. This type of organization has several advantages. It clearly allocates responsibilities of both functional and progress groups. It allows better problem monitoring and more managerial focus on major objectives and milestones. It also leads to more consistent construction activities under the supervision of the superintendant. However, this organization has several disadvantages. It requires a large staff of management personnel. It adds conflict to production responsibility. It also adds confusion to the functional role of area managers. Projects that favor this structure's use are moderate size projects that have intermediate complexity such as projects with physically separated work areas.

Area management with craft discipline staff. Area management with craft discipline staff organization is similar to the functional organization with area management. However, the area manager is responsible for all planning, implementation, and functional support duties. The general superintendant duties are limited to craft discipline supervision, resource management, construction support, and problem solving assistance. This type of organization has several advantages. It improves functional support, coordination, and communication. It delegates responsibilities to area managers and allows them to focus on their objectives. This organization also has several disadvantages. It adds to management confusion since there is dual reporting of project status. It adds to staffing problems because of the large number of craft supervisory personnel needed. It also adds to coordination difficulties because of problems that extend to more than one area. Projects that favor this structure's use are large complex projects that could be divided into physically separate areas. In addition to projects that demand technical consistency over all areas.

Autonomous area organization. Autonomous area organization divides the project into work areas that are geographically separated. This type of organization has several advantages. It clearly allocates accountability and responsibility by area. It simplifies reporting procedures since there is no dual reporting confusion. It divides the project into manageable sections. However, this organization has several disadvantages. It provides no consistency of disciplines among different areas. It leads to inefficient use of resources since personnel and functions are duplicated in different areas. Projects that favor this structure's use are large projects that are geographically separated.

Several organizational structures were presented in the research. However, they are not explained clearly. The research does not show how duties are allocated among different management levels. Moreover, it does not show clear lines of reporting and communication. Organizational structures' effect on the project outcome is not clear because the organizations were analyzed according to the author's opinion not according to a comprehensive evaluation done by a sufficient number of construction professionals.

Multi-Project Management

Megaprojects' vast size requires the division of construction works into smaller manageable packages. The parallel operation of multiple packages requires management practices that could handle the large number of work groups. Several studies were done to develop work practices that are capable of managing multi-projects.

Platje and Seidel (1993) provided that classical planning and control is not suitable for megaprojects and can result in bureaucratic, inflexible, and powerless organizations. Classical centralized control leads to a rigid chain of command that diminishes flexibility and the ability to steer the project. It also leads to a lower level of involvement and motivation of the lower management levels. In addition, classical planning and control leads to a large amount of informal communication that confuses general management.

The solution is to delegate responsibilities to the organizations' lowest possible levels. In other words, project managers and department heads would deal with most of the management burdens so that portfolio managers would not drown in irrelevant details. This solution would lead to a flexible and creative organization that is suitable for large projects.

Another method suitable for multi-project management is program management. The objective of program management is to streamline the effective delivery of multiple projects (Gray, 1997). Program management could be used interchangeably with project management to describe the project delivery of large construction projects (Ferns, 1991; Milosevic, 2007). Program management is characterized by its centralized managerial controls that provide clear visibility over projects and their progress (Ferns, 1991; Lycett et al., 2004; Pellegrinelli et al., 2007). It is also characterized by centralized allocation, leveling, and sharing of common resources among different projects (Kangari et al., 1988). The project management institute published general information about tools that would assist construction professionals in managing a portfolio of projects. The first main tool is a centralized rolled up portfolio management system for overview, analysis, and decision making. The second main tool is a financial reporting system for payments and payment prioritization (Project Management Institute, 2006). However, these tools are general and do not constitute a tangible work plan.

Another method that could improve cost and time performance of multiple parallel projects is the critical chain method (Goldratt, 1997). The critical chain was derived from the theory of constraints (Goldratt, 1984). The theory of constraints provided five steps in order to improve the performance of any system that is subjected to numerous constraints. The first step is to identify the system's determinant constraint (most critical). The second step is to exploit the determinant constraint (optimization of the system). The third step is to subordinate all other processes to the determinant constraint. The fourth step is to elevate the determinant constraint. Finally, to repeat the process since there would be a new constraint.

The critical chain is different than the critical path. When scheduling different activities (excavation, form work, concrete pouring, electromechanical works, and finishing works) the longest path of activities or the path of the least float is the critical path. On the other hand, when scheduling different resources (excavator, civil engineer, project manager, and foreman) the most occupied chain of resources is the critical chain. Critical chain scheduling is not different than resource driven scheduling. The critical chain method provided five steps in order to plan and execute multiple projects. The first step is to schedule projects in parallel as if they were one project. The second step is to remove the activities' buffers (float inserted to protect any activity from delay) and insert them at the end of the critical path to form the project buffer. The third step is to insert feeding buffers between the non-critical and the critical path to protect the critical path from delays that take place in non-critical paths. During the implementation phase, feeding buffers would be checked periodically because if they are consumed then there would be a new critical path. The fourth step is to remove resource dependency conflicts from all projects i.e. no activities of the same resource are done in parallel. The fifth step is to add resource buffers to protect the critical chain from any delay that could happen at any individual activity.

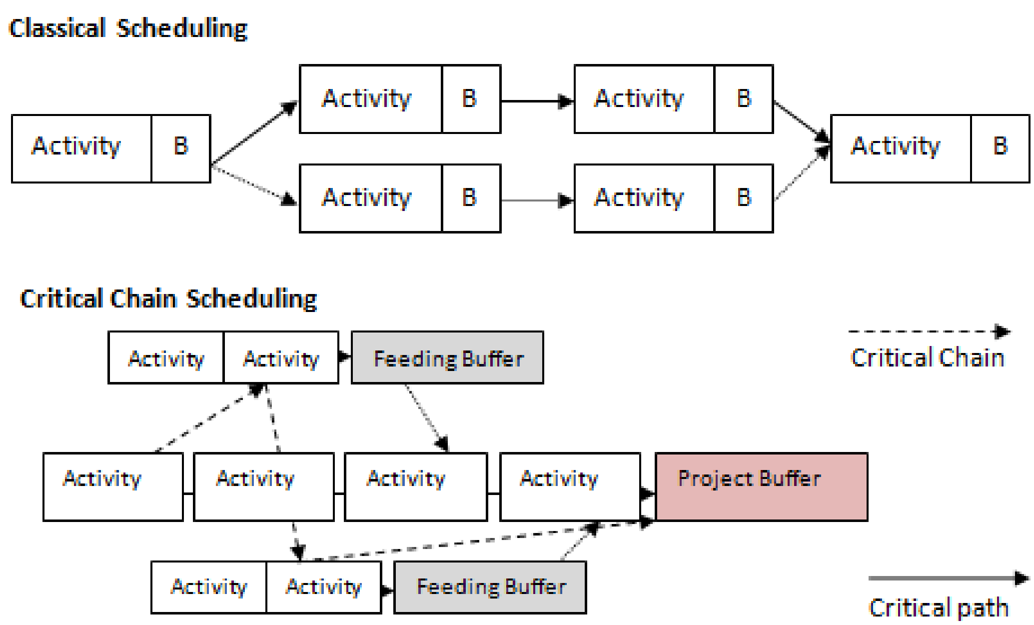


Figure 2-1. Critical chain scheduling as compared to classical scheduling

Goldratt claims that the method improves cost and time performance of multiple parallel projects. In addition, he claims that the method is able to decrease inefficient multitasking efforts, improve focus on the tasks at hand, and decrease the time needed to perform tasks.

The activities that the theory refers to are more compatible with information technology projects, product development projects, manufacturing, and services projects. Construction projects are more complex by which they constitute of many parallel activities, time dependencies, resource dependencies and activity float that cannot be removed. Furthermore, construction projects have a dynamic behavior where designs and schedules change frequently. Applying the critical chain to dynamic parallel projects that have a magnitude of parallel activities, time dependencies, and resource dependencies would improve neither cost nor time performance.

Project Organizational Structures Evaluation

Throughout the literature, different organizational structures have been evaluated according to several factors. Tatum and Fawcett (1986) evaluated organizational structures used on large scale construction sites. The structures researched were functional, functional with area coordination, functional with area management, area with discipline staff, and autonomous area organization. The evaluation factors were: external interfaces responsibility, lowest level single responsibility, lowest level resource integration, clear and effective reporting, and consistent resource utilization.

Oyetunji and Anderson (2006) evaluated different project delivery and contract strategies according to various factors. The twelve contract strategies studied were traditional design-bid-build, design-bid-build with early procurement, design-bid-build with project manager, design-bid-build with construction manager, design-bid-build with early procurement and construction manager, construction manager-at-risk, design build, multiple design build, parallel primes, design-bid-build with staged development, turnkey, and fast track. The twenty evaluation factors presented in the research were: cost growth control, lowest cost assurance, delay or minimization of expenditure rates, risk reduction or transfer to the contractor, early cost estimate facilitation, time growth control, shortest schedule assurance, early procurement promotion, ease of change, capitalization on low levels of changes, confidentiality protection, project conditions capitalization, owner's controlling role maximization, owner's controlling role minimization, owner's involvement maximization, owner's involvement minimization, well defined scope capitalization, poorly defined scope efficient utilization, minimization of contracted parties number, and efficient coordination of project complexity or innovation.

The factors of different alternatives were evaluated by thirty two experienced project managers. The results reported all of the alternatives' scores according to each of the evaluation factors.

Other researchers have evaluated organizational structures according to organizational effectiveness. There are several definitions for organizational effectiveness. Georgopoulos (1957) defined effectiveness as: "the extent to which an organization as a social system fulfills its objectives without incapacitating its means and resources and without placing a strain upon its members" (Handa and Adas, 1996, p. 341). Price (1972) defined effectiveness as the degree of accomplishment of multiple goals. Pennings and Goodman (1977) defined management effectiveness as the satisfaction of management constraints and achievement of multiple goals. In general, organizational effectiveness is classified into three classes. The first class or qualities of the organization approach (Peters et al., 1982) relates effectiveness to certain organizational characteristics such as communication openness, formalization, control level, and organizational culture. The second class or the goal setting approach (Hannan et al., 1977) relates the effectiveness to the degree of attainment of certain objectives. The third class or the systems approach (Georgopoulos, 1957) considers the organization as a system and assesses the effectiveness according to its inputs, outputs, and operation.

Gray et al. (1990) evaluated the effectiveness of organizational structures that were used in different countries according to four factors. The organizational structures presented were functional, functional matrix, balanced matrix, project matrix, and project teams. The factors were: meeting schedule, controlling costs, meeting technical performance parameters, and meeting commercial parameters. According to the research, there was no significant difference between the schedule objective, cost objective, technical objective, or commercial measures. The conclusion given was that the factors were probably tied together.

Handa and Adas (1996) presented a linear mathematical model composed of five variables that could predict management effectiveness. A multiple regression analysis was conducted on fourteen variables according to data retrieved from seventy six construction firms. According to the analysis, the significant variables were: firm's attitude toward change, multi-project handling ability, Level of planning, culture strength, and level of participation in the firm's decision making.

Dikmen, Birgonul, and Kiziltas (2005) presented a linear mathematical model composed of nine variables that could predict management effectiveness. A neural network analysis was conducted on twenty two variables according to data retrieved from one hundred and twelve questionnaires. The study concluded that only nine variables were significant. The significant variables were: organizational learning experience, joint venturing frequency, adaptability/flexibility, technical capability, ability to benefit from opportunity, financial capability, culture strength, and information flow effectiveness.

Project Organizational Structures Optimization

Different methods were presented in the construction management literature to determine the optimal organizational structure. The methods include decision models, mathematical models, and simulations.

Tatum (1986) presented a framework to select the most suitable organizational structure based on a simple decision model. The decision model i.e. evaluation matrix sums up the scores of alternatives and selects the alternative which attains highest score.

$$Evaluation\ Matrix: \begin{bmatrix} a_{11} & \cdots & a_{n1} \\ \vdots & \ddots & \vdots \\ a_{1m} & \cdots & a_{nm} \end{bmatrix}$$

$$Optimal\ Solution = \max \sum_i a_{ij} \quad for\ \ j = 1,2,\cdots m$$

$$\text{Where}: \text{a}_{\text{ij}} \text{ is the score of alternative j on criteria i}$$

However, the evaluation matrix does not take into account management objectives and priorities since all criteria have the same weights. In addition, the decision model was not used on any projects.

Oyetunji and Anderson (2006) presented a framework to select the most suitable organizational structure based on a multi-criteria decision analysis (MCDA) technique. MCDA allows the decision maker to assign priorities to different criteria since managers have different objectives.

$$Multicriteria\ Decision\ Matrix: \begin{bmatrix} a_{11} & \cdots & a_{n1} \\ \vdots & \ddots & \vdots \\ a_{1m} & \cdots & a_{nm} \end{bmatrix} x \begin{bmatrix} w_1 \\ \vdots \\ w_n \end{bmatrix} = \begin{bmatrix} t_1 \\ \vdots \\ t_m \end{bmatrix}$$

$$Optimal\ Solution = \max t_j \quad for \quad j = 1,2,\cdots m$$

Where : a_{ij} is the score of alternative j on criteria i

w_i is the weight of the criteria i

t_j is the total for alternative j

The contractual structures presented by Oyetunji and Anderson (2006) were applied to conventional construction projects only. Their research did not present management structures that were applied on large scale projects. In addition, the decision model was not used on any construction projects.

There are other methods that could determine the optimal organizational structure using mathematical modeling and computer simulation.

Cheng, Su, and You (2003) presented a framework to optimize organizational structures using an activity relationship matrix (ARM). Their method consisted of three steps. The first step was to assign a resistance coefficient for relationships between different structure units using an evaluation survey. The second step was to calculate a communication resistance matrix based on the project activity network. The third step was to calculate the total resistance of the structure. The authors conducted a case study to test the method on possible organizational structures of a port wharf construction project and concluded that the organizational structures with the minimum hierarchical levels are the optimal structures. They also concluded that the optimal organizational structure enhances coordination efficiency.

In organizational studies, there are numerous simulation approaches such as system dynamics approach, activity based simulation, and agent based simulation. The agent based simulation could simulate simultaneous actions of various artificial agents (Macal and North, 2007) that interact with each other and the environment (Epstein and Axtell, 1997). The simulations could be used to show how patterns emerge from the behaviors of agents (Epstein and Axtell, 1997). Researchers consider that agent based simulation is a suitable tool to model and optimize organizations since it captures interactions between agents (Watkins et al., 2009), simulates management processes that include multiple agents, considers agents as heterogeneous entities (Watkins et al., 2009), provides stochastic simulations of the processes, and simulates complex adaptive systems.

However, computer simulations are not the most appropriate tool to model and optimize organizational structures because they have many drawbacks.

The first drawback is that simulations do not capture the organizations' operation correctly. Simulation modelers include a large number of general assumptions that make the process applicable to the simulation tool not to reality. In addition, simulations capture a limited number of variables, whereas in construction projects there are numerous variables. Furthermore, construction administrative operations are not modeled realistically. For instance, an administrative activity is modeled as a continuous determinant activity, whereas in real life, activities are interrupted, modified, and even repeated as in design changes that require numerous back and forth steps.

The second drawback is that simulations require a large amount of unavailable statistical data to be reasonably accurate. Examples of unavailable statistical data include: percentage of problems that are solved on site, percentage of time consuming changes that need the intervention of upper management levels or diverse parties, percentage of changes and problems that lie on the critical path, percentage of changes that does not affect the critical path, the outcome distribution of delay periods, percentage of changes and problems that cause small cost increases, and percentage of changes and problems that cause cost overruns.

The third drawback is that simulations and mathematical models do not capture human behavior. In other words, they neither capture individual employee decision preferences nor the overall firms' decision making culture. Simulations are more applicable to machine-like consistent processes with predictable categorical outcomes such as queuing operations, not to unpredictable variable outcomes.

The fourth drawback is that construction simulations do not provide new managerial insights. In other words they do not provide more information than what the construction professional already knows which defeats the purpose of a simulation. Construction simulation researchers provide conclusions that are already known just to prove that their modeling approach is plausible.

CHAPTER 3
MEGAPROJECT DEFINITION

Two definitions are presented to classify and characterize megaprojects. The first definition is a new theoretical definition based on a project diagram that differentiates megaprojects from other conventional projects. The second definition is an industry definition that is based on the opinions of construction professionals who worked on megaprojects.

Theoretical Definition

A megaproject is similar to any other construction project. It includes numerous parallel activities, limited resources, tight schedules, and multiple decision making parties. However, megaprojects are different according to size and complexity. Therefore, a megaproject is defined in comparison to other projects according to size, managerial complexity, and design complexity. Three steps were conducted to develop the definition. The first step was to define project size and project complexity. The second step was to differentiate megaprojects from conventional projects. The third step was to develop a new project diagram that classifies projects according to size and complexity.

Size and Complexity Definitions

A system is a group of interconnected elements that could be work groups, activities, items, and designs, etc. The size of a system is defined by the number of items found in the system. Complexity is harder to explain. There are dozens of complexity concepts, definitions, and models one could obtain from the construction management literature. The meaning of project complexity is subjective and open to many interpretations. In this research, complexity is defined according to two dimensions: the number of interrelated parts, and the interrelatedness of these parts (Baccarini, 1996).

Every system is defined according to a size and a degree of complexity; complexity is determined by the number of different elements (e.g. different work groups) in the system and the interrelatedness of these elements; size is determined by the quantity of similar items (same function work groups) per element (Haidar, 2010). Accordingly, a project diagram (Figure 3-1) is developed to define and differentiate projects based on size and complexity dimensions. The complexity dimension is defined by two aspects: differentiation i.e. total number of dissimilar elements (illustrated by different geometrical shapes in Figure 3-1) and interdependence among these elements (illustrated by the number of arrows in Figure 3-1).

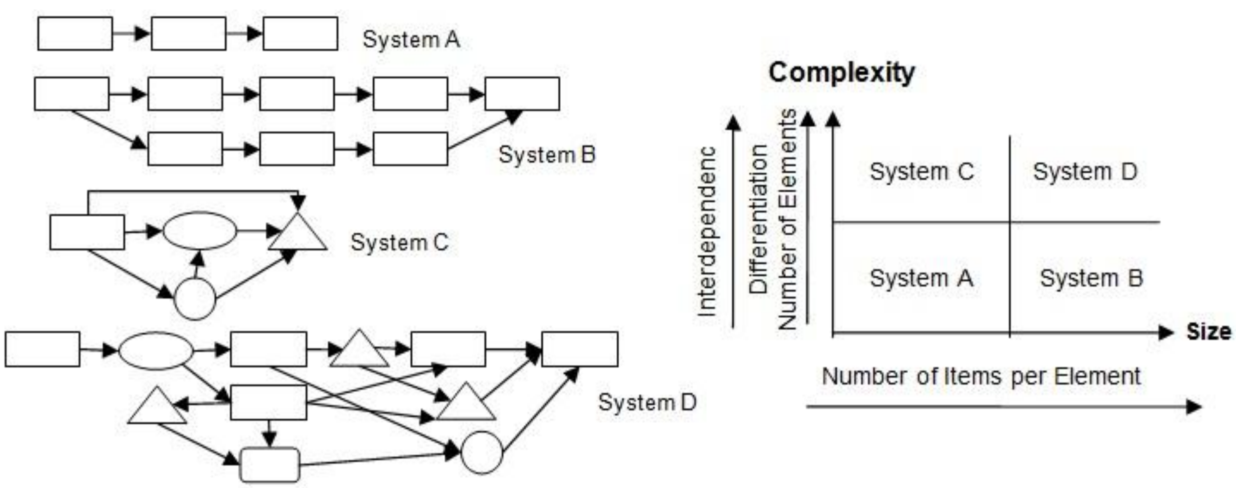


Figure 3-1. Project Diagram showing systems with different sizes and complexities

Project size. Project size is explained by the constructed area and the time frame needed to build the project. Constructed area and time frame are indications of the quantity of items used in the project such as work groups, labor, and material.

Project complexity. There is a multitude of aspects that could explain complexity. However, the most basic aspects that describe project complexity are design complexity and managerial complexity.

Design complexity is explained by the difficulty of integrating design steps of different design teams and engineering trades. It is determined by design differentiation and design interdependence.

Design differentiation is explained by two aspects. The first aspect is the number of different steps required to achieve the final product. For instance, a simple road design would be composed of a limited number of steps. Whereas a tunnel design that includes many geotechnical, structural, environmental, and safety elements would be composed of plentiful steps. The second aspect of design differentiation is the number of different engineering specializations included in the design. For instance, designing a complex power plant would require civil, electrical, and mechanical engineers in contrast to designing a simple road that would require a limited number of specializations.

Design interdependence is explained by the interrelatedness of different design steps. For instance, electrical and mechanical trades are more interrelated in industrial plants that include motor control centers than in simple buildings that include simple electrical and mechanical systems.

Organizational complexity is explained by the difficulty of integrating work crews and coordinating dissimilar engineering trades. Organizational complexity is determined by organizational differentiation and organizational interdependence.

Organizational differentiation is explained by the number of different entities to be managed. The entities could be different work groups or engineering trades. As the project increases in size, more work groups are added contributing to more organizational differentiation. Also, as the project increases in design complexity, more specializations are added contributing to more organizational differentiation.

Organizational interdependence is explained by the interrelatedness of different entities' works. Projects vary in their organizational interdependence depending on the nature of the works and the design complexity. For instance, physically integrated electromechanical works found in electric rooms are more interdependent than physically distant electrical and mechanical works.

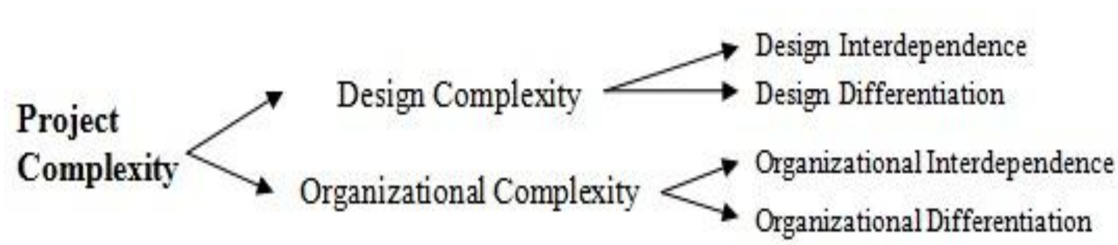


Figure 3-2. Project complexity explained by interdependence and differentiation

Megaproject Differentiation

Several case studies were conducted to determine how megaprojects differ from conventional projects. The case studies examined three organizational characteristics which are the number of contractors, design consultants, and owner organizations. The organizational characteristics are an indication of how large and complex the project is. Table 3-1 shows the projects studied and their corresponding characteristics in comparison to a conventional small scale project.

Table 3-1. List of projects and their corresponding characteristics

Construction Project	Number of Construction teams	Number of Design Teams	Number of Owner Organizations
Boston Artery Tunnel	- 2 Management Consultants -144 Contractors	- 2 Design Consultants	3 (FHWA, MTA, DOT)
Denver Airport Megaproject	- 2 Management Consultants - 134 Subcontractors - 2000 Subcontractors	-61 Design Consultants	3+ (FAA, City of Denver , Airliners)
Miami Stadium	- 3 Contractors - 1 Client Rep Firm - 80 Subcontractors	-1 consultant	3 (Miami Dade County, City of Miami, Miami Marlins Stadium Developer)
I-595 Expressway	- 4 Construction, QC organizations - 52+ Subcontractors	-1 main consultant -10 Sub-Consultants	3 (FHWA, FDOT, I-595 Concessionaire)
I-4/ Selmon Connector	- 2 Contractors	- 11 Design consultants - 30 Sub-Consultants	3 (FDOT, FTA, Tampa-Hillsborough Expressway Authority)
Conventional Project	- 1 Contractor	- 1 consultant	- 1 Owner

As shown in Table 3-1, megaprojects are different from conventional projects according to the three organizational characteristics i.e. number of construction teams, design consultants, and owner organizations. The main conclusion deduced from this comparison is that megaprojects are substantially different than conventional projects according to managerial complexity and design complexity. Managerial complexity is apparent in the number of construction teams and owner organizations. Design complexity is apparent in the number of design consultants.

Theoretical Definition

A new project diagram is developed to set a clear differentiation among different categories of projects. The project diagram is composed of the size axis and the complexity axis.

The size axis is composed of two aspects. The first aspect is the constructed area ranging from small area to very large area. The second aspect is the time frame ranging from 1 year to 5 years and above.

The complexity axis is composed of two aspects. The first aspect is the design complexity ranging from simple design to complex design. Simple design corresponds to a limited number of design steps and specializations. It also corresponds to limited interdependence among different design steps and among different specializations. Complex design corresponds to a large number of design steps and design specializations. It also corresponds to a high degree of interdependence among different design steps and among different engineering specializations. The second aspect is the organizational complexity that ranges from simple execution to complex execution. Simple execution corresponds to a small number of work groups with minimal interdependence among them. Complex execution corresponds to numerous groups with substantial interdependence among them.

The project diagram classifies four categories of projects which are: small projects (SP), large projects (LP), complex projects (CP), and megaprojects (MP).

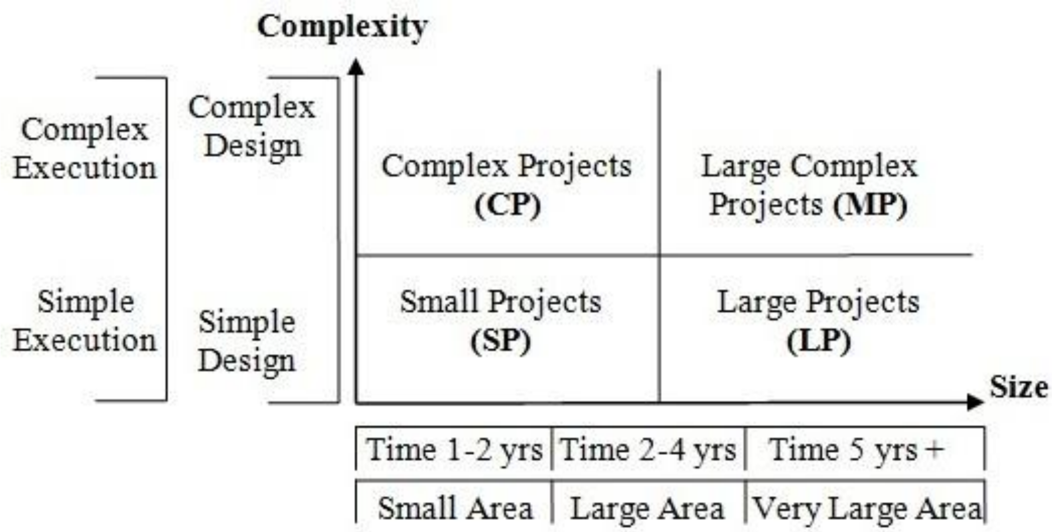


Figure 3-3. Project Diagram to differentiate categories of projects

Small and non-complex projects. Small non-complex projects are described to have a small constructed area and a relatively short construction time frame. They are simple to design and build. They neither require complex designs nor complex managerial organizations to have a successful project performance. Several projects could fit this category such as simple roads, houses, and small residential buildings.

Large and non-complex projects. Large projects have a large constructed area and a relatively long construction time frame. They neither require complex designs nor the services of many engineering trades. However, they require a complex organization to integrate and manage numerous work groups. Several simple yet large projects could fit this category for instance highways, bridges, and airport runways.

Small and complex. Complex projects have a relatively small constructed area as compared to large projects such as highways. The time scale would vary among different projects. They encompass complex designs since numerous specializations are required. They require complex management, integration, and coordination of different engineering trades. Examples of such projects are complex hospitals, hotels, and other specialized projects.

Large and complex i.e. megaprojects. As their name signifies, large and complex projects have a large constructed area and a long time frame. They encompass complex and challenging designs. They require complex management, integration, and coordination of different work groups. Furthermore, they require the integration and coordination of different engineering trades within each group and throughout the project. They require complex resource management given the limited labor resources and enormous material quantities. Examples of such projects are power plants, large industrial plants, airports, and large transportation projects.

Proposed Industry Definition

Academics, professionals, and researchers have varied views of what constitutes a megaproject. However, the most exact view is that of construction professionals who experienced the differences between megaprojects and conventional projects. Therefore, an industry definition of megaprojects is presented based on the collective opinions of construction professionals who have worked on megaprojects.

Interviews

Five interviews were conducted with different project officials who overviewed megaprojects' work groups, activities, and phases. The five interviewed officials occupied different management levels. Three of them where top level managers overseeing an entire megaproject and the other two were low level operational managers supervising subcontractors in one section of a megaproject. The interviewed project officials were: Boston Artery Tunnel FHWA project manager (C. Gottschall, personal interview, November 19, 2010), I-595 Expressway subcontractor construction manager (F. Alavi, personal interview, November 26, 2010), Miami stadium subcontractor construction manager (F. Alavi, personal interview, November 26, 2010), I-4 / Selmon Expressway Connector FDOT project manager (F. Richard, personal interview, December 28, 2010), and a project manager experienced in large scale projects (J. Turner, personal interview, April 15, 2011).

The interview was composed of four open ended questions that allowed the interviewed officials to discuss their views about what defines megaprojects. The questions were as follows:

- How are megaprojects different than the conventional projects?
- How is the design complexity different?
- How is the managerial complexity different?
- What other features differentiate megaprojects?

Industry Definition

Project officials shared similar opinions concerning the definition of a megaproject. According to them, megaprojects are not only defined by large size and expensive cost but also by massive complexities - mainly managerial complexity, design complexity, technology complexity, and external complexities. Although megaprojects and conventional projects have similar complexities, megaproject complexities are much more extreme and have a higher impact on project performance.

Managerial complexity. Project officials consider that megaprojects are more complex to manage due to the large number of interrelated contracts that are executed concurrently. They give numerous examples of managerial difficulties that are caused by the parallel operation of work groups. One of the difficulties is site congestion that results from inadequate coordination of workgroups. Another well known difficulty is the requirement to closely supervise interrelated activities and schedule dependant contracts. Another difficulty is management's inability to effectively assess the project's status in a timely manner due to parallel operation of work groups, activity interrelation, and the long management hierarchy.

Design complexity. Project officials consider that megaprojects' designs are more difficult to manage due to the large number of consultants, design packages, and engineers on record.

Integrating numerous design packages and coordinating construction-design activities leads to numerous management difficulties. One of the frustrating difficulties is the delay attributed to the engineers on record that stalls construction teams. Another well known difficulty is the design change follow-up process that requires tedious efforts and numerous time consuming "back and forth" steps.

New and complex technologies. According to project officials, megaproject construction methods frequently include new and complex technologies that add to their complexity. Ground freezing, tunnel jacking, segmental bridge construction, modular work practices, and other complex technologies require specialized work crews and work methods that are different than the conventional work methods. Consequently, complex technologies impose additional managerial requirements such as uninterrupted work flow, material and labor requirement, spaces for equipment storage, design requirements, etc.

External complexities. According to project officials, megaprojects are subjected to external conditions that add to the megaprojects' complexities. Many megaprojects are constructed in specific areas such as in dense urban areas, or over interstate highways, or deep underground. Such conditions impose numerous constraints such as continuous traffic flow through specified work zones, ground stabilization, local law constraints, and environmental law constraints. External complexities add to the managerial duties since they require complex planning, tedious management efforts, and coordinated operations.

CHAPTER 4
MEGAPROJECT PERFOMANCE PROBLEM ANALYSIS

Causes of Poor Managerial Performance

In megaprojects, three factors cause unconventional problems that contribute to poor managerial performance. The first factor is the project's large size that affects quantities and amount of work. Hence, the effects of changes, additions, and mistakes are augmented due to the large quantities imposed by the size. The second factor is the project's complexity that is caused by interrelated activities, schedules, and work groups. Hence, a change in any system would cause a ripple effect of unforeseen changes in other systems. The third factor is the dynamic nature of megaprojects that is caused by the parallel operation of work groups. Hence, problems, updates, and changes would take place concurrently leading to the loss of project oversight and control. The problems that face megaprojects are similar to the problems that face any conventional project. However, due to augmentation effects, ripple effects, and dynamic effects, the project operation would change from the steady manageable state to beyond the tipping point state (Gladwell, 2000), by which it would be hard to manage and perform according to cost, time, and quality objectives.

Megaproject Managerial Problems

Megaproject managerial problems are different than the problems faced in conventional projects. The managerial duties in conventional projects are limited to controlling a single work entity. With megaprojects' multiple work entities, the managerial duties differ substantially since the management team has to organize and integrate a complex web of systems over an enormous construction site. The problems that face megaproject managers are divided into three categories:

Managerial Duties Problem

Megaproject officials are faced with the challenge of handling immense managerial duties caused by the operation of numerous work groups. The management team has to conduct daily managerial duties such as supervision, inspection, and reporting with each of the work groups. In addition, the management team has to conduct painstaking managerial efforts to coordinate and streamline construction activities among different contractors, trades, and engineering specializations. Due to the dynamic nature of interrelated activities that progress concurrently, the management team has to update the schedule and cash flow of individual packages as well as the project's master schedule and cash flow. In addition, the management team is required to distribute and manage labor workforce, material, and equipment among different work groups.

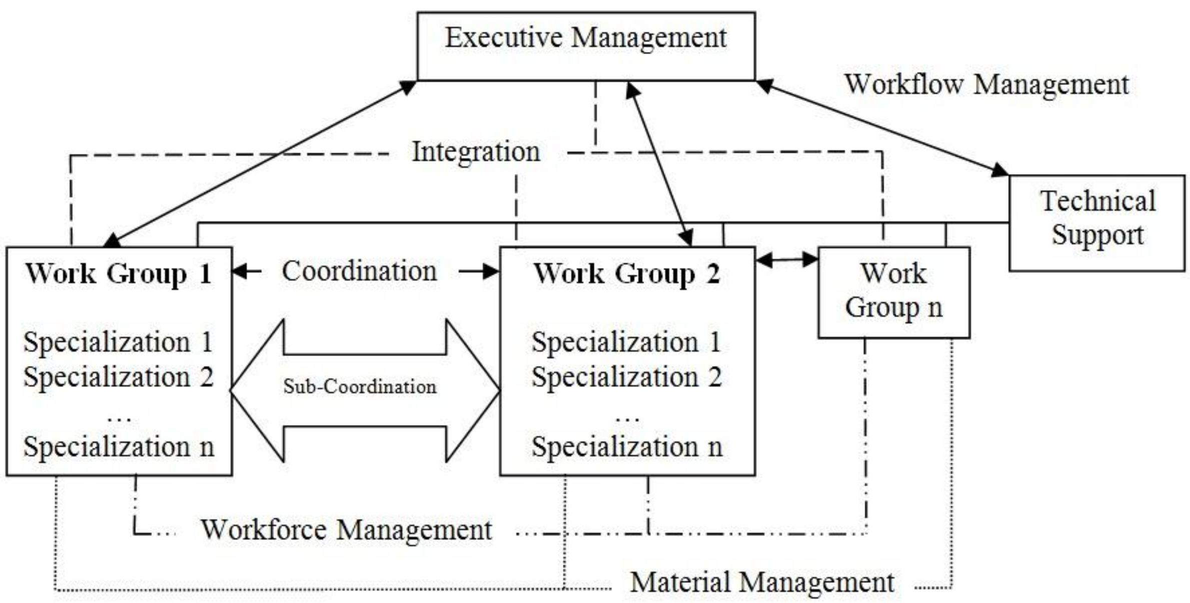


Figure 4-1. Managerial duties problem

The overwhelming number of interactions needed to manage all work groups would lead to a bottleneck at the management level and unutilized work crews at the operation level. In other words, the immense managerial load would lead to an inefficient and inflexible managerial system that is incapable to adapt to megaprojects' dynamic nature.

Oversight and Control Problem

Another challenge that faces megaproject officials is the problem of oversight and control. The management team suffers from insufficient oversight of the project's status and progress due to the large number of work groups, dynamic nature of the works, and reporting overload. The management team also suffers from the loss of control over workforce activities due to the fact that large management systems are decentralized and management responsibilities are delegated to lower management levels that are usually occupied by independent contractors.

Integration Problem

Another challenge that faces megaproject officials is the integration problem. Project officials have to integrate different decision making parties (contractors, owners, consultants, and designers), engineering specializations (civil, electrical, and mechanical), work groups (prime contractors and subcontractors), and management levels. Inadequate integration would lead to slow progress because of the complicated sequence of activities and the inactivity of uncoordinated workgroups. In addition, improper coordination would lead to time consuming error corrections, site congestion, and unutilized workforce.

CHAPTER 5
MEGAPROJECT CASE STUDIES

Several case studies were conducted to determine megaproject work practices. The case studies targeted large scale projects that belonged to the megaproject category. In other words the projects were characterized by an expensive cost, large size, design complexity, and execution complexity. The case studies were done through reviewing technical reports, management reports, and construction management literature. In addition to interviews conducted with project officials (Appendix A). The projects researched were: Boston Artery Tunnel, The Denver Airport Megaproject, Miami Stadium, I-595 Expressway, and I-4 Selmon Expressway.

The information researched includes a description of managerial work practices, difficulties faced, and lessons learned. The managerial work practices part describes the organizational structure, allocation of duties and responsibilities, and reporting and controls. The following is an outline of the information presented about each project:

1. Data collection
2. Description
3. Size and complexity
4. Management organization
   a. Description
   b. Structure and organization
   c. Allocation of duties and responsibilities in the organizational structure
   d. Reporting and controls
5. Difficulties faced and lessons learned

Boston Artery Tunnel

Data Collection

The data collected for this case study was from several sources. The first source of information was a report written by a group of experienced managers and researchers. The report, *Completing the Big Dig: Managing the Final Stages of Boston's*

Central Artery /Tunnel Project, provided research findings about managerial work practices applied on the Big Dig. The second source of information was a set of reports published by the project's parties. The report, *The big dig: Key facts about cost, scope, schedule, and management*, presented valuable information about the roles and responsibilities of different parties as well as control procedures applied in the project. The third source of information was an interview (Appendix A) conducted with a Federal Highway Administration (FHWA) project official (C. Gottschall, personal interview, November 19, 2010) who oversaw the project from its early phases up till its final phase. The interview provided valuable information about the project's organizational management, allocation of duties, project controls, and project communications.

Description

The Boston Artery/Tunnel is the largest and most expensive public works project ever taken in the United States. It is a 7.8 mile system of bridges and underground highways and ramps. It includes the world's widest cable-stayed bridge and a deep underwater connection. It imposed several engineering challenges. The construction site was a dense urban area so it was essential to keep traffic flowing. In addition, the tunnel section was constructed under existing structures so it was imperative to keep the soil stabilized in order not to cause damages. The project experienced time overruns and a cost increase of $13 billion. The cost and schedule increases could be attributed to many different reasons such as low original cost estimate, inflation (about half of the cost increase), changes and increased scope (third of the cost increase), unexpected technical complexities, mitigation costs (Environmental effects and movement of traffic), and decision making delays.

Size and Complexity

According to the project diagram (Chapter 3), the project would be considered as a megaproject since it is characterized by large size (7.8 miles of tunnels and bridges), expensive cost ($14.3 Billion), and managerial complexity. Managerial complexity is apparent in three aspects. The first aspect is the large number of contractors (approximately 144 contractors). The second aspect is the urban area condition which imposed additional managerial and coordination efforts. The third aspect is the application of new technologies such as ground freezing, slurry wall technologies, and tunnel jacking.

Management Organization

Description. The project's management organization consisted of three main parties. The Owners i.e. Massachusetts Turnpike Authority (MTA) and the Federal Highway Administration assigned a management consultant i.e. Bechtel/Parsons Brinkerhoff (B/PB) to provide construction administration services that included project oversight, monitoring, and reporting duties. In other words, the consultant was responsible for coordinating final engineers on record; coordinating construction contracts; monitoring construction works; providing recommendations to the owner for decision making; overseeing contractors' quality control; and reporting cost and schedule status to the owners. The decision making and contract awarding authorities were reserved to the owner organizations.

Structure and organization. The organization did not resemble the conventional owner-consultant-contractor organization. The consultant (B/PB) and the owner (MTA) formed an integrated project organization (IPO) under the owner's direction that reported to the Federal Highway Administration. Thus, the organization consisted of the owner's and the consultant's employees. For instance, the best qualified person available for a particular managerial position was selected regardless of which organization he came from. The IPO organization was formed to encourage better communication between parties, streamline the decision making process, and produce a more efficient project management. In the final phases of the project the Federal Highway Administration employees were also integrated in the organization. The organization was composed of a four level hierarchy.

The highest level consisted of the senior construction and project managers who were responsible for executive decision making.

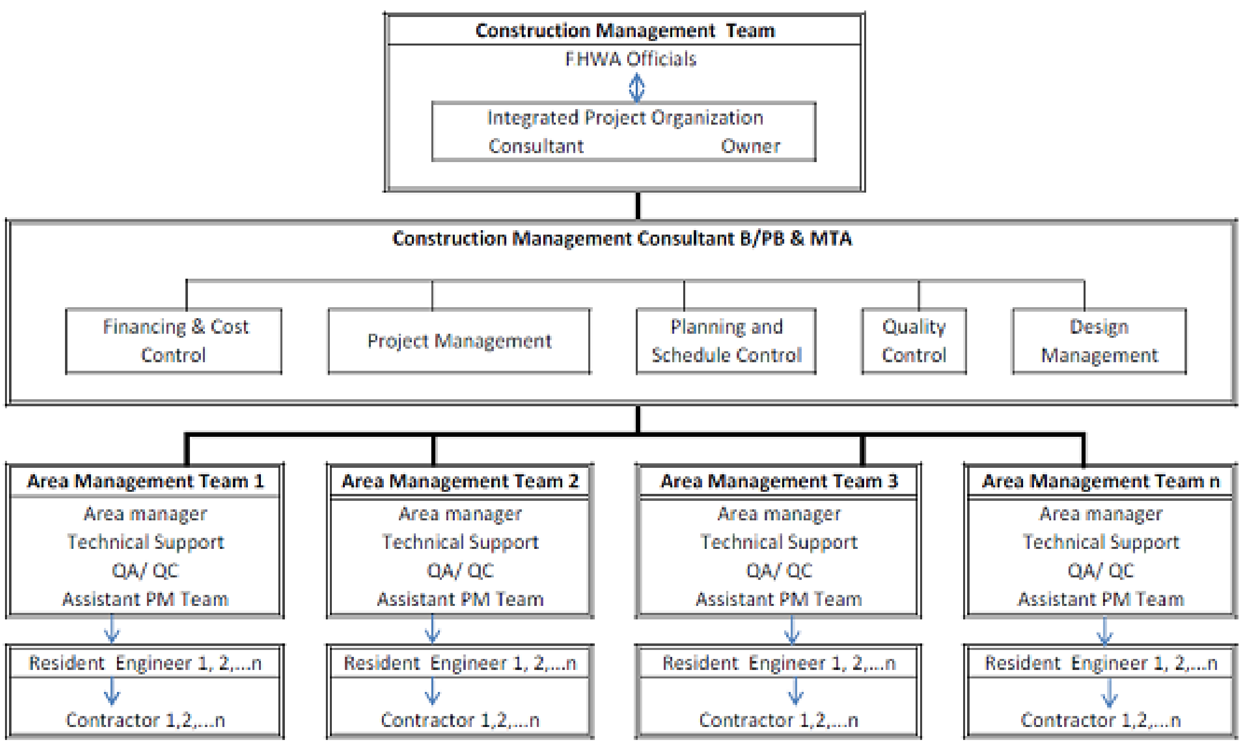


Figure 5-1. Boston Artery Tunnel organizational structure

The second level consisted of several functional entities. At this level, the consultant conducted all project management functions, design management functions, and quality control functions. The consultant established a separate scheduling control group to consolidate project schedules of all contracts and report any individual delay as well as the overall delay of the project. Furthermore, the consultant established a financing and cost control group to consolidate cash flow payments of all contracts and update the cash flow periodically according to the progress of different contracts.

The third level consisted of area management teams. As the name signifies, area management teams were responsible for the construction contracts in their designated areas. Area management teams were similar to the integrated project organization by which they consisted of the owner's and consultant's employees. Each area management team consisted of an area manager, project management staff (cost engineering, planning, scheduling, and contract administration), quality control staff, and support staff.

The fourth level consisted of the operational construction groups that were supervised by the consultant's resident engineers, field engineers, project supervisors, and superintendants. Each area was composed of either separate contractors operating under independent contracts or a main contractor that subcontracted the works.

Allocation of duties and responsibilities in the organizational structure. Duties and responsibilities were allocated in a way to make the organization effective and swift in responding to project updates and changes. The decision making authorities were decentralized to the lowest management levels. Accordingly, area managers had total control of the construction activities in their designated areas. In other words they were responsible for supervision and control of different contracts, subcontractor coordination, and limited design changes. For instance area managers were responsible for the approval of changes that did not exceed fifty thousand dollars.

The upper level management team was responsible for global control cost, global schedule control, inter-area coordination, long lead items, claims management, approval of major changes, and other issues that extend in more than one area.

Reporting and controls. The reporting system was centralized by which all area management groups reported to a single entity that consolidated the information. Reporting was done through meetings and reports. There were two different types of meetings conducted weekly. The weekly interface meeting consisted of the heads of different parties. The meeting addressed critical issues, outstanding items, project progress, and cost status. The second type consisted of high as well as low level project managers. It was conducted to manage the interplay of different contracts. Hence, it addressed coordination issues, work priorities, and work status of different areas.

Progress reports varied between hierarchy levels. The lower levels had to submit daily project management reports and a monthly progress report to the management consultant. The management consultant had to prepare two types of reports for the executive management. The first report i.e. Project Management monthly summarized individual schedules, overall schedule, budget, costs, safety records, and employment records. The second report i.e. Budget, Cost, Commitment, and Forecast Report summarized the financial issues such as the cash flows, cost status, and budget issues. In addition, the management consultant had to conduct quality control inspections and report the results to upper level managers.

Difficulties Faced and Lessons Learned

The management organization faced many difficulties. The integrated project organization caused numerous problems, conflicts, and legal claims between parties since it did not have clear lines of responsibility and accountability.

Another managerial difficulty was caused by the imbalance in the allocation of managerial resources. For instance, the owner had to supply more employees to support the management team and to handle the work load. Also, during peak construction time, the management team was not able to follow up with twelve different sections. As a result the quality of managerial services suffered.

The executive management also suffered from several difficulties. It had a hard time assessing the project's progress since there were many interdependent contracts. It also had a hard time managing different contractors who were working on parallel activities that had the same successor activity.

Other difficulties were caused by information overload problems. For instance, the project's comprehensive database produced excessive amount of information in different progress reports (6,400 data tables, 167,000 columns) that lacked strategic view.

There were several lessons learned that could be used to improve performance. The first lesson is that the scope of works should be determined to the most possible extent in order to limit future additions and changes that would substantially impact the project's cost and schedule. Another lesson is that a finance plan should be in place before any federal money could be allocated. The plan should be reviewed to see if the cost is accurate. It should also be risk assessed to determine the ability of project officials to make timely payments. In addition, there should be a comprehensive project management plan developed before any federal money could be allocated.

The Denver Airport Megaproject

Data Collection

The data collected for this case study was from several sources. The first source was a collection of articles that provided general information about the project. The second source was a book written by researchers and airport planners. The book, *Denver International Airport: Lessons Learned*, provided information about problems faced and lessons learned during planning, design, and construction. The third resource was a technical paper written by the project's high level officials i.e. project associate aviation director, consultant program manager, and consultant manager of construction. The paper, "The Denver Airport: Managing a Megaproject", provided valuable information about the project's organizational management, design management, roles and responsibilities, and managerial lessons learned.

Description

The Denver International Airport is one of the largest airports in the world. It was initially planned to cost 2.5 billion dollars in 1990, but that figure grew to a 5.3 billion dollars in 1995. The airport was built on a 53 square mile construction site and was composed 2 terminals, 3 airside concourses, 6 runways, 88 air carrier gates, and 32 commuter gates. The concourses were connected to the terminals through a 6,200 ft long tunnel system. The design team was enormous by which the design coordinator had to coordinate 61 different design contracts of different trades. The construction team was not so different since there were 134 different construction contractors and 2000 subcontractors. The project experienced time overruns and cost increases that could be attributed to several reasons such as changes, additions, and increased scope; delays caused by the baggage system failure; and management inefficiencies caused by the large number of contractors, poor managerial decision making, personnel changes, and understaffed management.

Size and Complexity

According to the project diagram (Chapter 3), the project would be considered as megaproject since it is characterized by large size (53 square miles of constructed area), expensive cost ($5.3 Billion), design complexity, and managerial complexity. Design complexity is apparent in two aspects. The first aspect is the complexity of the systems that demanded different engineering specializations. For instance civil engineers were needed for design of runways and buildings; electrical and mechanical engineers were needed for the design of the building and airport services (centralized airport control system, telecommunication systems, and baggage system). The second aspect is the complexity integrating the designs of 61 different consultants. Managerial complexity is apparent in the managerial efforts needed to control and coordinate a large number of contractors and subcontractors.

Management Organization

Description. In order to manage the sheer size of the project, the owner i.e. Denver City hired a program management consultant to help in managing the project. The program management consultant was a joint venture composed of an airport planning and design firm (Greiner Engineering Inc.) and a design and construction firm (Morrison-Knudsen Engineering). The program management consultant handled a wide range of construction, design, and project management services. However, city officials retained the decision making authorities such as negotiation and execution of contracts, payment approvals, Federal Aviation Administration approval facilitation, and settlement of claims and disputes.

Structure and organization. The organization resembled the owner-construction manager (agency)-contractor organization. The structure was designed to have a streamlined and efficient operation that would not be hampered by the bureaucracy of the long vertical hierarchy. The hierarchy had only two managerial levels and one operational level. The two-level management ensured one-on-one relationship between the lower level area managers and the higher level program manager. This two way communication kept the top level management updated with the most recent site information and allowed the area managers to respond to project changes and updates in a swift manner.

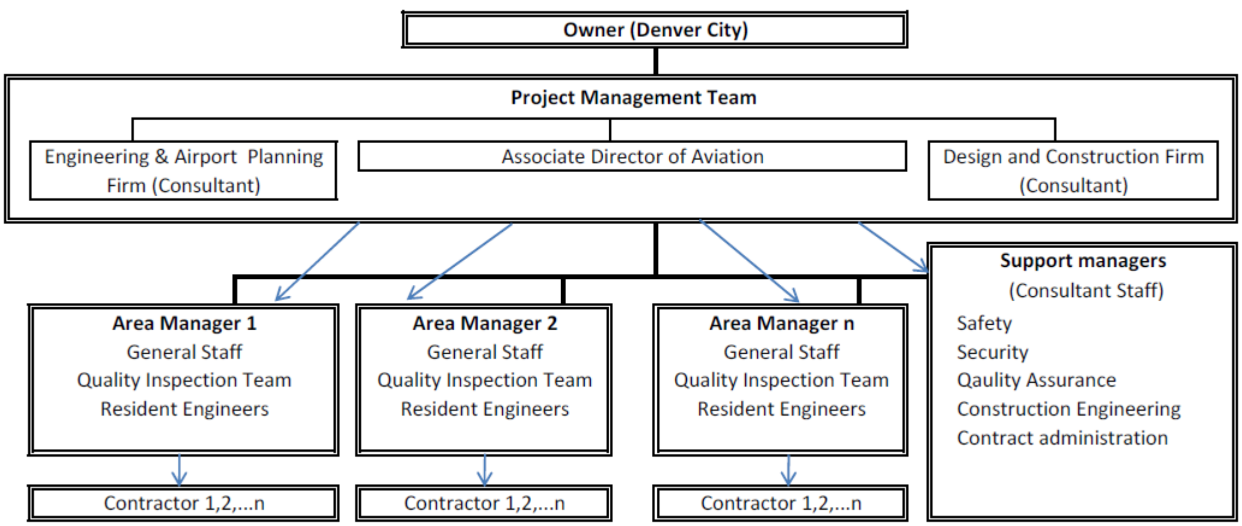


Figure 5-2. Denver Airport megaproject organizational structure

The highest level i.e. project management team was headed by the associate director of aviation of Denver City and consisted of the airport's staff and the consultants' staff.

The second level was composed of the area management teams. Each area management team was responsible for the construction contracts in its designated area. The main construction activities were divided into: site preparation, roadways, airfield, buildings, and utilities. Each area management group consisted of an area manager, general management staff, quality control staff, and resident engineers operating on separate contracts. Area management teams were assisted by a functional and technical support team which was established by the management consultant. The support team consisted of specialists in quality assurance, construction engineering, safety, security, and contract administration.

Allocation of duties and responsibilities in the organizational structure. Decision making authorities were allocated among different management levels to prevent top level bottlenecks and to keep the work flowing without interruptions. For instance, $5 million were authorized to be spent on field payments. In addition, some area managers were delegated with the authority to spend $500,000.

The duties and responsibilities allocated at the top management level i.e. project management team were: refining the master plan, coordinating the schedule of different areas, controlling the overall cost, coordinating activities common in several areas, and administering all construction contracts. In addition, the project management team had to manage all design contracts. In other words, the project owners were responsible for approving the design contracts and the management consultant was responsible for the coordination of all designers.

The lower level i.e. area management teams were delegated with sufficient decision making authority. They were responsible for the administration of all contracts in their designated areas and for coordinating their work with other areas. Site management responsibilities shifted from one area manager to another as the works changed. For instance, the site preparation area manager was changed to paving area manager as works progressed.

The support team was responsible for assisting area managers in duties such as construction engineering, contract administration, and quality assurance. The support team reported directly to the project management team. Furthermore, the support team developed program wide policies and procedures and ensured their implementation.

The third level was composed of the operational construction groups. Each area was composed of either separate contractors operating under independent contracts or a main contractor that subcontracted the works.

Reporting and controls. The reporting structure was not different than the organizational structure. The area managers reported directly to the program manger in the project management team. The support staff responsible for the program wide procedures also reported to the program manager.

Difficulties Faced and Lessons Learned

There management organization faced numerous difficulties. The first difficulty was in decision making and change approval. There was no central control mechanism to monitor and evaluate changes. Hence, most decisions were done on site to keep the work flowing. In addition, city officials took command from the specialized managers through their intervention and numerous changes that muddled the chain of command.

Another difficulty faced was caused by inadequate staffing. For instance, the airport committee members (owner’s staff) were understaffed and could not handle the mass of data caused by the large size of the project. In addition, contracting packages were cut to small sizes so that minority groups could get parts of the works but that lead to inadequate coordination and numerous disputes among contractors.

The project also suffered from numerous changes, acceleration costs, and schedule modifications due to the application of fast track design-build approach with a compressed schedule in order to finish as soon as possible.

Other difficulties were caused by the application of new technologies. A new baggage system was implemented to save money. Unfortunately, the baggage system failed and had no backup system causing delays and increased costs to design and install a new one.

There were several lessons learned that could be used to improve managerial performance. The first lesson is that reporting documentation should be designed to highlight problems and action items only. In addition, monthly reports should be designed to provide detailed and up-to-date information that facilitate decision making. The second lesson learned is in management organization. The design master plan should consist of no more than three prime contractors with sub-consultants reporting to the primes. This eliminates administrative delays for the owner and improves cooperation. Furthermore, management should invest in field managers with decision making experience. Design lessons were also learned. For instance, the design should be planned to have future additions and changes to limit the ripple effect of changes. Furthermore new technologies designed and implemented should have backup systems.

Miami Stadium

Data Collection

The data collected for this case study was from several sources. The first source was a collection of online web pages that provided general information about the project and the roles of different parties. The second source was a set of contractual agreements that were published by project officials. The contractual agreements provided valuable information about the responsibilities of different parties and the allocation of duties among different levels. The third source was an interview (Appendix A) conducted with one of the project's subcontractors (F. Alavi, personal interview, November 26, 2010) who reported directly to the construction manager. The interview provided valuable information about the project's organizational management, allocation of duties, project controls, and project communications.

Description

The Miami stadium or Marlin Ballpark is a new stadium with a seating capacity of 37,000 people. The stadium is planned to be equipped with a retractable roof. The construction activities of this project are phased. Phase one includes land development, foundations construction, and super columns construction. Phase two includes concrete structures construction. Phase three includes the installation a fixed roof, a retractable roof, electrical works, mechanical works, plumbing works, and architectural finishing. The project cost including the stadium and parking garages is estimated to be $600 million. The project's duration is estimated to be roughly two years and nine months.

Size and Complexity

According to the project diagram (Chapter 3), the project would be considered as megaproject since it is characterized by large size, design complexity, and managerial complexity. Although project's area (17 acres) is small when compared to the areas of the other megaprojects, the size of the constructed structures and the amount of material used is considerably large. For instance, the 8,300 ton retractable roof is supported by twelve 15 feet long x 8 feet wide x 40 feet high super columns. Design complexity is apparent in the complexity of systems that demand different engineering specializations such as civil (infrastructure and structural), electrical, and mechanical engineering. The stadium's managerial complexity is not different than that of other multibillion dollar projects. It is apparent in the managerial efforts needed to overview, control, and coordination the large number of contractors. For instance, the construction works of phases one and two were divided into roughly eighty different packages.

Management Organization

Description. The project's management organization was composed of multiple parties. There were three owners i.e. Miami Dade County, City of Miami, and Miami Marlins baseball team. Miami Marlins formed a Marlins Stadium Developer, LLC to act as the project developer and tenant. The project owners assigned a joint venture composed of International Facilities Group and URS Corporation to act as the client representative. The owners selected HOK sport to act as the primary architectural and design firm for their reputation in designing stadiums, arenas, and other sport facilities. The owners contracted with a joint venture composed of Hunt Construction Group and Moss & Associates in association with Mars Contractors Inc. to act as a construction manager. The construction manager's role was to manage different contract packages and construct the public infrastructure sections of the project. The construction manager was responsible for the project's time and cost performance since the construction management contract was a guaranteed maximum price "at risk" contract.

Structure and organization. The organizational structure was composed of three levels by which a different party occupied each level.

The highest level consisted of the project owners i.e. Miami Dade County, City of Miami, and the project developer Marlins Stadium Developer, LLC. It also consisted of a client representative who assisted the owners by reviewing design and construction management works. To be more accurate, the client representative's role was to review development agreements, construction agreements, design packages, and cost estimates.

The second level, i.e. construction manager's level, consisted of the program management sublevel and the area management sublevel. The program management sublevel consisted of a project manager, assistant project manager, superintendant, inspector, a third party quality control staff, and a project management support staff. Each of the area management groups consisted of a project manager, assistant project managers (number depending on the complexity of the area), quality control inspectors, and a superintendant.

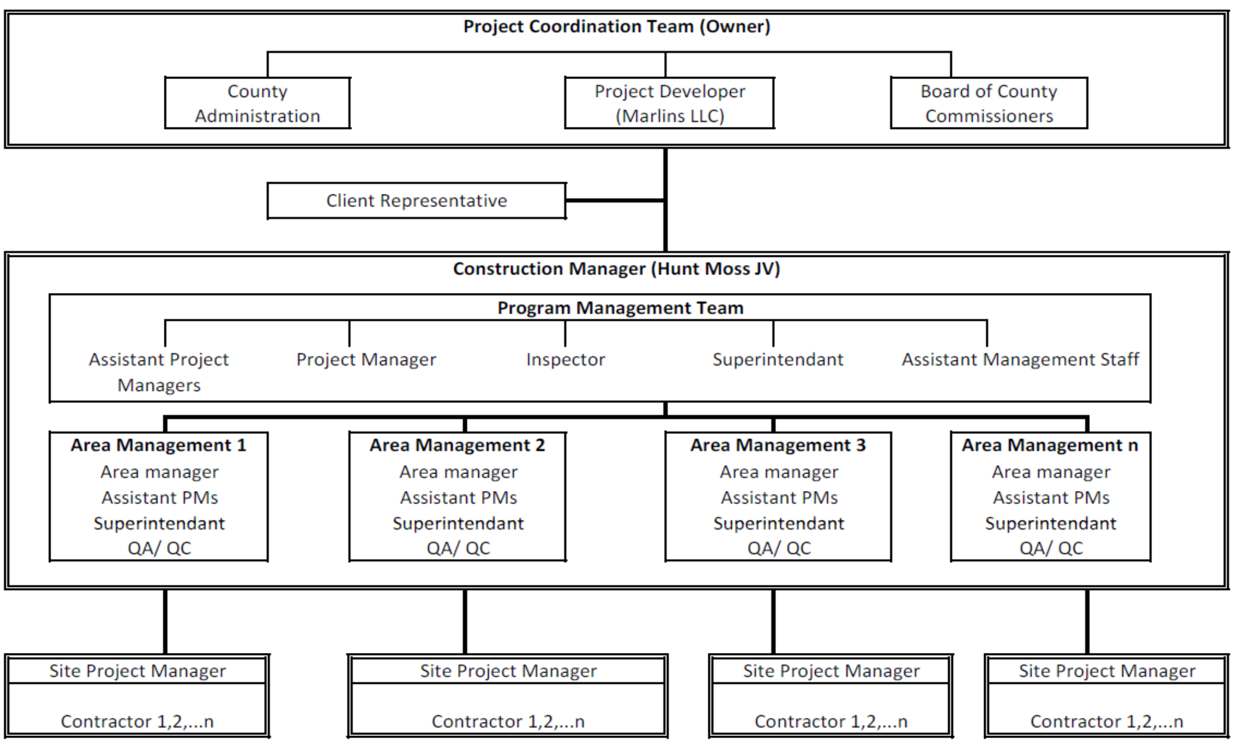


Figure 5-3. Miami Stadium project organizational structure

The third level was composed of subcontractors. Each area was composed of either separate contractors operating under independent contracts or a prime contractor that subcontracted the different works. As the project progressed from phase one to more advanced phases, the subcontractors that completed their works were replaced with different contractors with a different scope of works.

Allocation of duties and responsibilities in the organizational structure. The duties and responsibilities were allocated according to the conventional owner-consultant - contractor organization. The owners retained overall decision making responsibilities. In addition, the owners (i.e. project coordination team) duties were: review schedule, cost, and project budget reports; review quality control forms; review and approve change orders; review status and progress reports from the designer as well as from the construction manager; coordinate and facilitate communication lines between different parties especially the designer and construction manager; conduct periodic status meetings led by the stadium developer that would provide all updates and information regarding all aspects of the project; and conduct special meetings with project managers to solve outstanding problems and coordinate the works among different packages.

The duties and responsibilities allocated at the designer's level were to develop the design, report to the owner (project coordination team), and coordinate with the construction manager. One of the reasons that the project owners selected Hunt/Moss was to ensure adequate coordination between the design consultant and the construction manager since both parties worked together on previous successful projects. The duties and responsibilities allocated at the construction manager's level were not different than the duties of any contractor. The construction manager had total control of the construction project and was responsible for delays or cost overruns. The program management team was responsible for the project's overall cost control, schedule control, and inter-area coordination. Area managers were responsible for the supervision and control of different contracts in their designated areas. Furthermore, area managers had the duty to coordinate with different subcontractors in their areas as well as in other areas.

Reporting and controls. The reporting structure was not different than the organizational structure. The subcontractors reported to the construction manager and the construction manager reported to the project owner (project coordination team). The upper level reporting i.e. construction manager-owner reporting consisted of: individual updated package (i.e. area) schedules and the overall updated construction schedule that are submitted monthly; cost reports and the overall project budget report; quality control reports status and progress reports of the construction works; and project employee outreach reports.

The lower level reporting (i.e. subcontractor-construction manager reporting) consisted of individual reports submitted by each subcontractor and reports submitted by the construction manager's site inspectors and project managers. There were three types of reports submitted by the subcontractors' daily time sheets, certified payroll reports (minimum requirement of sub contractors for their employers); monthly status reports; and project employee outreach reports.

The construction manager was responsible for the project controls. Project problems were solved at the lowest possible level to keep the work flowing. However, as the problems extended from one area to another, more intervention was needed from the higher levels. As for the project changes, the construction manager was allowed to implement changes as long as they neither impact neither the schedule nor the cost. However, if the impact is substantial then the project coordination team (i.e. owner) would review and assess the change before it is implemented.

Difficulties Faced and Lessons Learned

There were numerous difficulties that the management organization faced. One of the difficulties was over congestion of numerous contractors in several construction areas which hindered the work flow and caused delays. In addition, the project suffered from contractors' coordination problems. For instance, contractors who finished their scope of work did not prepare the construction site to the new contractors who had to correct the predecessors' mistakes or prepare the site for different construction activities. Other difficulties were caused by management duties overload. For instance, the subcontractors had extensive reporting duties that included daily audit of time sheets, payroll reports, and other daily reports. The construction management team also had administrative work overload due to the large number of subcontractors, difference in status report formats, and difference in the amount and quality of information presented in the reports.

I-595 Expressway

Data Collection

The data collected for this case study was from three sources. The first source was the project's website that provided general information. The second source was a project management plan that was published by the project's parties. The project management plan had detailed information about the project's scope, agreements, management structures, controls, reporting, documentation, quality control, and other organizational issues. The third source of information was an interview (Appendix A) conducted with one of the project's subcontractors (F. Alavi, personal interview, November 26, 2010) who reported directly to the construction manager. The interview provided additional information about the management organization, allocation of duties, and project controls. In addition, it provided valuable information about the problems faced during construction.

Description

The I-595 Expressway is one of the largest transportation projects currently built in Florida. The project's total length is 10.5 miles. It extends from the I-75/Sawgrass Expressway interchange to the I-595/I-95 interchange. The project includes widening and reconstruction of 2.5 miles of the Florida Turnpike mainline; improvement of I-595/Florida's Turnpike interchange; addition of three new reversible express toll lanes to optimize traffic flow; addition of 13 sound barriers for twenty communities; building new connections and auxiliary lanes along with ramps, cross-road bypasses, and grade-separated entrance and exit ramps to minimize merge, diverge, and weaving movements; and addition of a bus rapid transit service.

The project's cost is $4.75 billion. The cost includes preliminary engineering, design, construction, engineering and inspection, right of way, utilities, operations and maintenance, geotechnical, resurfacing, stipidents, and bus rapid transit cost. The total value of all payments that FDOT will make to construct the project is $1.814 billion. The project's duration is estimated to be five years.

Size and Complexity

According to the project diagram (Chapter 3), the project would be considered as megaproject since it is characterized by a large construction size (10.5 miles), long project duration (5 years), expensive cost ($4.7 Billion), design complexity, and managerial complexity. Design complexity is apparent in the number of different designers needed to accomplish the project. For instance, design duties were allocated among ten different consultants who assisted the main consultant in accomplishing the design. Managerial complexity is apparent in the number of different parties, constructors, and subcontractors needed to accomplish the project.

Management Organization

Description. FDOT signed a concessionaire with ACS Infrastructure Development which later formed I-595 Express LLC to plan, design, finance, construct, operate and maintain the I-595 Expressway.

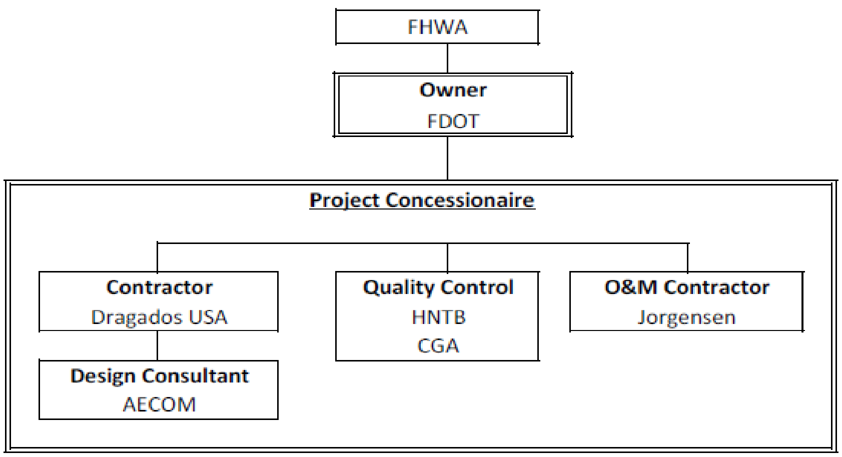


Figure 5-4. I-595 Expressway owner's organization

The concessionaire company was formed of Dragados USA, Inc (DUSA) to act as the prime contractor; AECOM Technology Corporation Inc (AECOM) to act as a design consultant that reported to the contractor; Jorgensen to act as a subcontractor that would assist the concessionaire in the operations and maintenance of the expressway for the first three years; HNTB/Calvin, Giardano & Associates (CGA) as the quality control and inspectors; and stakeholders. The project concessionaire formed an integrated project team that was responsible for project management and delivery.

However, according to the construction contract the contractor was responsible for the project's time, cost, and quality performance.

Structure and organization. The organizational structure had three main management levels. The upper management level i.e. owners level consisted of the FDOT staff and their consultant staff (RS&H). The second management level was composed two separate organizations which were the design-build contractor (DUSA-AECOM) and the quality controller (HNTB-CGA). The third level was composed of subcontractors and sub-consultants that operated in seven different construction segments. The allocation of works followed a functional distribution by which the managing groups were divided into trades instead of areas. The three levels were integrated into a project team by which the owner (FDOT) oversaw the operations of the contractor, consultant, and quality controller.

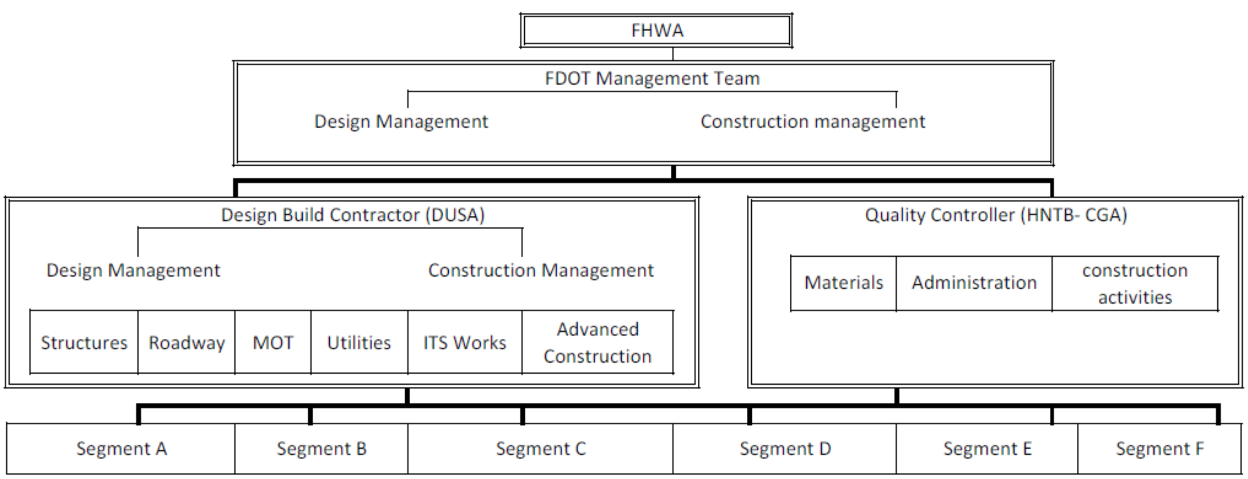


Figure 5-5. I-595 Expressway concise organizational structure

The FDOT oversight management level had two sublevels. The upper sublevel consisted of the oversight project manager, financial support staff (FDOT District 4), and legal support staff (FDOT District 4) who reported to FHWA and FDOT. The lower sublevel consisted of the construction management team and the design management team. The design management team followed a functional distribution by which each functional team (i.e. trade team) coordinated with the designer's corresponding functional team. The construction management team was divided into different departments in order to supervise the oversight consultant (Quality controller HNTB) and overview the contractors' operations using a pool of inspectors that operated in each of the project's segments.

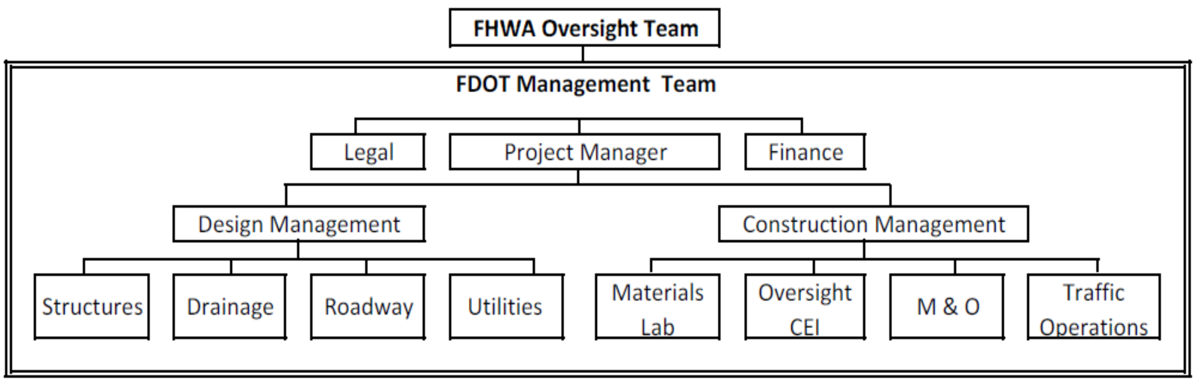


Figure 5-6. I-595 Expressway FHWA's organization

The contractor's management level was divided into three sublevels. The upper project management level consisted of the project manager, quality control staff, safety staff, and business management staff. The second sublevel consisted of two branches i.e. the construction management staff and the design management staff. The construction management staff followed a functional distribution by which there were seven managers of different trades reporting to the construction manager. The works were divided among the following trades: roadways, structures, management of traffic, utilities, intelligent transportation system (ITS) works, and advanced construction works. On the project site, the work packages where divided among six different zones where each of the zones' management teams reported to the functional managers. Each segment staff consisted of a project manager, an assistant manager, superintendant, inspector, MOT manager, utilities manager, and a coordination manager.

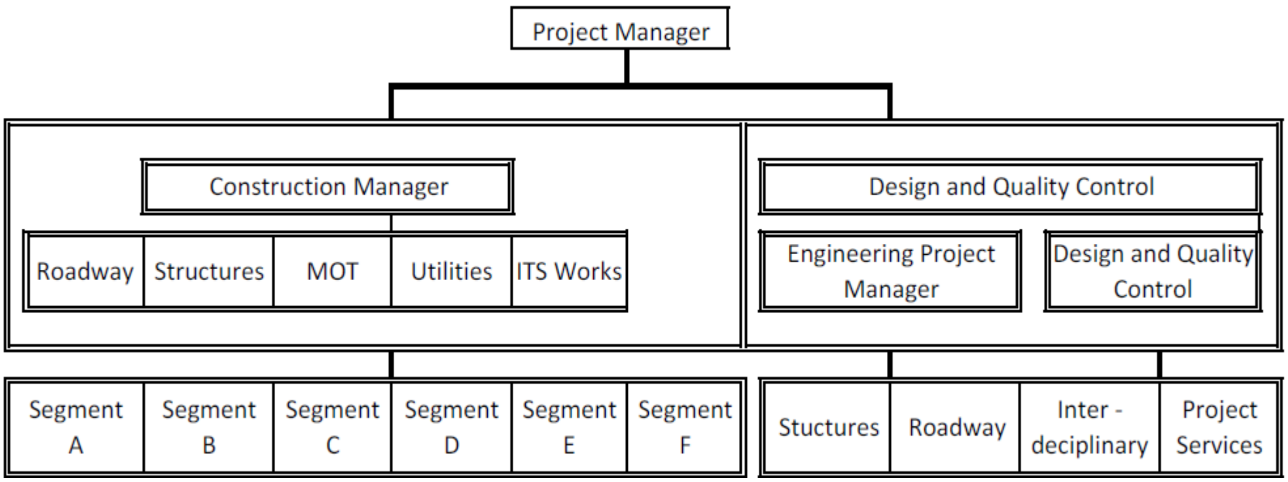


Figure 5-7. I-595 Expressway contractor's organizational structure

The contractor's design management staff consisted of the engineering management team and the engineering support management team. The engineering management team was staffed with engineers that coordinated the design works of the design consultant. It consisted of the engineering project manager, consultant design manager, utilities coordinator, permit coordinator, design coordinator, and shop drawing coordinator. The engineering support management team provided project management support for design and construction activities. The team consisted of a contract administrator, schedule coordinator, cost engineer, and document comptroller. The design activities of the design consultant were divided among three design groups i.e. the structures design team, the roadway design team, and the interdisciplinary design team. The interdisciplinary team consisted of all remaining trades such as: geotechnical, pavement design, utility coordination, safety/fire, environmental/permitting, noise analysis, drainage & hydraulics, landscape/aesthetics, lighting, surveying & mapping, traffic/ITS, MOT, traffic modeling, signing/striping, traffic signalization, ITS Infrastructure.

The design packages were divided into nine zones, where different sub-consultants designed each zone.

Allocation of duties and responsibilities in the organizational structure. The duties and responsibilities were allocated according to the conventional owner-contractor organization. The owner organization (FDOT) was the lead decision making authority in the project. In addition, FDOT's different management teams were responsible for numerous other aspects. FDOT's design management team was responsible for monitoring the designer's works in addition to technical, permitting, utility relocation, and other engineering issues. FDOT's construction management team was responsible for monitoring the contractor's construction operations, cost control, schedule control, and quality control. The team was also responsible for monitoring the operations and maintenance subcontractor. FDOT's project manager along with the financial and legal team were responsible for all administrative issues, technical issues, legal issues, financial issues, and agency coordination/agreements. Furthermore, the FDOT team was responsible for the direct supervision of the oversight inspector and quality controller.

The contractor's duties and responsibilities resembled the duties of a design- build contractor. In general, the duties were: designing and acquiring permits for the different sections of the project; cost and schedule control and reporting; quality control; and procurement and selection of different subcontractors.

However, the roles and responsibilities were allocated along different management levels. The lower level segments were composed of an integrated project management group that had representatives of all parties and functional groups. The segment management teams were responsible for managing different sub-contractors and reporting to all functional managers (structures, roadways, MOT, utilities, ITS) and parties (contractor, quality controller, FDOT inspector). The middle levels consisted of functional managers who were responsible for the management and coordination of a specific trade throughout the project. The upper level consisted of the project manager who was responsible for the overall project production control and coordination of the construction and design works. The project manager was assisted by the engineering management team that was responsible for the monitoring and management of the design consultant. In addition the engineering management team was responsible project management support duties such as contract administration, schedule update, cost and quantity update, and document control.

Reporting and controls. There were two formal reporting levels and other informal (internal reporting) levels. The first formal reporting level where the subcontractors reported to the prime's segment managers included: daily time sheets, certified payroll reports, monthly status reports, and project employee outreach reports.

The second formal reporting level consisted of a monthly progress report that was submitted by the prime contractor to FDOT. The report included four main constituents. The first constituent or activities and deliverables showed the progress of design, construction, and operation activities; QA/QC reports; cost and audit reports; third party negotiations and procurement awards; design, right of way, permit and construction milestones achieved. The second constituent or action items and outstanding issues showed all deviations from the schedule, scope, and budget; quality and safety deficiencies; contractual non-compliance issues. The third constituent or schedule status showed the individual segment progress as well as the project overall progress. It included the explanations of schedule delays and the actions taken for schedule recovery. The fourth constituent or cost status showed the latest approved budget baseline, variance between the approved budget and forecasted cost. It included an explanation for any cost deviations from the approved budget and initiatives being analyzed for recovery of cost overruns.

Other more frequent reports were submitted by the quality controller to FDOT. In addition, the contractor’s management groups had to submit frequent daily and weekly reports to the contractor’s project managers. Segment managers were responsible for project controls in their segments and the construction manager was responsible for the project wide controls. The project problems were solved at the lowest possible level to keep the work flowing. However, as the problem extended from one segment to another, more intervention was needed from the higher level functional managers depending on the problem and the trades included. Project changes were implemented at the lowest possible level. However, substantial changes required the intervention of several managers, FDOT inspectors, and quality control inspectors.

Difficulties Faced and Lessons Learned

Several difficulties have been faced in the construction of the project. One of the difficulties was management duties overload. For instance, the subcontractors had extensive reporting duties that included daily audit of time sheets, payroll reports, and other daily reports. The construction management team also had administrative work overload due to the large number of subcontractors, difference in status report formats, and difference in the amount and quality of information presented in the reports.

I-4 / Selmon Expressway Connector

Data Collection

The data collected for this case study was from several sources. The first source was a collection of online web pages that provided general information about the project and the roles of different project parties. The second source was an interview (Appendix A) conducted with the FDOT project manager (F. Richard, personal interview, December 28, 2010) who oversaw the activities of project parties and work groups. The interview provided valuable information about the project's organizational management, allocation of duties, project controls, and project communications.

Description

The project is composed of an interchange that connects I-4 with Selmon Expressway through multiple elevated one and two lane ramps. The ramps merge at one section to form a twelve lane toll roadway (six lanes in each direction). The project's major activities include the construction of twenty three new bridges in addition to the rehabilitation of the existing I-4 bridges, Lee Roy Selmon Expressway, and other roads. The total project duration is roughly three years. The total project cost is $613, 400, 000 which is divided into $68,600,000 for design and engineering, $67,600,000 for right of way acquisition, and $477,200,000 for construction and inspection.

Size and Complexity

According to the project diagram (Chapter 3), the project would be considered as megaproject since it is characterized by large size, design complexity, and managerial complexity. Although the project's area is small when compared to the areas of the other megaprojects, the volume of construction works is large by which the project consists of constructing 23 bridges (1.5 million square feet of bridge deck) and rehabilitating other bridges and major parts of Interstate 4. Design complexity is apparent in the efforts needed to coordinate the large number of designers. For instance, the main consultant had ten different bridge design teams working with thirty other design sub-consultants over a time period of 36 months. Managerial complexity is apparent in the careful coordination efforts needed to conduct the segmental bridge construction method. The execution operations were further complicated due to the urban area conditions that required a complex sequential construction plan.

Management Organization

Description. The project's complex management system was composed of multiple parties. The project owners were the Florida Department of Transportation - District Seven, the Turnpike Enterprise, and the Tampa-Hillsborough Expressway Authority. The project owners assigned a joint venture of PCL Civil Constructors and Archer Western Contractors. The project's engineer i.e. PBS&J was also assigned by the owner. The design build contractor was responsible for the project's time and cost performance.

Structure and organization. The structure resembled the classical owner - contractor organization. The highest level was composed of the project owners i.e. Florida Department of Transportation - District Seven, the Turnpike Enterprise, and the Tampa-Hillsborough Expressway Authority. The second level i.e. the contractor organization was composed of a Joint Venture of PCL and Archer Western. The construction site work groups were independent by which each contractor was responsible for specific duties. However, there was substantial coordination among the different work groups. The organization followed a segmental construction operation by which the work groups were progressing from span to span in a sequential orderly pattern. For instance the construction activities would start with the earthworks and foundations workgroup followed by the bridge construction workgroup.

Allocation of duties and responsibilities in the organizational structure. The duties and responsibilities were allocated according to the conventional owner – design/build contractor organization. The owners retained overall decision making responsibilities. In addition the owners were responsible for reviewing schedule, cost, and project budget reports; reviewing quality control forms; reviewing and approving change orders; approval of works by the engineer on record; and approval of shop drawings.

The second level i.e. the contractor organization was responsible for overall cost control, schedule control, and work group coordination. For instance, the contractor had to coordinate the roadway/foundations group and bridge construction group. In addition, the contractor had to refine the design and coordinate the design works with the FDOT state design office and the FDOT district design office.

Reporting and controls. In this simple hierarchy, there was only a single level of reporting by which the contractor reported to the owner parties. Three types of meetings were conducted periodically. Progress meetings were conducted weekly and included discussions and schedule updates. Priority meetings were conducted frequently and addressed more specialized issues such as RFIs, shop drawing, early submittals, and other important issues that needed to get done. Utility and other meetings addressed miscellaneous issues. As for the changes, all changes had to be approved by the engineer on record in accordance with the state design office whether they originated from the contractor or the owner.

Difficulties Faced and Lessons Learned

There were numerous difficulties that the management organization faced. The first difficulty was caused by the complex “span-by-span” construction operation that demanded coordination efforts to install all parts and pieces. In addition, the complex design review and approval process caused an overload of work duties and left project officials with no chance to improve or change the designs of different components. Another difficulty faced was the demanding design process that caused a bottleneck and required an increase in the state design staff and engineers on record staff.

CHAPTER 6
WORK PRACTICES APPLIED

The case studies provided a set of work practices that differ in the allocation of duties and responsibilities, division of works, extent of workgroup integration, and methods of operation. The work practices presented are management structures, contractual structures, and implementation methods. The following analysis includes a description of the work practices, advantages, disadvantages, and favorable conditions.

Management Structures

Management structures applied on megaprojects are similar to the structures applied on conventional projects. However, the scale is much larger since one megaproject part corresponds to a large construction project that is in the range of a hundred million dollars. Megaproject management structures are similar to the structure of a construction firm that is managing a portfolio of concurrent projects. The management structures analyzed are area management structure, independent area management structure, functional management structure, and matrix management structure. The structures differ in the allocation of duties among groups, trades, and management levels. They also differ in the extent of integration among different trades and workgroups. The following is a description of the management structures, advantages, disadvantages, and favorable project conditions.

Area Management Structure

Description and characteristics. The area management structure divides project works into several areas. The structure consists of three main levels i.e. executive management level, middle management level, and area management level. Executive management is responsible for major decisions such as the selection of contractors and approval of major changes. Middle management is responsible for the overall management of the project including cost control, schedule control, quality control, and design management. In addition, it is responsible for the organization and integration of all area works including design packages, activities, schedule, and cash flow. The area management level consists of area managers along with their supporting project management staff and engineering staff. Project management authorities are delegated to area managers by which they have total control over their areas. In addition, area managers are responsible for cost control, schedule control, and quality control in their designated areas. Middle and executive management would intervene only when intra area coordination is needed or if there are substantial delays and changes that might affect the overall cost or master schedule.

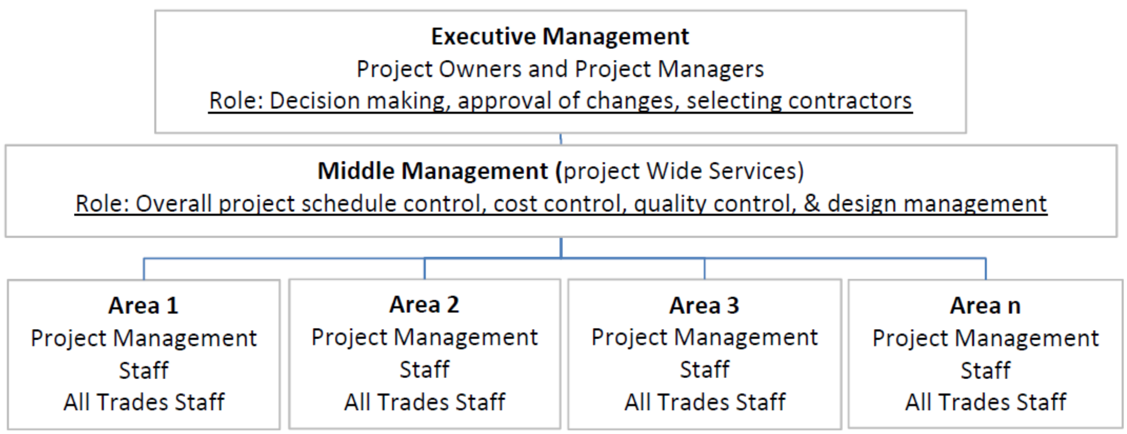


Figure 6-1. Area management structure

Advantages, disadvantages, and favorable conditions. The structure has many advantages. It is easy to implement by dividing the project into unambiguous areas with clear authority and centralized reporting procedures. It provides overall schedule and cost integration. It also provides efficient workflow in each area and effective coordination among different trades within the areas. The structure also has several disadvantages. It does not provide sufficient coordination among work teams of different areas. Changes, delays, and updates that involve more than one area are handled at upper levels with a slower pace. Projects favorable for this structure are the projects that could be easily divided into sections with minimal managerial intervention required for works that include two or more areas.

Independent Area Management Structure

Description and characteristics. The independent area management structure is similar to the area management structure by which project works are divided into several areas. However, the areas are not integrated that is they are treated separately by project executives and managers. The structure consists of two levels i.e. executive management level and area management level. By decreasing the number of levels, the organization operates in a streamlined and efficient way that is not hampered by the bureaucracy of the long vertical hierarchy. The two-level organization allows the upper management level to be informed of the most recent updates, and allows area managers to respond to project changes in a swift manner. Executive management is responsible for the main decisions such as selection of contractors and approval of major changes. The area management level consists of area managers along with their supporting project management staff and engineering staff. Project management authorities are delegated to area managers by which they have total control over their areas. In addition, area managers are responsible for cost control, schedule control, and quality control in their designated area. Area managers are assisted by a technical assistance team that helps in management and engineering duties such as quality control, scheduling, cost control, contract administration, design issues, and means and methods.

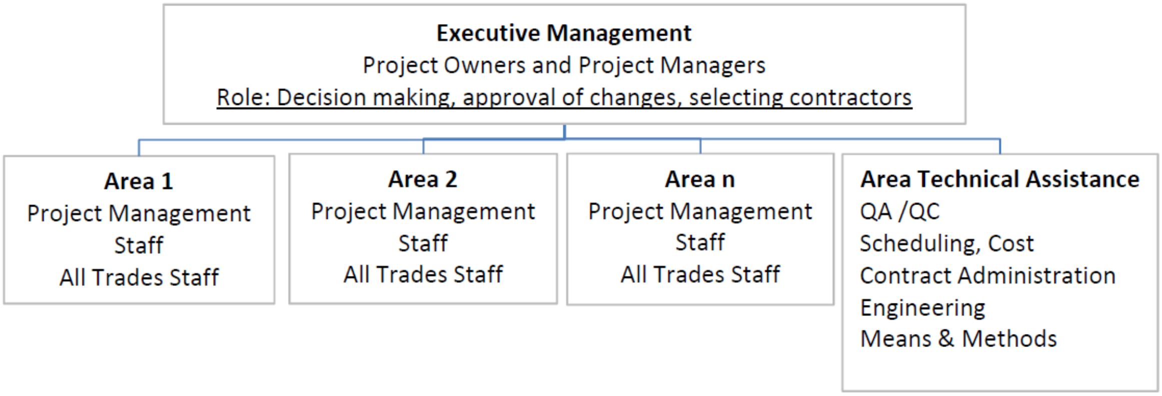


Figure 6-2. Independent area management structure

Advantages, disadvantages, and favorable conditions. The structure has many advantages. It is easy to implement by dividing the project into unambiguous areas with clear authority and centralized reporting procedures. It provides efficient workflow in each area and effective coordination among different trades within the areas. The structure also has several disadvantages. It does not provide overall schedule and cost integration since the areas are treated separately. It does not provide sufficient coordination among work teams of different areas. Changes, delays, and updates that involve more than one area are handled at upper levels with a slower pace. Projects favorable for this structure are the projects that could be easily divided into sections with no interactions among areas such as geographically separated areas.

Functional Management Structure

Description and characteristics. The functional management structure is different from area management structures by which the works are divided among different trades (i.e. specializations) instead of areas. The structure consists of three main levels i.e. executive management level, middle management level, and the contractors' level. Executive management is responsible for major decisions such as the selection of contractors and approval of major changes. The middle management level consists of several functional managers by which each functional manager is responsible for a single trade throughout the project sections. In addition, middle management is responsible for the overall management of the project including cost control, schedule control, quality control, design management, and integration of all trades. The contractors' level consists of project management staff and technical staff who report the status of different project sections to the functional managers and the project manager.

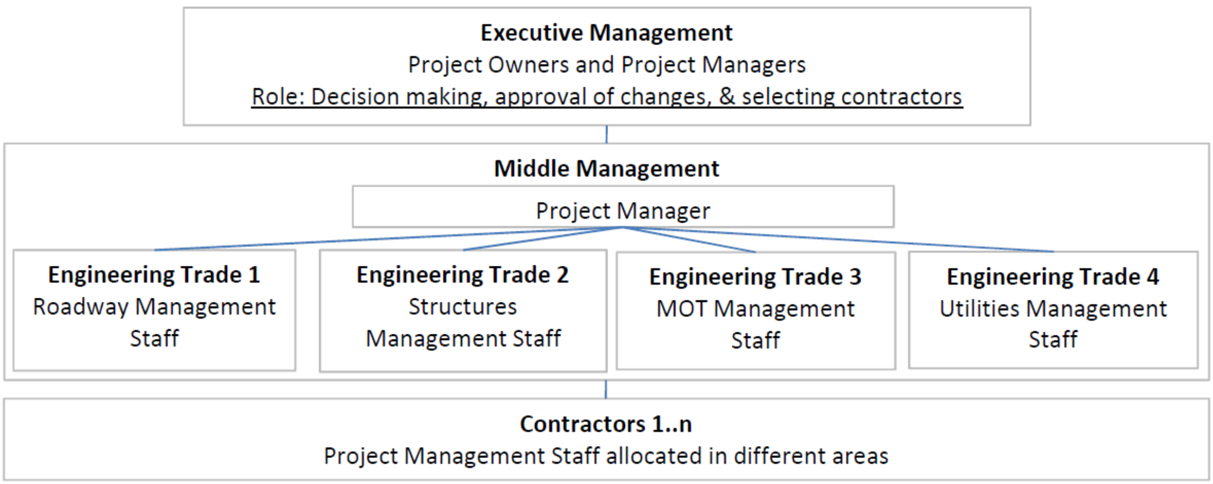


Figure 6-3. Functional management structure

Advantages, disadvantages, and favorable conditions. The structure has many advantages. It provides substantial coordination among different trades throughout the entire project since trade managers oversee all project segments. It provides overall schedule and cost integration. It allows easier coordination with the design teams since each of the construction trade managers is able to follow up with the corresponding trade design team. The structure also has several disadvantages. It does not provide clear lines of authority and reporting since multiple managers oversee the construction groups. This is solved if an internal mechanism is devised to centralize the decision making process. For instance, decision priorities could be given to a single functional manager who oversees the works of other functional managers. Projects favorable for this structure are complex projects that cannot be divided into clear-cut segments. In addition, projects that encompass complex designs which demand the integration of multiple trades throughout the project are favorable for this structure. However, the structure is not adequate to use when the scope of a single trade is not manageable by a single work group. This is solved if more than one functional manager and work group are assigned to manage a single trade.

Matrix Management Structure

Description and characteristics. The matrix management structure is similar to the area management structure by which project works are divided into several areas. The structure consists of three main levels i.e. executive management, middle management, and the area management level. Executive management is responsible for major decisions such as selection of contractors and approval of major changes.

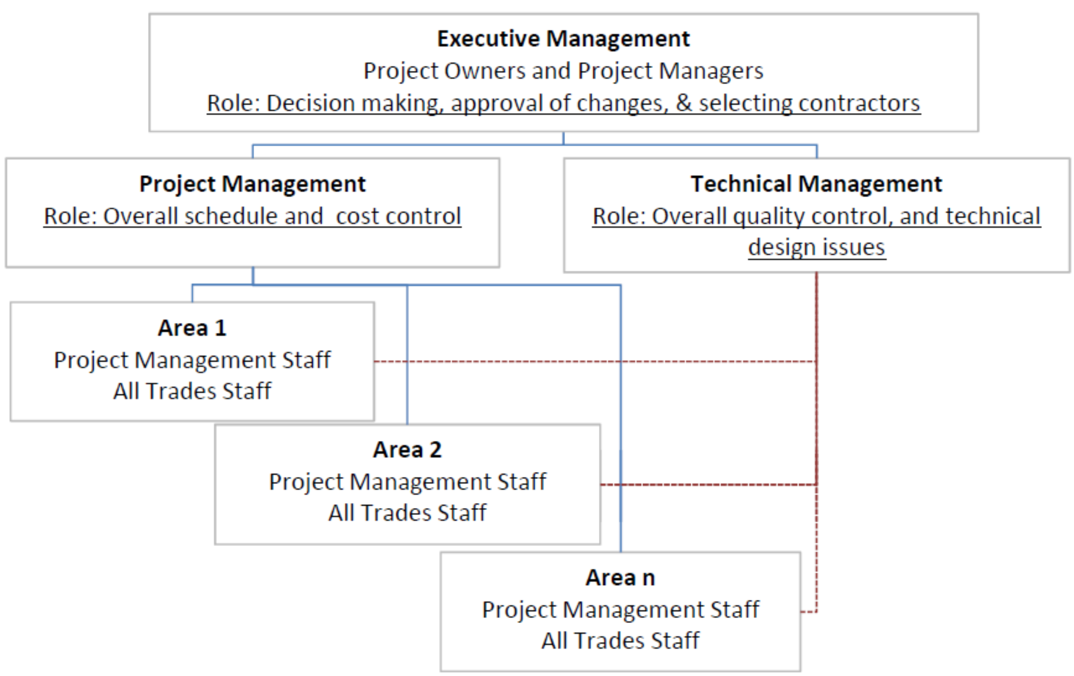


Figure 6-4. Matrix management structure

The middle management level is composed of two teams i.e. the project management team and technical management team. The project management team is responsible for cost control, schedule control, production control, and work integration of all areas. The technical management team is responsible for design management, design integration of all packages, design change follow up, and site quality control.

Advantages, disadvantages, and favorable conditions. The structure has many advantages. It provides substantial coordination of different trades throughout all areas since the technical management team oversees all project areas. It provides overall schedule and cost integration. It allows easier coordination with the design teams since the technical management team is able to follow up with design development as well as construction development. The structure also has several disadvantages. There are no clear lines of authority due to dual reporting. This could be solved if an internal mechanism is devised to centralize the decision making process as was applied in the I-595 Expressway project. For instance technical management could report to the project management team which would constitute the primary decision making authority. Projects favorable for this structure are complex projects that demand extensive quality control and design follow up. In addition, projects that involve complex designs which demand the integration of different design trades throughout the project are favorable for this structure.

Contractual Structures

Megaproject contractual structures are similar to the conventional structures. However, megaproject contractual structures are much more complex. Each organization refers to a group of coordinated firms with separate duties. For instance the design consultant refers to a group of designers working under a design management firm that integrates the design packages. The owner organization refers to the owner's management consultants, project managers, development firm directors, and public agency officials. The contractor refers to a single or multiple firms acting as a construction manager over project works. The types of contractual structures presented are owner-contractor organization, owner-design/build contractor organization, owner-management consultant organization, and integrated project organization. The contractual structures differ in the allocation of duties and the extent of integration of different parties. The following is a description of the management structures applied, advantages, disadvantages, and favorable conditions.

Owner - Contractor Organization

Description and characteristics. The owner-contractor organization is one of the most popular organizations. The organization consists of three main parties i.e. owner, design consultant, and contractor. The owner organization responsibilities include managing the design and coordinating the design-construction activities. The contractor is responsible for overall project cost, time, and quality control. Furthermore, the contractor is responsible for the selection of subcontractors.

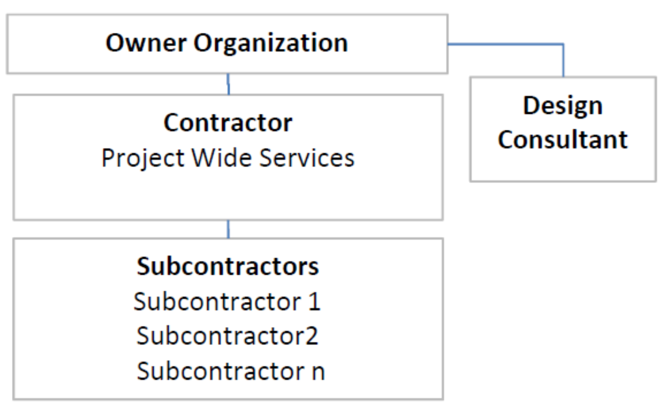


Figure 6-5. Owner-contractor organization

Advantages, disadvantages, and favorable conditions. The structure's advantage is that it provides the owner organization with control over the design activities. The structure also has several disadvantages. It is hard to implement by the owner's team since it demands numerous resources and expensive staffing. The design and construction parties are not as integrated in this structure as in other structures. Construction updates and design changes follow an inefficient process since they have to go through the approval process of multiple organizations. Favorable conditions for this structure are the owner's willingness and capability to assume design management responsibilities and design quality control responsibilities. Other favorable conditions are the local laws that require agencies to intervene in the design development and design approval processes.

Owner – Design/Build Contractor Organization

Description and characteristics. The organization consists of two main parties i.e. owner and design-build contractor. The owner organization has limited responsibilities that include following up with project progress and with other management issues.

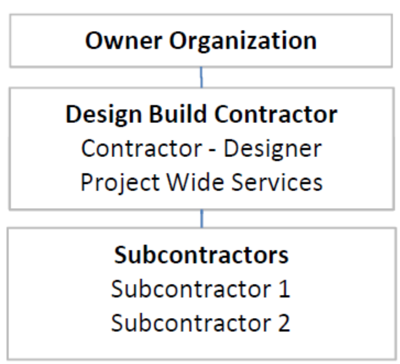


Figure 6-6. Owner-design/build contractor organization

The design-build contractor is responsible for almost all project issues such as overall cost control, schedule control, and quality control. In addition, the design-build contractor is responsible for subcontractor selection, design management, and design-construction activity coordination.

Advantages, disadvantages, and favorable conditions. The structure has many advantages. It liberates the owner organization from design and management responsibilities. It provides the contractor with decision making authority and control over the entire design-construction activities. Consequently, it leads to a more considerable design – construction integration as compared to the owner-contractor organization. It also provides an efficient operation with respect to design changes as compared to the owner-contractor organization. The structure also has several disadvantages. It is hard to implement by the contractor's team since it demands numerous resources and expensive staffing. Favorable conditions for this structure are the owner's inability to assume design management and control responsibilities. Other favorable conditions are the project's requirement to finish within a designated time frame.

Owner – Management Consultant Organization

Description and characteristics. The owner-management consultant organization consists of four main parties i.e. owner, management consultant, design consultant, and contractors. The owner organization is responsible for almost all project issues such as, overall cost control, overall schedule control, overall quality control, and subcontractor selection. The management consultant has limited responsibilities that include follow up with project progress, project monitoring, and project reporting. In addition, the management consultant is responsible for managing the design and coordinating the design- construction activities. The individual contractors and subcontractors are responsible for the cost, schedule, and quality control in their designated project portions.

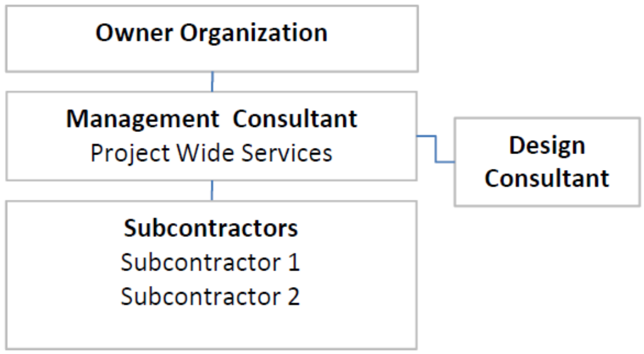


Figure 6-7. Owner-management consultant organization

Advantages, disadvantages, and favorable conditions. The structure has many advantages. It liberates the owner organization from design coordination responsibilities. It liberates the construction manager i.e. management consultant from several management responsibilities such as schedule control and cost control. It provides design – construction integration since these duties are done by a single entity. The structure also has several disadvantages. The owner is responsible for the overall cost and time objectives since the management consultant's duties are limited to monitoring and reporting. It does not provide an efficient operation with respect to design changes since changes have to go through the owner organization. It is difficult to implement by the owner's team since it demands numerous resources and expensive staffing. Projects favorable for this structure are the projects that do not necessitate rigid cost and time objectives. Other favorable conditions are the owner's willingness and capability to assume design and construction control responsibilities.

Integrated Project Organization

Description and characteristics. The integrated project organization is made of both the owner's employees and the management consultant employees. This organization is formed to encourage better communication between the parties and produce a more efficient and streamlined decision making. The integrated project organization is responsible for all project issues including overall cost, overall schedule, overall quality control, subcontractor selection, and design management.

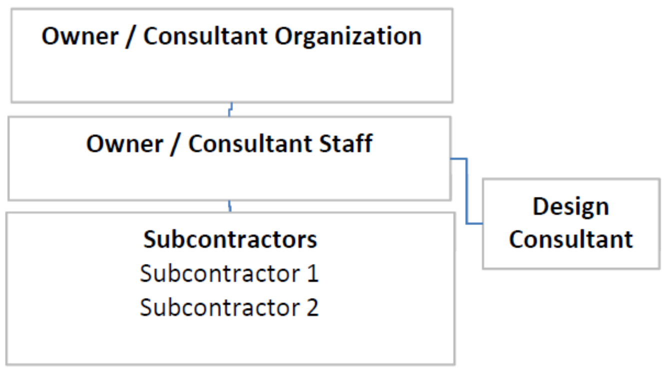


Figure 6-8. Integrated project organization

Advantages, disadvantages, and favorable conditions. The structure has many advantages. It provides maximal design – construction integration since these duties are done by the same entity. It is easy to implement by the owners since staffing is done by the management consultant employees. The structure also has several disadvantages. The owner employees are responsible for the overall project cost and time objectives since the management consultant's employees are responsible for monitoring and reporting. No clear lines of authority are set which leads to construction claims and disputes between different parties. Projects favorable for this type of structure are the projects that do not necessitate rigid cost and time objectives.

Operation Methods

Megaproject operation methods differ in how the project is constructed. This difference leads to differences in time consequences, cost consequences, management load, and project performance. The operation methods presented are: individual package operation, sequential package operation, and concurrent package operation. The following is a description of the operation methods applied, advantages, disadvantages, and favorable conditions.

Individual Package Operation

Description and characteristics. In the individual package operation, the overall project is divided into separate packages where each package is constructed independently. In other words, each package is handled as a separate project that is planned, designed, constructed, and open to public before any other package construction is started.

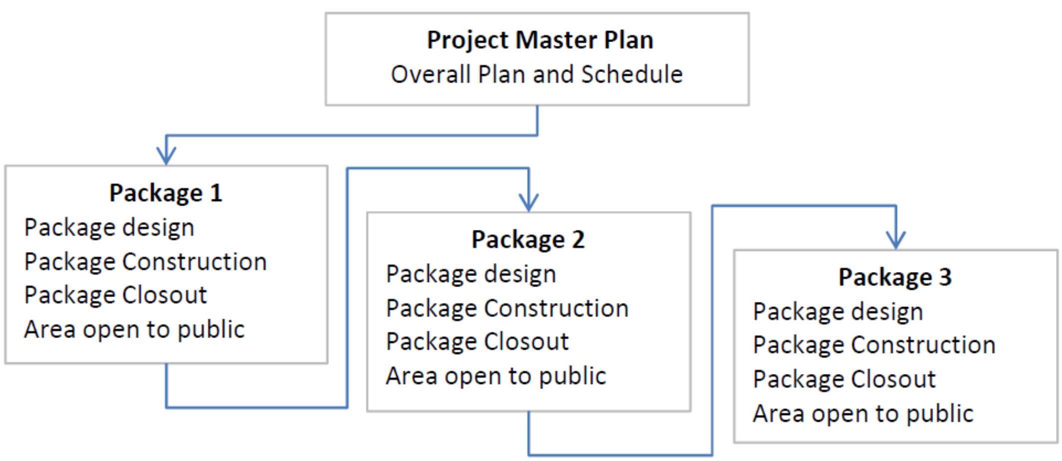


Figure 6-9. Individual package operation

Advantages, disadvantages, and favorable conditions. The individual package operation has many advantages. It provides the easiest method to manage a megaproject by dividing it into independent packages. It provides an alternative that does not necessitate plenty of management resources nor expensive staffing. One of its disadvantages is the long time frame needed to complete the overall project. One favorable condition for this method is the inability of the project owners to manage or finance the overall project. Projects favorable for this method are projects that do not require to be completed in a short period of time. In addition to projects that could be easily divided into clear cut packages.

Sequential Package Operation

Description and characteristics. In the sequential package operation, the overall project is also divided into separate packages. However, the packages are constructed sequentially i.e. construction activities would progress from package to package. For instance, earthworks would progress from package 1 to package 2 to package 3, followed by foundations progressing through packages 1 and 2, followed by structures commencing at package 1.This type of operation allows package managers to be changed from one trade to another as works progress.

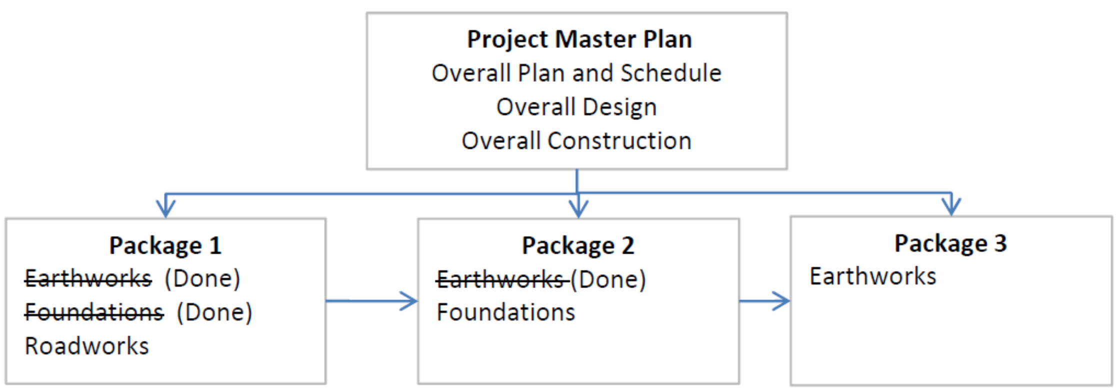


Figure 6-10. Sequential package operation

Advantages, disadvantages, and favorable conditions. The sequential package operation has many advantages. It provides a construction schedule that is shorter than the individual package operation. It provides an alternative that does not necessitate plenty of management resources nor expensive staffing because the resources get shifted from package to package as the project progresses. However, it demands more resources than the individual package operation. One of the disadvantages is the management load imposed on project officials to manage multiple packages. One favorable condition for this method is the project's necessity to finish in a short time frame. Another favorable condition is the availability of funding for all packages

Concurrent Package Operation

Description and characteristics. In the concurrent package operation, the overall project is also divided into separate packages. However, the packages are constructed concurrently in order to save time.

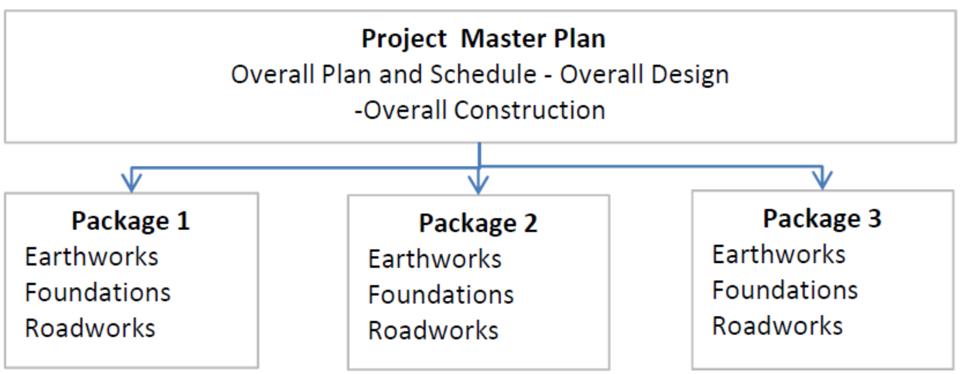


Figure 6-11. Concurrent package operation

Advantages, disadvantages, and favorable conditions. The concurrent package operation has many advantages. It provides the shortest construction schedule among all operation methods. It also has several disadvantages. It requires plentiful management resources and expensive staffing. Another disadvantage is the tremendous management load imposed on project officials to manage multiple packages. One favorable condition for this method is the necessity of the project to finish in a short time frame. Another favorable condition is the availability of funding for all packages.

CHAPTER 7
EVALUATION OF WORK PRACTICES

The application of different working level management practices leads to a range of performance outcomes. Work practices vary in their ability to achieve the project's cost, time, and quality objectives. In addition, each of the work practices provides a different approach to solve megaprojects problems i.e. managerial duties problem, managerial control problem, and integration problem. Therefore, a survey was conducted in order to evaluate the work practices according to the following performance measures:

- Ability to control cost, complete the project on time, and deliver according to the quality requirements as a solution for the poor performance problem
- Ability to streamline managerial tasks and make the management system more efficient and as a solution for the management duties problem
- Ability to provide adequate control and oversight over activities and workgroups as a solution for the management control problem
- Ability to provide adequate integration among work groups as a solution for the integration problem
- Cost consequences
- Time consequences

Survey Description

The survey consisted of four sections i.e. recipient information section, management structures evaluation section, contractual structures evaluation section, and operation methods evaluation section. It included twenty multiple choice and ranking questions (Appendix B). It also included a schematic and a brief description of the work practices to assist the recipients in answering the questions.

The recipient information section consisted of six multiple choice questions that requested information about:

- Recipients' party background i.e. designer, contractor, management consultant, or governmental agency.
- Recipients' years of experience
- Recipients' position background i.e. construction manager, program manager, project manager, site engineer, superintendant.
- Recipients' project background i.e. the cost of the most expensive project they have worked on
- Recipients' industry background i.e. transportation construction, building construction, heavy construction, industrial plants construction.

The management structures evaluation section consisted of five questions that required the recipient to rank four management structures i.e. area management structure, independent area management structure, functional management structure, and matrix management structure according to different performance measures. The ranking questions were as follows:

- Rank the management structures according to the best allocation of duties that would streamline the managerial tasks (example: limit managerial duties bottlenecks, and respond to project updates and changes in a swift manner)
- Rank the management structures according to the ability to provide upper management with adequate oversight and control over activities, workgroups, and project changes
- Rank the management structures according to the ability provide adequate integration among different trades and work groups on the construction site
- Rank the management structures according to the managerial ability to control cost, complete the project on time, and deliver according to the quality requirements
- Rank the management structures according to the cost of staffing and implementation from the least expensive to the most expensive

The contractual structures evaluation section consisted of six questions that required the recipient to rank four contractual structures i.e. owner-contractor organization, owner-design/build contractor organization, owner-management consultant organization, and integrated project organization according to different performance measures. The ranking questions were as follows:

- Rank the contractual structures according to the best allocation of duties that would streamline the managerial works (example: organize design-construction activities, limit managerial duties bottlenecks, and respond to project updates and changes in a swift manner)
- Rank the contractual structures according to the owner's involvement and ability to control the design and construction activities and changes
- Rank the contractual structures according to the ability provide adequate integration among different project parties
- Rank the contractual structures according to the managerial ability to control cost, complete the project on time, and deliver according to the quality requirements
- Rank the contractual structures according to the their ability to provide the least project cost (including management fees, contractor's overhead and profit, and construction costs)
- Rank the contractual structures described above according to the their ability to provide the least project time

The operation methods section consisted of three questions that required the recipient to rank three operation methods i.e. are individual package operation, sequential package operation, and concurrent package operation according to different performance measures. The ranking questions were as follows:

- Rank the operation methods according to the difficulty of managing the project from the least difficult to the most difficult
- Rank the operation methods according to the ability to provide the least project cost including staffing costs and construction costs of all packages

- Rank the operation methods according to the ability to control costs, limit schedule delays, and deliver according to quality requirements from the least difficult to the most difficult

Population Description

The survey targeted construction, engineering, and management professionals. The respondents worked at different project parties, construction industries, and management positions. The total number of responses was 80 for the management structures section, 70 for the contractual structures section, and 68 for the operation methods section. The following is a description of the respondents' population.

Respondent party background. The points of views of all project parties are represented in the survey as illustrated in Figure 7-1.

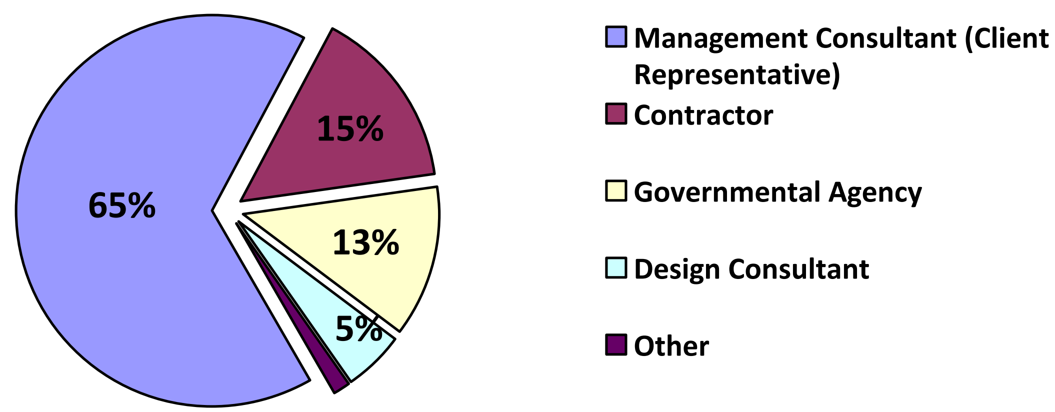


Figure 7-1. Respondents' party distribution

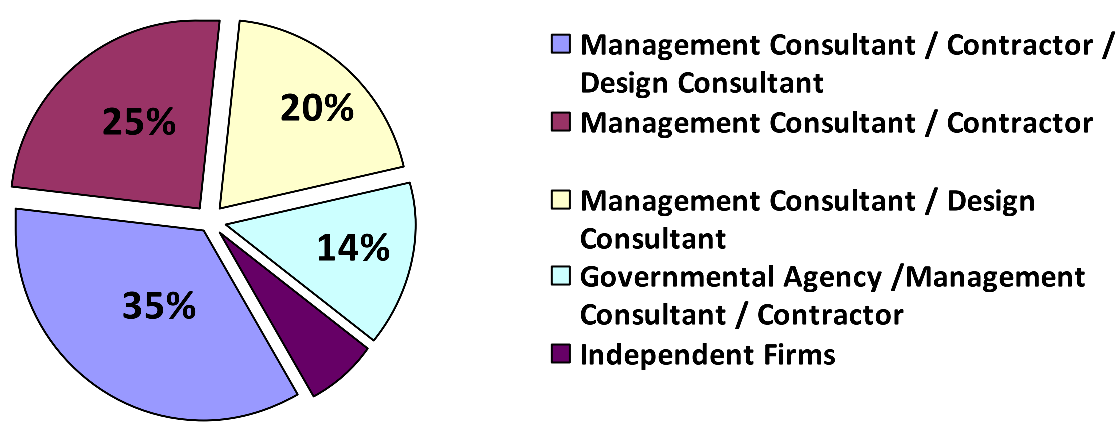


Figure 7-2. Respondents' party background distribution

However, the respondents' experience is not confined to the party they belong to. In other words, the majority of the respondents have worked in multiple parties (Figure 7-2) and experienced different management processes, which adds to the validity of the survey evaluations.

Respondent management experience. All respondents had an experience of ten years or more. The respondents have occupied a variety of management positions. However, the majority occupied high management levels such as project management and program management levels. This adds to the validity of the survey evaluations since managing a megaproject is similar to managing a program of projects that are constructed concurrently. The percentages were: 92.5% of the respondents occupied program management positions, 89% occupied project management positions, 62% occupied project engineer positions, 61.3% occupied assistant project management positions, 21.3% occupied design management positions, 22.5% occupied design positions, 35% occupied site engineering positions, 20% occupied project super Intend ant positions, 6% occupied academic positions, and 20% occupied other positions.

Respondent project background. The respondents worked in projects of different sizes and dollar values as illustrated in Figure 7-3. Almost fifty percent of the respondents have worked in projects that exceeded the billion dollar price tag. In addition, more than thirty five percent of the respondents worked in projects where the price ranged between one hundred and five hundred million. This implies that the three quarters of the respondents have worked in large scale projects, which adds to the validity of the survey evaluations.

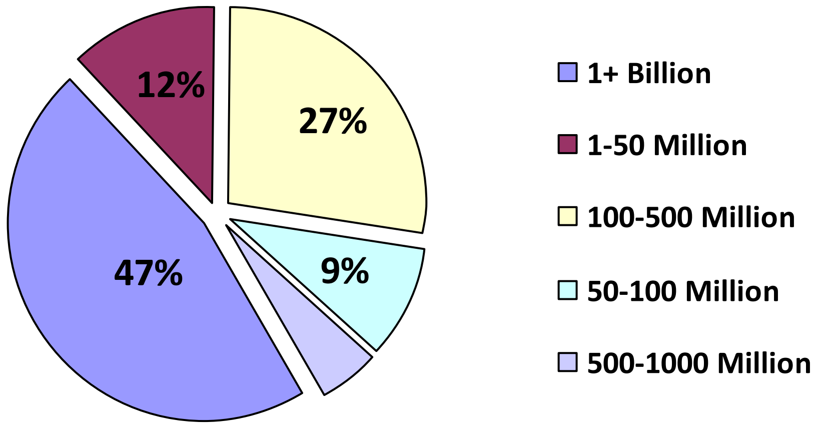


Figure 7-3. Projects' cost distribution

Respondent industry background. The respondents worked in mixed construction industries and experienced projects of different complexities (Figure 7-4). Almost a third of the respondents worked in all construction industries. In addition, three quarters have worked in mixed industries such as building and commercial / transportation; transportation / heavy construction; industrial and power plants / building and commercial.

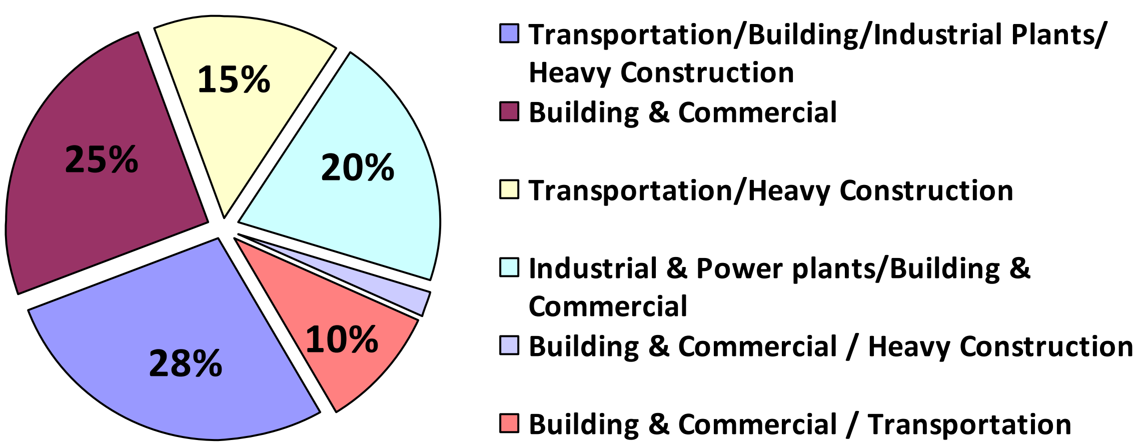


Figure 7-4. Construction industry distribution

Results and Analysis

The ranking of work practices varied according to different criteria. The results of the ranking questions, statistical analysis of results, and conclusions are presented in the following.

Management Structures

Ranking according to the best allocation of duties that would streamline the managerial tasks. An analysis of variance (1-way ANOVA) test was conducted to determine if there are differences between the management structures' ranking according to 5% significance level (P critical =0.05). In other words to test the hypothesis:

H0: $\mu 1 = \mu 2 = \mu n = 0$

Ha: At least μi is not equal to 0

The analysis (Appendix D) revealed that the structures are significantly different (P value = 0.0236 < P critical) according to their ability to allocate duties that would streamline the managerial tasks i.e. reject the null hypothesis. The ranking of the management structures along with the mean rank is as follows:

1. Area Management Structure (mean rank = 2.175)
2. Functional Management Structure (mean rank = 2.575)
3. Independent Area Management Structure (mean rank = 2.575)
4. Matrix Management Structure (mean rank = 2.675)

A pair-wise mean analysis to compare sample means was conducted according to Fisher's least significant difference test (LSD) to determine which structures differ and which are similar.

$$LSD_{ij} = t_{\alpha/2}\sqrt{S^2 w\left(\frac{1}{n_i}+\frac{1}{n_j}\right)} \; where\ \alpha = 0.05 \quad \cdots \quad (equation \quad 1)$$

The tests (Appendix D) revealed that the area management structure is significantly different than the other structures (P=0.0087). No significant difference was found among the other management structures (P=0.3). The following pair wise comparisons show which structures are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

Area Functional Independent Area Matrix

Construction professionals considered that the structure with unambiguous area limits, clear and centralized reporting procedures, and ability to integrate the works of all sections is the structure that would provide the most streamlined management operation.

Ranking according to the ability to provide upper management with adequate oversight and control over activities, workgroups, and project changes. The analysis of variance test (Appendix D) revealed that the structures are significantly different at a 5% significance level (P value = 0.0016 < P critical) according to their ability to provide upper management with adequate oversight and control. The ranking of the management structures along with the mean rank is as follows:

1. Area Management Structure (mean rank = 2.225)
2. Functional Management Structure (mean rank = 2.313)
3. Matrix Management Structure (mean rank = 2.638)
4. Independent Area Management Structure (mean rank = 2.825)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that there is significant difference between area management structure and functional structure on one hand and independent area management structure and matrix management structure on the other hand (P=0.0423). There is no significant difference between area management structure and the functional structure. The following pair wise comparisons show which structures are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

Area	Functional	Matrix	Independent Area

According to construction professionals, the structures that could integrate all works of all sections and centralize reporting are the structures that would provide the optimal oversight and control. However, there was no agreement if integrating areas or trades is better. This is due to the fact that the structures perform differently according to different project complexities.

Ranking according to the ability provide adequate integration among different trades and work groups. The analysis of variance test (Appendix D) revealed that the structures are significantly different at a 5% significance level (P value = 0.0013 < P critical) according to their ability to provide adequate integration among different trades and work groups. The ranking of the management structures along with the mean rank is as follows:

1. Functional Management Structure (mean rank = 2.25)
2. Area Management Structure (mean rank = 2.3)
3. Matrix Management Structure (mean rank = 2.588)
4. Independent Area Management Structure (mean rank = 2.863)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that there is significant difference between functional structure and area management structure on one hand and matrix management structure and independent area management structure on the other hand (P=0.048). There is no significant difference between area management structure and the functional structure. The following pair wise comparisons show which structures are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

Functional	Area	Matrix	Independent Area

According to construction professionals, the structures that could integrate all works of all sections and centralize reporting are the structures that would provide the best integration. However, the functional structure scored better than the area management structure since it could provide trade integration all over the project site.

Ranking according to the managerial ability to control cost, complete the project on time, and deliver according to the quality requirements. The analysis of variance test (Appendix D) revealed that the structures are not significantly different at a 5% significance level (P value = 0.25 > P critical) according to their ability to control cost, complete the project on time, and deliver according to the quality requirements. The ranking of the management structures along with the mean rank is as follows:

1. Area Management Structure (mean rank = 2.313)
2. Independent Area Management Structure (mean rank = 2.488)
3. Functional Management Structure (mean rank = 2.538)
4. Matrix Management Structure (mean rank = 2.663)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that there is significant difference between area management structure on one hand and matrix management structure on the other hand (P=0.0252).

By comparing the highest and the lowest scorers, it is clear that the structure that has the better ability to centralize reporting and integrate all management duties is the structure that would provide the better ability to control cost, complete project on time, and deliver according to the quality requirements.

Ranking according to the cost of staffing and implementation from the least expensive to the most expensive. The analysis of variance test (Appendix D) revealed that the structures are not significantly different at a 5% significance level (P value = 0.22 > P critical) according to their cost of implementation. The ranking of the management structures along with the mean rank is as follows:

1. Independent Area Management Structure (mean rank = 2.363)
2. Functional Management Structure (mean rank = 2.388)
3. Matrix Management Structure (mean rank = 2.544)
4. Area Management Structure (mean rank = 2.688)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that there is significant difference between the area management structure on one hand and all other management structures on the other hand (P=0.0388). The following pair wise comparisons show which structures are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

Independent Area   Functional   Matrix   Area

By comparing area management structure to all other structures, it is clear that providing work integration, reporting centralization, clear area authority, and resource replication increases the staffing costs.

Contractual Structures

Ranking according to the best allocation of duties that would streamline the managerial works. The analysis of variance test (Appendix D) revealed that the structures are significantly different at a 5% significance level (P value = 0.0001 < P critical) according to the best allocation of duties that would streamline the managerial works. The ranking of the management structures along with the mean rank is as follows:

1. Owner-Design/build Contractor Organization (O-DB) (mean rank = 1.943)
2. Integrated Project Organization (IPO) (mean rank = 2.271)
3. Owner-Management Consultant Organization (O-MC) (mean rank = 2.343)
4. Owner-Contractor Organization (O-C) (mean rank = 3.443)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that there is significant difference between owner-design/build contractor organization on one hand and integrated project organization and owner-management consultant organization on the other hand (P=0.0277). In addition, the owner-contractor organization is significantly different than all the other organizations (P=0.0001). The following pair wise comparisons show which structures are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

O-DB	IPO	O-MC	OC
	________	________	

According to construction professionals, the owner-design/build contractor organization provides the most efficient management operation and the owner-contractor structure provides the least efficient operation. It is clear that the more duties allocated at a single party, the more streamlined the management process becomes. In addition, the clearer the scope of works that the employees have the more efficient the management operation becomes.

Ranking according to the owner's involvement and ability to control the design and construction activities and changes. The analysis of variance test (Appendix D) revealed that the structures are significantly different at a 5% significance level (P value = 0.0001 < P critical) according to owner's ability to control the design and construction activities. The ranking of the management structures along with the mean rank is as follows:

1. Owner-Contractor Organization (mean rank = 2.1)
2. Integrated Project Organization (mean rank = 2.129)
3. Owner-Management Consultant Organization (mean rank = 2.6)
4. Owner-Design/build Contractor Organization (mean rank = 3.17)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that there is significant difference among all contractual structures except for the owner- contractor organization and integrated project organization. The following pair wise comparisons show which structures are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

OC IPO O-MC O-DB

According to construction professionals, the owner- contractor organization and the integrated project organization ranked first according to the owners' ability to control design and construction activities. As predicted, the more duties assigned to the owners' employees, the more control the owner has over design changes and construction activities.

Ranking according to the ability to provide adequate integration among different project parties. The analysis of variance test (Appendix D) revealed that the structures are significantly different at a 5% significance level (P value = 0.0001 < P critical) according to the ability to provide adequate integration among different project parties. The ranking of the management structures along with the mean rank is as follows:

1. Integrated Project Organization (mean rank = 1.857)
2. Owner-Management Consultant Organization (mean rank = 2.271)
3. Owner-Design/build Contractor Organization (mean rank = 2.429)
4. Owner-Contractor Organization (mean rank = 3.443)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that there is significant difference among all contractual structures except for the owner- management consultant organization and owner – design/build contractor organization. The following pair wise comparisons show which structures are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

IPO   <u>O-MC   O-DB</u>   OC

The integrated project organization ranked first and the owner-contractor structure ranked last according to the ability to provide adequate integration. Drawing fewer boundaries between employees and assigning more duties to a single party leads to more integration. However, more integration neither leads to more streamlined operation nor better ability to complete the project according to cost, time, and quality objectives.

Ranking according to the managerial ability to control cost, complete the project on time, and deliver according to the quality requirements. The analysis of variance test (Appendix D) revealed that the structures are significantly different at a 5% significance level (P value = 0.0001 < P critical) according to the ability to control cost, complete the project on time, and deliver according to the quality requirements. The ranking of the management structures along with the mean rank is as follows:

1. Owner-Design/build Contractor Organization (mean rank = 2.2)
2. Owner-Management Consultant Organization (mean rank = 2.2)
3. Integrated Project Organization (mean rank = 2.543)
4. Owner-Contractor Organization (mean rank = 3.057)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that there is significant difference among all contractual structures except for the owner – design/build contractor organization and owner- management consultant organization. The following pair wise comparisons show which structures are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

O-DB O-MC IPO OC

The owner-design/build contractor and owner-management consultant organizations ranked first and the owner-contractor structure ranked last according to the ability control cost, complete project on time, and deliver according to the quality requirements. Therefore, the more duties assigned to a single party and the clearer the scope of works, the better the ability to achieve project objectives. However the respondents did not agree if the owner organization or the contractor organization is better in achieving the project objectives.

Ranking according to the structures ability to provide the least project cost. The analysis of variance test (Appendix D) revealed that the structures are significantly different at a 5% significance level (P value = 0.0038 < P critical) according to the ability to provide the least project cost that includes management fees, contractor's overhead and profit, and construction costs. The ranking of the management structures along with the mean rank is as follows:

1. Owner-Design/build Contractor Organization (mean rank = 2.086)
2. Integrated Project Organization (mean rank = 2.571)
3. Owner-Contractor Organization (mean rank = 2.643)
4. Owner-Management Consultant Organization (mean rank = 2.7)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that the owner – design/build contractor organization is significantly different than all other organizations (p = 0.005). There is no significant difference among the three other contractual structures. The following pair wise comparisons show which structures are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

O-DB IPO OC O-MC

Construction professionals agreed that the owner-design/build contractor organization is the most cost effective. All other organizations scored almost the same.

Ranking according to the structures ability to provide the least project time. The analysis of variance test (Appendix D) revealed that the structures are significantly different at a 5% significance level (P value = 0.0001 < P critical) according to the ability to provide the least project time. The ranking of the management structures along with the mean rank is as follows:

1. Owner-Design/build Contractor Organization (mean rank = 1.6)
2. Integrated Project Organization (mean rank = 2.536)
3. Owner-Management Consultant Organization (mean rank = 2.58)
4. Owner-Contractor Organization (mean rank = 2.536)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that the owner – design/build contractor organization are significantly different than all other organizations (p = 0.0001). In addition, the owner-contractor organization is significantly different than all the other organizations (P=0.0001). The following pair wise comparisons show which structures are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

O-DB	IPO	O-MC	OC
	______	______	

Construction professionals agreed that the owner-design/build contractor organization ranks first and the owner-contractor organization ranks last in providing the least project time.

Operation Methods

Ranking according to the difficulty of managing the project from the least difficult to the most difficult. The analysis of variance test (Appendix D) revealed that the structures are significantly different at a 5% significance level (P value = 0.0001 < P critical) according to the difficulty of managing the project i.e. reject the null hypothesis. The ranking of the management structures along with the mean rank is as follows:

1. Individual Package Operation (mean rank = 1.632)
2. Concurrent Package Operation (mean rank = 2.132)
3. Sequential Package Operation (mean rank = 2.235)

The pair-wise mean analysis (Appendix D) i.e. Fisher's least significant difference test (equation 1) revealed that the individual package operation is significantly different than the other organizations (p = 0.0003). The sequential package operation and the concurrent package operation are not significantly different. The following pair wise comparisons show which methods are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

Individual Package Concurrent Package Sequential Package

The test proves that managing large scale complex projects is more difficult than managing simple independent projects. However, it is not clear if the concurrent operation or sequential operation was the most difficult to manage although the latter includes fewer resources to manage. This is explained by the fact that the management load needed to sequence different interrelated groups would be as demanding as the management load needed to handle more yet independent work groups.

Ranking according to the ability to provide the least project cost. The analysis of variance test (Appendix D) revealed that the structures are significantly different at a 5% significance level (P value = 0.0022 < P critical) according to the ability to provide the least project cost including staffing and construction costs i.e. reject the null hypothesis. The ranking of the management structures along with the mean rank is as follows:

1. Concurrent Package Operation (mean rank = 1.765)
2. Sequential Package Operation (mean rank = 1.985)
3. Individual Package Operation (mean rank = 2.25)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that all package operations are significantly different. Construction professionals agreed that the less fragmentation of the project, the less the overall project cost. However, the cost does not include interest or investment rates.

Ranking according to the ability to control costs, limit schedule delays, and deliver according to quality requirements from the least difficult to the most difficult. The analysis of variance test (Appendix D) revealed that the structures are not significantly different at a 5% significance level (P value = 0.0681 > P critical) according to the ability to control costs, limit schedule delays, and deliver according to the quality requirements. The ranking of the management structures along with the mean rank is as follows:

1. Individual Package Operation (mean rank = 1.809)
2. Sequential Package Operation (mean rank = 2.074)
3. Concurrent Package Operation (mean rank = 2.104)

The pair-wise mean analysis (Appendix D) conducted according to Fisher's least significant difference test (equation 1) revealed that the individual package operation is significantly different than the other organizations (p = 0.026). The sequential package operation and the concurrent package operation are not significantly different. The following pair wise comparisons show which structures are significantly different (not underlined by a common line) and which are not significantly different (underlined by a common line).

Individual Package   <u>Sequential Package   Concurrent Package</u>

The test proves that controlling costs, schedules, and work quality is more difficult in large scale complex projects than in simple independent projects. However, it is not clear if concurrent operation or sequential operation performs better in terms of cost, schedule, and quality control although the latter includes fewer resources to manage. This is explained by the fact that sequencing a few number of interrelated work groups is as difficult as managing a large number of independent work groups.

CHAPTER 8
MEGAPROJECT OPTIMIZATION

Optimal Work Practices Selection

Different approaches in the construction management literature have contradicting views of how to optimize organizational performance in large scale complex projects. The first contradiction lies in how organizational structures are designed and connected. Several management approaches such as the project governance approach propose that organizations should be integrated to form complex networks in order to optimize performance, whereas other approaches such as organization modeling and simulation approaches optimize organizations through minimizing network connections and hierarchy levels in order to streamline management processes. The second contradiction lies in the organizations' decision making and control procedures. The program management approach suggests that centralizing managerial controls and reporting provides better oversight of projects' progress (Ferns, 1991; Lycett et al., 2004; Pellegrinelli et al., 2007) and streamlines their delivery (Gray, 1997). Approaches that contradict this view suggest that authority decentralization to the lowest possible level leads to a flexible and adaptive organization that is suitable for large projects (Platje, 1993). The third contradiction lies in the organizations' distribution of roles and responsibilities. Institutional and corporate governance approaches suggest that the classical delivery methods that provide the owner with more control lead to better project performance, whereas other approaches suggest that delivery methods which provide better integration lead to better project performance.

All approaches are valid to some extent by which each approach optimizes the organization according to a specific objective. However, no organization could achieve all three management objectives i.e. maximal integration; optimal, streamlined, and efficient operation; and maximal oversight and control since achieving one objective contradicts achieving the other objectives. Thus, organizational structure optimization is achieved based on how officials want their organization to operate and behave.

A decision model based on the analytical hierarchy process (Saaty, 1980) was developed to determine the optimal work practices to be applied on a megaproject according to the user's predetermined objectives and performance goals. The analytical hierarchy process divides the decision problem into a hierarchy of three sub-problems. Each sub-problem level consists of a multivariate decision matrix. The sub problem levels are the project implementation strategy, project scope planning, and project organizational structure planning. The process has two limitations. The first limitation is that the successor level alternatives depend on the alternative chosen at the predecessor decision level. For instance, the individual package operation choice does not permit the use of other level alternatives.

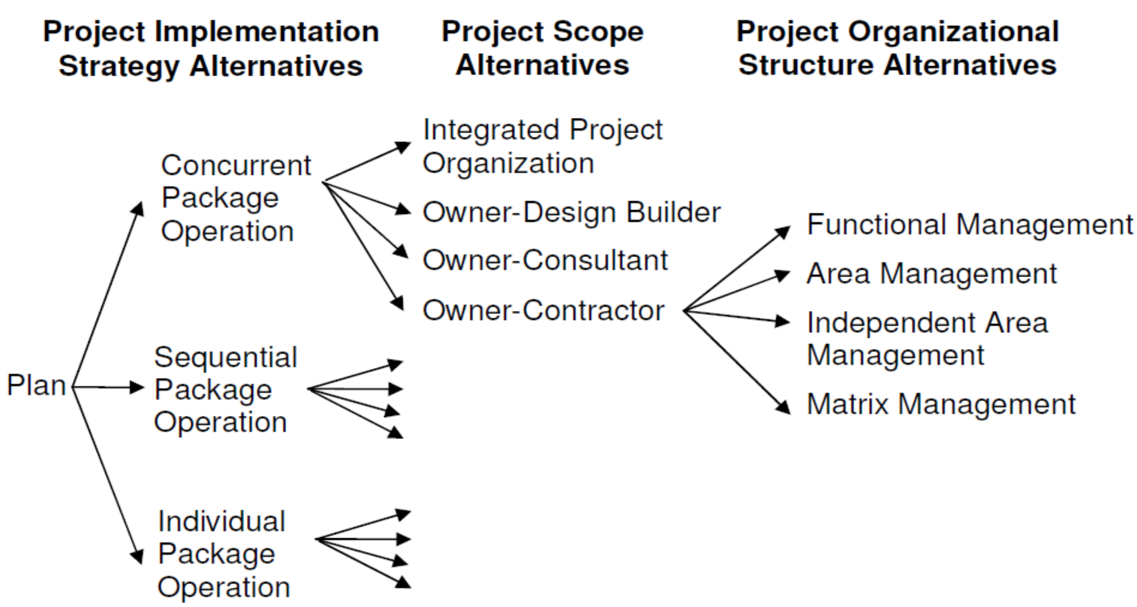


Figure 8-1. Analytical hierarchy process levels and alternatives

The second limitation is that the decision model does not recommend the optimal work practices based on the nature of works or project complexity. In other words, the decision model does not predict the best work practices to be applied if the project was a power plant, skyscraper, airport, or a transportation project.

Project Implementation Strategy

The first level of the decision making process is the project implementation strategy. At this preliminary planning level, several objectives are considered such as project financing, officials' ability to handle the project, necessity of the project to finish as early as possible, and other local considerations. Therefore the implementation strategy would be how to execute the project in the optimal way subject to the budgetary, managerial, and schedule constraints.

Decision variables. The decision variables are as follows:

- Project cost (Cost)
- Project time frame and the necessity to complete the project ahead of a deadline (Time)
- Managerial ability of the governing body i.e. owners to manage a large scale project (MgPr)
- Ability to select a contractor who could control cost, limit schedule delays, and deliver according to quality requirements (PjPr)

Decision alternatives. The decision alternatives are as follows:

- Constructing individual packages as independent projects
- Constructing project packages sequentially
- Constructing all project packages concurrently

Decision model. Level one decision model calculates the scores of different alternatives based on the weights provided by the user. The model selects the alternative with the maximum total.

$$Max\ T_j = \sum_i W_i S_{ij} \quad for\ \ j = 1,2,...,m$$

Where : S_{ij} is the score of alternative j according to decision variable i

W_i is the weight of the decision variable i (provided by user)

$\sum_i W_i = 1$

T_j is the total score for alternative j

m is the total number of alternatives

The scores of different alternatives were assigned according to the survey's ranking by which the highest rank was assigned with the highest score and the lowest rank was assigned with the lowest score (rank 1 was assigned with score of 3, rank 2 was assigned with score of 2, and rank 3 was assigned with score of 1) except for the time variable. The time variable scores were assigned according to the alternative's ability to provide the least time.

Therefore, the decision model with the corresponding alternatives' scores:

$$\begin{array}{r} \\ Individual\ Package \\ Sequential\ Package \\ Concurrent\ Package \end{array} \begin{array}{c} \begin{array}{cccc} Cost & Time & Mg\,\mathrm{Pr} & Pj\,\mathrm{Pr} \end{array} \\ \begin{bmatrix} 1.750 & 1.00 & 2.368 & 2.191 \\ 2.015 & 2.00 & 1.765 & 1.926 \\ 2.235 & 3.00 & 1.868 & 1.868 \end{bmatrix} \end{array} x \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \end{bmatrix} = \begin{bmatrix} T_1 \\ T_2 \\ T_3 \end{bmatrix}$$

Project Scope Planning

The second level of the decision making process is the project scope planning which deals with the selection of the contractual structure and the allocation of responsibilities. At this intermediate level, several objectives are taken into consideration. The first objective is the cost since different structures require different costs such as contractor's overhead and profit, management consultant fees, and employee staffing costs. The second objective is the time frame since many large scale projects have the necessity to finish ahead of a specific date. The third objective is the organization's ability to finish within the cost, time, and performance constraints. The remaining management performance objectives are based on the owner's preferences. Some owners prefer an efficient and streamlined management that minimizes bottlenecks and maximizes resource utilization. Other owners prefer an organization that provides them with maximal control over the construction activities. Other owners prefer an integrated organization that maximizes coordination and team work among parties.

Decision variables. The decision variables are as follows:

- Management cost (Cost)
- Project time frame (Time)
- Structure's project performance i.e. the ability to complete the project successfully on time, within budget, and according to the Quality requirements (PjPr)
- Managerial ability to perform streamlined coordinated works, limit managerial duties bottlenecks, and respond to project updates and design changes in a swift manner (MgP1)
- Managerial ability to control construction tasks and owner's active involvement in design and construction activities (MgP2)
- Managerial ability to provide adequate integration among project parties (MgP3)

Decision alternatives. The decision alternatives are as follows:

- Owner-Contractor Organization
- Owner-Design Builder Organization
- Owner-Consultant Organization
- Integrated Project Organization

Decision model. Level 2 decision model calculates the scores of different alternatives based on the weights provided by the user. The model selects the alternative with the maximum total.

$$Max\ T_j = \sum_i W_i S_{ij} \quad for\ \ j = 1,2,...,m$$

Where : S_{ij} is the score of alternative j according to decision variable i

W_i is the weight of the decision variable i (provided by user)

$\sum_i W_i = 1$

T_j is the total score for alternative j

m is the total number of alternatives

The scores of different alternatives were assigned according to the survey's ranking by which the highest rank was assigned with the highest score and the lowest rank was assigned with the lowest score (rank 1 was assigned with score of 4, rank 2 was assigned with score of 3, rank 3 was assigned with score of 2, and rank 4 was assigned with score of 1).

Therefore, the decision model with the corresponding alternatives' scores:

$$\begin{array}{l} \\ Owner-Contractor \\ Owner-DesignBuilder \\ Owner-Consult \\ Integrated\ Project\ Org \end{array}
\begin{array}{c} \begin{array}{cccccc} Cost & Time & Pj\,\mathrm{Pr} & MgP1 & MgP2 & MgP3 \end{array} \\ \begin{bmatrix} 2.357 & 1.700 & 1.943 & 1.557 & 2.900 & 1.557 \\ 2.914 & 3.400 & 2.800 & 3.057 & 1.829 & 2.571 \\ 2.300 & 2.386 & 2.800 & 2.657 & 2.400 & 2.729 \\ 2.429 & 2.429 & 2.457 & 2.729 & 2.871 & 3.143 \end{bmatrix} \end{array}
x \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ W_5 \\ W_6 \end{bmatrix} = \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \end{bmatrix}$$

Project Organizational Structure Planning

The third level of the decision making process is the organizational structure planning which deals with the allocation of responsibilities along the management levels and the division of work among groups. Different management structures have different advantages and the selection of the right structure mainly depends on the user's objectives and the project's complexity characteristics. The first objective is the cost since different structures demand different management resources and staffing costs. The second objective is project performance or the organization's ability to finish within the cost, time, and performance constraints. The remaining management performance objectives are based on the user's preferences. Some users prefer efficient and streamlined management structures that minimize bottlenecks and maximize resource utilization. Other users prefer an organization that provides the top management levels with maximal control over the construction activities. Other users prefer an integrated organization that maximizes coordination and team work among different trades.

Decision variables. The decision variables are as follows:

- Management staffing cost (Cost)
- Structure's project performance i.e. the ability to complete the project successfully on time, within budget, and according to the Quality requirements (PjPr)
- Managerial ability to perform streamlined coordinated works, limit managerial duties bottlenecks, and respond to project updates and design changes in a swift manner (MgP1)
- Managerial ability to control construction tasks and owner's active involvement in design and construction activities (MgP2)
- Managerial ability to provide adequate integration among different trades (MgP3)

Decision alternatives. The decision alternatives are as follows:

- Functional Management Structure
- Area Management Structure
- Independent Area Management Structure
- Matrix Management Structure

Decision model. Level 3 decision model calculates the scores of different alternatives based on the weights provided by the user. The model selects the alternative with the maximum total.

$$Max\, T_j = \sum_i W_i S_{ij} \quad for\;\; j = 1,2,...,m$$

Where : $\mathrm{S_{ij}}$ is the score of alternative j on decision variable i

$\mathrm{W_i}$ is the weight of the decision variable i (provided by user)

$\sum_i \mathrm{W_i} = 1$

$\mathrm{T_j}$ is the total score for alternative j

m is the total number of alternatives

The scores of different alternatives were assigned according to the survey's ranking by which the highest rank was assigned with the highest score and the lowest rank was assigned with the lowest score (rank 1 was assigned with score of 4, rank 2 was assigned with score of 3, rank 3 was assigned with score of 2, and rank 4 was assigned with score of 1).

Therefore, the decision model with the corresponding alternatives' scores:

$$\begin{matrix} & Cost & Pj\,\mathrm{Pr} & MgP1 & MgP2 & MgP3 \\ Functional\;\; Mngt & 2.613 & 2.463 & 2.425 & 2.688 & 2.750 \\ Area\;\; Mngt & 2.313 & 2.688 & 2.825 & 2.775 & 2.700 \\ Indep\;\; Area\;\; Mngt & 2.638 & 2.513 & 2.425 & 2.175 & 2.138 \\ Matrix\;\; Mngt & 2.425 & 2.338 & 2.325 & 2.363 & 2.413 \end{matrix} \; x \begin{bmatrix} W_1 \\ W_2 \\ W_3 \\ W_4 \\ W_5 \end{bmatrix} = \begin{bmatrix} T_1 \\ T_2 \\ T_3 \\ T_4 \end{bmatrix}$$

Guidelines and Recommendations for Organizational Design

Selecting the appropriate work practices is not enough to optimize megaprojects' managerial and project performance. Several other factors which are not addressed by the work practices decision model could cause managerial inefficiencies and lead to poor performance. Megaproject case studies provided numerous lessons learned from managerial difficulties that could be handled with adequate design and refinement of the management organization. Therefore, the following guidelines and recommendations are provided to design the optimal organizational structure.

Organizational Decision Making

Each of the projects in the case studies suffered from decision making inefficiencies, detrimental intervention, and counterproductive decision making.

Many of these problems could be attributed to the most important component in the organizational structure that is the human component. Project managers, engineers, and other decision makers have the ability to produce an effective organizational operation regardless of the organizational structure, project complexities, and other external conditions. Furthermore, the key decision makers have the ability to transform the organization into a self organizing system (Aritua et al., 2009) that is adaptable to megaproject's characteristics. Therefore, it is essential to invest in capable and experienced human resources who are able to adapt to megaprojects complexities. However, this solves half of the problem. Due to megaprojects' long construction periods, critical project personnel are replaced frequently which removes their project experience, management skills, and effective leadership until the replacement gets up to the speed of his predecessor. Therefore, the solution would be to require all project participants to keep their key managers until the project is complete (C. Glagola, personal communication, July 18, 2011).

In addition, decision making inefficiencies could be attributed to corrupt intervention and dishonest decision making (Flyvbjerg et al., 2002) that leads to catastrophic failure in terms of cost overruns and time extensions. Unfortunately, the topic of megaprojects comes hand in hand with politics, high level governmental decision making, and special interest groups. It is no surprise that megaprojects are influenced and affected by decisions that might not be in the best interest of the project or the project's end users. Therefore, it is essential to develop an ethical decision making culture and structure whose sole concern is the project's success and the welfare of the project's end users.

Management Organization

The management organization of any large scale system is composed of multiple subsystems that should be optimized according to the global system constraints instead of optimizing each subsystem according to its individual constraints. In other words, instead of the classical case by which each party designs its management and decision making processes according to its own constraints, global system optimization implies that parties and functional units should allocate their management resources and conduct their management processes according to global project constraints and constraints imposed by other functional units in the system. Global optimization is achieved by an oversight project strategy that would create an integrated adaptive organization. The strategy has three objectives. The first objective is to adapt the owner's decision making processes and management culture to handle the project's complexities. The second objective is to impact the contractor's decision making culture and adjust it to the owner's culture and project complexities. The third objective is to create an integrated execution process that takes into consideration all managerial, design, and external constraints.

In practice, the strategy would consist of several steps to design management levels, interfaces between parties, functions of different units, and decision making processes. The first step is the adequate preparation of the owner's organization to handle the work load of a megaproject through decision making walkthroughs, familiarization with the project, determination of their roles, and determination of the project's scope. The second step is the adequate adjustment of the contractor's organization to adapt to the owner's scope development process, decision making process, and management capabilities. The third step is work group familiarization with the work plan, scope, cultures of other organizations, decision making processes, project's constraints, and external factors at an early stage of the project. The fourth step is the advanced development of an integrated schedule that takes into consideration the constraints of all subsystems and the inputs of all participants.

The application of an oversight project strategy would produce a streamlined efficient management operation with more utilized work teams, less managerial bottlenecks, and more flexibility to handle changes.

Work Division and Packaging

In megaprojects, work division and packaging determines how interconnected and complex the project is. Accordingly, the extent of project fragmentation has a large effect on the ability to follow up and coordinate all project sections. In other words, selecting a group of parallel primes to conduct all construction works requires a management operation that is different than the operation of a single contractor. Project planners should find the right balance between two extremes i.e. a highly fragmented organization and a highly unified organization. The application of a highly fragmented organization leads to: less managerial load on the upper management (Owner's side); more managerial load on the lower management groups (Subcontractors' side); reporting overload due to the number of work groups; less upper management control due to decentralization; short management hierarchy leading to more swift managerial operation; coordination issues due to the number of different work groups; and site congestion problems due to the large number of independent work groups.

On the other hand, application of a highly unified organization leads to: more managerial load on the upper management (Owner's side); less managerial load on the lower management groups (Subcontractors' side); reporting overload due to the excessive amount of details; resource allocation issues (management, labor, and material resources); more upper management control due to centralization; rigid management procedures; and long management hierarchy leading to longer execution processes.

In addition, project complexities impose constraints on fragmenting the project. For instance highly interconnected systems such as power plants are not easily divided. Alternatively, minimally interconnected systems such as different sections of a highway are easily divided.

Therefore, to produce a harmonious streamlined operation, project planners should determine the appropriate quantity of packages that suits the capabilities of the oversight management and the limitations imposed by the project's complexity, as well as the appropriate amount of works per package that suits the capabilities of different organizations.

Controls and Reporting

Large scale projects consist of multiple interconnected systems by which elements of each system are connected to elements of all other systems. As more systems are added, the network connections diverge and cause more communication difficulties and management problems. Therefore, there should be a straightforward system with clear lines of reporting that enhance management processes instead of hindering them. The system should be designed to satisfy three objectives. The first objective is to provide adequate information flow that updates all management levels with sufficient decision making information. The second objective is to prevent information overload that burdens employees with excessive reporting duties and managers with unnecessary information. The third objective is to provide the ability to respond to updates in a swift manner and the flexibility to adapt to the project's dynamic nature.

In order to satisfy the three objectives, the reporting system should be designed at the early stages of the project and should consist of a centralized reporting network that converges at multiple key management positions in order to provide a broad manageable oversight which would ensure alignment of work groups. Furthermore, the reporting system should follow a standard reporting format to be used by all subcontractors that would allow consistent reporting as well as rapid data consolidation. The reporting format should highlight problems, action items, and a summary of performance indicators (cost, time, quality) for efficient and swift decision making. The reporting system should consist of a centralized financial system that updates the cost status of different project sections and consolidates all contractors' payments into one cash flow. The system should also consist of a centralized scheduling system that updates the schedules of individual work groups as well as the overall project schedule.

Design and Scheduling

Numerous design and scheduling lessons were learned from megaproject case studies. The lessons provided several planning guidelines that would limit managerial inefficiencies. When designing a large scale complex project, project designers are concerned with the quality and functionality of the design. However, an additional objective should be considered while designing a large scale complex project which is project manageability. In other words, project designers should carry out additional steps to produce a design that minimizes managerial difficulties and problems. Several issues should be taken into consideration to develop a manageable design. For instance, the design should be planned to have future additions to limit the ripple effect of changes. New technologies designed and implemented should have backup systems. The scope should be determined to the most possible extent in order to limit future additions and changes that would substantially impact the project's cost and schedule. In addition, the design should consist of modules by which a design change in any part of the project would affect a single module and not lead to a ripple effect of changes in other modules.

Similarly, project planners should carry out additional steps to produce a schedule that minimizes managerial difficulties and problems. Several issues should be taken into consideration to develop a manageable schedule. For instance, the schedule should be set according to the input of all participants which gives contractors and suppliers maximal flexibility to set their schedule (D'Olier et al., 2005). Construction activities of independent contractors should be scheduled according to the designer's ability to deliver packages and the owner's ability to approve these packages. Construction activities of independent contractors should be scheduled according to external factors such as traffic constraints, permitting constraints, and work methods constraints. The schedule should be relaxed as much as possible to limit acceleration costs, haste approval of change requests, and schedule modifications. In addition, the schedules of different work groups should be separated by a time buffer to limit the ripple effects of delays or changes that take place in one part of the project (Goldratt, 1997).

Future Work

Several issues were not addressed in this research. One of the issues is the difference in opinions of professionals who worked in different project parties and different industries concerning the ranking of the work practices. Therefore, the difference in opinions of professionals who worked in different project parties (owner, client representative, designer, contractor, governmental agency) and different industries (transportation, heavy industry, building construction) should be analyzed to determine which work practices are best suited to which organization and which industry.

In addition, the decision model presented does not recommend the optimal work practices based on the nature of works or project complexity. Therefore, a different decision model should be developed that would recommend the optimal work practices to be used on projects of different complexities (i.e. power plants, skyscrapers, airports, or transportation projects).

APPENDIX A
MANAGEMENT ORGANIZATION INTERVIEW FORM

Megaproject Management Organization

Organizational Structure Description

- Describe the Organizational Structure (management levels, work groups and teams).
- Describe the Upper Level management (Project Management Company, management consultant, or general contractor)
- Describe the Lower Level Management (operational work groups, Contractors, Subcontractors)

Organizational Structure Scope

- Describe the operational and managerial responsibilities assigned to the Upper Level Management (Project manager, or consultant, or general contractor)?
- Ex: Global control cost, schedule control, global project coordination, long lead items, approval of major changes, claims management
- Describe the operational and managerial responsibilities assigned to Lower Level Management (Work Groups, Contractors, and Subcontractors).
- Ex: Managerial responsibilities on their project portions, Daily Works, inspection, material procurement, labor supply, design changes.
- In what issues did the Lower Management have autonomy and in which issues did the Upper management intervene?

Organizational Structure Difficulties

- Describe the difficulties encountered that impacted the construction process negatively?
- Ex: Slower activities of the operational work groups
- Less efficient management (bottleneck of managerial duties- inactivity of work crews)
- How could you improve the organizational structure or make it more efficient?

Megaproject Controls and Reporting

Control and Reporting System Description

- Describe the reporting and control procedures (cost, schedule, and quality) used at the lower and upper levels E.g.: progress reports, weekly & monthly reports, manpower reports.

- Describe the reporting and control procedures (cost, schedule, and quality) used at the upper level to integrate and keep track of all lower level groups.

Control and Reporting System Scope

- Describe how the following are done in the lower levels and upper level throughout the project: Establishing goals, Measuring progress, Reporting, and Management action

- How did the upper management keep track of the lower level status (cost, schedule, and quality)? Which management level initiates management action (change, acceleration)?

Control and Reporting

- Describe the difficulties encountered that impacted the construction process negatively? Ex: Slower activities of the operational work groups

- Less efficient management (bottleneck of managerial duties)

- How could you improve the communication system or make it more efficient?

Megaproject Communications and Coordination

Communication System Description

- Describe the communication tools used at the lower management and upper management

- Ex: emails, meetings, cash flow reports, correspondence letters, oral communication (frequency).

- Ex: High tech IT tools used such as centralized networks, websites, PDAs…Please describe

Communication System Scope

- Describe the communication procedures between the lower management and upper management.

- Describe the communication and coordination procedures between the lower level work groups.

Communication System Difficulties

- Describe the difficulties encountered that impacted the construction process negatively?
- Ex: Slower activities of the operational work groups
- Less efficient management (bottleneck of managerial duties)
- How could you improve the communication system or make it more efficient?

APPENDIX B
MEGAPROJECT ORGANIZATIONAL STRUCTURE SURVEY

Informed Consent Form

Protocol Title: Megaproject Performance

Dear Participant,

I am a graduate student in the Civil and Coastal Engineering Department at the University of Florida. As part of my course work I am conducting a survey, the purpose of which is **evaluating various work practices that were applied on different megaprojects**. I am asking you to participate in this survey because you have been identified as an experienced professional in the construction industry. Participants will be asked to fill out a survey lasting no longer than 20 minutes. Your survey will be conducted online at any place and anytime you want, after you have read this informed consent. Only I will have access to the survey that you fill out. The statistical data collected from your survey and others will be documented in my PhD thesis. Your identity will be kept confidential to the extent provided by the law and your identity will not be revealed in the final manuscript. There are no anticipated risks, compensation or other direct benefits to you as a participant in this survey.

If you have any questions about this research protocol, please contact me at (352) 214 – 4102 or my faculty supervisor, Dr. Ralph D. Ellis, at (352) 392-3730. Questions or concerns about your rights as a research participant may be directed to the UFIRB office, University of Florida, Box 112250, Gainesville, FL 32611; Ph: (352) 392 – 0433.

By filling out the provided survey, you give me the permission to report your responses anonymously in the final manuscript to be submitted to my faculty supervisor as part of my course work.

Sincerely,

Adnan Haidar

I have read the procedure described above. I voluntarily agree to participate in the research study and I have received a copy of this description.

Please click on this link if you agree

Introduction

The following survey is to evaluate various work practices that were applied on different megaprojects. The work practices include management structures, contractual structures, and operation methods. The questions require the user to rank different work practices according to different performance criteria. A description of the work practices is included so that construction professionals of different backgrounds and experience could participate in the survey.

The survey is divided into 4 sections (20 questions in total):

1- Survey Recipient Information
Section 1 is composed of six multiple choice questions about the recipient's background. The questions request information about the recipient's experience, position background (duties), firm background (project party), and industry background.

2- Evaluation of Megaproject Management Structures
Section 2 is composed of five questions that require the user to rank four management structures according to project performance, management performance, and cost of implementation.

3- Evaluation of Megaproject Contractual Structures
Section 3 is composed of six questions that require the user to rank four contractual structures according to project performance, management performance, time consequences, and cost of implementation.

4- Evaluation of Megaproject Operation Methods
Section 4 is composed of three questions that require the user to rank three operation methods according to cost of implementation, project performance, and management difficulty.

Section 1 (out of 4)

Section 1: Recipient Background

Please answer the 6 multiple choice questions about your background:

1.) Select the type of engineering and construction firm you currently work in

( ) Construction Contractor

( ) Design Consultant

( ) Management Consultant (Owner's representative)

( ) Governmental Construction Agency (FDOT, FHWA, etc.)

( ) Other

) If you selected "Other", please specify:

____

2.) If you have worked in other types of construction and engineering firms please select all that apply

[ ] Construction Contractor

[ ] Design Consultant

[ ] Management Consultant (Owner's representative)

[ ] Governmental Construction Agency (FDOT, FHWA, etc.)

[ ] Other

3.) Select the number of years you have spent in the engineering and construction industry

( ) 1 - 2 years

( ) 3 - 5 years

( ) 5 - 10 years

( ) 10+ years

4.) Select the engineering and construction positions you have worked in

[ ] Program Manager / Construction Manager

[ ] Project Manager

[ ] Assistant Project Manager

[ ] Design manager

[ ] Designer

[ ] Project Engineer

[ ] Site Engineer

[ ] Project Superintendent

[ ] Academic / Professor

[ ] Other

) If you selected "Other", please specify:

____

5.) Select the dollar value of the most expensive project you have worked on

( ) 1 - 50 million

( ) 50 - 100 million

( ) 100 - 500 million

( ) 500 - 1000 million

( ) 1+ Billion

6.) Select the construction industry you have worked in

[ ] Transportation Projects (Roads and Highways)

[ ] Building and Commercial Construction

[ ] Industrial and Power Plants

[ ] Heavy Construction (Dams, Tunnels, and Large Bridges)

[ ] Other

) If you selected "Other", please specify:

____

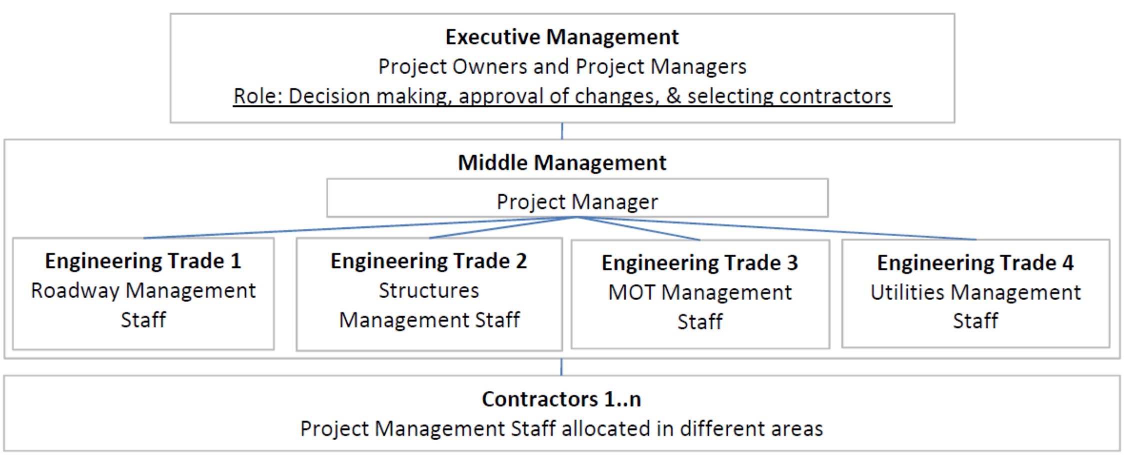
Section 2 (out of 4)

Section 2: Management Structures

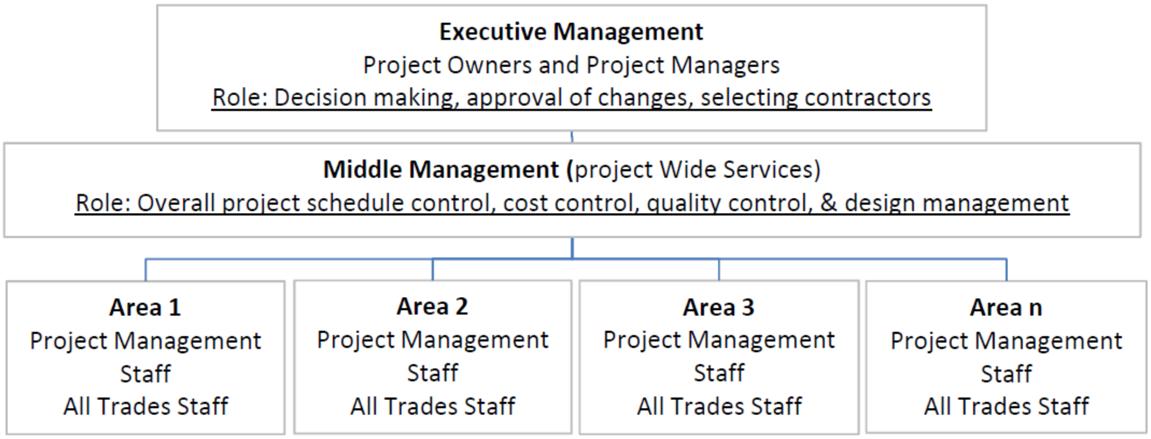
The objective of this section is to evaluate four management structures according to different performance criteria.
The section is composed of the structures' description followed by five ranking questions.
Please examine the organizational structures thoroughly and answer each question carefully.
If you find minimal differences among different alternatives, please comment on them at the end of the section.

Functional Management Structure:

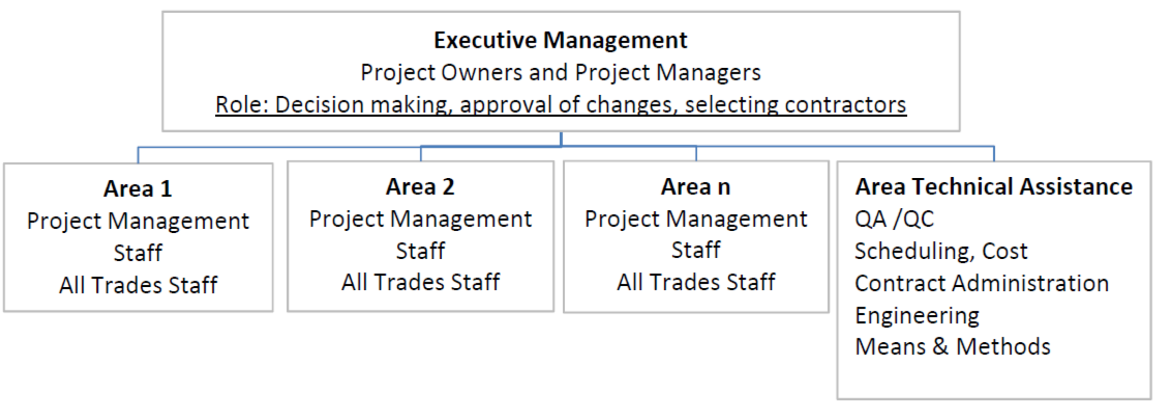
- The works are divided among different trades (i.e. specializations)
- Middle management organizes and integrates the works of all trades



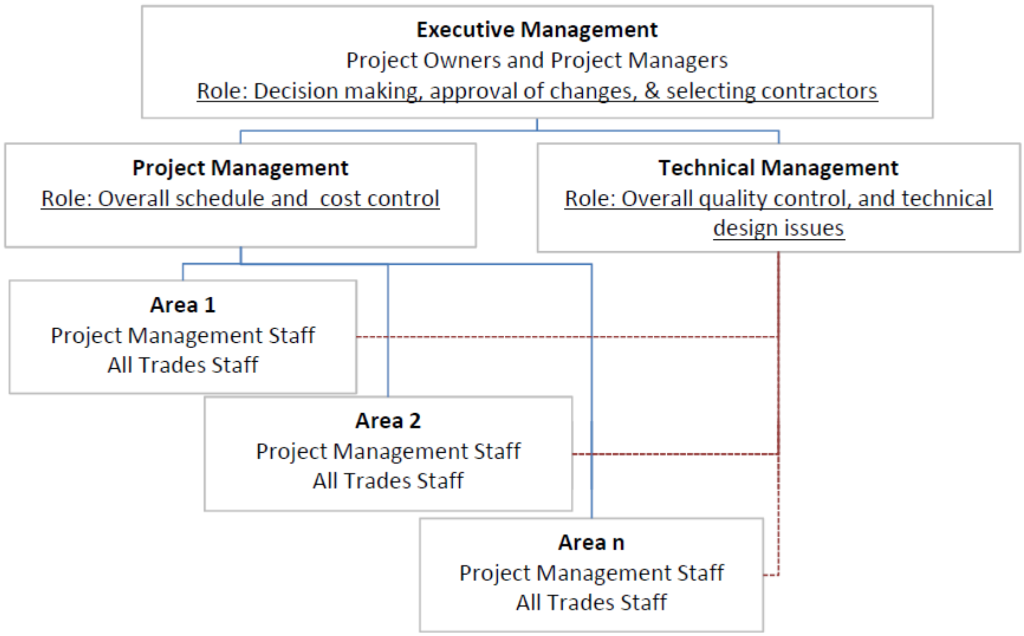
Area Management Structure:
- The works are divided among different areas
- Middle management organizes and integrates the works of all areas



Independent Area Management Structure:
- The works are divided among different areas
- No integration of works is done among different areas
- Areas are considered independent and are treated separately by the executive management level



Matrix Management Structure:
- The works are divided among different areas
- Responsibilities are divided among the project management team (cost, time, production) and technical management team (quality control and other design issues)



7.) Rank the management structures described above according to the best allocation of duties that would streamline the managerial tasks (example: limit managerial duties bottlenecks, and respond to project updates and changes in a swift manner)

________Functional Management Structure

________Area Management Structure

________Independent Area Management Structure

________Matrix Management Structure

8.) Rank the management structures described above according to the ability to provide upper management with adequate oversight and control over activities, workgroups, and project changes

________Functional Management Structure

________Area Management Structure

________Independent Area Management Structure

________Matrix Management structure

9.) Rank the management structures described above according to the ability provide adequate integration among different trades and work groups on the construction site

________Functional Management Structure

________Area Management Structure

________Independent Area Management Structure

_______Matrix Management structure

10.) Rank the management structures described above according to the managerial ability to control cost, complete the project on time, and deliver according to the quality requirements

_______Functional Management Structure

_______Area Manangement Structure

_______Independent Area Manangement Structure

_______Matrix Management structure

11.) Rank the management structures described above according to the cost of staffing and implementation from the least expensive to the most expensive

_______Functional Management Structure

_______Area Management Structure

_______Independent Area Management Structure

_______Matrix Management structure

) Any comments or thoughts concerning the ranking of the above management structures?

____

Section 3 (out of 4)

The objective of this section is to evaluate four contractual structures according to different performance criteria.

The section is composed of the structures' description followed by six ranking questions.

Please examine the contractual structures thoroughly and answer each question carefully.

If you find minimal differences among different alternatives, please comment on them at the end of the section.

Owner - Contractor Organization

<u>Owner Organization Responsibility</u>
Managing the design
Coordinating design-construction activities

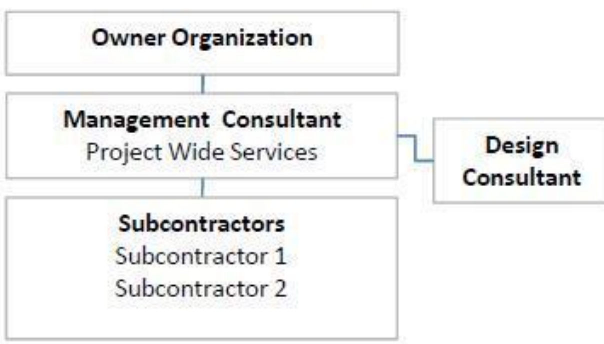
<u>Contractor Responsibility</u>
Selection of subcontractors
Cost, schedule, and quality control

Owner - Design/Build Contractor Organization

<u>Owner Organization Responsibility</u>
Followup with the management issues

<u>Contractor Responsibility</u>
Selection of subcontractors
Managing the design
Coordinating design-construction activities
Cost, Schedule, and Quality control

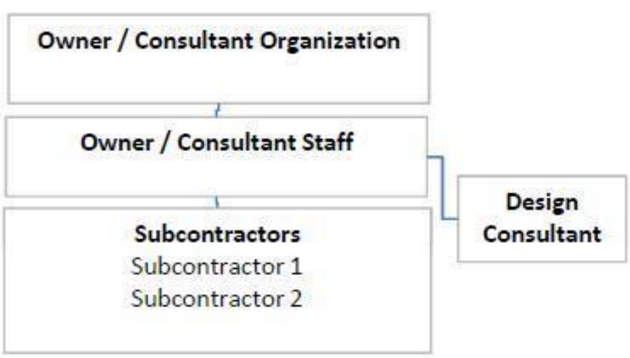
Owner - Management Consultant Organization



<u>Owner Organization Responsibility</u>
Followup with the management issues
Selection of subcontractors
Cost, Schedule and Quality control

<u>Management Consultant Responsibility</u>
Coordinating design-construction activities
Project monitoring and reporting

Integrated Project Organization



<u>Integrated Project Organization Responsibility</u>
Selection of subcontractors
Management of Design Packages
Coordinating design-construction activities
Cost, Schedule, and Quality control

12.) Rank the contractual structures described above according to the best allocation of duties that would streamline the managerial works (example: organize design-construction activities, limit managerial duties bottlenecks, and respond to project updates and changes in a swift manner)

_______Owner - Contractor Organization

_______Owner - Design/ Build Contractor Organization

_______Owner - Management Consultant Organization

_______Integrated Project Organization

13.) Rank the contractual structures described above according to the owner's involvement and ability to control the design and construction activities and changes

_______Owner - Contractor Organization

_______Owner - Design/ Build Contractor Organization

_______Owner - Management Consultant Organization

_______Integrated Project Organization

14.) Rank the contractual structures described above according to the ability provide adequate integration among different project parties

_______Owner - Contractor Organization

_______Owner - Design/ Build Contractor Organization

_______Owner - Management Consultant Organization

_______Integrated Project Organization

15.) Rank the contractual structures mentioned above according to the managerial ability to control cost, complete the project on time, and deliver according to the quality requirements

_______Owner - Contractor Organization

_______Owner - Design/ Build Contractor Organization

_______Owner - Management Consultant Organization

_______Integrated Project Organization

16.) Rank the contractual structures described above according to the their ability to provide the least project cost (including management fees, contractor's overhead and profit, and construction costs)

_______Owner - Contractor Organization

_______Owner - Design/ Build Contractor Organization

_______Owner - Management Consultant Organization

_______Integrated Project Organization

17.) Rank the contractual structures described above according to the their ability to provide the least project time

_______Owner - Contractor Organization

_______Owner - Design/ Build Contractor Organization

_______Owner - Management Consultant Organization

_______Integrated Project Organization

) Any comments or thoughts concerning the ranking of the above contractual structures?

____

Section 4 (out of 4)

Section 4: Operation Methods

The objective of this section is to evaluate three operation methods according to different performance criteria.

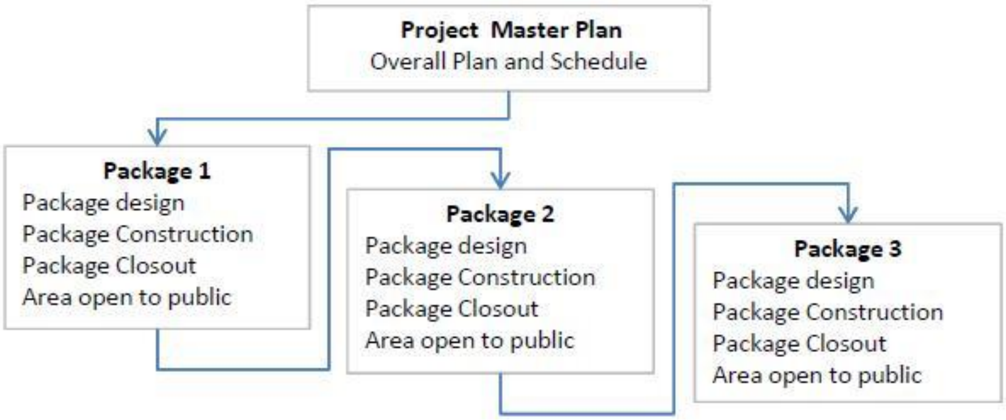
The section is composed of the methods' description followed by three ranking questions.

Please examine the operation methods thoroughly and answer each question carefully.

If you find minimal differences among different alternatives, please comment on them at the end of the section.

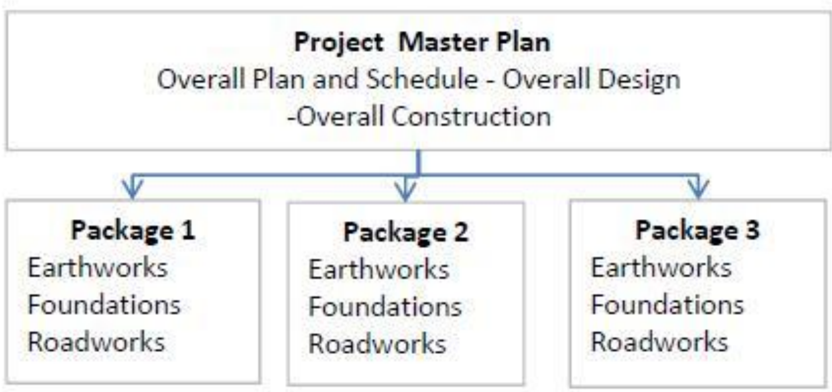
Individual Package Operation

The project is divided into separate packages that are constructed separately as independent projects



Sequential Package Operation
- The project major activities progress from package to the next package sequentially
- Package managers are changed from one trade to another as works progress

Concurrent Package Operation
All packages are constructed concurrently



18.) Rank the operation methods described above according to the difficulty of managing the project from the least difficult to the most difficult

_______Individual Package

_______Sequential Package

_______Concurrent Package

19.) Rank the operation methods described above according to the ability to provide the least project cost including staffing costs and construction costs of all packages

_______Individual Package

_______Sequential Package

________Concurrent Package

20.) Rank the operation methods described above according to the ability to control costs, limit schedule delays, and deliver according to quality requirements from the least difficult to the most difficult

________Individual Package

________Sequential Package

________Concurrent Package

) Any comments or thoughts concerning the ranking of the above operation methods?

____

Thank You!

Thank you for taking our survey. Your response is very important to us.

APPENDIX C
SURVEY RESULTS

Recipient Background Results

Response ID	202	203
Select the type of engineering and construction firm you currently work in	Management Consultant (Owner's representative)	Management Consultant (Owner's representative)
If you selected "Other", please specify		
Construction Contractor :If you have worked in other types of construction and engineering firms please select all that apply	Construction Contractor	
Design Consultant :If you have worked in other types of construction and engineering firms please select all that apply		
Management Consultant (Owner's representative):If you have worked in other types of construction and engineering firms please select all that apply		
Governmental Agency If you have worked in other types of construction and engineering firms please select all that apply	Governmental Agency (FDOT, FAHWA, etc.)	
Other:If you have worked in other types of construction and engineering firms please select all that apply		
Select the number of years you have spent in the engineering and construction industry	10+ years	10+ years
Program Manager / Construction Manager: Select the engineering and construction positions you have worked in	Program Manager / Construction Manager	Program Manager / Construction Manager
Project Manager: Select the engineering and construction positions you have worked in	Project Manager	Project Manager
Assistant Project Manager: Select the engineering and construction positions you have worked in	Assistant Project Manager	
Design manager: Select the engineering and construction positions you have worked in		
Designer: Select the engineering and construction positions you have worked in		
Project Engineer: Select the engineering and construction positions you have worked in	Project Engineer	
Site Engineer: Select the engineering and construction positions you have worked in	Site Engineer	Site Engineer
Project Superintendent: Select the engineering and construction positions you have worked in		
Academic / Professor: Select the engineering and construction positions you have worked in		
Other: Select the engineering and construction positions you have worked in		
If you selected "Other", please specify		
Select the dollar value of the most expensive project you have worked on	1+ billion	100 - 500 million
Transportation Projects (Roads and Highways):Select the construction industry you have worked in	Transportation Projects (Roads and Highways)	
Building and Commercial Construction: Select the construction industry you have worked in	Building and Commercial Construction	Building and Commercial Construction
Industrial and Power Plants: Select the construction industry you have worked in	Industrial and Power Plants	
Heavy Construction (Dams, Tunnels, and Large Bridges):Select the construction industry you have worked in	Heavy Construction (Dams, Tunnels, and Large Bridges)	
Other: Select the construction industry you have worked in		
If you selected "Other", please specify		

208	209	212	218	219	220	221
Management Consultant (Owner's representative)	contractor Engineering/Construction Management Consultant (Owner's representative)	Management Consultant (Owner's representative) Design Consultant Governmental Agency (FDOT, FAHWA, etc.)	Management Consultant (Owner's representative) Construction Contractor Design Consultant Governmental Agency (FDOT, FAHWA, etc.)	Other Part-time lecturer Management Consultant (Owner's representative) Governmental Agency (FDOT, FAHWA, etc.)	Management Consultant (Owner's representative) Design Consultant	Management Consultant (Owner's representative) Construction Contractor Design Consultant
10+ years	10+ years	10+ years	10+ years	10+ years	10+ years	10+ years
Program Manager / Construction Manager Project Manager Assistant Project Manager	Program Manager / Construction Manager Project Manager Design manager Designer Project Engineer other CM	Program Manager / Construction Manager Project Manager other Project Controls	Program Manager / Construction Manager Project Manager Designer Project Engineer Site Engineer	Program Manager / Construction Manager Assistant Project Manager Academic / Professor	Program Manager / Construction Manager Project Manager Assistant Project Manager Site Engineer	Program Manager / Construction Manager Project Manager Project Engineer Site Engineer
100 - 500 million	1+ billion	1+ billion	1+ billion	1 - 50 million	100 - 500 million	100 - 500 million
Building and Commercial Construction	Heavy Construction (Dams, Tunnels, and Large Bridges) Other Water/Wastewater	Transportation Projects (Roads and Highways) Building and Commercial Construction	Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants Heavy Construction (Dams, Tunnels, and Large Bridges)	Building and Commercial Construction Heavy Construction (Dams, Tunnels, and Large Bridges)	Transportation Projects (Roads and Highways) Heavy Construction (Dams, Tunnels, and Large Bridges) Other Railroads, Light Rail, Subways	Heavy Construction (Dams, Tunnels, and Large Bridges)

222	225	226	227	228	229	230
Management Consultant (Owner's representative) Construction Contractor Design Consultant Governmental Agency (FDOT, FAHWA, etc.) Other	Design Consultant Design Consultant	Governmental Construction Agency (FDOT, FAHWA, etc.) Construction Contractor Design Consultant Management Consultant (Owner's representative) Governmental Agency (FDOT, FAHWA, etc.)	contractor We do them all Construction Contractor Design Consultant Management Consultant (Owner's representative) Governmental Agency (FDOT, FAHWA, etc.)	Management Consultant (Owner's representative) N/A Construction Contractor Design Consultant	Management Consultant (Owner's representative) Design Consultant	Management Consultant (Owner's representative) Design Consultant
10+ years	10+ years	10+ years	10+ years	10+ years	10+ years	10+ years
Program Manager / Construction Manager Project Manager Assistant Project Manager Project Superintendent Academic / Professor other Project Controls Manager	Program Manager / Construction Manager	Program Manager / Construction Manager Project Manager Site Engineer Project Superintendent	Program Manager / Construction Manager Project Manager Project Engineer Site Engineer	Program Manager / Construction Manager Project Manager Project Engineer	Program Manager / Construction Manager Project Manager Design manager Designer Project Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Design manager Designer
1+ billion	100 - 500 million	100 - 500 million	1+ billion	1+ billion	1 - 50 million	1+ billion
Building and Commercial Construction Industrial and Power Plants Heavy Construction (Dams, Tunnels, and Large Bridges) Other Nuclear Power	Heavy Construction (Dams, Tunnels, and Large Bridges) water and waste water	Building and Commercial Construction Other Light Rail, Seattle, LA, San Francisco	Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants Heavy Construction (Dams, Tunnels, and Large Bridges)	Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants	Building and Commercial Construction Other LAUSD -school district	Building and Commercial Construction and Airport Terminals

231	234	236	237	238	239	241
Management Consultant (Owner's representative) Construction Contractor	Construction Contractor Construction Contractor Management Consultant (Owner's representative)	contractor EPC Mega Firm Construction Contractor Management Consultant (Owner's representative)	Governmental Construction Agency (FDOT, FAHWA, etc.) Construction Contractor Governmental Agency (FDOT, FAHWA, etc.)	contractor Full A/E with CM, often work as Owner's Rep, have our own Construction division	Governmental Construction Agency (FDOT, FAHWA, etc.) Construction Contractor	Management Consultant (Owner's representative) Construction Contractor
10+ years	10+ years	10+ years	10+ years	10+ years	10+ years	10+ years
Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer Site Engineer Project Superintendent	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Superintendent	Program Manager / Construction Manager Project Manager Project Engineer Site Engineer Academic / Professor other Quality Manager	Program Manager / Construction Manager Project Manager Assistant Project Manager Designer Project Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Design manager Designer Project Engineer Site Engineer other Worked as consultant in Owners organization overseeing projects and programs	Program Manager / Construction Manager Project Manager Project Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer
100 - 500 million	100 - 500 million	1+ billion	100 - 500 million	1+ billion	1 - 50 million	50 - 100 million
Building and Commercial Construction Industrial and Power Plants	Transportation Projects (Roads and Highways) Building and Commercial Construction	Transportation Projects (Roads and Highways) Heavy Construction (Dams, Tunnels, and Large Bridges)	Building and Commercial Construction	Transportation Projects (Roads and Highways) Building and Commercial Construction Other Transportation-Aviation	Transportation Projects (Roads and Highways) Heavy Construction (Dams, Tunnels, and Large Bridges)	Building and Commercial Construction Industrial and Power Plants

242	247	248	252	253	256	257
Management Consultant (Owner's representative) Design Consultant Governmental Agency (FDOT, FAHWA, etc.)	Governmental Construction Agency (FDOT, FAHWA, etc.) Design Consultant Management Consultant (Owner's representative)	Management Consultant (Owner's representative) Construction Contractor Design Consultant	Construction Contractor Full service EPCM Construction Contractor Design Consultant	Management Consultant (Owner's representative) Construction Contractor Design Consultant	Management Consultant (Owner's representative) Construction Contractor Governmental Agency (FDOT, FAHWA, etc.)	Construction Contractor Construction Contractor Management Consultant (Owner's representative)
10+ years	10+ years	10+ years	10+ years	10+ years	10+ years	10+ years
Program Manager / Construction Manager Project Manager Assistant Project Manager Designer Project Engineer Site Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Designer Project Engineer Project Superintendent	Program Manager / Construction Manager Project Manager Project Engineer Project Superintendent	Program Manager / Construction Manager Project Manager Design manager	Program Manager / Construction Manager Project Manager Assistant Project Manager Design manager Designer	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer
1+ billion	1 - 50 million	1+ billion	100 - 500 million	1+ billion	50 - 100 million	1+ billion
Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants Heavy Construction (Dams, Tunnels, and Large Bridges)	Building and Commercial Construction Industrial and Power Plants	Transportation Projects (Roads and Highways) Building and Commercial Construction	Industrial and Power Plants	Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants Heavy Construction (Dams, Tunnels, and Large Bridges)	Building and Commercial Construction	Building and Commercial Construction Industrial and Power Plants

259	260	261	264	267	268	269
Management Consultant (Owner's representative) Construction Contractor Management Consultant (Owner's representative)	Management Consultant (Owner's representative) Construction Contractor Design Consultant	Management Consultant (Owner's representative) Construction Contractor Design Consultant Management Consultant (Owner's representative)	Governmental Construction Agency (FDOT, FAHWA, etc.) Municipality Construction Contractor	Management Consultant (Owner's representative) Management Consultant (Owner's representative) Governmental Agency (FDOT, FAHWA, etc.)	Construction Contractor Design / Management/ Contractor Construction Contractor Design Consultant Management Consultant (Owner's representative)	Management Consultant (Owner's representative) Construction Contractor
10+ years	10+ years	10+ years	10+ years	10+ years	10+ years	10+ years
Program Manager / Construction Manager Project Superintendent other Expert Witness	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Superintendent Academic / Professor	Program Manager / Construction Manager Project Manager Project Engineer	Program Manager / Construction Manager Project Superintendent other Construction Tradesman	Program Manager / Construction Manager Project Manager Design manager Project Engineer	Program Manager / Construction Manager Design manager	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer Project Superintendent
1+ billion	1+ billion	100 - 500 million	100 - 500 million	1+ billion	50 - 100 million	100 - 500 million
Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants Heavy Construction (Dams, Tunnels, and Large Bridges)	Building and Commercial Construction	Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants	Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants Heavy Construction (Dams, Tunnels, and Large Bridges) Other Utilities	Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants	Building and Commercial Construction	Building and Commercial Construction Industrial and Power Plants

271	272	273	274	275	276	277
Management Consultant (Owner's representative) Construction Contractor Design Consultant Management Consultant (Owner's representative) Governmental Agency (FDOT, FAHWA, etc.)	Governmental Construction Agency (FDOT, FAHWA, etc.) Management Consultant (Owner's representative) Governmental Agency (FDOT, FAHWA, etc.)	Management Consultant (Owner's representative) Construction Contractor Management Consultant (Owner's representative) Other	Management Consultant (Owner's representative) Construction Contractor	contractor Construction / Project Management Construction Contractor	Management Consultant (Owner's representative) Design Consultant	Management Consultant (Owner's representative) Construction Contractor Design Consultant
10+ years	10+ years	10+ years	10+ years	10+ years	10+ years	10+ years
Program Manager / Construction Manager Project Manager Assistant Project Manager Designer Project Engineer Site Engineer	Program Manager / Construction Manager Project Manager Design manager Project Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Site Engineer other Sustainability Lead	Program Manager / Construction Manager Project Manager Project Engineer other Estimator	Program Manager / Construction Manager Project Manager Project Superintendent	Program Manager / Construction Manager Project Manager Assistant Project Manager Designer Project Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer Site Engineer
500 - 1000 million	1+ billion	1+ billion	50 - 100 million	50 - 100 million	100 - 500 million	1+ billion
Industrial and Power Plants	Transportation Projects (Roads and Highways) Building and Commercial Construction Heavy Construction (Dams, Tunnels, and Large Bridges)	Transportation Projects (Roads and Highways) Building and Commercial Construction Other Airports, Amusement parks, Hotels	Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants	Building and Commercial Construction Other Higher and Lower Education	Transportation Projects (Roads and Highways) Building and Commercial Construction	Transportation Projects (Roads and Highways) Heavy Construction (Dams, Tunnels, and Large Bridges) Other Wastewater treatment

278	279	281	282	285	286	288
Management Consultant (Owner's representative) Construction Contractor Design Consultant	Management Consultant (Owner's representative) Design Consultant	Governmental Construction Agency (FDOT, FAHWA, etc.)	Management Consultant (Owner's representative) Construction Contractor Design Consultant Management Consultant (Owner's representative)	Management Consultant (Owner's representative) Construction Contractor	Management Consultant (Owner's representative) Construction Contractor	Construction Contractor
10+ years	10+ years	10+ years	10+ years	10+ years	10+ years	10+ years
Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer Site Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer Site Engineer	other Field Inspeactor, Office Engineer	Program Manager / Construction Manager Project Manager Project Engineer Project Superintendent Guest Lecturer (Academic)	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer	Project Manager Project Engineer
500 - 1000 million	1+ billion	1 - 50 million	1+ billion	1+ billion	1+ billion	1+ billion
Transportation Projects (Roads and Highways) Building and Commercial Construction Heavy Construction (Dams, Tunnels, and Large Bridges)	Transportation Projects (Roads and Highways) Industrial and Power Plants Heavy Construction (Dams, Tunnels, and Large Bridges)	Transportation Projects (Roads and Highways)	Building and Commercial Construction Other Technology, Govt, Media (CNN)	Building and Commercial Construction	Transportation Projects (Roads and Highways) Building and Commercial Construction Heavy Construction (Dams, Tunnels, and Large Bridges)	Industrial and Power Plants

290	291	292	294	295	296	297
Management Consultant (Owner's representative) Owner Design Consultant Management Consultant (Owner's representative) Governmental Agency (FDOT, FAHWA, etc.)	Management Consultant (Owner's representative) Construction Contractor	Governmental Construction Agency (FDOT, FAHWA, etc.) Management Consultant (Owner's representative) Governmental Agency (FDOT, FAHWA, etc.)	Management Consultant (Owner's representative) Construction Contractor Design Consultant Management Consultant (Owner's representative)	Management Consultant (Owner's representative) Construction Contractor	Construction Contractor Management Consultant (Owner's representative) Governmental Agency (FDOT, FAHWA, etc.)	Management Consultant (Owner's representative)
10+ years	10+ years	10+ years	10+ years	10+ years	10+ years	10+ years
Program Manager / Construction Manager Project Manager Design manager	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer Site Engineer	Project Manager Assistant Project Manager other cost/schedule engineer, consultant	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Site Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Design manager	Program Manager / Construction Manager Project Manager Assistant Project Manager
500 - 1000 million	1+ billion	1+ billion	1+ billion	50 - 100 million	100 - 500 million	1+ billion
Building and Commercial Construction	Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants Heavy Construction (Dams, Tunnels, and Large Bridges) Other Sports Facilities, Convention Centers	Building and Commercial Construction Heavy Construction (Dams, Tunnels, and Large Bridges)	Transportation Projects (Roads and Highways) Building and Commercial Construction Other Simiconductor plants	Building and Commercial Construction	Transportation Projects (Roads and Highways) Building and Commercial Construction Heavy Construction (Dams, Tunnels, and Large Bridges)	Building and Commercial Construction Other Theme Parks

298	299	300	301	304	305	306
Design Consultant Management Consultant (Owner's representative)	Construction Contractor Design Consultant	Management Consultant (Owner's representative) Construction Contractor Design Consultant Management Consultant (Owner's representative)	Governmental Construction Agency (FDOT, FAHWA, etc.) Construction Contractor	Management Consultant (Owner's representative) Construction Contractor Design Consultant Management Consultant (Owner's representative)	Management Consultant (Owner's representative) Construction Contractor Design Consultant	Management Consultant (Owner's representative) Construction Contractor Design Consultant
10+ years	10+ years	10+ years	10+ years	10+ years	10+ years	10+ years
Program Manager / Construction Manager Project Engineer Site Engineer	Project Manager Assistant Project Manager Project Engineer Project Superintendent	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer	Program Manager / Construction Manager Assistant Project Manager Project Engineer Site Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Designer Project Engineer Site Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Design manager Designer Project Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer Site Engineer Project Superintendent
1 - 50 million	100 - 500 million	1 - 50 million	1 - 50 million	1+ billion	1+ billion	1+ billion
Transportation Projects (Roads and Highways)	Building and Commercial Construction Industrial and Power Plants	Transportation Projects (Roads and Highways) Building and Commercial Construction	Transportation Projects (Roads and Highways) Building and Commercial Construction	Transportation Projects (Roads and Highways) Other Domestic Water Treatment Plants and Wastewater Treatment Plants	Other Water and Wastewater	Transportation Projects (Roads and Highways) Building and Commercial Construction Heavy Construction (Dams, Tunnels, and Large Bridges)

307	308	310	312	313	314	315	317
Management Consultant (Owner's representative) Construction Contractor Design Consultant Governmental Agency 10+ years	Management Consultant (Owner's representative) Construction Contractor Management Consultant (Owner's representative) 10+ years	Management Consultant (Owner's representative) Construction Contractor Management Consultant (Owner's representative) 10+ years	Management Consultant (Owner's representative) Construction Contractor Design Consultant 10+ years	Management Consultant (Owner's representative) Construction Contractor 10+ years	Design Consultant 10+ years	Governmental Construction Agency (FDOT, FAHWA, etc.) Design Consultant 10+ years	Governmental Construction Agency (FDOT, FAHWA, etc.) Design Consultant Management Consultant (Owner's representative) 10+ years
Program Manager / Construction Manager Project Manager	Program Manager / Construction Manager Project Manager Assistant Project Manager other Project Controls	Program Manager / Construction Manager Project Manager Assistant Project Manager Design manager Project Engineer Site Engineer Academic / Professor	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer other Risk Manager	Program Manager / Construction Manager Project Manager Assistant Project Manager Design manager Project Engineer Site Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Project Engineer Site Engineer Project Superintendent other Consultant	Project Manager Project Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Design manager Designer Project Engineer Site Engineer
1 - 50 million	1+ billion	100 - 500 million	1+ billion	1+ billion	100 - 500 million	1 - 50 million	1+ billion
Building and Commercial Construction Industrial and Power Plants	Building and Commercial Construction Heavy Construction (Dams, Tunnels, and Large Bridges)	Industrial and Power Plants	Transportation Projects) Building and Commercial Construction Industrial and Power Plants Heavy Construction (Dams, Tunnels, and Large Bridges)	Building and Commercial Construction Industrial and Power Plants Heavy Construction (Dams, Tunnels, and Large Bridges)	Building and Commercial Construction	Building and Commercial Construction	Transportation Projects Heavy Construction (Dams, Tunnels, and Large Bridges)

318	319	320	321	322	323	324
Management Consultant (Owner's representative) Construction Contractor Governmental Agency (FDOT, FAHWA, etc.)	Management Consultant (Owner's representative) Construction Contractor Design Consultant	Management Consultant (Owner's representative) Design Consultant Management Consultant (Owner's representative)	Management Consultant (Owner's representative) Design Consultant Governmental Agency (FDOT, FAHWA, etc.)	Design Consultant Management Consultant (Owner's representative)	Management Consultant (Owner's representative) Design Consultant	Management Consultant (Owner's representative) Governmental Agency (FDOT, FAHWA, etc.)
10+ years	10+ years	10+ years	10+ years	10+ years	10+ years	10+ years
Program Manager / Construction Manager Project Manager Assistant Project Manager	Program Manager / Construction Manager Project Manager Assistant Project Manager Design manager Project Superintendent other Schedule consultant, Claims consultant, Chief Estimater	Program Manager / Construction Manager Project Manager Design manager Designer	Project Engineer Site Engineer other Resident Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Designer Project Engineer Site Engineer	Program Manager / Construction Manager Project Manager Assistant Project Manager Designer	Program Manager / Construction Manager Project Manager Assistant Project Manager Designer Project Engineer
1+ billion	100 - 500 million	100 - 500 million	100 - 500 million	100 - 500 million	50 - 100 million	500 - 1000 million
Transportation Projects (Roads and Highways) Building and Commercial Construction Industrial and Power Plants	Building and Commercial Construction	Building and Commercial Construction	Transportation Projects (Roads and Highways) Building and Commercial Construction	Industrial and Power Plants	Building and Commercial Construction	Transportation Projects (Roads and Highways) Building and Commercial Construction

Management Structures Ranking

Rank according to the best allocation of duties that would streamline the managerial tasks																										
Functional Management Structure	2	2	3	4	3	3	4	3	1	4	1	3	4	2	4	2	1	4	4	1	4	1	3	4	3	1
Area Management Structure	1	1	1	3	1	1	3	2	2	3	2	1	2	4	2	1	2	2	3	3	3	2	2	3	2	3
Independent Area Management Structure	3	3	2	1	2	2	2	1	3	2	3	2	1	3	3	3	3	3	2	4	2	3	1	2	4	2
Matrix Management Structure	4	4	4	2	4	4	1	4	4	1	4	4	3	1	1	4	4	1	1	2	1	4	4	1	1	4
Rank according to the ability to provide upper management with adequate oversight and control over activities, workgroups,& project changes																										
Functional Management Structure	2	2	3	4	3	3	4	2	1	4	2	3	4	2	4	2	3	4	2	1	1	2	3	2	1	1
Area Management Structure	1	1	1	1	1	1	3	3	2	2	1	1	2	4	2	1	4	1	3	2	2	1	2	3	2	2
Independent Area Management Structure	3	3	2	2	4	2	2	1	3	3	3	4	1	3	3	3	1	2	4	3	3	4	1	1	4	3
Matrix Management structure	4	4	4	3	2	4	1	4	4	1	4	2	3	1	1	4	2	3	1	4	4	3	4	4	3	4
Rank according to the ability provide adequate integration among different trades and work groups on the construction site																										
Functional Management Structure	2	3	1	2	1	3	4	1	1	4	1	2	4	1	4	3	1	1	3	1	4	1	1	1	2	1
Area Management Structure	1	1	3	1	4	2	3	3	2	1	4	3	2	4	1	1	2	4	2	2	1	2	2	2	1	3
Independent Area Management Structure	4	4	4	4	2	1	2	2	3	3	2	1	1	3	3	4	4	2	1	4	2	4	3	4	3	2
Matrix Management structure	3	2	2	3	3	4	1	4	4	2	3	4	3	2	2	2	3	3	4	3	3	3	4	3	4	4
Rank according to the ability to control costs, limit schedule delays, and deliver according to quality requirements from least to most difficult																										
Functional Management Structure	1	2	3	1	3	3	3	2	1	4	2	1	4	1	4	3	1	4	1	2	4	2	3	1	4	3
Area Management Structure	3	1	1	2	2	1	4	3	2	2	3	3	2	4	2	2	3	1	4	1	3	1	2	2	3	2
Independent Area Management Structure	2	3	2	4	4	2	2	1	3	3	1	2	1	3	3	4	4	2	3	4	2	4	1	3	1	1
Matrix Management structure	4	4	4	3	1	4	1	4	4	1	4	4	3	2	1	1	2	3	2	3	1	3	4	4	2	4
Rank according to the cost of staffing and implementation from the least expensive to the most expensive																										
Functional Management Structure	2	3	3	1	3	2	3	2	1	4	3	4	1	1	4	2	1	3	1	2	4	1	3	1	4	1
Area Management Structure	1	4	2	2	2	3	4	1	2	2	4	3	3	2	1	3	2	1	3	4	3	2	1	2	3	3
Independent Area Management Structure	3	2	1	3	4	1	2	3	3	3	1	2	4	3	2	1	4	4	4	3	2	4	2	4	1	2
Matrix Management structure	4	1	4	4	1	4	1	4	4	1	2	1	2	4	3	4	3	2	2	1	1	3	4	3	2	4

2	2	3	1	3	4	4	3	3	3	2	4	3	3	4	1	1	2	3	2	3	1	4	1	2	4	2	4	4	4	2	3	1	2	1	1	4	2	1	4	4	4	1	4	1	1	2	2	4	2	2	2	2	1
1	3	2	2	4	1	2	2	1	1	1	3	2	1	2	3	2	3	1	1	4	2	2	2	4	3	3	1	3	1	4	1	3	3	3	2	1	3	3	3	2	3	2	1	2	2	1	3	2	1	3	3	1	4
3	1	1	3	2	2	1	1	2	4	3	2	1	2	1	4	4	4	2	4	2	3	3	3	3	2	4	2	1	3	3	4	4	4	4	3	3	4	2	2	1	2	3	2	4	3	3	4	3	3	1	4	3	2
4	4	4	4	1	3	3	4	4	2	4	1	4	4	3	2	3	1	4	3	1	4	1	4	1	1	1	3	2	2	1	2	2	1	2	4	2	1	4	1	3	1	4	3	3	4	4	1	1	4	4	1	4	3
3	3	3	1	1	3	3	2	1	3	3	4	1	1	2	4	1	1	1	2	3	1	4	4	2	1	2	2	1	1	2	3	1	2	2	1	4	2	1	4	4	4	1	4	1	1	2	2	4	4	1	2	3	1
2	2	2	2	2	4	2	1	2	1	1	3	3	4	3	2	2	3	2	1	4	2	2	3	4	2	3	3	2	2	4	1	2	3	3	3	1	3	3	3	2	2	2	1	2	2	1	3	2	3	3	3	4	2
1	4	1	3	3	1	1	4	3	4	2	2	4	3	4	1	4	4	3	4	2	3	3	1	3	4	4	1	4	3	3	4	3	4	4	4	3	4	2	2	3	1	4	3	4	3	3	4	3	1	2	4	2	4
4	1	4	4	4	2	4	3	4	2	4	1	2	2	1	3	3	2	4	3	1	4	1	2	1	3	1	4	3	4	1	2	4	1	1	2	2	1	4	1	1	3	3	2	3	4	4	1	1	2	4	1	1	3
2	1	1	1	2	4	1	4	3	3	1	4	4	4	4	1	2	2	3	3	3	1	4	1	3	3	2	4	1	1	1	3	1	1	2	2	4	2	1	2	4	3	1	4	1	1	2	2	3	3	1	2	4	4
1	3	2	2	3	2	2	1	1	1	2	3	3	3	2	3	1	3	2	2	4	2	2	3	2	1	3	3	2	3	4	1	2	3	4	1	1	3	3	4	2	4	2	1	2	3	1	3	2	2	3	3	3	3
3	4	3	3	4	3	3	3	2	4	3	2	1	2	1	4	4	4	1	4	2	3	3	4	4	2	4	2	4	2	3	4	3	4	3	3	3	4	2	3	3	2	4	2	3	2	3	4	4	1	2	4	1	2
4	2	4	4	1	1	4	2	4	2	4	1	2	1	3	2	3	1	4	1	1	4	1	2	1	4	1	1	3	4	2	2	4	2	1	4	2	1	4	1	1	1	3	3	4	4	4	1	1	4	4	1	2	1
3	3	3	1	1	4	3	2	3	3	1	4	1	1	3	1	2	3	2	3	3	1	4	4	3	3	2	4	4	3	2	3	2	2	4	3	4	2	1	4	4	4	4	4	1	1	3	2	4	3	1	2	1	1
2	2	1	2	4	3	2	1	1	1	2	3	2	2	2	2	4	2	1	4	4	2	2	3	2	2	3	1	3	1	4	1	1	3	2	4	1	3	3	3	3	2	1	1	2	2	2	3	3	2	4	3	4	3
1	1	2	3	2	2	1	4	2	4	3	2	3	3	1	4	3	1	3	1	1	3	3	1	4	1	4	2	2	2	3	4	3	4	1	2	3	4	2	2	2	1	2	2	4	3	1	4	2	4	2	4	2	4
4	4	4	4	3	1	4	3	4	2	4	1	4	4	4	3	1	4	4	2	2	4	1	2	1	4	1	3	1	4	1	2	4	1	3	1	2	1	4	1	1	3	3	3	3	4	4	1	1	1	3	1	3	2
2	3	2	1	4	1	4	3	1	3	3	4	1	2	4	4	3	3	1	2	3	3	3	3	2	4	2	2	4	1	3	3	1	1	2	1	4	1	1	4	1	3	4	1	1	1	1	3	2	3	2	2	4	4
1	2	3	2	3	2	3	1	3	1	4	3	3	4	2	2	4	2	4	4	4	4	4	4	3	2	3	4	3	3	4	4	3	2	3	2	1	3	3	3	2	2	1	4	2	2	2	2	4	4	4	3	3	2
3	4	1	3	2	3	2	2	2	4	2	2	4	3	1	1	1	1	2	3	2	1	2	1	4	3	4	3	1	2	1	2	2	3	1	3	3	4	2	1	3	1	2	2	3	3	3	1	1	2	3	4	1	1
4	1	4	4	1	4	1	4	4	2	1	1	2	1	3	3	2	4	3	1	1	2	1	2	1	1	1	1	2	4	2	1	4	4	4	4	2	2		2	4	4	3	3	4	4	4	4	3	1	1	1	2	3

Contractual Structures Ranking

Rank according to the best allocation of duties that would streamline the managerial works																										
Owner - Contractor Organization	4	4	4	4	4	4	4	4	4	2	4	4	3	4	3	4	2	4	1	1	4	4	1	4	4	3
Owner - Design/ Build Contractor Organization	2	1	2	1	3	2	3	3	2	1	1	1	1	2	2	2	1	3	2	3	3	3	4	3	1	2
Owner - Management Consultant Organization	3	3	3	3	2	1	2	2	1	3	2	3	2	3	4	3	4	1	4	2	2	2	2	1	3	1
Integrated Project Organization	1	2	1	2	1	3	1	1	3	4	3	2	4	1	1	1	3	2	3	4	1	1	3	2	2	4
Rank according to the owner's involvement and ability to control the design and construction activities and changes																										
Owner - Contractor Organization	4	1	1	2	4	1	4	2	4	1	2	1	1	3	4	2	1	1	1	2	2	1	2	3	4	3
Owner - Design/ Build Contractor Organization	2	2	4	4	3	4	3	3	1	2	4	4	4	4	3	4	4	4	3	3	4	4	4	4	2	2
Owner - Management Consultant Organization	1	4	3	3	2	3	2	4	2	3	3	2	3	2	2	3	3	3	4	4	1	3	3	2	3	1
Integrated Project Organization	3	3	2	1	1	2	1	1	3	4	1	3	2	1	1	1	2	2	2	1	3	2	1	1	1	4
Rank according to the ability provide adequate integration among different project parties																										
Owner - Contractor Organization	4	4	3	2	4	4	4	4	3	3	4	3	3	4	3	3	3	4	1	4	4	4	2	4	4	4
Owner - Design/ Build Contractor Organization	2	1	2	4	3	2	2	3	2	1	2	1	4	1	2	4	2	2	2	1	3	2	4	3	2	3
Owner - Management Consultant Organization	1	3	4	3	2	1	3	2	1	2	3	4	1	3	4	2	4	3	4	2	2	3	3	1	3	1
Integrated Project Organization	3	2	1	1	1	3	1	1	4	4	1	2	2	2	1	1	1	1	3	3	1	1	1	2	1	2
Rank according to the ability to control cost, complete the project on time, & deliver according to the quality requirements																										
Owner - Contractor Organization	4	4	2	4	4	4	4	1	4	1	4	1	1	3	3	1	3	4	1	4	3	3	4	3	4	4
Owner - Design/ Build Contractor Organization	2	1	4	1	3	2	2	2	1	4	1	2	4	1	2	3	1	1	2	1	4	1	1	4	1	3
Owner - Management Consultant Organization	1	2	1	3	2	1	3	3	2	3	2	4	3	2	4	4	4	3	4	2	1	4	3	1	3	1
Integrated Project Organization	3	3	3	2	1	3	1	4	3	2	3	3	2	4	1	2	2	2	3	3	2	2	2	2	2	2
Rank according to the cost of staffing & implementation from the least expensive to the most expensive																										
Owner - Contractor Organization	4	1	1	4	4	1	2	1	3	3	1	1	3	3	3	4	2	4	2	3	1	2	4	2	3	4
Owner - Design/ Build Contractor Organization	2	4	3	3	3	3	1	2	1	2	4	2	1	1	1	3	1	2	1	2	4	1	1	4	1	3
Owner - Management Consultant Organization	1	2	2	2	2	4	4	3	2	4	2	4	4	4	4	2	4	3	4	1	2	4	2	3	4	1
Integrated Project Organization	3	3	4	1	1	2	3	4	4	1	3	3	2	2	2	1	3	1	3	4	3	3	3	1	2	2
Rank according to the ability to provide the least project time																										
Owner - Contractor Organization	4	4	4	4	4	4	4	1	4	3	4	4	2	3	3	4	3	4	3	3	4	4	4	4	4	4
Owner - Design/ Build Contractor Organization	2	3	2	1	3	1	3	2	1	1	3	1	1	1	1	1	1	1	1	2	1	1	1	2	1	2
Owner - Management Consultant Organization	1	1	3	3	2	2	2	3	3	2	1	3	3	2	4	3	4	3	4	1	2	3	2	3	3	1
Integrated Project Organization	3	2	1	2	1	3	1	4	2	4	2	2	4	4	2	2	2	2	2	4	3	2	3	1	2	3

4	3	4	3	4	4	4	4	4	4	4	3	2	3	3	4	3	4	4	4	1	4	4	4	4	4	3	3	3	3	4	3	4	4	4	4	4	1	4	3	1	4	4	4
3	4	1	1	1	3	1	2	1	3	3	4	1	2	4	1	2	1	3	1	2	2	1	3	1	3	1	1	1	1	1	2	1	1	1	3	1	2	2	2	2	3	2	1
1	2	2	2	3	2	2	3	3	1	1	1	3	1	2	2	4	3	1	3	3	1	3	2	2	1	2	4	2	4	2	4	3	3	3	2	3	3	1	4	3	2	1	2
2	1	3	4	2	1	3	1	2	2	2	2	4	4	1	3	1	2	2	2	4	3	2	1	3	2	4	2	4	2	3	1	2	2	2	1	2	4	3	1	4	1	3	3
1	1	1	2	1	4	1	1	1	2	3	3	1	4	1	1	2	1	4	1	1	2	4	4	4	1	2	1	3	2	3	2	3	3	2	2	1	1	1	1	3	3	4	1
4	4	4	4	4	3	4	4	4	4	2	4	2	3	2	2	3	4	3	3	2	4	2	2	1	3	4	2	1	3	1	4	4	4	4	4	4	3	4	4	4	1	3	2
3	2	3	1	3	2	3	2	3	3	1	2	3	1	4	4	4	2	1	4	3	3	3	3	2	2	3	3	2	4	2	3	2	2	3	3	3	2	3	3	1	2	2	3
2	3	2	3	2	1	2	3	2	1	4	1	4	2	3	3	1	3	2	2	4	1	1	1	3	4	1	4	4	1	4	1	1	1	1	1	2	4	2	2	2	4	1	4
4	3	4	4	3	4	4	4	4	4	4	3	4	4	1	4	4	4	4	4	1	3	4	4	4	4	3	4	3	4	2	3	4	3	4	4	3	1	3	4	4	1	4	4
2	4	1	2	4	3	2	3	1	3	3	4	2	3	4	3	3	3	3	2	2	2	2	2	1	3	1	3	1	1	4	4	3	4	2	2	2	2	1	3	3	4	2	1
1	1	3	1	2	2	1	2	3	2	1	2	1	1	2	1	2	1	1	3	3	1	3	3	3	2	2	2	2	3	3	2	2	2	3	3	4	3	2	2	2	3	3	3
3	2	2	3	1	1	3	1	2	1	2	1	3	2	3	2	1	2	2	1	4	4	1	1	2	1	4	1	4	2	1	1	1	1	1	1	1	4	4	1	1	2	1	2
4	3	3	4	3	4	4	4	1	4	3	1	2	4	1	4	3	1	4	4	1	3	4	4	1	2	3	4	3	4	4	3	4	4	4	4	3	1	3	3	4	1	4	4
3	4	2	2	4	3	1	2	3	3	2	2	1	3	3	1	2	4	3	3	2	1	2	2	4	3	1	3	1	1	1	1	1	3	1	2	4	3	1	4	3	2	2	1
1	1	1	1	1	2	2	1	2	2	1	4	3	1	2	2	4	2	1	1	3	2	3	3	2	1	2	1	2	3	2	4	3	2	2	3	2	2	2	2	1	3	1	2
2	2	4	3	2	1	3	3	4	1	4	3	4	2	4	3	1	3	2	2	4	4	1	1	3	4	4	2	4	2	3	2	2	1	3	1	1	4	4	1	2	4	3	3
3	3	1	2	1	4	1	4	2	3	4	1	2	4	1	4	3	4	4	1	1	3	4	4	1	1	2	2	3	3	4	3	4	3	4	3	3	1	3	3	4	1	4	3
4	2	4	1	2	3	4	1	1	2	1	4	1	1	2	1	2	1	3	2	2	4	2	2	4	3	3	1	1	1	1	1	1	4	1	2	1	2	4	1	1	2	3	1
1	4	2	4	3	2	2	2	3	1	2	3	4	2	3	2	4	3	1	4	3	1	3	3	2	2	1	3	2	4	3	4	2	2	2	4	4	3	2	4	2	3	2	2
2	1	3	3	4	1	3	3	4	4	3	2	3	3	4	3	1	2	2	3	4	2	1	1	3	4	4	4	4	2	2	2	3	1	3	1	2	4	1	2	3	4	1	4
4	4	2	3	4	4	3	4	2	4	4	3	2	3	1	4	3		4	4	1	2	4	4	1	2	3	2	3	3	4	3	4	4	4	4	3	2	1	4	2	3	4	4
2	1	4	1	1	3	1	2	1	3	1	1	1	1	2	1	2	1	3	1	2	4	2	2	4	3	1	1	1	1	1	1	1	1	2	2	1	1	2	1	1	2	1	1
1	3	3	2	2	2	4	3	3	2	2	4	3	2	3	2	4		1	3	3	1	3	3	2	1	2	3	2	4	3	4	2	3	3	3	4	3	3	3	4	1	2	3
3	2	1	4	3	1	2	1	4	1	3	2	4	4	4	3	1		2	2	4	3	1	1	3	4	4	4	4	2	2	2	3	2	1	1	2	4	4	2	3	4	3	2

Operation Methods Ranking

Rank according to the difficulty of managing the project from the least difficult to the most difficult																																	
Individual Package	3	1	1	1	1	1	1	3	1	1	1	3	3	2	1	1	1	1	1	1	2	3	2	1	2	3	1	3	1	2	2	1	1
Sequential Package	2	2	2	2	3	2	2	2	3	3	3	2	2	3	2	2	2	2	2	2	1	2	1	2	3	2	2	2	2	3	3	3	2
Concurrent Package	1	3	3	3	2	3	3	1	2	2	2	1	1	1	3	3	3	3	3	3	3	1	3	3	1	1	3	1	3	1	1	2	3
Rank according to the ability to provide the least project cost including staffing costs and construction costs of all packages																																	
Individual Package	3	3	2	3	1	3	1	3	2	1	3	1	3	2	2	2	3	3	3	2	1	2	3	3	2	3	3	2	3	2	1	1	1
Sequential Package	2	1	3	2	3	2	2	2	1	3	2	2	2	3	1	1	1	2	1	1	2	3	2	2	3	2	2	3	2	3	3	3	2
Concurrent Package	1	2	1	1	2	1	3	1	3	2	1	3	1	1	3	3	2	1	2	3	3	1	1	1	1	1	1	1	1	1	2	2	3
Rank according to the ability to control costs, limit schedule delays, and deliver according to quality requirements from the least difficult to the most difficult																																	
Individual Package	3	2	3	1	1	1	1	3	3	2	3	1	2	2	2	1	3	2	1	1	1	3	1	1	1	2	1	3	2	2	1	1	2
Sequential Package	2	1	2	2	3	2	2	2	1	1	1	2	1	3	1	2	1	1	2	3	2	2	2	2	3	3	2	1	1	3	3	3	1
Concurrent Package	1	3	1	3	2	3	3	1	2	3	2	3	3	1		3	2	3	3	2	3	1	3	3	2	1	3	2	3	1	2	2	3

1	3	2	3	3	2	1	2	2	1	2	2	1	1	3	2	1	1	1	1	2	2	3	1	1	2	1	1	1	3	1	1	1	2	1
2	2	3	1	2	1	3	3	1	3	1	1	3	3	2	3	3	3	2	2	3	3	2	2	3	1	3	3	2	1	2	2	3	3	2
3	1	1	2	1	3	2	1	3	2	3	3	2	2	1	1	2	2	3	3	1	1	1	3	2	3	2	2	3	2	3	3	2	1	3
3	3	2	3	3	2	1	2	2	3	3	3	3	2	3	3	3	3	2	1	1	1	3	1	3	2	1	3	1	3	3	3	2	2	1
2	2	3	1	2	1	2	3	3	2	2	2	2	1	2	2	2	2	1	2	2	2	2	3	1	1	2	1	2	2	1	1	1	3	3
1	1	1	2	1	3	3	1	1	1	1	1	1	3	1	1	1	1	3	3	3	3	1	2	2	3	3	2	3	1	2	2	3	1	2
1	1	2	1	3	2	1	2	1	1	2	3	1	3	3	3	2	1	1	1	2	2	3	1	1	2	1	1	1	3	2	3	2	2	3
2	2	3	3	2	1	3	3	2	3	1	2	3	2	2	2	3	3	2	2	3	1	2	3	2	1	3	3	2	2	1	1	3	3	2
3	3	1	2	1	3	2	1	3	2	3	1	2	1	1	1	1	2	3	3	1	3	1	2	3	3	2	2	3	1	3	2	1	1	1

APPENDIX D
STATISTICAL ANALYSIS OF SURVEY RESULTS

Management Structures Q1
Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	80	206	2.575	1.336075949
Row 2	80	174	2.175	0.880379747
Row 3	80	206	2.575	0.98164557
Row 4	80	214	2.675	1.715822785

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	11.8	3	3.9333	3.201786021	0.02357	2.63318
Within Groups	388.2	316	1.2284			
Total	400	319				

t-Test: Two-Sample Assuming Unequal Variances

	funct	area
	Variable 1	*Variable 2*
Mean	2.575	2.175
Variance	1.336076	0.88038
Observations	80	80
Hypothesized Mean Difference	0	
df	152	
t Stat	2.40312	
P(T<=t) one-tail	0.008731	
t Critical one-tail	1.65494	
P(T<=t) two-tail	0.017461	
t Critical two-tail	1.975694	

t-Test: Two-Sample Assuming Unequal Variances

	funct	matrix
	Variable 1	*Variable 2*
Mean	2.575	2.675
Variance	1.33607	1.71582
Observations	80	80
Hypothesized Mean Difference	0	
df	156	
t Stat	-0.51199	
P(T<=t) one-tail	0.30469	
t Critical one-tail	1.65468	
P(T<=t) two-tail	0.60938	
t Critical two-tail	1.97528	

Management Structures Q2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	80	185	2.3125	1.28085443
Row 2	80	178	2.225	0.860126582
Row 3	80	226	2.825	1.158860759
Row 4	80	211	2.6375	1.525158228

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	18.825	3	6.275	5.202072539	0.00161	2.63318
Within Groups	381.175	316	1.2062			
Total	400	319				

t-Test: Two-Sample Assuming Unequal Variances

	funct	area
	Variable 1	*Variable 2*
Mean	2.3125	2.225
Variance	1.280854	0.86013
Observations	80	80
Hypothesized Mean Difference	0	
df	152	
t Stat	0.534868	
P(T<=t) one-tail	0.296761	
t Critical one-tail	1.65494	
P(T<=t) two-tail	0.593523	
t Critical two-tail	1.975694	

t-Test: Two-Sample Assuming Unequal Variances

	funct	matrix
	Variable 1	*Variable 2*
Mean	2.3125	2.6375
Variance	1.28085	1.52515
Observations	80	80
Hypothesized Mean Difference	0	
df	157	
t Stat	-1.73534	
P(T<=t) one-tail	0.04232	
t Critical one-tail	1.65461	
P(T<=t) two-tail	0.08464	
t Critical two-tail	1.97518	

t-Test: Two-Sample Assuming Unequal Variances

	indep	matrix
	Variable 1	*Variable 2*
Mean	2.825	2.6375
Variance	1.158861	1.52516
Observations	80	80

Hypothesized Mean Difference	0
df	155
t Stat	1.023655
P(T<=t) one-tail	0.153797
t Critical one-tail	1.654744
P(T<=t) two-tail	0.307593
t Critical two-tail	1.975387

Management Structures Q3

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	80	180	2.25	1.430379747
Row 2	80	184	2.3	0.921518987
Row 3	80	229	2.8625	1.031487342
Row 4	80	207	2.5875	1.43528481

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	19.325	3	6.4416	5.347255971	0.00132	2.63318
Within Groups	380.675	316	1.2046			
Total	400	319				

t-Test: Two-Sample Assuming Unequal Variances

	funct	area
	Variable 1	*Variable 2*
Mean	2.25	2.3
Variance	1.43038	0.92152
Observations	80	80
Hypothesized Mean Difference	0	
df	151	
t Stat	-0.29161	
P(T<=t) one-tail	0.385492	
t Critical one-tail	1.655007	
P(T<=t) two-tail	0.770983	
t Critical two-tail	1.975799	

t-Test: Two-Sample Assuming Unequal Variances

	area	matrix
	Variable 1	*Variable 2*
Mean	2.3	2.5875
Variance	0.92151	1.43528
Observations	80	80
Hypothesized Mean Difference	0	
df	151	
t Stat	-1.67502	
P(T<=t) one-tail	0.048	
t Critical one-tail	1.65500	
P(T<=t) two-tail	0.09599	
t Critical two-tail	1.97579	

t-Test: Two-Sample Assuming Unequal Variances

	indep	matrix
	Variable 1	*Variable 2*
Mean	2.8625	2.5875
Variance	1.031487	1.43528
Observations	80	80
Hypothesized Mean Difference	0	
df	154	
t Stat	1.566077	
P(T<=t) one-tail	0.059692	
t Critical one-tail	1.654808	
P(T<=t) two-tail	0.119383	
t Critical two-tail	1.975488	

Management Structures Q4

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	80	203	2.5375	1.28971519
Row 2	80	185	2.3125	0.951740506
Row 3	80	199	2.4875	1.18971519
Row 4	80	213	2.6625	1.568196203

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.05	3	1.6833	1.346837152	0.25918	2.63318
Within Groups	394.95	316	1.2498			
Total	400	319				

t-Test: Two-Sample Assuming Unequal Variances

	area	funct
	Variable 1	*Variable 2*
Mean	2.3125	2.5375
Variance	0.951741	1.28972
Observations	80	80

t-Test: Two-Sample Assuming Unequal Variances

	area	matrix
	Variable 1	*Variable 2*
Mean	2.3125	2.6625
Variance	0.95174	1.56819
Observations	80	80

Hypothesized Mean Difference	0
df	154
t Stat	-1.3442
P(T<=t) one-tail	0.090431
t Critical one-tail	1.654808
P(T<=t) two-tail	0.180862
t Critical two-tail	1.975488

Hypothesized Mean Difference	0
df	149
t Stat	-1.97205
P(T<=t) one-tail	0.02522
t Critical one-tail	1.65514
P(T<=t) two-tail	0.05045
t Critical two-tail	1.97601

t-Test: Two-Sample Assuming Unequal Variances

	funct	*matrix*
	Variable 1	*Variable 2*
Mean	2.5375	2.6625
Variance	1.289715	1.5682
Observations	80	80
Hypothesized Mean Difference	0	
df	157	
t Stat	-0.66135	
P(T<=t) one-tail	0.254679	
t Critical one-tail	1.654617	
P(T<=t) two-tail	0.509358	
t Critical two-tail	1.975189	

t-Test: Two-Sample Assuming Unequal Variances

	indep	*matrix*
	Variable 1	*Variable 2*
Mean	2.4875	2.6625
Variance	1.18971	1.56819
Observations	80	80
Hypothesized Mean Difference	0	
df	155	
t Stat	-0.94253	
P(T<=t) one-tail	0.17369	
t Critical one-tail	1.65474	
P(T<=t) two-tail	0.34739	
t Critical two-tail	1.97538	

Management Structures Q5

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	80	191	2.3875	1.303639241
Row 2	80	215	2.6875	0.977056962
Row 3	80	189	2.3625	1.120094937
Row 4	79	201	2.5443	1.584550471

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	5.48551	3	1.8285	1.468368719	0.22310	2.63327
Within Groups	392.2574	315	1.2452			
Total	397.7429	318				

t-Test: Two-Sample Assuming Unequal Variances

	indep	area
	Variable 1	*Variable 2*
Mean	2.3625	2.6875
Variance	1.120095	0.97706
Observations	80	80
Hypothesized Mean Difference	0	
df	157	
t Stat	-2.00731	
P(T<=t) one-tail	0.023217	
t Critical one-tail	1.654617	
P(T<=t) two-tail	0.046433	
t Critical two-tail	1.975189	

t-Test: Two-Sample Assuming Unequal Variances

	indep	matrix
	Variable 1	*Variable 2*
Mean	2.3625	2.54430
Variance	1.12009	1.58455
Observations	80	79
Hypothesized Mean Difference	0	
df	152	
t Stat	-0.98512	
P(T<=t) one-tail	0.16306	
t Critical one-tail	1.65494	
P(T<=t) two-tail	0.32613	
t Critical two-tail	1.97569	

t-Test: Two-Sample Assuming Unequal Variances

	matrix	area
	Variable 1	*Variable 2*
Mean	2.544304	2.6875
Variance	1.58455	0.97706
Observations	79	80
Hypothesized Mean Difference	0	
df	148	
t Stat	-0.79713	
P(T<=t) one-tail	0.213328	
t Critical one-tail	1.655215	
P(T<=t) two-tail	0.426655	
t Critical two-tail	1.976122	

t-Test: Two-Sample Assuming Unequal Variances

	funct	area
	Variable 1	*Variable 2*
Mean	2.3875	2.6875
Variance	1.30363	0.97705
Observations	80	80
Hypothesized Mean Difference	0	
df	155	
t Stat	-1.77678	
P(T<=t) one-tail	0.03878	
t Critical one-tail	1.65474	
P(T<=t) two-tail	0.07757	
t Critical two-tail	1.97538	

Contractual Structures Q1

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	70	241	3.4428	0.859006211
Row 2	70	136	1.9428	0.895238095
Row 3	70	164	2.3428	0.895238095
Row 4	70	159	2.2714	1.12815735

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	89.34286	3	29.781	31.53392524	1.47E-17	2.63731
Within Groups	260.6571	276	0.9444			
Total	350	279				

t-Test: Two-Sample Assuming Unequal Variances

	ipo	o-db
	Variable 1	*Variable 2*
Mean	2.271429	1.94286
Variance	1.128157	0.89524
Observations	70	70
Hypothesized Mean Difference	0	
df	136	
t Stat	1.932584	
P(T<=t) one-tail	0.027683	
t Critical one-tail	1.656135	
P(T<=t) two-tail	0.055366	
t Critical two-tail	1.977561	

t-Test: Two-Sample Assuming Unequal Variances

	man con	ipo
	Variable 1	*Variable 2*
Mean	2.34285	2.27142
Variance	0.89523	1.12815
Observations	70	70
Hypothesized Mean Difference	0	
df	136	
t Stat	0.42012	
P(T<=t) one-tail	0.337528	
t Critical one-tail	1.65613	
P(T<=t) two-tail	0.67505	
t Critical two-tail	1.97756	

t-Test: Two-Sample Assuming Unequal Variances

	man con	contr
	Variable 1	*Variable 2*
Mean	2.342857	3.44286
Variance	0.895238	0.85901
Observations	70	70
Hypothesized Mean Difference	0	
df	138	
t Stat	-6.94859	
P(T<=t) one-tail	6.68E-11	
t Critical one-tail	1.65597	
P(T<=t) two-tail	1.34E-10	
t Critical two-tail	1.977304	

Contractual Structures Q2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	70	147	2.1	1.337681159
Row 2	70	222	3.1714	0.984679089
Row 3	70	182	2.6	0.736231884
Row 4	70	149	2.128	1.244099379

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	53.11429	3	17.704	16.45924358	7.22E-10	2.63731
Within Groups	296.8857	276	1.0756			
Total	350	279				

t-Test: Two-Sample Assuming Unequal Variances

	contr	ipo
	Variable 1	*Variable 2*
Mean	2.1	2.12857
Variance	1.337681	1.2441
Observations	70	70
Hypothesized Mean Difference	0	
df	138	
t Stat	-0.14877	
P(T<=t) one-tail	0.440975	
t Critical one-tail	1.65597	
P(T<=t) two-tail	0.881951	
t Critical two-tail	1.977304	

t-Test: Two-Sample Assuming Unequal Variances

	ipo	man con
	Variable 1	*Variable 2*
Mean	2.12857	2.6
Variance	1.24409	0.73623
Observations	70	70
Hypothesized Mean Difference	0	
df	129	
t Stat	-2.80283	
P(T<=t) one-tail	0.00292	
t Critical one-tail	1.65675	
P(T<=t) two-tail	0.00584	
t Critical two-tail	1.97852	

t-Test: Two-Sample Assuming Unequal Variances

	man con	o-db
	Variable 1	*Variable 2*
Mean	2.6	3.17143
Variance	0.736232	0.98468
Observations	70	70
Hypothesized Mean Difference	0	
df	135	

t Stat	-3.64445
P(T<=t) one-tail	0.000191
t Critical one-tail	1.656219
P(T<=t) two-tail	0.000381
t Critical two-tail	1.977692

Contractual Structures Q3

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	70	241	3.4428	0.772049689
Row 2	70	170	2.4285	0.973084886
Row 3	70	159	2.2714	0.867287785
Row 4	70	130	1.8571	1.080745342

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	95.17143	3	31.723	34.35945734	6.7E-19	2.63731
Within Groups	254.8286	276	0.9232			
Total	350	279				

t-Test: Two-Sample Assuming Unequal Variances

	IPO	man con
	Variable 1	*Variable 2*
Mean	1.857143	2.27143
Variance	1.080745	0.86729
Observations	70	70
Hypothesized Mean Difference	0	
df	136	
t Stat	-2.48342	
P(T<=t) one-tail	0.007114	
t Critical one-tail	1.656135	
P(T<=t) two-tail	0.014228	
t Critical two-tail	1.977561	

t-Test: Two-Sample Assuming Unequal Variances

	man con	o-db
	Variable 1	*Variable 2*
Mean	2.27142	2.42857
Variance	0.86728	0.97308
Observations	70	70
Hypothesized Mean Difference	0	
df	138	
t Stat	-0.96915	
P(T<=t) one-tail	0.16708	
t Critical one-tail	1.65597	
P(T<=t) two-tail	0.33416	
t Critical two-tail	1.97730	

t-Test: Two-Sample Assuming Unequal Variances

	o-db	contr
	Variable	*Variable*

	1	2
Mean	2.428571	3.44286
Variance	0.973085	0.77205
Observations	70	70
Hypothesized Mean Difference	0	
df	136	
t Stat	-6.42384	
P(T<=t) one-tail	1.03E-09	
t Critical one-tail	1.656135	
P(T<=t) two-tail	2.07E-09	
t Critical two-tail	1.977561	

Contractual Structures Q4

Anova: Single Factor

SUMMARY

Groups	Count	Sum	Average	Variance
Row 1	70	214	3.0571	1.359006211
Row 2	70	154	2.2	1.176811594
Row 3	70	154	2.2	1.002898551
Row 4	70	178	2.5428	1.03436853

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	34.45714	3	11.485	10.04636001	2.65E-06	2.63731
Within Groups	315.5429	276	1.1432			
Total	350	279				

t-Test: Two-Sample Assuming Unequal Variances

	o-db Variable 1	IPO Variable 2
Mean	2.2	2.54286
Variance	1.002899	1.03437
Observations	70	70
Hypothesized Mean Difference	0	
df	138	
t Stat	-2.00973	
P(T<=t) one-tail	0.023205	

t-Test: Two-Sample Assuming Unequal Variances

	o-db Variable 1	man con Variable 2
Mean	2.2	2.2
Variance	1.00289	1.17681
Observations	70	70
Hypothesized Mean Difference	0	
df	137	
t Stat	0	
P(T<=t) one-tail	0.5	

t Critical one-tail	1.65597
P(T<=t) two-tail	0.046409
t Critical two-tail	1.977304

t Critical one-tail	1.65605
P(T<=t) two-tail	1
t Critical two-tail	1.97743

t-Test: Two-Sample Assuming Unequal Variances

	IPO	contr
	Variable 1	*Variable 2*
Mean	2.542857	3.05714
Variance	1.034369	1.35901
Observations	70	70
Hypothesized Mean Difference	0	
df	136	
t Stat	-2.7813	
P(T<=t) one-tail	0.003092	
t Critical one-tail	1.656135	
P(T<=t) two-tail	0.006183	
t Critical two-tail	1.977561	

Contractual Structures Q5

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	70	185	2.6428	1.363354037
Row 2	70	146	2.0857	1.267908903
Row 3	70	189	2.7	1.053623188
Row 4	70	180	2.5714	1.14699793

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	16.6	3	5.5333	4.580683863	0.00378	2.63731
Within Groups	333.4	276	1.2079			
Total	350	279				

t-Test: Two-Sample Assuming Unequal Variances

	o-db	IPO
	Variable 1	*Variable 2*
Mean	2.085714	2.57143
Variance	1.267909	1.147

t-Test: Two-Sample Assuming Unequal Variances

	IPO	contr
	Variable 1	*Variable 2*
Mean	2.57142	2.64285
Variance	1.14699	1.36335

Observations	70	70
Hypothesized Mean Difference	0	
df	138	
t Stat	-2.61505	
P(T<=t) one-tail	0.004957	
t Critical one-tail	1.65597	
P(T<=t) two-tail	0.009913	
t Critical two-tail	1.977304	

Observations	70	70
Hypothesized Mean Difference	0	
df	137	
t Stat	-0.37718	
P(T<=t) one-tail	0.35331	
t Critical one-tail	1.65605	
P(T<=t) two-tail	0.70662	
t Critical two-tail	1.977431	

t-Test: Two-Sample Assuming Unequal Variances

	IPO	man con
	Variable 1	*Variable 2*
Mean	2.571429	2.7
Variance	1.146998	1.05362
Observations	70	70
Hypothesized Mean Difference	0	
df	138	
t Stat	-0.72514	
P(T<=t) one-tail	0.234797	
t Critical one-tail	1.65597	
P(T<=t) two-tail	0.469595	
t Critical two-tail	1.977304	

Contractual Structures Q6

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	69	226	3.2753	0.908354646
Row 2	70	112	1.6	0.736231884
Row 3	69	178	2.5797	0.835464621
Row 4	69	175	2.53623	1.164109122

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	98.70275	3	32.900	36.13897717	1.06E-19	2.63766
Within Groups	248.5391	273	0.9104			

Total	347.2419	276

t-Test: Two-Sample Assuming Unequal Variances

	o-db	ipo
	Variable 1	*Variable 2*
Mean	1.6	2.53623
Variance	0.736232	1.16411
Observations	70	69
Hypothesized Mean Difference	0	
df	130	
t Stat	-5.65715	
P(T<=t) one-tail	4.68E-08	
t Critical one-tail	1.656659	
P(T<=t) two-tail	9.36E-08	
t Critical two-tail	1.97838	

t-Test: Two-Sample Assuming Unequal Variances

	man con	ipo
	Variable 1	*Variable 2*
Mean	2.57971	2.53623
Variance	0.83546	1.16410
Observations	69	69
Hypothesized Mean Difference	0	
df	132	
t Stat	0.25540	
P(T<=t) one-tail	0.39940	
t Critical one-tail	1.65647	
P(T<=t) two-tail	0.79880	
t Critical two-tail	1.97809	

t-Test: Two-Sample Assuming Unequal Variances

	o-man con	contr
	Variable 1	*Variable 2*
Mean	2.57971	3.27536
Variance	0.835465	0.90835
Observations	69	69
Hypothesized Mean Difference	0	
df	136	
t Stat	-4.37589	
P(T<=t) one-tail	1.2E-05	
t Critical one-tail	1.656135	
P(T<=t) two-tail	2.39E-05	
t Critical two-tail	1.977561	

Operation Methods Q1

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	68	111	1.6323	0.624012291
Row 2	68	152	2.2352	0.451273047
Row 3	68	145	2.1323	0.743415277

ANOVA

Source of Variation	SS	df	MS	F	P-value	F crit
Between Groups	14.14706	2	7.0735	11.66799421	1.61E-05	3.04082
Within Groups	121.8529	201	0.6062			
Total	136	203				

t-Test: Two-Sample Assuming Unequal Variances

	indiv	concurr
	Variable 1	*Variable 2*
Mean	1.632353	2.13235
Variance	0.624012	0.74342
Observations	68	68
Hypothesized Mean Difference	0	
df	133	
t Stat	-3.52592	
P(T<=t) one-tail	0.00029	
t Critical one-tail	1.656391	
P(T<=t) two-tail	0.00058	
t Critical two-tail	1.977961	

t-Test: Two-Sample Assuming Unequal Variances

	concurr	sequen
	Variable 1	*Variable 2*
Mean	2.13235	2.23529
Variance	0.74341	0.45127
Observations	68	68
Hypothesized Mean Difference	0	
df	126	
t Stat	-0.77663	
P(T<=t) one-tail	0.21941	
t Critical one-tail	1.65703	
P(T<=t) two-tail	0.43883	
t Critical two-tail	1.97897	

Operation Methods Q2

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	68	153	2.25	0.667910448
Row 2	68	135	1.9852	0.492317823
Row 3	68	120	1.7641	0.749780509

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	8.029412	2	4.0147	6.305791772	0.0022	3.04082
Within Groups	127.9706	201	0.6366			
Total	136	203				

t-Test: Two-Sample Assuming Unequal Variances

	concurr	sequen
	Variable 1	*Variable 2*
Mean	1.764706	1.98529
Variance	0.749781	0.49232

t-Test: Two-Sample Assuming Unequal Variances

	sequen	indiv
	Variable 1	*Variable 2*
Mean	1.98529	2.25
Variance	0.49231	0.66791

Observations	68	68
Hypothesized Mean Difference	0	
df	128	
t Stat	-1.63215	
P(T<=t) one-tail	0.052553	
t Critical one-tail	1.656845	
P(T<=t) two-tail	0.105107	
t Critical two-tail	1.978671	

Observations	68	68
Hypothesized Mean Difference	0	
df	131	
t Stat	-2.0265	
P(T<=t) one-tail	0.02237	
t Critical one-tail	1.65656	
P(T<=t) two-tail	0.04474	
t Critical two-tail	1.97823	

Operation Methods Q3

Anova: Single Factor

SUMMARY

Groups	*Count*	*Sum*	*Average*	*Variance*
Row 1	68	123	1.8088	0.664398595
Row 2	68	141	2.0735	0.576602283
Row 3	67	141	2.1044	0.731343284

ANOVA

Source of Variation	*SS*	*df*	*MS*	*F*	*P-value*	*F crit*
Between Groups	3.579358	2	1.7896	2.723691255	0.06806	3.04105
Within Groups	131.4157	200	0.6570			
Total	134.9951	202				

t-Test: Two-Sample Assuming Unequal Variances

	indiv	sequen
	Variable 1	*Variable 2*
Mean	1.808824	2.07353
Variance	0.664399	0.5766
Observations	68	68
Hypothesized Mean Difference	0	
df	133	
t Stat	-1.95944	
P(T<=t) one-tail	0.026076	
t Critical one-tail	1.656391	
P(T<=t) two-tail	0.052153	
t Critical two-tail	1.977961	

t-Test: Two-Sample Assuming Unequal Variances

	sequen	concurr
	Variable 1	*Variable 2*
Mean	2.07352	2.10447
Variance	0.57660	0.73134
Observations	68	67
Hypothesized Mean Difference	0	
df	131	
t Stat	-0.22222	
P(T<=t) one-tail	0.41224	
t Critical one-tail	1.65656	
P(T<=t) two-tail	0.82486	
t Critical two-tail	1.97823	

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BIOGRAPHICAL SKETCH

Adnan Haidar was born in Beirut, Lebanon. He obtained his Bachelor of Engineering in Electrical Engineering degree from the American University of Beirut in 2005. After his undergraduate studies, he obtained his Master of Engineering Management degree from the American University of Beirut with emphasis in industrial management. During and after his graduate studies, he worked in the construction industry where he acquired engineering and management skills and knowledge in cost estimating, project management, and legal claims preparation. In 2008, he was admitted to the University of Florida for graduate studies in construction engineering and management. In 2009, he received his Master of Engineering degree in civil engineering. He concluded his education by getting his PhD in civil engineering in 2011. He plans to use his academic and professional knowledge to help educate, build, and improve the world.