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Owner and Contractor Job Site Organizations

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OWNER AND CONTRACTOR JOB SITE ORGANIZATIONS

by

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A Report to
Construction Industry Institute
The University of Texas at Austin

Under the Guidance of
CII Research Team 261
Optimizing Job Site Organizations

CII Research Report 261-11
February 2012

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Printed in the United States of America.

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Executive Summary

Job site management functions and associated staffing levels among both Owners and Contractors have increased in number and complexity over the past 30 years in response to the demands for greater levels of job site planning, resource management, and performance oversight. However, there is little published guidance or clarity on job site organization metrics or approaches. The primary purpose of this research was to identify and describe industry norms pertaining to Owner and Contractor job site organizational functions and staffing levels, especially those that provide the best value for different types of projects under different circumstances.

This is the first job site organization benchmarking study of its kind. The study targeted recent industrial projects with total installed cost between \$50 million and \$800 million. The study examined thirty-one projects under construction over the last two years in terms of job site organization parameters, project characteristics, execution parameters, and project success parameters. Benchmark metrics derived from this research pertain to Owner and Contractor job site organization size and constituent roles. Organization size is reported and analyzed in terms of both staff full-time equivalent (FTE) and craft-to-staff ratio (CSR).

For the sample of projects examined, job site organization team sizes and CSR metrics vary significantly. These values range from three to 69 FTE for Owners and from five to 143 FTE for Contractors. The mean Craft-to-Staff ratio for Owners is 13.0 and 4.3 for Contractor teams. From an FTE perspective, Petro-chemical projects have the largest Owner teams, while Construction-only projects have the smallest Owner teams. EPC/Design-build projects have the largest Contractor teams, while Construction-only projects have the smallest Contractor teams.

High CSR values translate to smaller job site management teams. Power utility and Construction-only projects have the largest Owner CSR values, while Cost-reimbursable and EPC/Design-build projects have the smallest Owner CSR values. Lump sum projects have the largest Contractor CSR values, while Petro-chemical, Power utility, and EPC/Design-build projects have the smallest Contractor CSR values. CSR variability is quite large for Owners, but much less so for Contractors. Regression analyses indicate strong correlations between Contractor staff size (FTE) and either Project capital cost or Construction craft work hours.

The sampled projects suggest that there are six core job site organization roles with FTE > 1.0 for Owners, and 16 such roles for Contractors. Owner job site staffs are dominated by the management functions of quality, coordination, and commissioning; while Contractor job site staffs are dominated by the functions of field engineering, quality, materials management, safety, craft superintendents, procurement/supplier coordination, and area superintendents. Staff support for the four Contractor roles of area superintendent, craft superintendent, HSE management, and QA/QC management are generally scalable – or correlated with project size.

Two-thirds of the projects examined entail the outsourcing of job site staff functions by Owners, and this approach appears to be a growing trend. The amount of outsourcing for these projects ranged from seven percent to 92 percent. Contractor project managers have a mixed opinion on their level of satisfaction with outsourced Owner staff.

Projects with larger Owner and Contractor job site staffs appear to be safer than those projects with smaller staffs. Both Owners and Contractors should ensure that their management staffs are sufficient to promote worker safety.

Association trends have been analyzed for those projects that perform better-than-average with smaller-than-average job site teams. Success-enabling factors appear to be trust growth between Owner and Contractor, thoroughness of definition of team roles, higher quality of technical documents, thoroughness of change management, thoroughness of start-up planning, thoroughness of constructability planning, and thoroughness of front-end planning, among others. Thus, there appear to be links between team effectiveness and implementation of CII best practices.

It is believed that job site organization approach can play a key role in helping achieve project success – at a time when there's little tolerance for underperformance. Thus, it is important to understand both quantitative and qualitative dimensions of job site organizations and their links with project performance.

CH 1. Introduction

1.1. Background

Job site management functions and associated staffing levels among both Owners and Contractors have increased in number and complexity over the past 30 years in response to the demands for greater levels of job site planning and performance oversight. For example, there's much greater effort directed now toward safety management, and cost and schedule controls efforts have grown in complexity. Such changes have been influencing the structure and makeup of job site management teams.

Job site management teams are being structured in a wide variety of ways – with different implications on performance. For example, there's growing use of the Owner-managed approach, and Owners are involving greater numbers of contract personnel to supplement their management staffs at the job site.

However, there is little published guidance or clarity on job site organization metrics or approaches. In fact, job site organization benchmark information remains mostly closely held at the company level. As a result, this information is generally not well understood at either the project or industry levels.

It is believed that job site organization approach can play a key role in helping achieve project success – at a time when there's little tolerance for underperformance. Thus, it is important to better understand quantitative and qualitative dimensions of job site organizations, their links with project performance, and the mechanics of improving project performance by better job site organization staffing strategies.

1.2. Purpose and Hypotheses of the Research

The primary purpose of this research was to better understand why and how some approaches to job site organization are more effective—or more responsive to project needs and objectives. Therefore, it is crucial that industry norms pertaining to job site management functions and staffing levels should be identified, especially those norms that provide the best value for different types of projects under different circumstances.

To achieve the primary research purpose, some supporting objectives were pursued, specifically the objectives listed below:

- Understand how project job site organizations vary in size and makeup, and seek insights into how they vary with respect to project type, contract type, etc.
- Examine associations between size of job site organizations and project performance.
- Study job site staffing constituent roles and staff sizes, and look into their associations with project characteristics and/or project performance.
- Acquire lessons-learned regarding the structuring and optimal staffing of job site organizations.

1.3. Research Scope Limitations

The study scope did not include or address the following issues:

- Small projects (less than \$35 million);
- Craft foremen and craft labor staffing levels;
- Recruitment and assignment of team members;
- Training and orientation of team members;
- Day-to-day aspects of team leadership of job site organization;
- Purely manual staffing ratios, such as general foreman/foreman ratios, foreman/craft-worker ratios, and manual skilled/manual unskilled worker ratios; and
- Labor camp staffing issues (but projects with labor camps were not explicitly excluded).

1.4. Structure of the Research Report

The structure of this report is as follows:

- Literature Review (Ch. 2),
- Methodology (Ch. 3),
- Study Results (Ch. 4,5,6),
- Conclusions and Recommendations (Ch. 7), and
- Appendices (Interview guides and References, Ch. 8).

CH 2. Literature Review

2.1. Overview of Literature Review

To know about how to cope with the research objectives, it is important to consolidate the body of knowledge on job site organization, staffing strategy, and topics relating to them. Evaluating the subjects that have already been studied before would help pave the path for more comprehensive learning on the scope of RT 261. Therefore, thorough literature review is indispensable.

The first step of literature review is to determine the scope of review by developing a list of key terms that were identified by prior publications. A categorized list of topics, extracted from these key terms, was then put together. The process of the literature review, like most processes in the research project was iterative: as the research developed, more subjects were identified as relevant and requiring investigation. Table 2.1 lists the key terms that were searched in finding relevant material.

Several terms of frequent appearance in reviewed literature were extracted and used to yield the key terms of RT 261. According to the findings from the initial publication review, the following terms were selected to guide more in-depth review:

- Job site organizations,
- Owner's role and work structure,
- Integrated project teams,
- Owner-Contractor trust,
- High performance teams, and
- Organization design and organization chart.

Publications with any of each selected terms as a keyword were then scrutinized. The results are illustrated individually in following paragraphs.

Table 2.1: Key Terms for Searching Relevant Material for Literature Review

➤ Job Site Management Functions
➤ Job Site Management Staffing
➤ Job Site Management Teams
➤ Job Site Organization Structure
➤ Job Site Staffing Levels
➤ Job Site O-E-P-C Organizational Structure
➤ Job Site O-E-P-C Function
➤ Job Site O-E-P-C Staffing Level
➤ Staffing Job Site Organization
➤ Owner/Contractor Job Site Organization
➤ Owner Job Site Organization Structure
➤ Owner Job Site Organization Function
➤ Contractor Job Site Organization Structure
➤ Contractor Job Site Organization Function
➤ Construction Organization Functional Composition
➤ Line vs. Matrix vs. Staff Form
➤ Owner-Contractor Staffing Relationships
➤ Owner Participation in contractor Functions
➤ Integrated/Complementary Structure vs. Dual/Twin Structure
➤ Critical Command Chain
➤ Owner to Contractor Ratios
➤ Non-Manual to Manual Ratios
➤ Planner to Manual Ratios
➤ Contractor to Subcontractor Staff Ratios
➤ Site Organization Design
➤ Owner Decisions Effect Contractor
➤ Contractor Decisions Effect Owner
➤ Owner-Contractor Trust
➤ Integrated Project Teams
➤ High Performance Teams
➤ Owner's Role in Project Success
➤ Organization Chart

2.2. Job Site Organizations

“Effective Project Organization in Construction” (Yau 1991) is a general overview of project organizations. It includes descriptions of various project roles and contains a discussion of the project delivery approaches: traditional approach, design and construction approach, construction management approach, and the project management approach. These approaches are then illustrated in three case examples, in which the approaches are discussed in the context of actual projects. The article concludes that there is not fixed criteria that define a good project manager, but rather the criteria depend on the nature of the project and the Owner’s requirements. Also, benefit comes from the project manager having clear authority over the project (Yau 1991). The subject of authority is relevant for the research of RT 261; one of the questions in the interview guide asks about the thoroughness and timeliness of the definition of roles and responsibilities.

Another article with a parallel relation to the scope of the research of RT 261 is *“Influence of Organization on Project Implementation”* (Melchers 1977). It emphasized that in delivery of a project, management organization and coordination can be as important as engineering techniques, design, and theory. The article is written from a structural engineering perspective. It discusses research, in which management and organization structures were studied for three bridge projects, which had later failed structurally. It concludes that there is a link between poor organization/management and construction errors and structural failure.

The research of RT 261 measures the success of an organization based on its ability to achieve project goals such as meeting the target schedule and budget. However, this article only strengthens the premise of the high level of importance that is to be placed on structuring the project management organization and customizing it to the particular characteristics of the project at hand. While the article is insightful about the importance of customizing project management teams to the unique characteristics of the project, it does not discuss recommendations on how this should be done.

An article discussing some of the considerations and challenges faced by management at the level that will be researched by RT 261 is *“Revisiting Site Manager Work: Stuck in the Middle?”* (Styhre and Josephson 2006). The article discusses challenges and opportunities that are faced by middle management. This article does not place a specific title, or functional designation with the terms “middle management,” but it is implied that “middle management” refers to such titles as construction manager and site manager, where “middle” refers to being between company management at the home-office and the superintendents on site. The challenges that middle managers face are mostly associated with being stuck between the expectations of top

management and those of construction workers, and being conflicted between priorities, objectives and goals (Styhre and Josephson 2006). The article pinpoints that the primary “stressor” for middle management is the tradeoff in prioritizing between production works versus administrative concerns. The implication that this article can potentially have on the research of RT 261 is related to details of the functional composition of the on-site team. For example, proper structuring of a team can help in avoiding personnel having to share a production function with an administrative function so that the “stressors” in this article can be avoided.

A subject that is important for the research of RT 261 is how to evaluate the success of a project management team. “*Design-Construction Organizations*” (Rowlinson and Newcombe 1986) addresses this question as well as those contextual variables that should be considered in structuring a design/build team. The article discusses the changing nature of the construction industry: the practice of design/build was once rare, and now has become common practice. This has caused both inter-and intra-organizational changes (Rowlinson and Newcombe 1986). There is then a discussion about characterizing a successful project management team. The element with the highest authority in determining the effectiveness of the project management team is the Owner.

The article concludes that the three most important factors to consider in structuring the project management team are: complexity of the project, the Owner’s management team, and the Owner’s criteria for judging project success. These observations are consistent with the methodology utilized by RT 261. Among other criteria, some of the measures in RT 261 interview guides are Owner satisfaction (measured by willingness of Owner to work with Contractor again), project complexity, prime project driver (schedule or budget driven), and the ability to meet target budget and schedule (Rowlinson and Newcombe 1986).

An alternative perspective to the factors to be considered in structuring an organization is presented in the article “Guidelines for the Development of Authority Structures for Heavy Industrial Construction Projects” (Randolph et al. 1984). The article proposes that there are nine factors that influence the choice of “authority structure.” This includes: project size and duration, organizational experience, resources, skill difference (variance within the organization), importance of, technology uncertainty, financial uncertainty, number of projects, and cost and schedule control. The article also discusses organization form, and proposes that organizations can be categorized in three general ways: the functional form, the matrix form, and the project form, which are contingent on whether authority in the project management team is functional based, or project based authority. The matrix structure is a balance of the two.

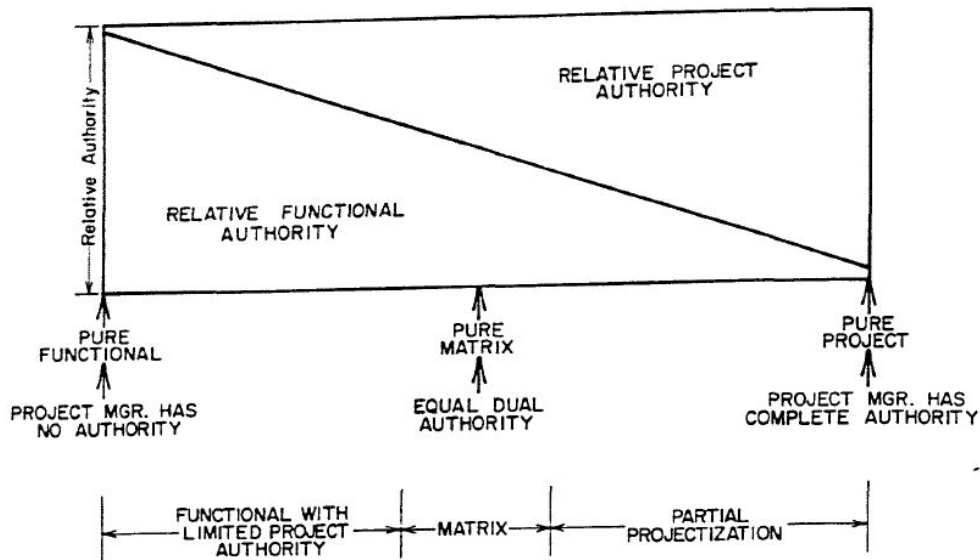


Figure 2.1: The Relationship between Level of Authority and Organization
(Randolph et al. 1984)

The source with the most comprehensive and relevant information on the subject of project organizations, with particular attention to job site organizations were two textbooks from the series “Project Manpower Management” titled “*Management Processes in Construction Practice and Decision-Making Processes in Construction Practice*” (Anderson and Woodhead 1981).

In “*Management Process in Construction Practice*” the chapters reviewed were 6-9. These chapters discuss the project team structure, where each chapter is written about the structure of a different class of project. The first is the small firm environment, which corresponds to the ‘Project Team Component’ concept. These are characterized by firms with construction volume of less than \$3 million and less than four permanent employees. The next class is the medium-sized firm environment, corresponding to the model of the traveling project manager. Characteristics of firms in this class are yearly construction volume between \$4 million to \$50 million and between 20 to 200 salaried personnel. Chapters 8 and 9 discuss the Large firm environments from two perspectives: field based project management (chapter 8), and total field autonomy (chapter 9), categorized by projects that are typically upward of \$60 million, with an engineering and construction cycle of up to ten years, and a project that is highly complex and technical in nature.

Chapters 8 and 9 are of particular relevance to the research of RT 261 because for projects to be considered within the scope of the research, they must have a total installation cost of between \$50 million to \$800 million, and are typically industrial, or technical by nature. While chapters 6 and 7

are insightful, they discuss project organizations, and organization structures that are too small to fit those of the projects researched by RT 261. (Anderson and Woodhead 1981)

For each chapter there is a discussion about the organization structure, graphs displaying management responsibilities on a non-detailed/macro scale, charts for the project team and hierarchy of authority distribution, a list of functions/responsibilities for personnel titles, and graphical division of responsibilities per titles broken into which responsibilities take place at the home office, and which on the field. These breakdowns are helpful in chapter 8 and 9 because they serve as a baseline to compare projects researched by RT 261, and based on their staffing practices and authority distribution, they can be defined as having field based project management or total field autonomy. The Figure 2.2 and 2.3 are organization charts from chapter 8 and 9 representing a typical field based project management team and a total field autonomy project management team, respectively (Anderson and Woodhead 1981).

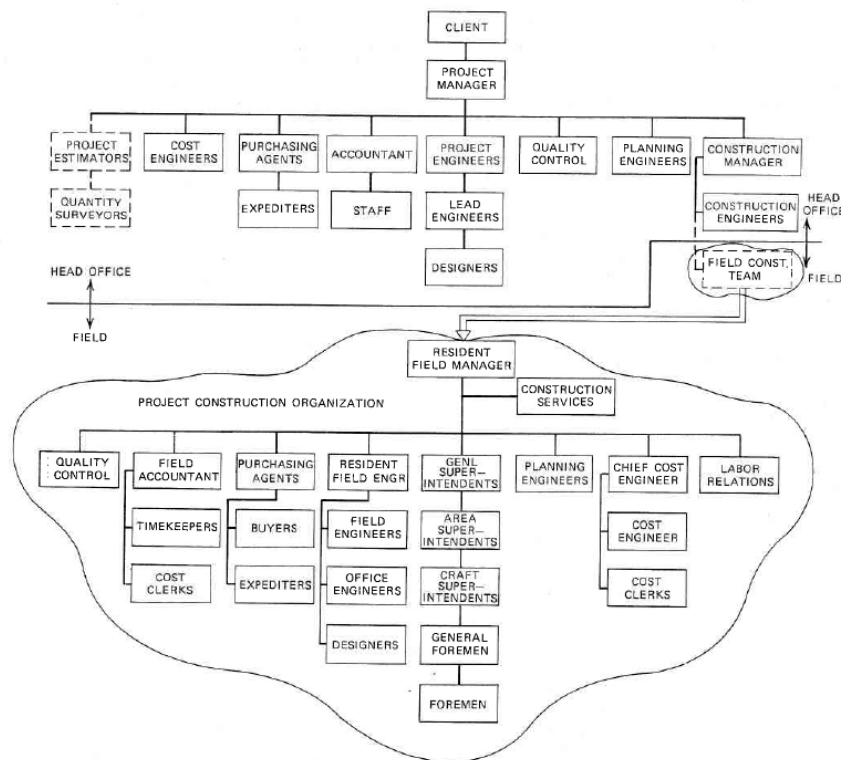


Figure 2.2: Typical “Field Based Project Management Team” Organization Chart
(Anderson and Woodhead 1981)

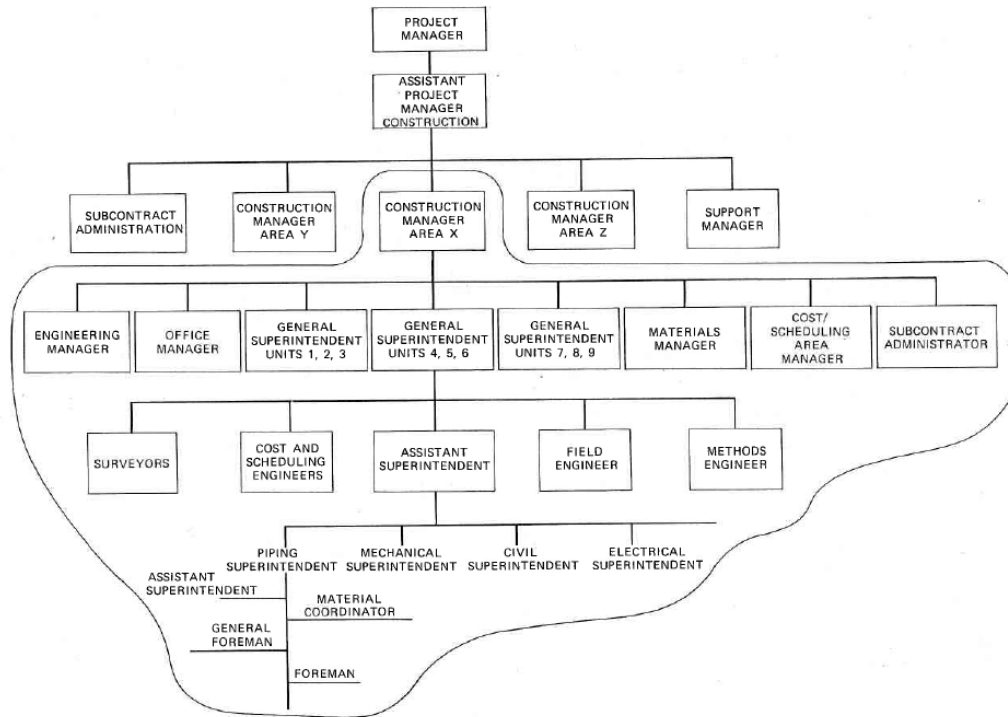


Figure 2.3: Typical “Total Field Autonomy Project Management Team” Organization Chart (Anderson and Woodhead 1981)

Overall, the subjects covered in the discussed chapters matched the research of RT 216 closely. For both, attention is paid as to which functions are performed by which titles, variety of organization structures, location of function (home office versus field), and which functions are shared.

The second textbook in the “Project Manpower Management” series that was reviewed was “*Decision-Making Process in Construction Practice*” (Anderson and Woodhead 1981). In it, the three reviewed chapters were 8, 9, and 10 on the subjects of field staffing, crew planning, and crew management, respectively. Of these, the most relevant chapter for the research of RT 261 is chapter 8, field staffing. Highlights of this chapter include an identification and description of major decision problems associated with field staffing. Also presented, is a progressive order of procedures for creating a field staff, from evaluating desirable field project team structures, at the start of the process, to adjusting the project field team as project conditions, scope, and client/owner requirements change as a last step.

The remainder of chapter 8 discusses different staffing approaches to correspond with the different types of projects as discussed in “*Management Processes in Construction Practice*.” These are: the project team component (for the small project), the traveling project manager (the medium

project), field based project management, and total field autonomy (both of which correspond to large projects). Because each of the project types is unique, they each require a unique approach to staffing. The relevance of this chapter to the research of RT 261 can mostly be related to the type of target deliverables. RT 261 aims to create guidelines on staffing practices based on specific conditions of the project at hand. In essence, they will be the same type of recommendations with two differences. First the staffing recommendations of RT 261 will be oriented to what the completed field staff should look like, where chapter 8 is more oriented towards the process and individual stages of staffing. The other difference is that RT 261 will take into account more variables about the project for giving recommendations, whereas chapter 8 classifies projects into one of four groups discussed above.

Chapter 9 and 10 are on the subjects of crew planning and crew management respectively. They both follow the same structure as in chapter 8. They introduce the subject with the basics of the involved decision process, and follow with the major decision problems and chronological procedures (Anderson and Woodhead 1981); they then offer techniques for each of the types of projects discussed above. These chapters are highly detailed and informative on the subjects of crew planning and management. However, they are not particularly relevant for the research of RT 261. It is explained in these chapters that the functions of crew planning and management can be performed by foremen or superintendents. In the scope of the research of RT 261 the personnel that are studied include everyone from the project manager to the superintendent. In this sense, there is an overlap: both RT 261 and crew management/planning are concerned with the work of superintendents. However, at the level of superintendent, the scope of RT 261 includes the FTE count but does not involve the particular functions performed by superintendents. For this reason, detailed discussion of the particular functions performed by superintendents falls outside of the scope of RT 261. Note that in the staffing details section of the RT 261 interview guides, some of the staff are referred to by title (such as project manager and superintendents), and some are referred to by function (such as subcontractor managers and rigging/heavy lift managers).

Many other articles on the subject of job site organizations have been read, but not mentioned in this literature review. The reason for this is that while the subjects of these articles are related to job site organizations, they fell outside of the scope of the research done by RT 261. For example, articles focusing on “soft” characteristics of teams such as initiative, motivation, commitment to company goals, sense of responsibility, etc. are not being investigated by RT 261. The following sections of this literature review discuss subjects that are related to job site organizations, and have been identified as relevant and worth consideration.

2.3. Owner's Role and Work Structure

In the attempt to optimize the organization at the job site in terms of structure of the organization and function levels present at the job site, there is a need to understand the dynamics between the Owner and Contractor's organizations. To learn about these dynamics, the literature review included two CII publications (research summaries) by RT 111 and RT 204 on the subjects of Owner's competencies and Owner's roles, respectively.

The first: the research summary of *"Owner/Contractor Work Structure: A Preview"* (RT 111) (CII 1996) is written as a solution to address the issue of competencies shifting from the Owner's organization to the Contractor's organization. The research of RT 111 was done in two phases. Phase I describes the process of Owner's competencies shifting to the Contractor's organization: percent change in organization size, and which competencies have shifted to the Contractor, shown in Table 2.2. Phase I also identifies and defines 30 core project competencies, shown in Table 2.3.

Table 2.2: Shifting of Owner Competencies to Contractor (CII 1996)

Owner Project Skills Reduced or Eliminated					
Detailed design	Project management	Process engineering	Construction management	Technical expertise	Project controls

Contractor Project Skills Added						
Computer/Software	Project management	Project controls	Team building	Project finance	Project scope development	Process engineering

Table 2.3: Identified and Defined Core Competencies (CII 1996)

Alliance/partnering	Benchmarking/metrics	Business development	Commissioning/start-up/performance testing	Conceptual cost estimating
Construct-ability	Construction	Construction management	Convert research to project/scale up	Definitive cost estimating
Detail design	Environmental/permits	Field quality control	Financial approval	Legal/contract administration
Lessons learned	Maintenance and operability	Preliminary design/scope development	Process/conceptual design	Procurement
Project controls	Project management	Project management oversight	Project planning/scheduling	Risk management
Safety	Setting project goals, objectives and priorities	Team building	Technical expertise	Total quality management

Phase II identifies the reasons and consequences of Owner downsizing, as well as which competencies are to be performed strictly by the Owner, strictly by the Contractor, and which will require structural alignment in the organization. These are shown below in Table 2.4. Phase II results in the creation of two graphical models for the process of alignment for corporate work structure and project work structure hierarchical framework.

Table 2.4: Competencies Performed by Owner, Contractor, and Requiring Structural Alignment (CII 1996)

Owner	Structural Alignment		Contractor
Business Dev.	Alliances/Partnering	Lessons Learned	Construction
	Benchmarking/Metrics	Maint. & Operability	
	Commissioning/Start-up/Perf. Testing	Prelim. Design/Scope	
Financial Approval	Conceptual Cost Est.	Process/Concept.Design	
	Constructability	Procurement	
PM Oversight	Construction Mgmt.	Project Controls	
	Convert Research to Project/Scale Up	Project Management	
	Definitive Cost Est.	Planning & Scheduling	
	Detail Design	Risk Management	
Setting Project Goals, Objectives & Priorities	Environmental/Permits	Safety	
	Field Quality Control	Team Building	
	Legal/Contract Admin.	Technical Expertise	
		TQM	

The developed solution of RT 111 is a systematic method to align Owner and Contractor work structures by understanding the competencies of the Owner and Contractor organization. The tool is a process for making strategic decisions about how to organize, and it is flexible such that it can be applied to many types of organizations.

The research of RT 111 is similar to that of RT 261 in that RT 261 also aims to provide a systematic method to create organizations strategically. The difference is that RT 261 aims to strategize staffing levels in specific functions, rather than for general core competencies. Also, organization structuring recommendations of RT 261 will take into account unique project characteristics such as contract type, delivery system, and industry sector.

The second reviewed publication is “*The Owner’s Role in Project Success*” (RT 204) (CII 2006), a research summary. The purpose of RT 204 was to identify the Owner’s role in maximizing project success by determining the right level of Owner involvement in different aspects of the project. Prior to forming results, RT 204 defined project success by identifying the main project participants (Owner, User, Design team, Contractor, and Subcontractor), and noted which participants play a role in 29 “success factors.” The research then created a further breakdown of Owner entities involved in the project process. They include: financial experts, engineering consultants, environmental consultants, real estate specialists, planning consultants, attorneys, general consultants, architects, and construction professionals.

The method of RT 204 for identifying the optimal level of Owner involvement was by defining drivers of system performance, which were used as metrics in the analysis. They are: pre-planning index, Owner involvement index, leadership performance index, and project management index. These indices were then used to generate regression coefficients, indicating which areas are to be given the most effort for different measurements of project performance: duration performance, cost performance, business performance, quality performance, and an overall project success rating. The research resulted in the creation of a tool named the ‘Project Priority Calculator’ for monitoring the outcome of specific success criteria throughout the project. Utilizing the Project Priority Calculator can allow Owners to concentrate effort in their stated objectives.

The research of RT 261 will also seek a relationship between project success and Owner’s involvement. However, the Owner’s involvement will be examined at the level of full time equivalent (FTE) personnel for specific functions and titles on the job site. In addition to this, the interview guide for RT 261 asks contractors to assess the level of Owner involvement in the areas of: decision making, quality assurance, safety/environmental/permits, change management, cost and schedule control, materials management, commercial management, Contractor personnel issues, and methods.

2.4. Integrated Project Teams

Another practice for improving the project performance is the use of integrated project teams. Integrated project teams are the approach to staffing and organizing human resources in the process of concurrent engineering (CE), also called simultaneous engineering or parallel engineering. Articles on the subject of integrated project teams and CE were included in the literature review in preparation for the research of RT 261.

The article “*Organizational Structures to Support Concurrent Engineering in Construction*” (Anumba et al. 2002) is a comprehensive discussion about integrated project teams and CE from the origin of CE in manufacturing to its more recent application in the construction industry. The article begins with the origins of CE: in the manufacturing industry, to respond to the need to reduce the time involved in introducing new products into the market from the conceptual phase. They state the definition: “CE is a systematic approach to the integrated, concurrent design of products and their related processes including manufacture and support. This approach is intended to cause the developers, from the outset, to consider all elements of the product life cycle from conception through disposal, including quality, cost, schedule, and user requirements.” (Anumba et al. 2002)

The article continues with a background of concurrent engineering detailing the aspects, features, and framework, which include: goals, objectives, strategy, and tools and techniques. The discussion then shifts to CE in the construction industry, explaining that its adoption into the construction industry was with the same drivers as with the manufacturing industry. In construction, CE is defined as an “attempt to optimize the design of the project and its construction process to achieve reduced lead times, and improved quality and cost by the integration of design, fabrication, construction and erection activities and by maximizing concurrency and collaboration in working practices” (Anumba et al. 2002).

A discussion of the application of CE in construction leads to the need to develop and empower multi-disciplinary teams. This is done with appropriate organizational structuring at both the corporate and project level. There is then a comparative discussion on organization structures (functional structure and matrix structure), with a diagram of what a typical organization structure would look like for an integrated project team. Figure 2.4 depicts a typical organization structure for an integrated project management team.

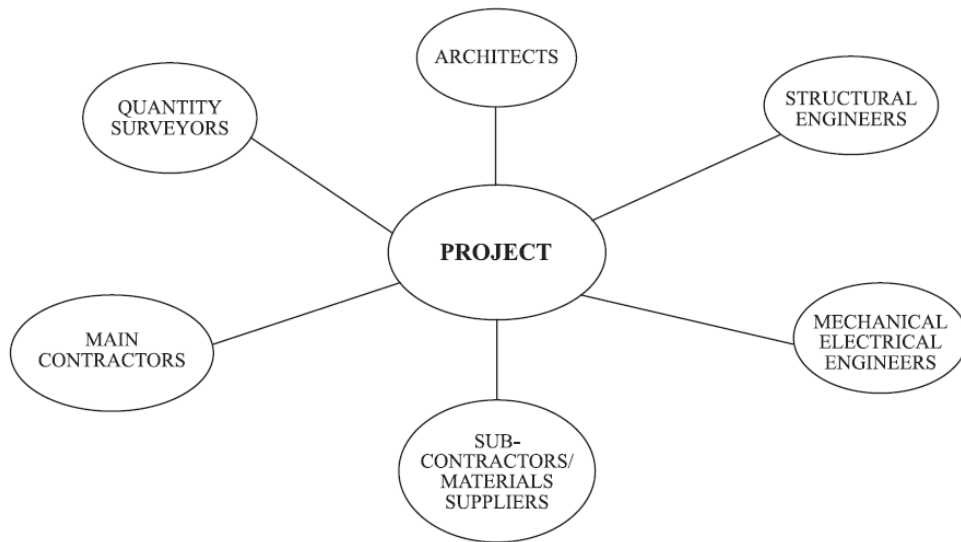


Figure 2.4: A Model of the Integrated Project Team (Anumba et al. 2002)

The article then presents case studies that investigated the organization structures and related issues of three companies in the construction industry. The organization structures of the three investigated companies were: divisional corporate structure, functional/hierarchical, and centralized hierarchical structure. The conclusions from the case studies were that despite innovation in structuring practices in the construction industry, there is still a strong tendency towards traditional, hierarchical structures, where larger firms tend towards divisional corporate level structures. These traditional approaches can hinder the effectiveness of the organization by slowing down the communication process and not utilizing the competencies of the staff optimally. It is also noted that traditional hierarchical structures do work, however they should be made less rigid to support a team work environment on the project level (Anumba et al. 2002).

The subject of this article is highly relevant for the research of RT 261 in studying organization structures and the consequences associated with them. The major difference between the research of RT 261 and the case studies in this article is that RT 261 is concerned with project level structures, and this article addresses corporate level structures. Integrated project teams are addressed in the RT 261 interview guides in a question asking if there was any attempt to use an “integrated project team,” “best players approach,” or “lean construction approach.”

2.5. Owner-Contractor Trust

The subject of Owner-Contractor trust was identified as a potentially relevant issue to investigate in the research of RT 261. The reason that trust is relevant for RT 261 is because it can play a role in explaining Owner staffing levels at the job site. There exists a relationship between the level of trust that an Owner has for the Contractor, and the amount of supervision that the Owner will have over the Contractor's work. The issue of trust is expressed for the research of RT 261 in the interview guides in a question asking to rank the perceived level of trust at the start of construction, and most recently. This section will discuss articles that study the relationship between project performance, and inter-organizational trust.

The article "*Partnering: Agreeing to Agree*" (Slater 1998) discusses the subject of trust in the context of a partnering relationship. The article is not based on systematic research or case studies, but rather is written in the tone of the experience of the author. Key insights from the article discuss methods for successful partnering and benefits that arise from a successful partnership. The article points out the relationship between trust and alignment. Alignment leads to mutual understanding between organizations, which in turn leads to trust. Methods for proper alignment include: workshops to take place at the start of the partnering, clear communication of expectations, concern for each other's goals, and being resolution-oriented (Slater 1998). Some of the discussed benefits from a successful partnership include: heightened productivity, improved decision/reaction time, and reduced exposure to claims and litigation.

"*Project partnering: Improving the Likelihood of Win/Win Outcomes*" (Lazar 2000) is a peer-reviewed paper, which also notes the inherent connection between trust and partnership. However, this paper takes a more cautious approach, proposing that unfounded trust can actually be harmful: "premature insistence on the presence of inter-organizational trust as a precursor to collaborative behavior between Owner and Contractor may actually be fatal to the development of a successful partnering relationship" (Lazar 2000). This paper proposes that there are three forms of trust: trust that can 1) grow or develop over time, 2) spontaneously appear in a relationship, or 3) pre-exist in a relationship.

Depending on which of these three forms of trust are present, the level of trust will have a different cost impact on the organization. The article concludes that in order for the presence of trust to improve project performance rather than hinder it, trust needs to be developed and earned, and this process needs to be understood by key project players to foster the development of trust. Blind trust can be costly to the organization and the success of the project.

“Trust in Projects: An Empirical Assessment of Owner/Contractor Relationships” (Pinto, Slevin, and English 2008) investigated the impact of trust between Owners and Contractors by conducting empirical survey. The study stated that not only the trust of the Owner and the Contractor that directly influence the project success, but also consensus of satisfaction with working relationship, driven by trust from both the Owner and the Contractor. Also, the study measured the Owner-Contractor trust in four elements:

- integrity trust
- competence trust
- working relationships
- project success.

The results indicated that trust has different meanings for Owners and Contractors, as its impact on satisfaction with relationship and positive project outcomes varies depending upon which group is surveyed (Pinto, Slevin, and English 2008).

2.6. High Performance Teams

The ultimate goal of RT 261 is to establish recommendations for staffing and structuring job site management organizations that will result in the highest project performance. For this, it was determined to include the subject of high performance teams in the literature review. This section will discuss sources that have studied high performance teams (also referred to as breakthrough teams) in terms of characteristics of high performance teams, how to measure these characteristics, as well as recommendations for staffing for high performance teams.

The article *“Leadership, Team Building, and Team Member Characteristics in High Performance Project Teams”* (Ammeter and Dukerich 2002) discuss research, in which 51 project teams were surveyed in the engineering and construction industry. The first stage of their research was to identify themes that are common to high performance teams. The nine most common themes, along with the percentage of respondents identifying each theme, are outlined in Table 2.5.

Table 2.5: High Performance Team Themes (Ammeter and Dukerich 2002)

High Performance Team Themes	Percentage of Respondents
Team orientation: sense of belonging to a team, working well together	71%
Critical leader behaviors	67%
Team communication: frequent team meetings	61%
Ownership: sense that personal success is directly tied to project's success	47%
Location: collocation and/or physical isolation of team	43%
Performed team building (formal and informal)	43%
Competition: sense of competition with other or previous projects	35%
Reward or bonus for excellence: use of team perks	25%
High level support: sponsorship/high-profile/high-visibility of project	20%

The second stage of the research was to measure project performance based on four constructed models. These are 1) Perceptions of project high performance, 2) Perceptions of team high performance, 3) Cost growth, and 4) Schedule growth.

Then, based on these models, to find which of the previously identified nine themes of high performance teams are linked closest to project success. This was done using regression analysis, which found coefficients for the influence of each of the nine high performance project themes on each of the four project success models (Ammeter and Dukerich 2002).

The research concluded that of the nine identifying themes, “critical leader behaviors” was the only significant predictor of both budget performance, and perceptions of project team performance. In other words, there is a connection between perceived team performance and actual success, and that they are influenced by the behavior of critical leaders (Ammeter and Dukerich 2002).

Another insightful article on the subject is “*Applying the High Performance Work Team to EPC*” (Chen 2002). The article presents a case study, in which the concept of the High Performance Work Team (HPWT) was applied to a large pulp and paper project with an EPC delivery system and a cost-reimbursable contract. The HPWT in the case study was created and maintained throughout the project seeking the following pursuits:

- Respect the capabilities of all team members.
- Share common project objectives.
- Manage the project by behavioral principles.
- Focus on results with accountability.

- Use goal-setting and problem-solving techniques to build ownership.
- Genuinely apply team concepts.
- Communicate openly.

The article details each of these characteristics and discusses what must be applied for the characteristics to hold. A definition is then given for a “high performance” project based on CII research: a project that achieves an improvement of 10 percent or more on the cost or schedule target, which has been “aggressively set” (Chen 2002).

In the case study, the established target goal has a 10 percent reduction in engineering and construction work-hours, to result in saving \$75,000 from the Total Installed Cost (after considerations for the HPWT training cost). The article then details the process of developing the HPWT, educating the team, a list of team responsibilities, and the challenges faced by implementing the HPWT.

The results of the case study include factors which have contributed to productivity, or hurt productivity. However, more quantitative results were inconclusive. While there was \$199,075 allocated for the total price of education for the HPWT, while the value contributed from implementing HPWT on the entire EPC project was difficult to establish (Chen 2002).

2.7. Organization Design and Organization Chart

Unlike other key term category items, organization design and organization chart are a topic that mostly consist of qualitative and non-standardized data, which often obfuscate the project managers when trying to organize a project team. So a review of publication to clarify this problem is imperative.

“*Understanding the Company Organization Chart*” (White, 1963) verified the reasons for developing an organization chart for each project team and, more importantly, highlighted the basic elements and types of structure of organization chart. According to this publication, the key information embedded implicitly in an organization chart includes specialization, line-and-staff organization, and authority. However, it noticed that the rank and status information are not a good source for analysis. By learning these, the research team was able to summarize data embedded in the organization charts collected from the sample projects and to draw conclusive results.

“Understanding the Company Organization Chart” (White, 1963) did a good job in generalizing the information that an organization should have, but it did not address much about the potential of analyzing the information, nor did it mention about how to analyze the information. RT 261 has figured out how to integrate the idea delivered in this work with other study variables. Chapter 3 will include more details about the methodology.

Also, the publication *“Organization Charts”* (Maurer et al. 1996) presents a collection of organization charts of over 200 businesses in various industries. It helped offer a general sense of what an organization chart should look like, which improved the quality of the review on collected organization charts.

2.8. Summary

This literature review has cited prior works that underscore the need for more insight into job site organizations and staffing schemes. Many of the reviewed publications have indicated certain association between project team staffing and performance. Many of these works support the need for the work accomplished by RT 261. The complete bibliography list can be found in Appendix D.

CH 3. Research Methodology and Data Sample

3.1. Methodology Overview

Figure 3.1 provides an overview of the research methodology applied in this research. The flow chart displays activities in chronological order from the study preparation phase, data collection phase, data analysis phase, to the final presentation phase. The methodology flow chart contains activities both on the macro-level displayed in large boxes and the breakdown of macro-level activities depicted in smaller boxes. Some core elements of the breakdown activities are also listed. Detailed descriptions of each activity are described in this chapter.

3.2. Study Preparation

Study Planning

The planning phase included the effort of setting up the research purpose, research scope, limitations, and expected outputs, as discussed previously in Chapter 1.

Literature Review

During the literature review phase, the research team searched for related publications that provided insights into the various aspects of capital project job site organizations. The results are reported (and were discussed) in Chapter 2 of this report.

Interview Guides

The interview guides (IGs) serve as the structured tool for guiding the project-oriented interviews with Owner and Contractor project managers. The development of the IGs was an iterative process, which took place in the pre-interview phase of the research project. The research team was particularly helpful in shaping the IGs to include the most appropriate questions and assessments in order to maximize the effectiveness of the data gathering process. Two interview guides were developed: one targeted for project Owners, and another targeted for project Contractors. Approximately 60 percent of the content of the two IGs was common to both, while the balance of 40 percent was specific to the type of targeted interviewee, Owner or Contractor project manager.

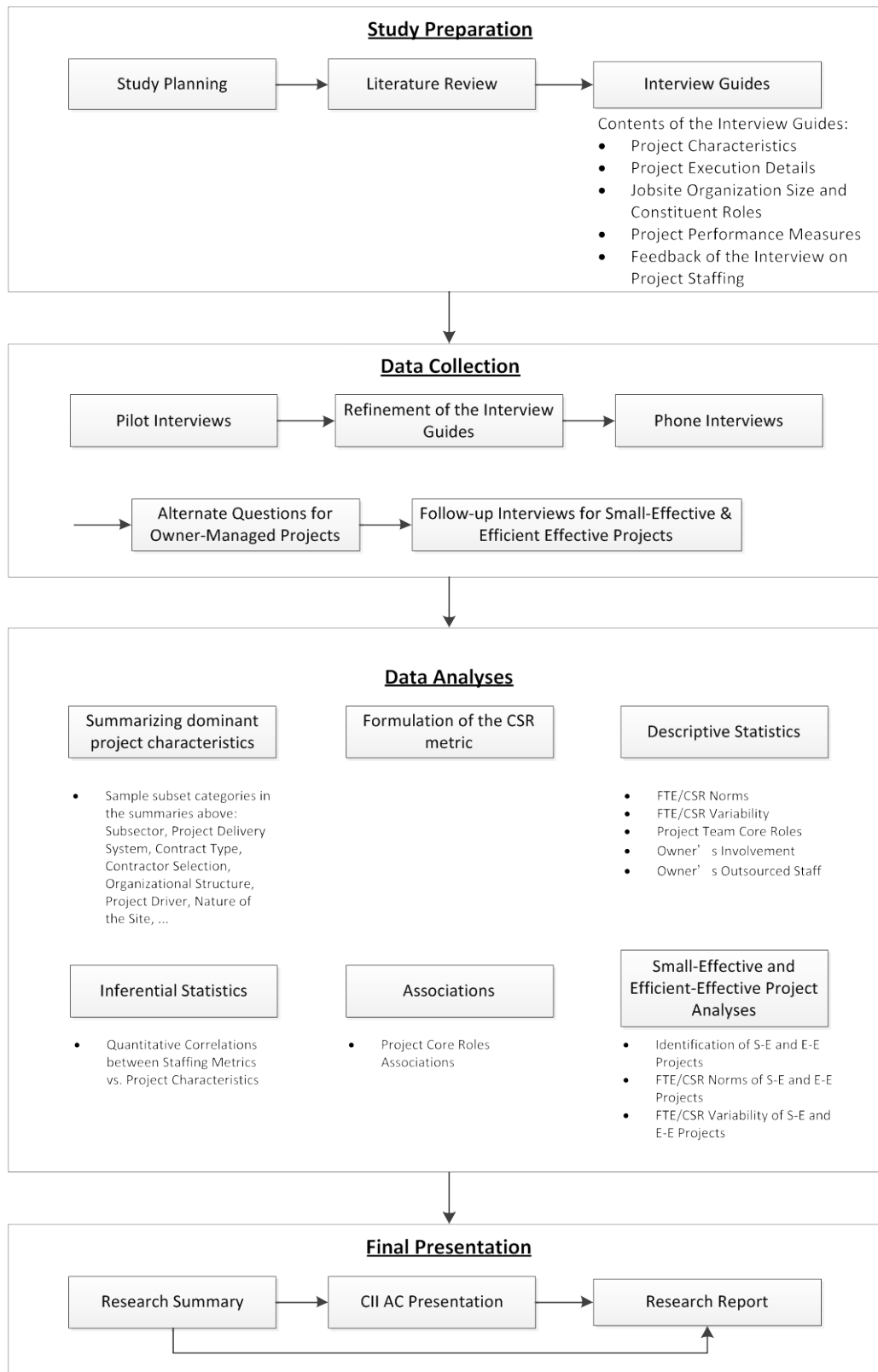


Figure 3-1: RT 261 Methodology Overview

The interview guides incorporated questions and assessments addressing project characteristics, project execution details, job site organization design, job site organization size and constituent roles, project performance measures, and general “lessons-learned” on the issue of job site organizations. More detailed characterization of the data collected follows, and the IGs may be found in the appendices to this report.

Project Characteristics

The project characteristics data collected was useful in understanding the nature of the data sample and in facilitating subsequent analyses of different project types. The following items were the primary project characteristics selected from the interview guides:

- Subsector
- Project delivery system
- Nature of the project site
- Contract type
- Contractor selection method
- Project driving factor
- Project size (craft work hours)
- Project size (capital cost)
- Percentage of modularized effort
- Project complexity
- Relative difficulty of the project

Project Execution Details

The project execution data collected provided insights into how the team executed the project, the key tools and best practices employed, and likely causes or drivers of project performance. The primary project execution details included the following items:

- Extent of implementation of planning and best practices
- Adoption of lean construction, integrated project team, or other unique
- approaches
- Union/Open shop labor
- Use of IT tools
- Identification of project “upset factors.”

Job Site Organization Size and Constituent Roles

Data on job site organization size and constituent roles provided a quantitative view of how the project site management team was staffed. The detailed project role listings are provided with the IGs in Appendices A and B. Questions on Owner outsourcing of job site staff were also included in the Contractor IG, including assessment of associated levels of satisfaction.

Project Performance Measures

A major emphasis of the study was to better understand associations between job site organization parameters and project performance. Thus, data on various forms of project performance was collected. Also, the project performance measures helped identify the smaller-more effective

project teams and the efficient-more effective project teams, which are described later. For these purposes, the following performance categories were assessed:

- Safety
- Cost
- Schedule
- Quality
- Productivity
- Owner-Contractor trust
- Owner/Contractor satisfaction
- Overall team effectiveness.

Lessons Learned on Staffing

If given the chance, respondent project managers were asked what they would do differently next time with respect to formation of the job site organization. The questions were deliberately open-ended, but focus was added on opportunities for adding to, subtracting from, or modifying the job site staff structure. Many interesting learnings resulted from this line of questioning.

IG Tool/Process Validation: Pilot Interviews and Refinements

The IGs were tested, refined, and validated as a result of pilot application/testing on a large petro-chemical project in the gulf coast region involving face-to-face interviews. Feedback was acquired after the separate pilot interviews with both Owner and Contractor project managers. As a result, both the IG tools and the interview processes applied were modified to enhance their breadth, robustness, and overall effectiveness. The final IG versions for Owners and Contractors can be found in Appendices A and B, respectively.

3.3. Data Collection

Phone Interviews

While the original research methodology plans had provided for all face-to-face interviews, the pilot data collection test indicated that phone-based interviews could be just as effective, since most data collected should be readily recallable by study participants. Accordingly, subsequent interviews were planned and executed on a phone-call basis. This approach proved to be sufficiently effective and much more cost- and time-efficient than travel-intensive face-to-face interviews.

In the phone interview process, the study principal investigator lead each study participant (i.e., Owner or Contractor project manager) through each question in the appropriate IG, making notes on both optional responses selected and additional commentary or qualifications as provided by the participant. The time consumed for each phone interview ranged from 45 to 90 minutes, averaging approximately 60 to 70 minutes.

The most challenging part of the interview process was gaining the commitment of Owner and Contractor project managers to participate in the brief interviews. During the 2009-2010 timeframe of the data collection effort, the condition of the industry mirrored the difficulties felt across the entire national economy, and relatively few capital projects were available for investigation. Each personal connection with a potential study participant required as much as five separate emails and four phone calls over a three-month period. It was not unusual to experience a four- or five-month lead time for setting up a single interview. Many potential participants declined to participate for a variety of reasons. For every single participant that agreed to participate, the principal investigator had to make direct personal contacts with approximately 2.5 individuals. Accordingly, over the 17-month data collection period, only 31 projects (via their respective project managers) participated in the study.

Alternate Questions for Owner-Managed Projects

For Owner-managed projects, there was often no dominant (or single) prime contractor with sufficient project work scope (and job site management staff) to be included in the study. Yet many Contractor IG questions were still relevant and needed for the study. Accordingly, a separate, brief set of supplemental interview questions were identified (from the Contractor IG) and included in the Owner project manager interviews. The complete question set for Owner-managed projects is provided in Appendix C.

Follow-up Interviews for Smaller-effective and Efficient-effective Project Teams

Subsequent to the initial interviews, during data analysis projects were compared for job site organization team size and project performance relative to sample median values. This analysis resulted in the identification of smaller-than-average/better- performing-than-average teams. With this knowledge in hand, a second round of brief, follow-up phone interviews was conducted in order to identify any additional special or unique strategies applied by these project managers in setting up the job site organization. For example, project managers of these teams were asked to share information such as prior experience of project staffing, company guides or rules-of-thumb for staffing, and further insights into possible key factors leading to higher levels of success. The follow-up interview guide is presented in Appendix D for reference needs.

3.4. Characteristics of Data Sample

The sample of projects examined was neither a random sample nor necessarily one representative of the makeup of CII's overall membership. Accordingly, it is important to understand the nature of the sample itself, irrespective of job site organization parameters.

Owing to the difficulty in gaining study participation, the RT was less selective in screening which projects would be included vs. excluded in the study. The targeted project type was to be between \$50 million and \$800 million in terms of total installed cost and in a reasonably steady-state in terms of job site team size (which typically occurs on projects when in excess of 30 percent construction complete). Thus, most projects examined were in the mid- or later stages of construction, with a few projects having recently been completed (but still being fresh in the PMs' memories).

Data sample characteristics include the following:

- Projects in the sample are diverse in size:
 - Mean cost: \$338.1 mil.; Median cost: \$300.0 mil.
 - Lowest cost: \$38.0 mil.; Highest cost: \$1,200.0 mil.
 - Work hour mean: 1.71 mil.; Work hour median: 0.98 mil.
 - Petro-chemical project mean cost: \$309.5 mil. (N=10)
 - Power Utility project mean cost: \$426.6 mil. (N=10)
 - EPC/Design-Build project mean cost: \$473.4 mil. (N=13)
 - Private project mean cost: \$342.6 mil. (N=22)
 - Public project mean cost: \$259.3 mil. (N=7).
- Projects in the sample are dominated by (but not limited to) the following:
 - Domestic locations (84 percent)
 - Power Utility & Petro-Chemical projects (65 percent)
 - Teams comprised of mostly highly experienced individuals (63 percent) and with low staff turnover (14.4 percent average turnover rate)
 - Contractors selected by Best Value (57 percent)
 - Projects judged in general as Difficult or Extremely Difficult (63 percent), and often upset by weather, scope change, and/or delays.
- Projects in the sample are approximately balanced between the following:
 - Lump Sum (52 percent) and Cost Reimbursable (61 percent) (including mixes of the two)
 - EPC/D-B (42 percent) and Construct Only (39 percent)
 - Greenfield (42 percent) and Addition/Revamp (39 percent)
 - Owner line organizations (48 percent) and Owner matrix organizations (39 percent).

3.5. Data Analyses

Overview: Most data analyses pertain to full-time equivalent (FTE) or craft-to-staff ratio (CSR) norms, dispersion measures, variation associations with project characteristics, Owner and Contractor core team roles, or variation associations with project performance.

FTE and CSR Metrics

Two staffing metrics—full-time equivalent (FTE) and craft-to-staff ratio (CSR)—are of primary interest in this study. FTE is a common measure used by industry for quantifying staffing levels. It denotes the effort-equivalence relative to that of a single full-time worker. However, FTE is an absolute measure that lacks the normality needed to correct for project size. Thus, for many managers, FTE is not the best indicator when it comes to generalized staffing metrics.

Early-on, RT 261 recognized the need for a normalized staffing metric. While no such metric emerged from the review of published literature, several RT members were aware of proprietary in-house normalized metrics. The team considered several approaches. After a series of iterations, the research team selected and formalized the normalized Craft-to-Staff Ratio (CSR), computed as follows:

$$CSR = \left(\frac{WH}{DUR} \right) \times \left(\frac{1}{FTE} \right) \times \left(\frac{1}{50} \right)$$

where

CSR = Craft-to-Staff ratio

FTE = Job site organization staff level in Full-Time Equivalent (Owner or Contractor)

WH = Onsite direct craft work hours

DUR = Duration in weeks from site mobilization to mechanical completion

50 = Typical work hours per week (needed for dimensional unity).

As indicated in the equation, the CSR metric varies approximately as the inverse of the FTE metric. High CSR values translate to smaller job site management teams. The value of CSR increases when the value of FTE decreases, implying a leaner team.

FTE and CSR Norms and Variability of Sample Set and Subsets

Establishing norms for FTE and CSR metrics can help one better understand current industry trends of how project managers staff their job site teams. The primary FTE and CSR norms that RT 261 computed and reported are sample and subset means and ranges. The sample mean is a prevalent way to convey the expected value of a sample metric. Range, rather than standard

deviation, was chosen as the dispersion measure due to limited sample size, particularly for sub-sets of the sample (such as industry segments). In some statistical analyses for small sample subsets, the sample/subset median, rather than mean, is reported to avoid possible distortion of results stemming from any asymmetric data distribution.

In the analysis phase, the established norms of means and ranges and related differences among subsets were used to either confirm or challenge conventional wisdom, however informal, regarding job site team staffing.

Regarding Owner CSR findings, some data from the CII Benchmarking Database afforded the opportunity for limited forms of validation. Such analyses were possible with two types of Owner CSR data: Heavy industrial (N=12), and Cost reimbursable (N=9). Other data subsets were judged to be too small for comparison purposes.

Core Team Roles

Core team roles are job site positions that deserve deliberate concern and attention by project managers. When a project manager undertakes the task of job site staffing, important questions to assess are “What roles do I need to establish ... and how many people do I need on the team to have it adequately staffed?” Observed differences in the levels of job site staff support for each of the various project functions examined allowed for the identification of core team roles for both Owner and Contractor teams. Specifically, core team roles are presented in this study as critical roles/functions with mean staff size greater than 1.0 FTE.

In addition, the team used regression analysis to examine four Contractor job site roles for their linear scalability with project size. From these results managers can learn what roles/functions are seen as critical and observe what the data sample suggests as “step-up” points for increasing function staff size relative to project size.

Associations with Performance

Company executives and project managers are very interested in what constitutes an effective job site organization. Thus, a significant component of this study was to examine associations between job site organization size and make-up vs. levels of project performance. RT 261 selected six common, important project performance metrics for study: safety, quality, schedule, cost, site productivity, and composite performance (being the average of the other five). The strength of statistical associations was examined between these project performance metrics and job site organization variables, including the following, among others:

- FTE
- CSR
- Industry subsector Contract type
- Contract type
- Delivery strategy
- Owner type
- Site type.

Other Data Analyses

Additional analyses were conducted, as suggested by RT hypotheses or by the data itself. These analyses included the following, among others:

- Owner involvement and Owner-Contractor staff balance;
- Owner outsourcing of staff and associated Contractor satisfaction levels; and
- Organizational learnings from project managers.

3.6. Statistical Tests

A variety of statistical analyses and tests were conducted on portions of the data collected, depending on the particular research hypothesis and/or the data format. Many different analyses were performed in order to discern the strength of associations between various parameters. The substance and approach to these tests are described in this section.

The Concept of P-value and Statistical Significance

The concept of p-value and significance is widely employed in statistical tests. It provides a commonly accepted and objective threshold to verify whether there are associations between different variables.

Statistically speaking, researchers use the term *significance* to depict comparative results of a hypothesis test. The significance level determines the size of the rejection (to the null hypothesis) region of a hypothesis test. Sample results in the rejection region are called *statistically significant at the nominated level*. In definition, the P-value approach is the lowest level of significance at which the observed value of the test statistic is significant (Walpole, Myers, Myers 1998).

The P-value is the smallest level of significance for which the observed data indicate that the null hypothesis should be rejected. The smaller the P-value, the more evidence there is in favor of the alternate hypothesis. The concept of P-value was widely applied in most RT 261 statistical analyses pertaining to hypothesis tests.

Pearson Chi-square Test of Independence

Researchers used the Pearson chi-square test primarily to verify the independence between two variables or the normality of a distribution. The chi-square test statistic is a function of the squares of the deviations of the observed counts from their expected values, weighted by the reciprocals of their expected values (Wackerly, Mendenhall, and Scheaffer 2008). This test was adopted when we wanted to know whether a variable could be predicted by the result of another. It is based on the counts in a contingency (cross-tabulation) table. For example, Table 3-1 shows a subset of the summarized Owner FTE vs. cost performance data collected from the interviews.

Table 3.1: Sample RT 261 Contingency Table

<u>Owner FTE</u>	<u>Cost Performance</u> Owner point-of-view	
	<u>Better than Historical Norm</u>	<u>Historical Norm or Worse</u>
> 23.5 (N = 9)	N=2, 22%	N=7, 78 %
< 23.5 (N = 20)	N=7, 35 %	N=13, 65 %

The chi-square test statistic indicates a calculation of chi-square (χ^2) value:

$$\chi^2 = \sum_i \frac{(O_i - E_i)^2}{E_i}$$

where O_i denotes the observed value, and E_i means the expected frequency obtained by (Number of Rows) $\times$ (Number of Columns) $\div$ (Grand Total Number), with a degree of freedom (v) = (Number of Rows – 1) $\times$ (Number of Columns – 1). For the case of Table 3-1, $\chi^2 = 40.41$ with $v = 1$.

Chi-square tests were mainly applied to the analyses of associations between project staffing characteristics and performance indices, which are presented in Chapter 6.

Kendall's Tau (τ) Rank Correlation Coefficient

In statistics, the Kendall rank correlation coefficient, commonly referred to as Kendall's Tau (τ) coefficient, is a statistic used to measure the association between two measured quantities. Artest is a non-parametric hypothesis test which uses the coefficient to test for statistical dependence and is handy when dealing with ranking data rather than numeric measures. RT 261 used τ coefficient to illustrate the associations between parameters that any of them is categorical or roughly

segregated.

Two kinds of τ test are often introduced: τ -a test and τ -b test. The τ -a statistic tests the strength of association of the cross tabulations. Both variables have to be ordinal. τ -a will not make any adjustment for ties. The τ -b statistic, unlike τ -a, makes adjustments for ties and is suitable for square tables. Values of τ -b range from -1 to $+1$. A value of zero indicates the absence of association.

The Kendall's τ coefficient can be calculated by the following equation:

$$\tau_B = \frac{(\text{number of concordant pairs}) - (\text{number of discordant pairs})}{\sqrt{\left(\frac{n(n-1)}{2} - \sum_i \frac{t_i(t_i-1)}{2}\right)\left(\frac{n(n-1)}{2} - \sum_j \frac{u_j(u_j-1)}{2}\right)}}$$

where t_i denotes the number of tied values in the i_{th} group of ties and u_j the number of tied values in the j_{th} group. (Kendall, 1990)

R-square Correlation Coefficient

The R-square correlation coefficient, also known as the coefficient of determination, is essential for the quality of regression analysis. It is a measure of how well the outcomes are likely to be predicted by the regression model. Along with the standard error of estimate, it is the most frequently quoted measure in applied regression analysis. With a value always between 0 and 1, the coefficient of determination can be interpreted as the fraction of variation of the dependent variable explained by the regression line. It is often expressed as a percentage, so that we talk about the percentage of variation explained by the regression line (Albright, Winston, and Zappe 2006). The higher the R-square value, the more definitive the regression is. In each regression analysis RT 261 performed, an R-square value was calculated to evaluate how well the chosen independent variable explains the variance of the dependent variable.

The R-square coefficient value can be calculated by the following equation:

$$R^2 = 1 - \frac{\sum e_i^2}{\sum (Y_i - \bar{Y})^2}$$

where e_i denotes the residual.

Non-linear Regression

Besides ordinary linear regression analyses, some non-linear regression approaches were also applied in the search for any strong statistical associations. One typically includes nonlinear transformations in a regression equation because of curvature detected in scatter plots (Albright, Winston, and Zappe 2006).

In RT 261, two non-linear functions were examined as association models between staffing metrics and other project variables. These included the logarithmic and power function models.

- The Logarithmic function transforms the value of the variable into an exponent with a designated base, often the base of the natural logarithm. It is useful when the scatter plot of variables shows some skew.
- The power function transforms the values by raising the power of independent variables in the expected regression equation. Such a transform is often performed to check higher-power correlations.

For the work of RT 261, non-linear regression was applied in the analysis of the relationship between Owner staffing metrics and Project size, because the relationship is not as direct (i.e., linear) as that for Contractor staffing metrics.

Logistic Regression

In statistics, logistic regression (sometimes called the logistic model or logit model) is used for prediction of the probability of occurrence of an event. It is noticeable that logistic regression is a generalized linear model used for binomial regression. Moreover, it makes use of several predictor variables that may be either numerical or categorical, or even a mix of them. Logistic regression is used when there are categorical dependent variables, and is more flexible and frequently encountered in research reports (Vogt 2007).

The concept of logistic regression was originated from linear probability model (LPM). Unlike ordinary least square (OLS) regression, LPM adopts the concept of probability to illustrate the dependent y more specifically when it is a qualitative parameter.

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k \quad (\text{OLS})$$

$$E(y|x) = P(y=1|x) = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \dots + \beta_k x_k \quad (\text{LPM})$$