

**System Architecture of a Consulting Engineering Services Firm
and its Application to Information System Development**

by

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B.S., Electrical Engineering

University of Lowell, 1988

Submitted to the Engineering Systems Division and the Civil and Environmental
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Master of Science in Civil Engineering Information Technology

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Abstract

Building Information Systems (IS) requires employees to have a clear understanding of not only the daily work of the company, but of value delivery mechanisms throughout the firm. The three major success factors for IS projects are: user involvement, executive management support and a clear statement of requirements according to the Standish Group (The Standish Group International, 1994). Identifying these factors requires a holistic understanding of the organization.

Existing literature contains numerous frameworks for the analysis of organizational structure, management guidelines, and strategic decision making processes of service organizations. This thesis uses system architecture, a Systems Engineering methodology involving the analysis of the entire firm, to study a consulting, engineering, construction and operations (CECO) service company. The resulting architecture document provides a model of the organization that is useful in the evaluation, justification, and definition phases of internal information technology (IT) projects. The model combines, in a single document, the firm's beneficiaries and goals and the functions, processes and forms created within the firm to achieve those goals.

Results show that, when an internal IT project is proposed, the idea can be projected onto the system architectural model to clarify the proposal's support for organizational goals and functions and therefore, discern the project's value. During the early design phases of the internal IT project, the model helps identify stakeholders, beneficiaries, related existing systems, scope and needs. The model contributes to the project by determining value and by providing the three most important factors of project success; identification of users, stakeholders and requirements.

Thesis Supervisor: Edward F. Crawley

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Chapter 1 Introduction

In a competitive industry like consulting engineering, a firm's ability to generate value for their client through the use of internal systems can be crucial to the firm's survival. Information Technology (IT) tools supplement processes if they are well implemented within the company system. However, research by the Standish Group shows that only 29% of software projects are completed on time and on budget and that the three key reasons for their success are user involvement, executive management support and clear statement of requirements and business objectives (Hartmann, 2006; The Standish Group International, 1994).

A consulting, engineering, construction and operations (CECO) firm is a complicated organizational structure that relies on employees for its ability to efficiently solve client problems. It is both a business existing for profit and a service organization working to satisfy the needs of its clients and the environment. A simple perspective on client service value delivery is shown in Figure 1.1.

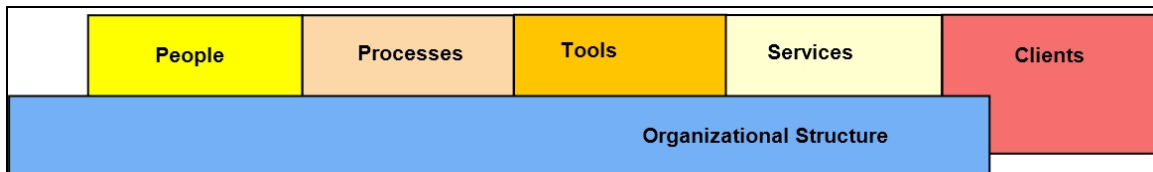


Figure 1.1: Simplified view of CECO firm value delivery

To provide clients and employees with the right total solution for their particular problems, employees within the firm must understand the relationships among these elements and know how to apply them to both external and internal projects appropriately. In reality, when these organizational components are viewed from another perspective, the relationships among these and many more elements of the firm are actually much more complex and have more in common with the representation shown in Figure 1.2. Creating information systems (IS) that facilitate connections among the elements of the firm is beneficial to the organization, but also expensive and challenging.

Internal projects undertaken by the corporate staff, like IT projects, must be driven by the design of the organization. Projects whose requirements do not integrate into the organization's system will not succeed and will not contribute to the strategic goals of the firm. Money and resources spent on such projects are wasted or, worse, damaging to the established organizational architecture.

A complicated system like a consulting firm is difficult to understand in its entirety. Systems Engineering as a discipline was developed to consider both business and technical requirements and to provide a quality product that meets user needs (INCOSE, 2006). This thesis will show that system architecture (Maier and Rectin, 2002), a Systems Engineering tool, may be used as a framework to thoroughly analyze a consulting firm and to understand what the firm is and why.

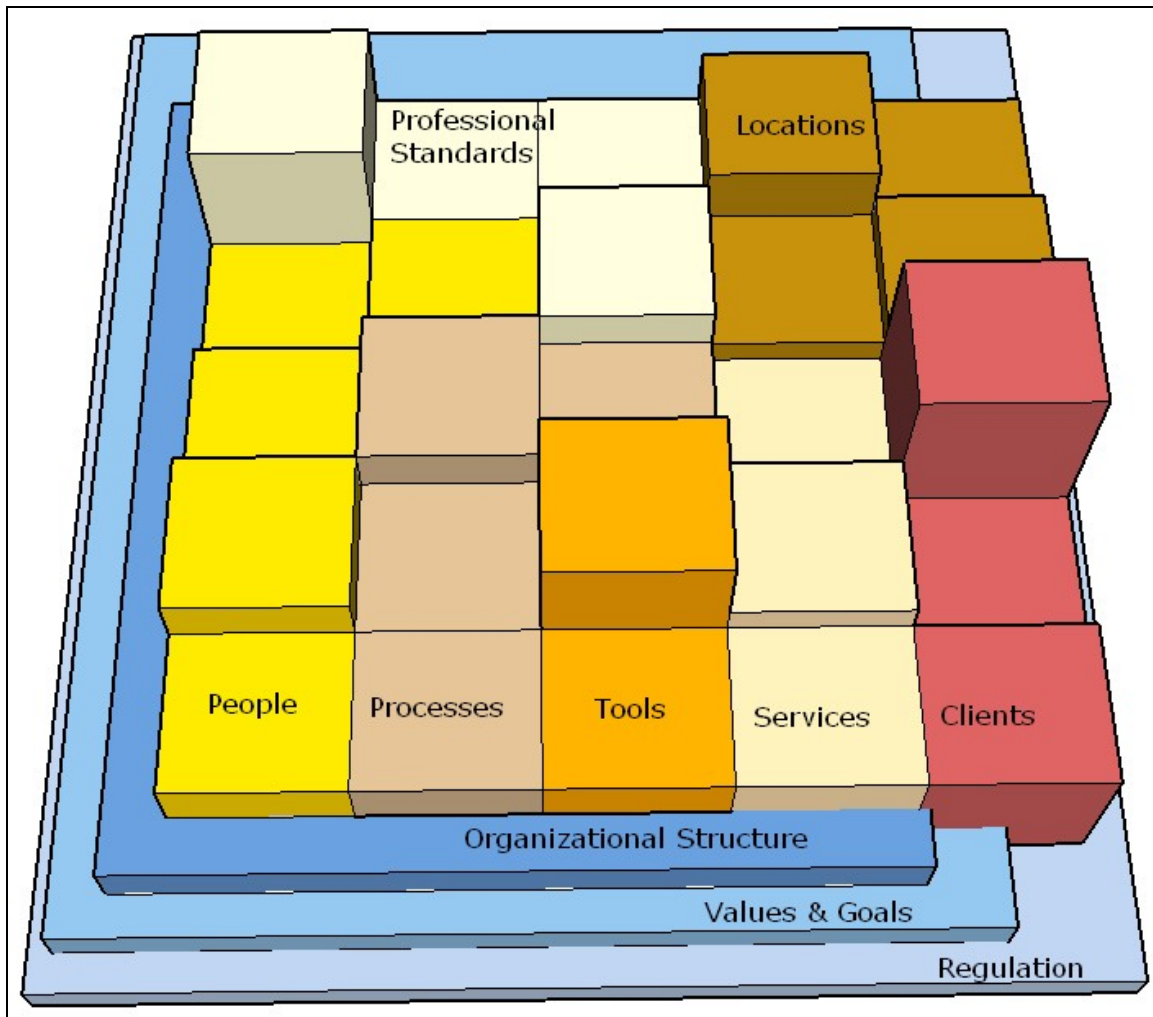


Figure 1.2: More realistic, complex view of value delivery

The holistic understanding of a firm should not be restricted to strategic managers at the apex (Mintzberg, 1979) (refer to Figure 1.3 which shows the five basic parts of the organization as defined by Mintzberg.) According to Mintzberg’s organizational structure, the strategic apex, the middle line and the large operating core are connected through formal authority, and the technostructure (analysts) and support staff are at the sides where they indirectly affect the core. These structural elements are organized by a company specific group of design parameters. Mintzberg states “The design parameters [of the organization] form an integrated system in which each is linked to all the others as a dependent as well as independent variable: change any one design parameter and all the others must be changed as well.” (Mintzberg, 1979)

Since members of the corporate staff are integral to the success of the firm but outside of the direct line of authority and core business, it can be inferred that business context and strategy are only indirectly communicated to the members of these organizational groups.

A framework is required to communicate this information with everyone in the company, re-evaluate motivation and needs on a regular basis (these things change rapidly), and to act as a model for planning and design of company projects.

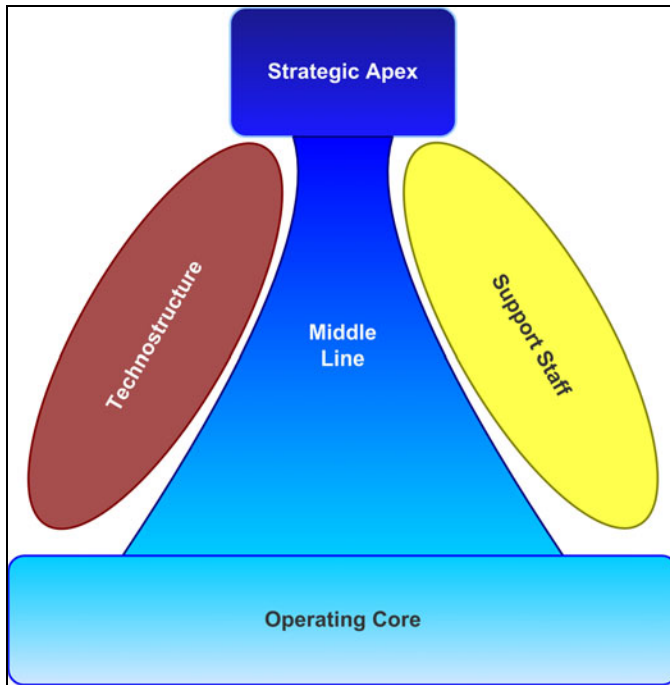


Figure 1.3 The five basic parts of organizations (Mintzberg, 1979)

The objective of this thesis is to supply a firm's internal groups with a Systems Engineering based tool for understanding the entire organization holistically, and for identifying opportunities to improve production processes or better support the work of producers by providing them with a more complete view of the value delivery process. The thesis of this work is that a system architectural study of the internal and external context of the firm is just such a tool. The study will investigate how an architectural model of a CECO firm is useful in an information technology proposal and project definition process. The developed model provides detailed information to the determination of project value, uses, users, stakeholder identification and requirements, contributing to the probability of project success.

Chapter 2 provides background information on consulting engineering as a business, system architecture, and issues related to IT development. In Chapter 3 the methodology of the case study is defined based on business literature and system architecture frameworks. This methodology is applied in Chapter 4 which details the system architecture model, and also in Chapter 5 which is a review of the applicability of that model to IT project proposal and definition processes. Conclusions are presented in Chapter 6. Appendix 1 provides a "user friendly" version of the system architecture model, which was used for IT department related communications.

Chapter 2 Problem Definition

Information systems (IS) consist of increasingly large, complex, integrated environments (Martino, “Interview with Peter Palmisano,” 2006). More than ten years ago it was documented that building these environments or adding to them cost the United States in excess of \$250 billion dollars (The Standish Group International, 1994). A well designed and implemented information system can enforce standards and processes and enable information sharing throughout the corporation; valuable benefits contributing to the reason that approximately 175,000 (in 1994) application development projects are undertaken each year in the United States alone (The Standish Group International, 1994). Of these projects, only approximately 29% are completed on time and on budget (Hartmann, 2006).

IS projects frequently fail because they are not well defined. Executive management support and the cooperation of the intended users to help to define project requirements and objectives are the three most important factors in the success of the project (Hartmann, 2006; The Standish Group International, 1994). Each of these three factors is rooted in an understanding of the organization. The context of the problem must be understood before the solution can be properly identified. For an IS solution, the context is the business organization that uses it. A system architecture of the business can provide that context to the IT employees and other employees throughout the firm.

2.1 The Engineering Consulting Business

The American Council of Engineering Companies (ACEC) defines its members as firms “engaged in a range of works that ... allow Americans to drink clean water, enjoy a healthy life, take advantage of new technologies and travel safely and efficiently” (American Council of Engineering Companies, 2006) These firms are found in all areas of the world, and, as mentioned in the quote above, they support many aspects of infrastructure development including consulting, engineering, construction and facilities operations (CECO).

The reliance on relationships and expertise in every consulting engagement, and the real-time aspect of the work differentiates engineering consulting from product-based and manufacturing-based businesses. In the latter companies, a physical and time separation exists between the development of the product and its delivery. Products can be tested repeatedly and perfected before being released to the marketplace and customer. In consulting there is immediacy of production and a level of personalization very different from selling a standardized product through a retail channel.

Consulting brings clients into direct contact with the employees of the company during the creation of the product. Direct service contact, the relationship developed between clients and employees, is the primary revenue and growth generation mechanism for the firm, a relationship which is forged over technically challenging projects whose completion demands highly skilled engineers. Because of this demand for skill and client

contact the engineering/technical and scientific employees of these firms are highly sought after and valued.

Often no packaged product is sold by the company. Typically they rely on employees to generate business. The firms may formalize their processes in order to enable the work force to repeat success and/or they may have ground-breaking technologies, but these do not take the place of expertise in the profession and the ability to build relationships.

These are “Professional Services Firms” (PSF) and there exists much variability in the firms found within this category. Yet, they are all similar in that they have few fixed costs and most do not enjoy substantial economies of scale. “The finite commodity in the market are strong client relationships and, since these are the core assets of PSFs, the easiest means of maximizing income is extending the business done through key clients by providing a ‘one-stop shop’” (Scott, 1998) .

CDM Inc. (CDM) is a consulting, engineering, construction and operations firm established in Cambridge, Massachusetts. Its commitment to quality and integrity has built strong client relationships and grown the company from a three-member firm in 1947 into a worldwide corporation with 3,800 employees.

Founded as the partnership of Thomas R. Camp, Herman G. Dresser, and Jack E. McKee, the company built a reputation as an engineering practice specializing in water supply and water pollution control. Since the 1960’s CDM has expanded geographically in domestic and international markets. Beginning in the 1980’s the firm diversified into hazardous waste management. Full service capabilities for design-build and construction now combine with CDM’s expertise in other scientific, engineering, and management consulting services including the fields of transportation, operations, information management and geotechnical services.

2.2 System Architecture

Architecture is a way to manage complex systems which may have interactions in unexpected ways. A good architecture effectively communicates design intent, concept and planning through the use of models. “System architecture is an abstract description of the entities of a system and the relationships between those entities.”(Crawley et al., 2005) The communication of a system’s architecture through simplified models can assist in illuminating the inner most and outermost determinants of system operations.

The understanding of a system starts with simplification. This can be achieved by focusing on the system’s essentials. As the MIT Media Laboratory’s Simplicity research program points out in the First Law of Simplicity (Maeda, 2005), simplification can be accomplished by grouping functions. This statement can be extended to the analysis of a complex system by adding to it that simplification of the system can be accomplished by grouping needs into intent and goals to understand the system’s true objectives.

The system architecture process combines basic aspects of the system: intent, concept, function, form, and context into an understanding of the system as a whole. Other

properties are also important to the architecture. Often referred to as the “ilities,” they are durability, maintainability, flexibility, and manufacturability, which are related to the life cycle of the system. Architecture can assist the analyst with establishing expectations in addition to providing a snapshot of the system’s form and function.

Maier and Rectin define the contrast between system architecting and engineering by stating that “architecting is an inductive process...engineering is concerned with quantifiable costs, architecting with qualitative worth...Engineering is more of a science, architecting more of an art.” (Maier and Rectin, 2002)

2.2.1 Application of system architecture to system design

Creating the system architecture of a new system ensures that desired behaviors and needs are well understood from the beginning of the design process. This ensures that the beneficiaries’ needs and the intent of the stakeholders are foremost in the minds of the designers as they determine the system concept.

Specifying a system concept greatly assists with the difficulty of keeping all members of the design team “on the same page”. The concept, a clear brief statement, defines the core ideas and references from which the rest of the system design will flow. Selecting a system concept can provide access to canonical patterns with well understood behaviors, or help to specify sub-systems, which can be designed separately, but whose interfaces are well defined.

The architecture also conveys the arrangement of system elements within the system context. The identification of this arrangement enables analysis for unexpected, emergent behaviors within the system, as well as design for expected behaviors. Understanding the context and environment within which the system will operate ensures completeness of design and suitability to task “in the field.”

Architecture includes planning for life-cycle concerns related to platform alignment, reusability, and supportability. These are concerns to be considered early in the design effort to ensure that the system remains viable throughout its lifespan, and that the concept continues beyond that lifespan (if well planned).

The complexity of a large scale system is such that, unless design begins with a clear reference, it is easy to lose the concept of the system in the details of interfaces and behaviors. Well planned system architecture will simplify this process by laying much of the foundation for the system before there is a great deal of investment in detailed design, and by allowing the details to be worked out later within the architectural framework.

2.2.2 Application of system architecture to system analysis

Architecture is useful in system analysis in a different way than in design. There are advantages to discovering and modeling a system which are beneficial to the stakeholders and managers of the system as well as to the operators.

The architectural model of the firm is a simplified representation of the system, a model to be used as an effective communication tool that provides detailed information about how the system functions and how the sections interact. It may be used for operational instructions, strategic communications, or as a tool for planning.

In preparation for system re-design, an architectural analysis or an update of an original architecture may illustrate possibilities for improving the system. If there are significant changes since the original design, their motivation may be important to the re-design effort's statement of intent.

The system's structure might be well understood, but an architectural analysis may uncover beneficiaries with needs that have been fulfilled by emergent behaviors. These beneficiaries may have been unrealized in the common understanding of the system.

An architectural analysis provides a holistic image of the system that includes aspects of form, function, intent and behavior. It incorporates the context within which the system operates and the effects that this context may have on system behavior.

2.3 Applying System Architecture to a Business Organization

“Like biological systems, many contemporary artificial complex social and man-made systems have evolved over years of human history without an explicitly stated, predetermined, well-defined goal. This is especially true for systems with an intensive human component, namely organizations of various kinds. Still, in retrospect, by examining a system's architecture, or its structure-behavior combination, one can usually infer its function, that is, the goal or purpose it serves.”(Dori, 2003)

This quote speaks to the applicability of the methodology to analysis of an organizational firm. The determination of the goal of the organization, in the case of a business, should be clear (profitability, quality service), but the business's beneficiaries, intents and delivered value which combine to contribute to the goal may be key in determining strategy.

This kind of analysis can help members of the firm understand details of their responsibilities to the firm. More importantly, this model can illustrate how those responsibilities affect other sub-organizations within the firm, and the overall success of the firm's delivery of value to beneficiaries.

When these concepts are forgotten or misunderstood a situation arises like that described by Lorsch and Tierney. The death of the firm Gaston & Snow was caused by partners putting their own financial interests ahead of the firm's. With no leadership to resolve the problem, the company ended in bankruptcy. (Lorsch and Tierney, 2002)

The way the organization is structured will affect the outcomes experienced by clients and employees. As Crawley states “The architecture of a system has a strong influence on its behavior.”(Crawley et al., 2005) Just as the strategy of the firm determines the structures, the interrelationships and level of coordination between the divisions and sub-organizations will affect the firm's ability to respond to environmental stresses and

opportunities. This is especially true for professional services firms in the way partners are leveraged. The leveraging of their time against the time of juniors will affect the cost of delivering services, the quality of the work, and the competition in the careers of the junior employees. The architecture of the firm relative to the partner/junior interface is a major factor in the way the firm is perceived by both potential employees and potential clients.

An evaluation of the firm based on an analysis of ten attributes (see Table 3.1) will create a holistic image of the organization. This detailed analysis will incorporate the system's needs, context, structure, technology and more and a model framework against which strategic decisions can be based. This framework will be in a format accessible to employees outside of the typical strategic layer of the company, empowering them with an understanding of the firm beyond organizational structure and strategic direction.

2.4 Organizational Benefit

Every aspect of the firm's operation benefits from a clear understanding of the firm's value delivery process and markets. Employees will not understand the context of their project work unless there are direct relationships between a process and the work of the operating firm's goals. The value that the firm expects to deliver to their clients is clearly the responsibility of this group and is specified by the system architecture.

The architecture, technologies and risks of the firm are also important areas for members of the technostructure and support staff. The expectation that these groups will provide guidance and assistance to the core of the company requires this understanding.

The firm's communication processes (interfaces) are the mechanisms that keep the organization directed and coordinated to achieve goals. Unless they are well understood and utilized, the organization's business units (components) may become disconnected. Disconnected business units are likely to be working to achieve different objectives and the organization will not be efficient.

A consulting firm is a complex system. Understanding the way the firm's sub-organizations work together to fulfill the needs of the beneficiaries provides employees with context. Without this understanding, they are doing their jobs as best they understand them, but often without basic knowledge. With the understanding, they are capable of strategic thinking beyond the requirements of their own niche in the firm, able to support the firm with innovation and initiative not possible when they do not comprehend their impact on the firm's value delivery processes.

In the reengineered corporation, processes are designed so that responsibility and authority to make successful decisions rests with every employee. At one time the middle line or strategic apex managers determined every course of action and imposed their decisions on the operating core for implementation. After reengineering, the operating core of the company is wide and flat with few middle line managers. Decisions are made in the operating core where they are implemented and where their ramifications are most likely to be apparent (an excellent example of this is the Hannaford story in Champy's

“Reengineering Management”(Champy, 1995 24)). If the employees in the operating core are unclear about the firm’s architecture, especially the firm’s needs and context, they will be making on the spot, strategic decisions without complete information.

2.4.1 Corporate uses for Architecture

Corporate administrative functions of the technostructure and support staff provide the back bone of the company’s value delivery system. Employees in these divisions seldom have an opportunity to meet with clients or even use the tools and reports they provide for those who deliver value directly to the customer. These employees need a clear understanding of the details of their company’s intent and goals in order to make the many small decisions that contribute to the corporate infrastructure.

2.4.2 Communication mechanisms

The links between sub-organizations of the company require communication interfaces. If the link is of strategic importance to the company, corporate communications may manage the contact. If the link is between two operating units, they may, of necessity not be strategically directed.

The need to coordinate the latter communication will fall to the units on either side of the link. Unless they are aware of the need to communicate information may be missing as processes move forward. It is important that organization decision makers are aware of the informational links between elements of the system architecture and ensure those communications.

2.4.3 Innovation

Creative ideas most often come from employees of the company. They are experts in their fields and exposed to the marketplace. Their combination of expertise and knowledge of client’s needs provide the necessary inspiration for innovation. Committees within the firm are responsible for assigning resources to develop these ideas. The innovations most likely to receive funding are those that fit within the goals and intent of the firm. Employees best contribute to the success of the organization by tailoring innovations to this need.

2.4.4 Decision making

As discussed in the header to this section, decision making within the consulting firm is not simply a function of the strategic apex. Every day employees make decisions that affect the company on their own projects and within their units.

Employees who have a holistic understanding of the organization, its needs, intent, and context, are better able to predict the outcome of their decisions. The ramifications will be more readily identifiable if the decision maker is aware of the situation before and after the decision. Also, if the architecture includes figures of merit, the ramification of a decision can be measured quantifiably after it is rendered.

2.4.5 Organizational improvements

Mintzberg states that “as goals and missions change, structural redesign is initiated from the top down; as the technical system of the operating core changes, it proceeds from the bottom up.” (Mintzberg, 1979) Changes in strategic direction can affect many aspects of the firm’s architecture. When there is a change to the “bottom” of the architecture, in the area of corporate value delivered to the beneficiaries, the entire architecture might be altered. The system architecture provides a framework for considering changes and ensures a holistic perspective on the transformation.

When strategic direction changes, frequently there are organizational changes to the firm’s structure. Ramifications are identifiable during planning if the architectural models of the firm are updated as well.

The process of identifying changes required throughout the firm becomes simplified if the model includes all system elements and their interfaces. The updated model can identify necessary alterations to communication plans and company processes as well as corporate organization.

2.5 Example of Use: Application to an Information Technology System

IT systems are expensive, complicated and notoriously difficult to complete on time and on budget. Custom designed and implemented IT systems are highly complex projects involving many expensive person-hours of labor and large investments in infrastructure and technology. These projects are highly risky and frequently fail. However it has been established that the projects with the highest likelihood of success are those that have active user involvement, executive management support and well defined system requirements.

2.5.1 Establishing Business value

Before a proposed project can be implemented, IT must be able to analyze the idea on its merits to determine the value it would deliver to the organization. The larger and more complex the problem to be solved, the more resources will be required to complete the project. The ability of the proposal to demonstrate support for the delivery of value to the client is likely to determine the level of executive sponsorship the project enjoys, but it is a difficult task to determine the value of a proposed system and to establish the business case for it.

Access to an organizational system architecture model (OSA) facilitates the process of creating a business case by providing details of current systems and processes. The OSA also enhances communications by supplying a common foundation for discussion of organizational structures.

2.5.2 Identifying Stakeholders

When an idea or concept emerges as a candidate for an IT project, it is often spearheaded by one or more people committed to seeing the system implemented. The OSA enables IT to broaden the view to a company-wide review of the proposed system that determines which processes and company roles will be impacted by the solution. The ability to identify jobs throughout the firm affected by the project early provides IT with more complete information from multiple users, as opposed to using information provided by a few spearheading users.

2.5.3 Defining Project scope

The OSA framework facilitates the work of the IT department in defining the scope of the potential system. The framework contains details of existing processes and systems onto which project planners project the proposed project solution. This highlights how structures and processes change when the solution is implemented, and where existing systems should be integrated.

2.5.4 Specifying Project Requirements

The improvements in stakeholder identification and project scope provide improved input into the system requirements definition by ensuring that relevant players are involved in the process. A clear understanding of the design parameters of the organization provides a foundation for determining system requirements. In addition, the projection of the proposed system onto the current environment using the OSA provides context for requirements definition.

2.5.5 Identifying Project Platform

Once the context of the proposed system is clearly defined, commonalities may be determined between the new system and one or more existing systems. If so, the IT project team may find it advantageous to leverage the platform(s) on which the related systems are built to support to the new project.

Chapter 3 Methodology

3.1 Organizational Frameworks from Business Literature

A number of frameworks can be used to describe a company system. Frameworks are found in business literature written for analysis of organizations and for learning about corporate structure. Frameworks useful to development of the method for this system architectural analysis were found in books on organizational structure, service industry writings and consulting firm management.

3.1.1 Organizational Structure

In his writing about organizational structure, Henry Mintzberg (Mintzberg, 1979) decomposes the firm into basic elements of form, process and internal function. He defines five basic forms, five coordinating mechanisms (processes) and nine design parameters (internal functions) that can be used to describe organizational structures and components. The five basic forms are shown in Figure 1.3. The elements consist of:

- Forms describe the structure of employees and their work. The operating core of employees who do the basic work of the organization are shown along the bottom. Two management groups are indicated, the strategic apex at the highest part of the hierarchy and their personal staff that ensures the organization is serving the needs of those who control or have power over the organization (stakeholders), and the middle line which makes up the chain of command and has direct authority over the operators. The technostucture contains the analysts who standardize the work of others and help the organization adapt to its environment at all levels of the hierarchy, and the support staff that supports the functioning of the cooperating core indirectly (from R&D, cafeteria, legal counsel, payroll, public relations to the mailroom).
- Coordinating mechanisms describe the methods used to hold the structure together and manage the work of the firm. These include: mutual adjustment through communication of information between workers, direct supervision provided by the middle line, standardization mechanisms, work processes instructions that determine content of work, standardization of outputs specifying output dimensions of work, and standardization of skills specifying the training required for work.
- Nine design parameters describe the methods used to organize the groups within the five employee structures to fulfill the function of the firm.
 - job specialization
 - behavior formalization
 - training and indoctrination
 - unit grouping
 - unit size
 - planning and control systems

- liaison devices
- vertical decentralization
- horizontal decentralization

The combinations of the 5 forms, their design parameters, and the way they work is directed on all levels by some combination of the coordinating mechanisms describe the form of the architecture.

3.1.2 Professional Service Firm analysis

Mark Scott's "Intellect Industry" (Scott, 1998) describes Professional Services Firms (PSFs) as organizations which "attract, train and motivate highly intelligent people and garner, package and share knowledge with great efficiency, PSFs are also masters of customization and have to remain perpetually creative and innovative in their approach to providing client service." He describes the consulting engineering business well, also mentioning that "The finite commodity in the market are strong client relationships and, since these are the core assets of PSFs, the easiest means of maximizing income is extending the business done through key clients by providing a 'one-stop shop.'" It is crucial to the firm that the "stars" (Lorsch and Tierney, 2002) (as Jay Lorsch and Thomas Tierney refer to outstanding employees) are valued and nurtured as well as clients.

Growth strategies of PSFs mentioned by Scott are:

- Global networks
- Service bundling
- Client sector specialization

Scott analyses the life stage of a PSF based on size determined by number of employees, offices, and fee income. According to this analysis firms are less likely to function as a group of "grey hair" experts when the firm grows in size, and more likely to achieve that growth by highly leveraging the firm's partners and "institutionalizing methodologies." His descriptions explain some of the context of the firm and provide insight into strategy and measurement of organizational growth and success.

David Maister (Maister, 2005) decomposes a firm into "Finders," "Minders" and "Grinders," with the leverage structure determining the mix within the employment pool. Maister agrees with Scott that "Getting the leverage structure right is key to the consulting firm's success. ... Matching the skills required by the work to the skills available in the firm (i.e., managing the leverage structure is central to keeping the firm in balance)."

By evaluating firms based on the leverage structure (ratio of juniors to seniors), he categorizes forms into four kinds of professional practice.

- The pharmacist who relies on juniors, process and systems to deliver a standardized service with a minimum of senior professional time

- The nurse whose practice is more consultative and guidance-based but uses established procedures and tools. The better the counseling skills, the higher the fees the nurse's practice can charge.
- The brain surgeon, who combines high levels of customization, creativity and innovation with a low degree of client interaction. Junior resources and standard methodologies are less useful in this practice, which charges very high fees.
- The family doctor, who provides highly consultative work with the highest level of the client organization and few junior staff. This practice either charges high fees or refers clients to other practices as a "relationship manager."

The types of firms described above vary from the growth oriented categories described by Scott. However, each of them provides insight into characteristics of a consulting practice that differentiate it from a product-based or manufacturing-based organization. The firms all require direct contact with the client, even in the most standardized "pharmacy" type and the most technical "brain surgeon" type firm. Contact with the client and the ability to maintain and grow relationships while leveraging expertise effectively determines the success of a service based firm.

3.1.3 Systems Engineering Frameworks

The decomposition of a system typically involves breaking it down into *what* is desired from the system, and *how* this desire is achieved. In the System Design literature these tools are most often used to assist with the design of a new system. Alternatively they can be used to deconstruct an existing system to determine if it is capable of meeting its goals.

"What" and "how" are formally defined by various decomposition methods including Axiomatic Design and Object Process Methodology.

Suh's Axiomatic Design (Suh, 2001) breaks the design world into four domains, which provide the macro structure for decomposition of the system into its elemental parts:

- Customer Domain is characterized by the needs of the customer
- Functional Domain specifies customer needs into functional requirements (FRs) and constraints (C) (together Customer and Function Domain define the "what")
- Physical Domain specifies the design parameters (DP) that determine the infrastructure of the system
- Process Domain process variables (PVs) provide guidance for using DPs to provide value back to the customer (together Physical and Process Domain define the "how")

The internal elements described above are crucial to ensuring that the system returns the intended value back to the customer. The specification of the elemental requirements,

constraints, parameters and variables involves detailed analysis of the both the system and its context.

Dori's Object Process Methodology is a holistic methodology for system design and system specification (Dori, 2003). Dori's technique models the system in both diagrams [OPD] and language [OPL] using three basic elements: objects, processes and states. "Objects exist, and processes transform the objects by generating, consuming, or affecting them. States are used to describe objects, and are not stand-alone things." (Dori, 2003) Objects are depicted as rectangles and processes as ellipses in an OPD, connected by links that specify actions or relationships between them. Using Dori's technique the entire system can be described in a single set of models at increasing levels of complexity by creating OPD models.

The above methodologies model the system in order to simplify the complex process of analysis. Each provides insight into some aspects of the system. However, they are both methodologies that require training to digest their meaning. A description of a consulting engineering services firm useful to members of the organization not trained in system design will need to present these elements in more comprehensible way.

3.2 System Architecture Framework development

An organization has been evaluated using a system architecture framework developed for analysis of a consulting engineering services firm. This framework provides questions enabling the architect to discover the details of the system's function and architecture. The answers to the questions will uncover the forms, structure, processes, needs, value, and intents that define the organization.

The system's architectural model specifies the system's building blocks – entities, objects, states, and the processes that transform the objects, along with structure and procedural relationships among them. (Soderborg, Crawley and Dori, 2003) The intention is to establish a framework that describes the firm as a system designed to fulfill the needs of beneficiaries and stakeholders. The system's structure is a means to fulfill these needs within the context of the environment within which the firm operates. "Expressed in the very simplest terms, a business concept represents a harmony between the market, the product and the organization." (Alvesson, 1995 210)

To fulfill the needs of beneficiaries (company stakeholders like employees and stockholders), the company must deliver value to their customers. To continue to grow its customer base and differentiate itself, the company must add to the expected value and deliver innovative service to its clients.

The framework is created from the answers to questions researching ten attributes of the system and elements of each of these attributes. This framework was completed using data from a series of interviews with company stakeholders, employees and clients.

Attributes of the system architecture are both internal and external to the system. Each of the attributes contributes to the function of the organization in order to fulfill the value

proposition of the company. The framework is an adapted product system architecture that considers the particular attributes of a firm.

3.2.1 Defining an appropriate system architecture framework

3.2.1.1 Basis of analysis

The basic framework for an architectural analysis of the organization is shown in Table 3.1. The framework has been adapted from the work of Crawley (Crawley, 2005) in order to support its application to a services firm.

The most important features of the firm become evident as they are directly or indirectly associated with the firm's need fulfillment as it benefits the stakeholders.

Table 3.1: Architectural framework questions for a service firm based on Crawley's system architectural framework (Crawley, 2005)

Case Topic	Item	Questions
Needs of the system (the firm)		
Benefit		
		Who are the beneficiaries?
		What are their needs?
		What or who is the agent of the beneficiaries?
		Are there indirect stakeholders who might benefit from fulfilling this need?
		Who is the agent for this stakeholder?
		Who is the operator?
		Who is the agent for the operator?
		How are all beneficiaries' needs identified?
		How are all stakeholders' needs validated?
		How are needs communicated within the firm?
Market(s)		
		What is the market that will benefit from the work of the firm?
		Who is in this market?
		What is the size of the market?
		Where is this market located geographically?
		What are the habits of the members of this market?
		What is the potential for sales to this market?
		What is the potential for growth of this market?
Value		
		What is the value related operand?
		What is the solution neutral transformation of the

Case Topic	Item	Questions
		operand?
		How is the firm positioned to deliver this value?
	Goals	
		Have all needs been translated into goals?
		What is the system goal statement?
		Are the key system drivers identified and met?
		What are the market goals?
		What are the goals for the downstream processes and “ilities”?
		What are the regulation related goals?
		Are the goals attainable?
		Are the goals solvable?
		What are the metrics for achieving these goals?
	Intent	
		What is the firm’s purpose? - statement of intent
		Do the firm’s goals deliver the required benefit to the stakeholders?
		Will the goals deliver the function with benefit at price?
	Requirements	
		Are all of the stakeholders’ needs accounted for in the goals?
		Are the goals consistent and complete?
		Are there other system goals that are not covered in the value transformation? Aesthetic, spiritual?
	Context	
	Environment of the system	
		What is the environment/context?
	Regulatory environment	
		What are the sources of regulation?
		What are the sources of perceived regulation (pseudo-regulations)
		What are the internal regulations?
	Organizational environment	
		How does the parent organization contribute to or constrain the system?
		How do the other companies within the conglomeration or federation contribute to or constrain the organization?
	Employee capabilities	
		What are the necessary employee skills or capabilities?
		Are their capabilities ensured and cultivated? How?

Case Topic	Item	Questions
		How are appropriate employees brought into the company?
	Competition	
		Who are the primary competitors of this organization?
		What is the competitive environment of the firm?
		What is the differentiator for clients in choosing this firm over others?
	Technological	
		What is the state of technology in the firm's industry?
		What is the state of technology within the firm?
Architecture		
	Function	
		What is the solution neutral function statement of the firm?
		Is this function based on the goals, intent and requirements?
		Is the function achievable?
		What is the functional decomposition of the system?
	Concept	
		What is the concept?
		Does the concept meet the stakeholders' needs?
	Process	
		What alternative goals and intent have been considered for this firm?
		Have alternative options been presented?
		What is the specific system operating process?
		Does the operating process fulfill the intent?
		Does the operating process fulfill the goals of the enterprise?
	Form	
		What is the organization's structure?
		Does the structure allow for the execution of ALL functions?
		Does this structure meet the needs of the stakeholders?
		Does the structure have environmental dependencies?
		What is the structure decomposition?
		Why is the structure decomposed this way?
		What are the element interfaces? How is communication accomplished between elements?
		What are the system interfaces? How is interdepartmental

Case Topic	Item	Questions
		communication accomplished?
		Are the interfaces appropriate? Are the communication mechanisms effective and appropriate?
		What are the system figures of merit?
		The most basic elements of form in an organization are people – what are the parameters of their positions in the firm? (Mintzberg, 1979)
		1) Job specialization/formalization 2) Training and indoctrination 3) Unit grouping and size 4) Planning and control systems 5) Liaison devices 6) Decentralization
	Architecture	
		How is the concept modeled and communicated?
		Are there emergent functions?
		How are emergent functions handled?
<i>Technologies: IT, developed technologies, technology tools for function delivery</i>		
	Platform	
		Is the firm's underlying platform standard to the industry/market/parent enterprise and/or partnering firms?
		Are there platform modifications necessary for the system?
	Specific	
		Is the technology related to or supporting enterprise core competency?
		What technology is used?
		What technologies are planned for the future?
		How do future technologies support strategic initiatives of the firm?
		Can the technology be implemented?
		Is the system technology an actual or perceived standard?
		Is the system technology well understood?
		Is the system technology reliable?
		Is the system technology supportable and/or maintainable?
		Is the technology provider likely to be around for the life span of the system?
Regulation		

Case Topic	Item	Questions
Regulation		
		How does regulation affect the business of the firm?
		Does the firm create any liabilities?
		- what are these and how are they handled?
		Does the system comply with regulations?
Perceived regulation		
		Does the firm comply with external expectations for a system of this type?
		Will the outside beneficiaries of the architecture perceive it as beneficial to the context?
Legacy, Reuse and Supply Issues		
Legacy		
		Would the firm's architecture allow it to establish a new standard or identity if that were strategically desirable?
Reuse		
		Is the firm's architecture applicable to other problems?
		Could this firm's architecture be reused to create another firm?
		Can this firm expand by acquiring other firms and combining their characteristics into the architecture?
Supply		
		Is this firm able to provide infrastructure and value in a cost effective manner?
		Are there possible efficiencies related to reuse of this structure?
		How does the firm fit with existing components or subsystems within the environment or parent organizations?
Platform Alignment		
Enterprise platforms		
		Does the organization take advantage of platform architectures?
		Does the architecture fit within existing operational platforms?
Enterprise systems		
Lifecycle Plans – ability of the organization to survive its past, present and future		
Design		
		What is the plan for the system design?
		Is the system durable enough to last the expected lifespan of the system in reasonable condition?

Case Topic	Item	Questions
		Can the system be designed?
	Evolution	Does the firm have an expected lifecycle? Can the firm evolve beyond its expected lifecycle? Can the firm evolve beyond its current industry and market?
	Operate	Is there a failover plan for operation in an emergency? Are there special skills or capabilities necessary for operation? Will the system be maintainable over the lifespan of the system?
	Support	What are the support costs for the system for both the implementer and the operator? Are there special skills or capabilities necessary for support?
	Implement	Is the system produce-able in a cost effective manner? Are new tools, skills or capabilities needed for implementation? Are new skills needed for implementation? Are new capabilities needed for implementation?
	Retire	Extending the life of the firm – under what conditions might the firm no longer exist? Will the firm be retired? Under what conditions will this happen? How will the firm be retired? Can the firm be upgraded or extended beyond possible retirement?
Architecture and Interface control plan		
	Architecture	How is the architecture controlled through design, implementation and beyond?
	Interfaces	How are interfaces and communications controlled and provided both now and in the future lifespan of the firm?
Risk		
	Risk	

Case Topic	Item	Questions
		What are the risks for this firm? (Those not previously mentioned above.)
		How are the risks mitigated? (Not mentioned above.)

3.3 Applying this framework to an engineering consulting firm:

The framework was designed as a list of questions with answers that determine features relevant to the function of the organization. To derive answers to these questions (see Table 3.1), interviews were held with strategists and leaders of the firm, including the President, C-level executives, senior technical staff and senior managers, experts in how the firm achieves its daily objectives. Their answers, along with company research were compiled into a system architecture document that models the organization.

3.4 Application of the System architecture

3.4.1 Project definition

One objective of this thesis is to investigate the usefulness of the system architecture when applied to the work of the Information Technology (IT) corporate services department. The architectural document provides a framework for an in-depth understanding of the firm. All features of the firm are documented, from the most basic core values and goals through the functions, form and future development parameters.

3.4.2 Applying the architecture document to IT systems

Using this in-depth analysis as a map of the organization, we can identify links between IT systems and elements and processes of the form and see how the IT structures support the system to deliver value to the stakeholders.

Once it is identified we can apply the architecture to new system development activity. If the new system fits into the architecture and supports the functions of the firm in their delivery of value to the stakeholders, it is shown to be an appropriate system for this organization.

Similarly, the system under investigation can be further defined by “projecting it” onto this architecture model, comparing the two systems, and providing further information about how the new system would fit within the existing organization.

3.4.3 Using the System Architecture

A full architectural analysis of a consulting engineering firm is a complex and detailed document. The system architecture result of this thesis (Chapter 4) is a long document which is not very accessible as a reference to employees within the firm.

To complete this project, a more streamlined and “user friendly” version of the architecture document was written (“The Summarized Architecture of CDM,” see Appendix I). The resulting document was used as the basis for conversations with IT leaders. It was important to provide these leaders with a document containing the framework and benefits of the system architecture, but readable by them and the average employee as a job task, without extreme effort or endurance.

The resulting document was used as a tool to define the functional and technical requirements of a new system for the case study firm. This process provided detailed information related to the value of the proposed system, users, project stakeholders and some insights into project technical and business requirements.

Chapter 4 Case Study of an Engineering Services firm

The system architecture presented in this chapter is a model of Camp Dresser & McKee Inc. in the summer of 2006, created based on interviews with CDM employees including members of the Office of the Chairman, the Senior Management team, and subject experts. The architecture attempts to document the benefits and value rendered by the firm and the way they are managed and determined. It includes the major functions, which support benefits and value and the processes which achieve those functions, as well as information related to the context within which the firm operates, how that affects the firm and generates opportunity and challenges. The system architecture is a thorough analysis of what the firm is and why it is that way.

Referential numbering is retained in order to facilitate citation of the System Architecture document.

4.1 Vision and Core Values

The vision of the firm is the concept of the organization. It is “who we want to be inside and outside.” (Martino, 2007)

“Successful enterprises have a vision of who they are, why they succeed, and where they are going... shared values and principles that guide them through changing markets and unrelenting competition.

CDM will be a global consulting, engineering, construction, and operations firm committed to exceptional client service to improve the environment and infrastructure.

To achieve our vision, we will be:

- Pre-eminent in the eyes of clients by delivering the right total solutions and setting the standard for exceptional value and service.
- The employer of choice by providing superior opportunities for the best people in the industry.
- A full-service, global firm that is financially strong and growing through the business and technical performance of our people.

CDM will remain a privately owned firm, free to determine our own direction, committed to building a stronger enterprise for each future generation.

As a worldwide provider of diversified services, we have high ideals and a commitment to quality and integrity. We know who we are, where we want to go, and how we plan to get there. Our goals are far reaching. Working as a team we will realize our vision.”

Core values of the organization are not the same as the system value which is delivered to the client in the form of the project goal plus intent (see Figure 4.1). These core values

describe the “cultural underpinning of the firm.”(Martino, 2007) The core values are unchanging and are central to all aspects of the organization.

- Excellence
- Initiative
- Shared Commitment
- Integrity
- Teamwork

The vision and core values seldom change. The vision may shift when there are major changes to the firm, an example: When the firm changed from an environmental to an infrastructure firm, or when the maturity of the business caused a shift from being a firm of individual innovators to a business which works together. The vision indicates where the firm is going, and the values indicate “how to behave” (Martino, 2007) while pursuing the plan which is the corporate goals.

The Board of Directors and the Office of the Chairman (OOCH) defined the vision and core values. They are reinforced within internal communications with employees and through artwork in corporate offices.

4.2 Needs of the system (the firm)

A well-designed system is organized and constructed to meet the needs of its beneficiaries, accomplished by carefully determining those needs and using them to define the system’s specific goals. The intent of the system defines what it will do to achieve these goals. The delivery of this stated intent combined with the achievement of goals is the system’s delivered value.

CDM’s beneficiaries’ needs (see the Object-Process Methodology based model in Figure 4.1) are analyzed and combined into project related goals in the business development stage. The needs are interpreted and then used to define a project whose intent is to achieve specified goals by altering the state of the problematic site or situation.

OPM diagrams like the one shown below use ellipses to model processes and rectangles to model objects. In the diagram of Figure 4.1, CDM is shown surrounding the objects and processes which the organization manages or defines, and the Project Goal is shown as a circle surrounding the definition of the project and the delivery of the solution, because the goal is both the intent and the solution. Arrows between objects and processes show their relationships, but the large red “Value” arrow designates the value, which is delivered to the beneficiaries of the system.

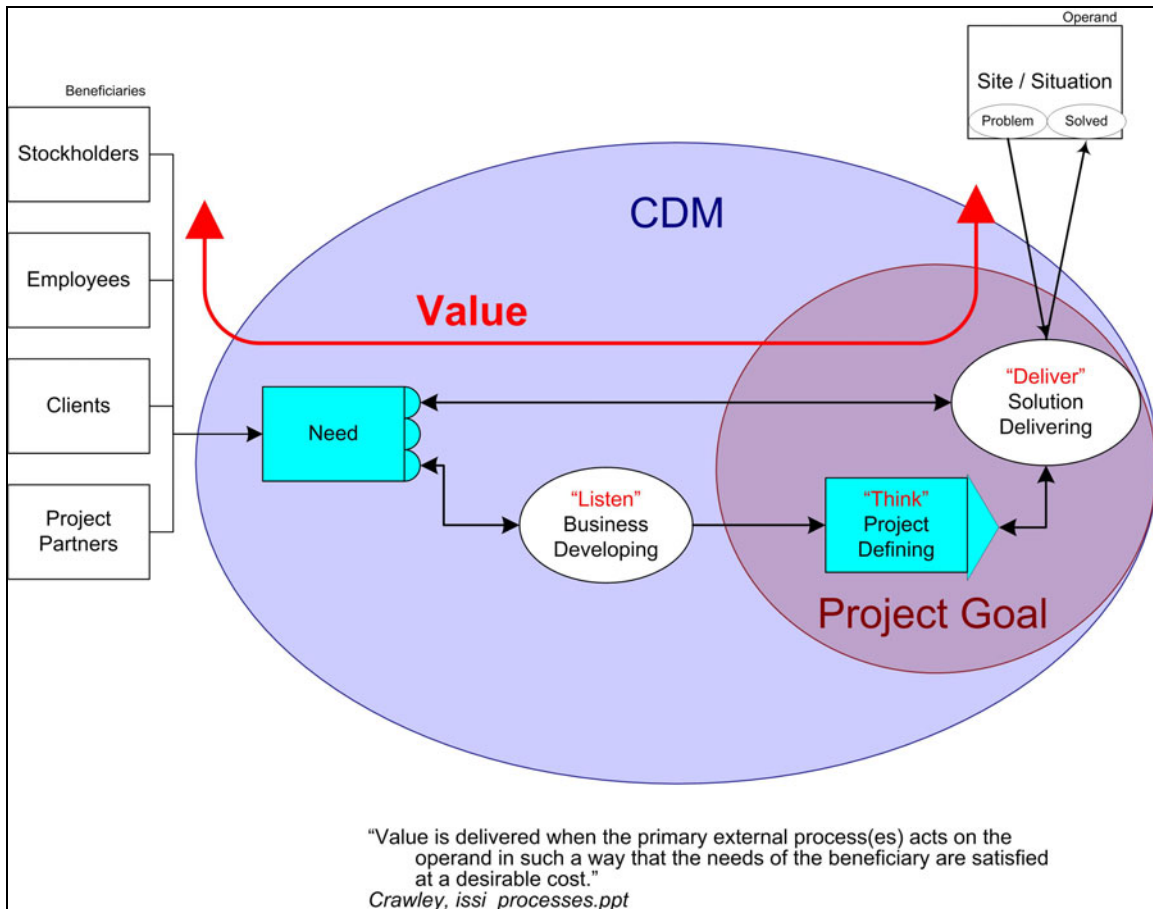


Figure 4.1: Value delivery to beneficiaries

4.2.1 Benefit

The benefits of delivered value from the organizational system are delivered to the beneficiaries. At CDM, there are four primary beneficiaries of most projects:

4.2.1.1 Beneficiaries

Employee stockholders

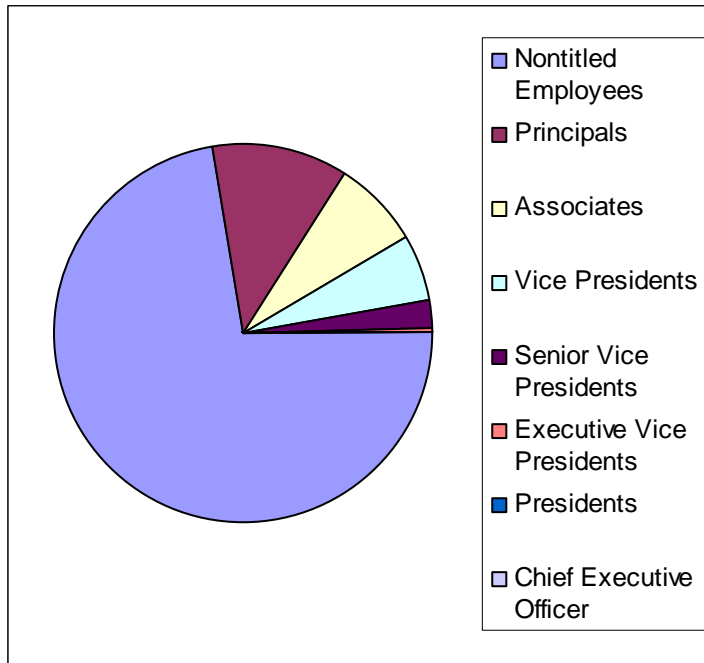


Figure 4.2: Ratio of titled employees to non-titled

As an employee owned firm, all titled employees (over 27% of employees) are eligible to own stock in the company as shown in Figure 4.2. Stockholders in the firm have invested both professionally and financially in the success of the organization, they need the growth of their investments. Employee stockholders are working for themselves and rely on the continued financial success of the firm for a return on their investment. They contribute to the high level decision making process of the firm through annual shareholder's meetings and officer elections.

The needs of the stockholders are validated by the Board of Directors and OUCH, who work to ensure the company remains privately owned by its employee stockholders. Strategic analysis of this group has determined that in order to remain flexible and self directed the company needs growth and profitability. In addition to analysis tools for validating the needs of the stockholders, OUCH has also identified that the firm must remain true to their stated organizational values.

That employee stockholders need for growth and profitability is understood by Unit Presidents, who report to OUCH and the Board of Directors. OUCH and the Board of Directors respond with corporate strategy and planning, addressing stockholder needs for growth and long-term profitability. Progress in meeting needs is also tracked through corporate financial and sales related reporting.

Employees

CDM's employees are highly skilled professional engineers, scientists, project managers, client service professionals, administrative support personnel, and managers. Retaining and hiring employees of this caliber are high priority activities. Employees of the firm are in direct contact with the firm's clients and must have both excellent communication and technical skills.

The firm's growth benefits employees by providing opportunities for career and personal growth as well as financial reward. Challenging work assigned to senior members of the organization results in their professional growth and intellectual stimulation, while junior staff members learn skills required to complete project tasks and support the work of senior staff. Both groups, through mentoring and the setting of professional standards are thus provided with profession growth opportunities.

Employees in a professional service firm (PSF) are often driven by something other than the need for profit (Martino, "Interview with Richard Fox," 2006). PSFs provide a platform for assisting individuals (examples of this are law or health care) and communities (exemplified by engineering or architecture) in a case specific manner, which limits the scope of the organization's work to individual assignments. The satisfaction of delivering an effective, tailored solution is additional reward to employees. The people drawn to work of this type are typically less interested in profit, which is more readily found in mass sale of product.

The employees benefit from the growth and profitability of the firm through their salary and job stability. The corporate Human Resources department conducts regular evaluations of salary levels to ensure that employee pay is commensurate with market levels.

Other needs related to personal and professional growth and overall job satisfaction are validated in the employee survey offered every two years. The survey, consisting of as many as 85 questions, asks employees to rate the firm's performance. The questions relate to the employees' perspectives on:

- organizational support of core values (as described in section 4.1)
- level of engagement of employees with the firm's objectives
- organizational leadership
- professional growth opportunities
- personal growth opportunities
- support systems
- work life balance

The needs of employees are communicated throughout the firm:

- Survey responses are distributed throughout the firm so that everyone understands employees' needs.
- Employees have access to an anonymous IT feedback mechanism called the Employee Suggestion Program (ESP), which submits all comments and suggestions directly to the most appropriate members of the upper management team and publicly posts responses to inquiries and suggestions.
- Individual employees are encouraged to discuss job related matters with their managers or HR coordinators. However, the matrix organization which places employees into temporary project groups can make this difficult because the temporary nature of the group may make employees feel disconnected and they may lack clear management structure.

Clients

CDM will “use technical talent to find solutions that provide the client with a solution that goes beyond the singular need” (Martino, “Interview with Bruce Conklin,” 2006).

CDM's primary resource is the relationship of its employees with their clients. If the relationship is based on trust and mutual benefit, the client will maintain contact with CDM. This enables CDM to assist the client with defining their problems as well as responding to Requests for Proposals (RFPs) by proposing solutions.

In order to maintain a relationship based on trust, CDM cannot be focused solely on short-term profits. CDM's role may be to assist the client with the definition of a problem in addition to determining the most appropriate solution. An example: CDM was brought in to create a water system Geographic Information System (GIS) for a client. Instead, CDM created a GIS system that would support any infrastructure system. In this case, CDM analyzed the client's problem in a context broader than the RFP, finding a solution that saved the client from spending considerable money to later re-engineer the GIS system to support other systems. (Martino, “Interview with Bruce Conklin,” 2006)

A client may be represented by a number of individuals. During the sales process the Client Service Manager (CSM) from CDM may work with an economic buyer responsible for the financial support of the project but not knowledgeable about technological aspects. The CSM may also work with a technical buyer who is responsible for making technical recommendations on the project, but may not have the final decision-making power. The CSM must be able to communicate with either or both of the customers equally well.

CDM's fulfillment of client needs is validated in a few different ways. Clients rate CDM's ability to fulfill their needs when they hire CDM to complete their projects, at the end of a project when they complete a client Satisfaction Survey Questionnaire (CSSQ) and especially when they bring CDM back repeatedly. This is the most significant validation. In addition, when work is completed by CDM, adherence with regulations and professional standards help ensure that clients receive value.

Clients communicate their needs to their project's team. The client's decision makers and Project Manager are in regular communication with the CSM or with the CDM Project Manager (PM) during and after the business development phase. Client communications can also take place at a higher level between the client's higher level managers and CDM's Area Manager (AM) or Vice President (VP). This communication is very effective in the business development phase of the project and during project definition.

During the project data gathering and execution phases, the nature of the work and the need for CDM's on-site presence often means other members of the project team spend more time with the client team than the managers of the project. This situation requires skillful handling. Client needs communicated directly to project team members must be passed back to CDM's project manager, a delicate communication because the inadvertent commitment to a scope change or change in specification of the project could be detrimental to the project schedule and/or budget.

Project Partners

Project partners are a set of firms that are beneficiaries of CDM, but also may be competitors. Frequently projects require work a single firm cannot complete individually. Partnering is an effective way to win a project that would otherwise be unobtainable. CDM is sometimes involved in projects that need specialized skills or labor the company cannot provide. Partnering with another firm ensures all needs are met and the project work is completed properly.

Partnering with another firm is mutually beneficial because it provides access to project opportunities neither organization could complete alone, or access to clients beyond those known to one firm. Because project partners are not direct beneficiaries of CDM, their needs have no formal communication mechanisms within the organization.

This relationship can be challenging. Each firm must share information about the project and have a trusting relationship with their partner. Still, some project information from clients to CDM employees relates to future business development opportunities and should not be available to project partners. Project partners are both members of the project team and competitors. Communication of their needs must be skillfully handled by the PM on the project in order to ensure that they are supported as team members. However, it is important that CDM's needs are communicated to the partners are filtered such that business information they do not need for project completion is not accessible to them.

4.2.1.2 Emergent Beneficiaries

There are a number of other beneficiaries of CDM who are not directly considered as beneficiaries in the design of the system, but gain from the work of the organization.

Community and environmental needs are represented by the regulations and professional standards of the engineering and scientific professions. They are well understood and monitored by CDM professionals, and are communicated within the profession's

societies. Membership and active contribution in these societies ensures that CDM engineers and scientists are aware of these needs.

Community and Environment

As members of communities all over the world, the employees of CDM work to ensure that, not only are client needs represented in the work of the firm, but that projects are beneficial to the communities as well. CDM employees have architected opportunities with benefits reaching beyond the needs of a single client to others within the community.

An example: During a recent series of park upgrades for Boston Parks and Recreation, the City of Boston had little money to spend. CDM employees found that universities in the area needed space and fields for sports programs. The universities paid for upgrades to the city owned parks. The city received new facilities and partial use of the parks (Martino, "Interview with Bruce Conklin," 2006).

The company and employees are committed to providing the best service possible for their communities, and to affording environmentally sound and safe solutions.

Professional Organizations

The engineering profession and professional organizations are "emergent beneficiaries." They benefit indirectly because the firm has a commitment to maintain the licenses of its employees and the leadership development those employees receive as a result as members of these societies. CDM employees are encouraged to present papers at society conferences and take on committee and officer roles.

In order to facilitate the search for the best and brightest engineering students, CDM fosters relationships with professors and administrators at certain universities. These relationships benefit the school and the professors professionally as well as providing CDM with excellent potential new graduate hires - a valuable resource for a professional services firm.

Organizations that provide funding to municipalities and other clients for projects are another example of "emergent beneficiaries" because they profit on the project work, although they do not directly benefit by the work of the firm.

4.2.1.3 Operator

Every system must be operated by some entity. In the case of CDM the primary operator is the client who drives the definition of the project.

Client

The CDM client typically hires the firm to complete work on their own property. Work may also be mandated by government regulation on a property the client once owned. CDM's contact with the client is typically managed by the CSM. In some cases, the Area Manager or a Vice President may have the closest client relationship. If this is the case,

they will oversee the long-term relationship while the CSM manages the communications related to the specific project.

CDM went through a re-branding in 2000. The research for that endeavor included a fifty-client interview survey aimed at determining clients' perception of CDM and its work. The questions investigated differentiators between CDM and its competitors, the company's identity in the minds of the clients, and the name clients used when thinking about the firm and its subsidiaries. Overall CDM was seen by clients as trustworthy, a firm that succeeds through the development of relationships with clients. The firm was perceived as having excellent tech expertise, but the key to the delivery of value was found in the relationship. Clients said that CDM listened, took each project on as though it were internal, and tracked the big picture down to smallest detail. (Martino, "Interview with Marlene Hobel," 2006)

Mandating agency

Mandating agencies, like the Environmental Protection Agency (EPA), do not directly "operate" the firm by hiring it for a project. However, many projects become necessary when a regulatory agency demands that a site be cleaned up, or a treatment plant be updated to comply with regulation. Current or past property owners may hire CDM to ensure site compliance.

CDM's experts understand regulations and are able to identify the most cost-effective solutions to address compliance. The project's client is most often not the mandating agency, but is frequently a municipality or business with limited funds to address unplanned compliance issues. The firm must be able to find an affordable, practical solution compliant with all applicable regulations now and in the foreseeable future.

4.2.2 Delivered value

4.2.2.1 Value related operand

Typically, the operand is a job site or a situation which is problematic for the client. As a firm traditionally known for water and wastewater services, CDM completes many water treatment plant designs and hazardous waste site clean up projects. However, a physical site does not have to have a problem. CDM offers Information Management skills and Management Consulting services, which do not require a physical location. The operand, then, is a process or even a strategy that needs a solution.

4.2.2.2 Value delivery

CDM delivers value to the client by carefully interpreting the client's need related to the operand and then considering solutions to solve the need in the best way. The best solution for the client is part of the value. This may mean that CDM finds a less invasive or drastic method for solving the problem, even if it reduces the overall value of the contract, for instance, counseling the client so they do NOT have to complete the project. An example: CDM was brought in to assist a municipality with water treatment and

CDM found that they could help the client prove that they were attempting to meet an inapplicable regulation. (This example was cited by a number of CDM employees as an exemplary project solution despite the fact that it meant lesser billings for CDM. It is commonly used as an illustration of outstanding client service.)

4.2.3 Market

4.2.3.1 What are the characteristics of the industry?

Traditionally CDM has been a wastewater and water resources services oriented firm operating in the United States of America. For this reason most projects were designed for public organizations and industries with environmental concerns.

More recently, CDM has expanded its capabilities to provide full infrastructure services by adding construction, operations, and management, and it has expanded its ability to provide services worldwide. This has added markets for GIS projects, construction, development planning, and facilities management consulting as well as environmental work. Overall the company's annual work consists of about 25% design/build projects, 25% design, and 50% consulting, which includes planning, general consulting, management consulting, and engineering management services.

The markets fluctuate with the client's ability to finance facilities improvements. It is interesting that the organization is somewhat shielded from the effects of fluctuations in the money markets by providing work to both the public and private sectors. When the interest rates are higher and financing costs limit the amount of work contracted by private industry, government bond ratings tend to increase due to money market changes. These same higher interest rates enable communities to sell bonds to finance projects. The process also works in reverse, providing some protection for CDM against economic cycles.

CDM's primary competitors are Black & Veatch, CH2MHill, TetraTech, and MWH, firms well established in engineering and environmental services. All have been in business for at least 40 years. CDM also competes with a number of smaller consulting firms that may have only a few experts in specific technologies or techniques.

4.2.3.2 What are the market sectors?

Public

CDM provides more services to the public sector than any other sector. This segment of the market provided about 66% of the work of the firm in 2005 (Martino, "Interview with Jon Dyer," 2006). The projects executed for CDM's public clients typically include design or design/build water or wastewater projects, a value that can fluctuate with the availability of Federal funds for municipal projects, and with the cost of borrowing.

Industrial (private industry)

Private industry provided approximately 12% of CDM's work in 2005 (Martino, "Interview with Jon Dyer," 2006). The projects executed for this group of clients are similar to those provided to municipalities and the Federal government. Air Quality work and hazardous waste cleanup are services frequently required by companies in this sector (Martino, "Interview with Julia Nault," 2006).

Federal

The United States of America Federal Government contracted CDM for approximately 13% of CDM's total project work in 2005 (Martino, "Interview with Jon Dyer," 2006). Much of the work executed by CDM for the Federal Government includes water or wastewater work, investigation of contaminated properties, hazardous waste cleanup, and policy analysis.

International

International markets are providing an increasing proportion of CDM work each year. The remaining 9% of CDM's total work in 2005 was contracted by this sector (Martino, "Interview with Jon Dyer," 2006). CDM work in other countries frequently focuses on water and water resources projects. However, CDM may also contract with governments or overseas funding agencies to build schools (Martino, "Interview with William Howard - CDM Architecture Topics," 2006) or rebuild infrastructure in war-torn areas.

The cited work percentages are approximations based on 2005 fiscal data, percentages relatively stable from one year to the next. However, the ratio of work completed by the International Group may fluctuate more than others because the size of contracts is very large. The timing of signing a new, large contract may cause International's overall work percentage to appear higher in a given year.

CDM's work is predominately in service areas, with 78% of 2005's contract signings based on service contracts. Construction contracts were 22% of total signings in 2005 (Martino, "Interview with Jon Dyer," 2006).

4.2.3.3 Are the markets growing?

Design engineering

CDM operates in the highly competitive market of design engineering. Design engineering is becoming a commodity as skilled professional services firms in India and China enter the market.

Analytical tools available today, combined with a good process and the right input information make design a "straight forward task." You are able to buy a pump off the shelf and put its performance parameters into your design; unlike the past engineer, who worked with the pump manufacturer to specify the design of the pump (Martino, "Interview with Richard Fox," 2006).

In this mature market, a solid, standardized process oriented to control time will enable the firm to make money on the design. However, the profit is fixed at about 6% of the

cost of construction and is not a growth opportunity (Martino, “Interview with Paul Camell,” 2006).

Other engineering project types can be more profitable:

The commoditization of design means that CDM must find other opportunities to serve the needs of clients and make a profit. CDM has a relatively large proportion of senior technical professionals, expensive and highly skilled. When their time is charged to a project, the profitability of the project can lower unless the project rate schedule reflects the value of their skills, adding to CDM’s need to find services which demand a higher rate structure than design.

- Alternative delivery projects

An alternative delivery project combines design and build phases to streamline both processes. When design and build contracts are executed together by the same provider, the project can save money for both the client and CDM; work is decreased and communications are streamlined between the project’s phases. For such projects, profit may be higher, up to about 20% of project cost.

- Project Planning and Management Consulting

Although design has become commoditized and standardized, the processes that surround decision making related to infrastructure projects remain complex and difficult both technically and managerially. Many clients are not experienced with projects of this type.

Client services have been expanded to include the supporting of projects through planning, approval, financing, and project management. These skills are uniquely applied on every project and are, therefore, chargeable at a higher rate. They demand skilled and experienced consultants.

- Program management

Large programs, which can include a number of infrastructure projects running simultaneously or sequentially, represent another opportunity for CDM to leverage highly skilled engineering talent. CDM may provide to a client services to oversee many projects at one time.

4.2.3.4 Economics

Leverage

In a professional services firm, the economic principle of leverage drives both profitability and the growth potential for junior employees. It is to the firm’s advantage to find project work that allows more experienced personnel to bring innovative thinking to a unique problem, but to then turn over the implementation of the concept to junior people with a higher billing rate to salary multiple.

At CDM, the Group Leader, Project Manager and administrative Corporate Managers fill the more experienced roles. Their responsibilities include promoting professional skills

and discipline groups among employees, conducting reviews, and managing the use of teams' junior members. They are also responsible for their own chargeability rate (utilization), lowered to allow them time for mentoring. The CSM is leveraged in that this role is tasked with finding work to occupy more junior employees.

This differs with the concept of leverage as described by Mark Scott (Scott, 1998) in that the senior partner is not necessarily a constant presence as a manager and mentor to the juniors. Because of the matrix structure of the organization, a junior employee may work for many project managers in just a few years with the firm.

Overhead charges and Administration

CDM makes all of its profit on client billings. There is no other source of income. All expenses not directly related to project expenses are distributed throughout the firm as overhead charges, including all administrative costs, and project costs that cannot be recovered (new business expenses, for example).

As a result, the Administrative groups do not grow with increased project work. Although there are some situations where administrative personnel bill projects when their skills are required, they cannot recover expenses apart from increasing overhead rates, or raising their administrative budgets.

4.2.4 Intent and Goals

4.2.4.1 Strategy 2008

The Office of the Chairman (OOCH) in collaboration with the unit presidents defines strategic intent. After the intent is defined, committees are formed to set specific program goals, which reflect the intent. In 2003, this resulted in eight strategic programs grouped under the name "Strategy 2008," goals based on three basic concepts:

- Growth - winning new projects and expanding markets, geography, and the services offered
- Value - delivering exceptional value to clients
- Strength - of the employees doing the work

4.2.4.2 Specific strategic goals

High level goals are set through corporate strategy at the apex (The strategic apex of the firm as defined by Mintzberg in Figure 1.3). Goals as defined by the Strategy 2008 (CDM Corporate Communications, 2003) 5-year strategic initiative are:

To bring CDM to annual revenues in excess of \$1 billion using increased capabilities, services, and volume of work. This will be accomplished by:

- doubling the volume of core services for public clients
- doubling the volume of work for industrial clients

- tripling the volume of work for federal clients
- doubling the volume of work for international clients

while also maintaining paced growth to double our construction revenues

using:

- reinforced sales capabilities within the Client Service Groups
- flexibility in assigning engineers/technical experts and scientists (E/T/S) from the Construction and Engineering Division (CED) and Constructors to projects where their skills are most needed as provided by the matrix structure
- acquisition of firms with needed services, capabilities, and geographic locations.

4.2.4.3 Operational goals

In order to serve its stakeholders and continue to generate profit, the firm has the following operational goals: (CDM Corporate Communications, “About CDM: Values and Vision,” 2006; Martino, “Interview with Richard Fox,” 2006)

- To develop and maintain exceptional, trusted client relationships
 - by:
 - finding the right total solution to the client’s needs: assisting with defining the problem, and facilitating client decision making
 - setting standards for engineering: CDM standards and professional standards via professional society participation and educational support
 - using the matrix structure to reinforce the ability of the Client Services Groups to focus on the client relationship and the Client Satisfaction Survey Questionnaires (CSSQ) sent from the Office of the Chairman after each project to measure client relationship success.
- To be the employer of choice
 - by:
 - retaining staff
 - hiring a skilled resource pool of experienced professionals and graduates
 - using:
 - increased flexibility provided by the matrix organizational structure to provide stimulating opportunities for work
 - exposure at professional societies to increase outside awareness of the projects and culture of CDM

- the corporate Human Resources department to build relationships with universities' job placement organizations
 - the bi-annual Employee Survey and employee feedback from managers and HR to measure employee relationship success.
- To provide full services to global clients:
 - by:
 - remaining financially strong to ensure stability
 - structuring the organization to provide increasing service capabilities to clients worldwide while balancing opportunity against acceptable risk.
 - using:
 - acquisition to leverage local contacts and rates
 - the CSG structure to ensure a focus on business development among CSMs
 - upper management surveys of services and capabilities to confirm that all relevant services are available worldwide.
- To remain privately owned to stay self directed
 - by:
 - staying profitable
 - keeping corporate focus on the growth and strength of CDM
 - using:
 - strategic goals to grow the corporation
 - employee stock ownership interest to measure ownership success.

4.2.4.4 Goal communication through Corporate Communications (CC) and hierarchical communications

Corporate Communications

Senior managers in marketing and communications created the Strategy 2008 brochure by reducing the output strategies from the strategic initiatives committees. CC communicated these strategies with a short booklet outlining all of them

Implementing a strategy related to emphasis on a service or capability requires that both CDM employees and clients know CDM's abilities in that area. For example, to promote CDM's capabilities in Design/Build (d/b), CC writes press releases about d/b projects, articles about d/b projects for the company newsletter, CDM News, and features the

strategy on the web site, along with case studies and Viewpoint (features and interviews) articles.

CC created an internal bi-monthly electronic newsletter called “Celebrate!” after the company re-organization to a matrix structure in 2004. “Celebrate!” shows examples of resources across the company and all of the divisions that collaborate successfully and create new jobs within the firm. Each issue picks one person and shows how they benefit from the new organization, spotlighting its success and how it has been proven to work. The newsletter capitalizes on the theme of Strategy 2008 to show the process of becoming the CDM of 2008 and how the goal of achieving one billion dollars in revenue is working. There is a growth item that features an example of a new project won via cross unit cooperation, an item which illustrates generation of value for a client through project innovation in technology or approach, and an item which describes the strength of CDM through the growth of an employee’s career, and his/her contribution to CDM’s success.

Hierarchical Communications

The most effective communication is face to face (Allen, 1984). The hierarchy (senior managers) of the company should work to effectively spread strategic initiatives. CC provides such tools as strategy brochures and internal notifications to facilitate this process. Information is expected to flow down through the company from OUCH to Unit Presidents to Managers, and on to every employee. However, this is not always the case, and it is sometimes assumed that employees understand their role within the strategy of the firm better than they do.

Business Unit Communications

Some business units have their own internal newsletters, which are effective communications of corporate level information “down the chain.”

They are not formal business unit communications mechanisms, and CC does not have the staff to support all of them. The units themselves take the responsibility for the newsletters, which includes crafting the strategic messages. An example: A CDM Constructors Inc. (CCI) newsletter includes the mission of CCI, information from CCI Human Resources, CDM messages, CCI identity, and team building articles, community building with family, and charity activities. Consulting and Engineering Division (CED) and the Client Services Groups (CSG) have newsletters as well, including the Federal, Public, Industrial, and International.

4.2.4.5 Marketing implications of strategy

Strategic plans within “Strategy 2008” include goals to double and triple the work in the market sectors: public, private, international, and federal by the year 2008. They are specific goals demanding cooperation among the various marketing groups and coordination between the divisions.

4.2.4.6 Organizational implications of strategy

Architectural impact of Corporate or Business Unit Strategy

The company is responsive to opportunities for growth, improvement, and market changes. Corporate and Business Unit strategies change as CDM's markets change. New strategies impact the corporate structure and infrastructure; however, CDM's core values do not change: Integrity, Teamwork, Excellence, Initiative, and Shared Commitment. Although strategy for providing value to employee shareholders might vary over time, the basics of the way business is done with clients do not.

Strategy changes typically expand the services provided by the firm or re-organize it to improve the sales and delivery of services. Important directives focus on improving access to sales channels and customer needs. Other strategies aim at improving the enterprise knowledge available to engineers in order to share collective company competence.

The form of the company must adapt to provide new functions regularly, as illustrated in Ed Crawley's diagram in Figure 4.3. New organizations are created or acquired and they are incorporated into CDM's systems, their capabilities added to CDM's "supply chain." This often causes changes to infrastructures in corporate services, and provides new opportunities for cross-divisional work to all Business Units. Company infrastructures are designed to accommodate these changes.

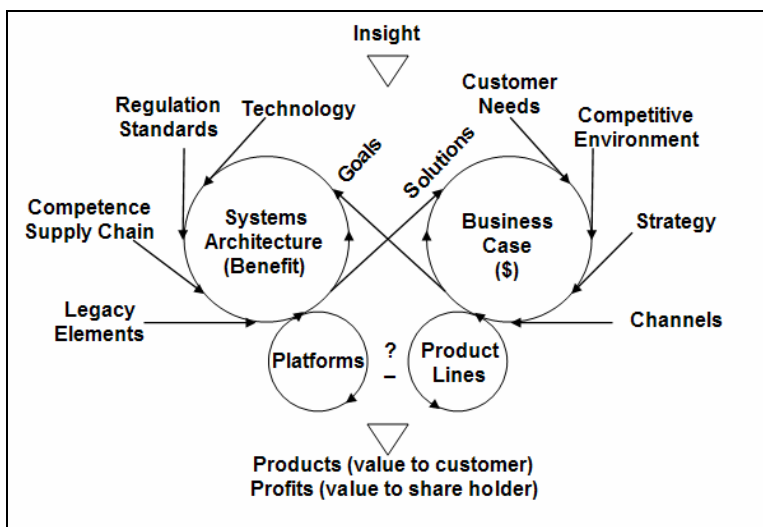


Figure 4.3: Corporate Architecture and Business case (Crawley, 2005)

Matrix Organization

David Maister describes three types of project workers, which are mixed depending on the company leverage structure. These three groups are:

- Finders – usually the most senior personnel, who build client relationships and bring in contracts for project work
- Minders – mid-level professionals, who ensure project delivery and quality
- Grinders – typically junior level employees, who complete the tasks necessary (Maister David, 2005)

At CDM, in order to provide flexibility in project skills delivery, the minders and grinders are managed in two pools of technical resources called Consulting and Engineering Division (CED), and CDM Constructors Inc. (CCI). The finders are categorized into four divisions based on market area: Public Service Group (PSG), Industrial Services Group (NSG), Federal Services Group (FED), and International Services Group (ISG) (see Figure 4.4 below).

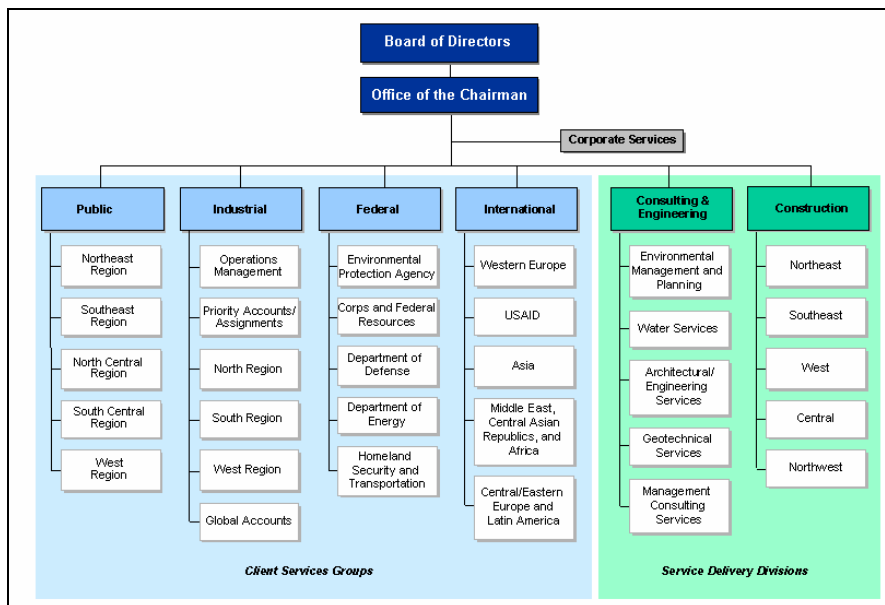


Figure 4.4: The CDM Organization

Chart from the CDM intranet (CDM Corporate Communications, “CDM Organization,” 2006).

Emphasis on growth

To achieve the profitability increases specified by the goals of Strategy 2008, CDM has emphasized growth in a number of areas. To achieve the required level of growth in core services, the number of clients hiring the firm to complete projects in these existing service areas must grow. At the same time, new services are provided to the clients with whom CDM has existing productive relationships. To effectively leverage the company’s expertise in facilities and infrastructure management and systems, there is an increasing emphasis on selling these highly valued services to both new and existing clients.

Acquiring firms in geographic areas or service areas where CDM has not previously had a presence enables the firm to quickly increase the volume of work while improving the ability of the organization to compete with local economic rates. However, the potential acquisition firms are carefully evaluated to ensure the organization's culture is compatible with CDM's.

4.2.5 Requirements

4.2.5.1 Skilled professionals

Lorsch and Tierney point out that "The central difference - and distinguishing characteristic - of the PSF business model is its reliance, its absolute dependence, on skilled and motivated professionals." (Lorsch and Tierney, 2002). CDM currently has hundreds of open jobs and approximately 3,800 employees, mostly in Civil and Environmental Engineering. Although the company has traditionally been "top heavy" with experts, Strategy 2008 includes major initiatives aimed at addressing the mix of senior professionals to junior.

The majority of jobs at CDM are in the "Technical" career path, which refers to professionals in engineering/technical/or scientific fields. Administrative job openings are mostly in IT and administrative, and these are all considered to be on the "Administrative" career path, despite a wide divergence of professions, which include financial, legal and managerial.

The company hires at three levels, emphasizing the lower levels that are cheaper to pay, have a higher billing rate, and can be trained by senior professionals through project collaboration, the disciplines, and CDM University. Hiring has become more difficult as the economy improves and engineers are more often hired by firms outside of the engineering profession who are looking for employees with technical analysis skills

Although every CDM office has its own culture, and employment guidelines vary by division, there are some attributes that every successful CDM candidate must demonstrate. Corporate regulations demand that every engineer have an Engineer in Training (EIT) certification or, if grade 5 or above, a Professional Engineers license (PE). Communication skills and a willingness to follow through on commitments are both imperative in a PSF where every employee may be exposed to the client during tightly scheduled project work or the sales cycle. Additionally, company core values are often used as guidelines in hiring. "It's going to sound silly, but a lot of times we just go back to the core values - integrity is very important in a hire."(Martino, "Interview with Lauren Courtemanche," 2006)

Retention is important to this company; the retention rate for technical professionals is 12%, which is typical for the industry. It is crucial that "stars" (as Lorsch and Tierney describe them: employees "whose performance is crucial to their organization's success" (Lorsch and Tierney, 2002)) are identified. These people are to be cultivated within the firm, given assignments that stimulate their interest and encourage career growth, and

paid well. They are told, and it is considered important to tell them, that they are stars of the company in order to prevent them from leaving. Career growth is the most typical reason an employee leaves the firm, but, as the population ages, CDM is starting to lose highly skilled senior professionals, who tend to be mostly in the over 55 age range.

Contrary to the expectation that a new hire will do generalized work and specialize as their skills grow in one area, at CDM a new hire is generally put to work in the technical field of their academic experience. As their skill levels grow, they are exposed to more project work and other technical disciplines. The outstanding employees who show an inclination become project managers, executing more generalized work. This job requires a basic knowledge of a number of disciplines, and management skills, which are taught at CDM University (CDMU). Project Managers earn this role by attending the CDMU technical courses related to project management, and by practicing on evolving project assignments.

4.2.5.2 Participation in Professional societies

Professional societies contribute to the quality of the firm's employees in a number of ways. They provide the continuing education credits demanded by professional licensing boards in many states for the maintenance of PE licenses. They provide the opportunity for employees to practice leadership, communication, working with diverse groups of people, and delivering bad news, as well as developing skills, leadership, and contacts through participation in organizational committees. They provide professional contacts for individual networks and hiring, and they keep the company's "face forward" through the presentation of advanced technology, and the hosting of events.

Other benefits include knowledge transfer and the advantage of demonstrating technical leadership by delivering conference papers. CDM awards an Honorarium and sponsors Best Paper contests to encourage employee participation. CDM projects are featured at conferences where CDM employees may learn from both competitors and clients in a collaborative forum. Conferences are an opportunity to "take a pulse" of the industry, of technology, and of the competition, and to hear from the client things you do not hear on the job (Martino, "Interview with William Howard - Professional Societies and Regulation," 2006).

There are many professional societies and each defines their own code of conduct. Participation contributes to the transparency and integrity of the profession by establishing standards all members must follow. Committees can leverage ethical and technical leadership by coordinating their efforts to influence ill-advised legislation related to the discipline, or to spur action.

4.3 Context of the firm

4.3.1 Operating environment

In the US, the infrastructure industry generally refers to civil construction: residential, commercial, industrial, and municipal. According to October's Business Monitor Online, this industry shows growth in 2006, but is expected to "go through a slouch over the next couple of years" (Business Monitor International, "United States Infrastructure Report - Infrastructure Forecast - Q3 2006," 2006). There are approximately 670,000 active construction companies in the US, of which 40,000 specialize in civil engineering and transportation. Two thirds employ fewer than 10 people. Relatively few firms have national scope (Business Monitor International, "United States Infrastructure Report - Infrastructure Forecast - Q3 2006," 2006). Bechtel and Halliburton are the largest global firms, but there are a number of firms operating globally, who are within the 1,000 to 5,000-employee size range.

However, the Clean Water Trust Act of 2005 is expected to provide \$7B to fund water and wastewater infrastructure projects in the United States. EPA Gap Analysis reports list the total US requirement for clean wastewater facilities in excess of \$270B over 20 years. Drinking water facilities needs are close to \$265B.

In Europe, Asia, and the Middle East, civil infrastructure projects are growing. They are often financed either by economic growth or through infrastructure improvement loans. Water projects are necessary to provide water for industry and improve living conditions in many areas of India and China. They are also necessary for flood control and energy production. (Business Monitor International, "China Infrastructure Report - Infrastructure Forecast - Q4 2006," 2006, , "India Infrastructure Report - Infrastructure Forecast - Q4 2006," 2006, , "Poland Infrastructure Report - Infrastructure Forecast - Q4 2006," 2006, , "Saudi Arabia Infrastructure Report - Infrastructure Forecast - Q4 2006," 2006, , "Singapore Infrastructure Report - Infrastructure Forecast - Q4 2006," 2006)

4.3.2 Strategic decision making processes

OOCH determines strategic goals in meetings with the Board of Directors. Once set, OOCH, working with the Management Committee, creates specific programs designed to reach those goals and a member of the firm is assigned responsibility for achieving each of these initiatives (Initiative Champions [IC]).

4.3.3 Regulatory environment

4.3.3.1 Regulation drives opportunity:

Big drivers for the firm are:

- Population Growth
- Aging infrastructure

- Regulatory Environment

Much of CDM's work for clients is required by consent decree. An example: An ultraviolet light water treatment plant that CDM recently designed for New York City (NY). NY had an EPA consent decree for this project. Treatment plants especially are regulatory driven, particularly in the northeastern United States. In the southwestern US, projects are also required in order to meet regulations, but most of them are also driven by growth. An older statistic states that California is adding the population of Massachusetts every ten years.

A downside of this environment is that a municipality without money to spare may be required to spend money on a wastewater treatment plant that is unpopular politically. These projects are not well liked; expansion is more accepted by the ratepayers. However, the infrastructure is aging all over the northeastern US.

CDM works to help clients to comply with regulations. The EPA sets the pollutant load for a river, and CDM works with communities along the river to determine the pollutant levels. CDM will assist communities to comply in the right way. If the drinking water is pure enough, then CDM can help communities convince agencies they don't need expensive and unnecessary systems.

4.3.3.2 Employment

As a multinational corporation, CDM has many state and national employment regulations to comply with. In the United States, a few are:

- ADA
- HIPPA
- Affirmative Action
- State laws
- Fair labor standards
- A sexual harassment training requirement in California mandates training in person every year
- Submission of the I9 form for authorization to work in US is now required by Homeland Security

Professional licensing

Engineers at CDM must have either their EIT or PE. The PE license is a requirement for engineering employees grade 5 or above, and must be obtained for each state in which they do engineering work.

Informal employment regulations

It is now a company practice to require a background check on each hire, permanent or temporary.

Professional societies play a large role in setting standards. The most important thing that professional societies do is set ethical standards for the profession and standards of behavior. Each state has its own rules, but these organizational rules can help to unify the policies. Many societies and have their own code, but generally they are similar. CDM uses their professional codes of ethics as a guide for setting standards of behavior within the firm. The ethical dilemma training offered by some professional societies is an example of organizational standards that help the consulting firm. The National Society of Professional Engineers has, in their monthly magazine, ethics case studies useful for learning and guidance.

4.3.4 Professional capabilities of employees

CDM's reputation was built in water and wastewater. The firm is known as a leader in water related environmental engineering, including water resources management, hazardous waste removal, and site remediation. However, the firm is building a reputation in construction, design/build, operations and information management systems especially in projects related to water treatment or infrastructure.

CDM is known for having highly skilled, senior professionals. There are more engineers of level 6 and above than there are under level 4. This encourages the firm's reputation for skillful listening and execution, since the employees have a great deal of experience. Senior employees mentor junior engineers, and the quality of all project work is carefully monitored by Quality Managers and Client Service Managers.

4.3.5 Competition

CDM operates in competitive industries. There is competition from both large firms and small, single consultant operations. Regional competition as well as global firms may bid on jobs.

Firms are encouraged to "combine forces" and subcontract or partner on jobs in order to get the right set of skills. CDM stresses the ability to work closely with another firm on one project while still bidding against them on others.

4.3.6 Technological Environment

Although the technological environment in which CDM operates is changing rapidly, CDM does not have dedicated research and development groups. CDM relies on employee knowledge of professions to bring new technology.

This requires that CDM have a close relationship with manufacturers. However, the company must be careful to stay "at arms length." (Martino, "Interview with William Howard - CDM Architecture Topics," 2006) In the current, post Big Dig ceiling collapse accident, "era of skepticism." (Martino, "Interview with William Howard - CDM

Architecture Topics,” 2006) The firm must avoid a perception of impropriety between its employees and technology manufacturers.

4.3.7 Projects

Mainstream projects for CDM include design work and construction projects related to water and wastewater projects. The traditional delivery process involves executing a design project and then taking the design out to bid for construction work by another firm. CDM is moving into design/build projects in which a single firm or partnership is responsible for both the design and construction. Design and building issues can be identified early, which saves time and money for the client on iteration.

CDM has four main selling divisions. The work in each division may vary, but some examples are:

- Public Sector
 - Water and wastewater projects including studies and design
 - Infrastructure rehabilitation
- Federal
 - Majority of work is investigation and remediation of contaminated property
 - Research for EPA to set regulations. An example: assistance with research on gas storage tanks
- International
 - Water and wastewater projects
 - Infrastructure building
- Private Sector
 - Hazardous waste compliance and clean up
 - Industrial waste minimization and treatment

CDM frequently executes studies, which may include regulatory compliance studies to make sure that clients know what regulations apply to them, and studies to evaluate sites for environmental impact assessment.

CDM's other fields of expertise:

- Information management and IT
 - GIS
 - Instrumentation and control systems for facilities
 - Customer service information management systems for utilities
- Water Resources studies
 - Flood analysis and storm water management
 - Integrated planning and management of water resources (water, storm water, wastewater)
 - Wetlands assessment
- Planning

- Permitting for construction projects
- Infrastructure rehabilitation
- Air Quality
 - Small sector with a big impact
 - Airport expansion air quality
- Management Consulting
 - Program management
 - Improving work processes of clients

4.4 Architecture

The architecture of the organization is the combination of its function, concept, processes and form.

4.4.1 Functions

Functions are the actions or transformations that enable the system to accomplish its goals.

4.4.1.1 Functions of the firm

In a business organization like CDM, functions exist on two levels: the operational functions at which the organization must excel to continue to offer its goods and services to its clients, i.e., hiring; and there are functions that are determined by long term strategic goals and at which the organization must strive, to provide in order to grow, i.e., growing the corporation's annual revenues.

In the case of the strategic functions, the implementation of the function may be less important to the survival of the system than completion of more basic functions. However, long-term growth of the system requires that strategic functions are well defined and that goals are attempted.

High level (strategic) functions

These functions map to the specific goals of the firm. In the case of the strategic functions from "Strategy 2008," the goals' intent is to grow the size of the organization to benefit both stockholders and employees.

- Growing the companies' annual revenues, more specifically:
 - Increasing solution services for public clients
 - Increasing sales revenue to industrial, federal, and international clients
 - Increasing construction revenues

Operational functions

- Nurturing client relationships

- Globally providing all services
- Hiring and staff retention
- Retaining self ownership

4.4.1.2 Are the functions achievable?

The strategic functions as listed above may or may not be achievable within the specified time frame. However, the firm's strength and stability are based on the repeated achievement of the generalized functions on a daily basis.

The goals specified in "Strategy 2008" were ambitious when stating multiples of revenue goals. Implementing the functions listed in section 4.4.1.1 would indicate the ability to ultimately achieve the goals, and would begin to grow the organization (which provides the desired growth benefit to the stockholders). Though, since the goals were stated with specific measurement levels that are highly ambitious, implementing the functions may not be enough to achieve each of the goals as stated.

4.4.2 Functional Decomposition

The image in Figure 1.1 shows the primary elements of structure within the firm. Each major group within the firm encompasses the list of functions and processes for which they are responsible. The functions listed in section 4.4.1.1 are combined into the major corporate processes that support them. Where processes are completed by the combined efforts of multiple groups, they are enclosed in an outer grouping rectangle that specifies the processes.

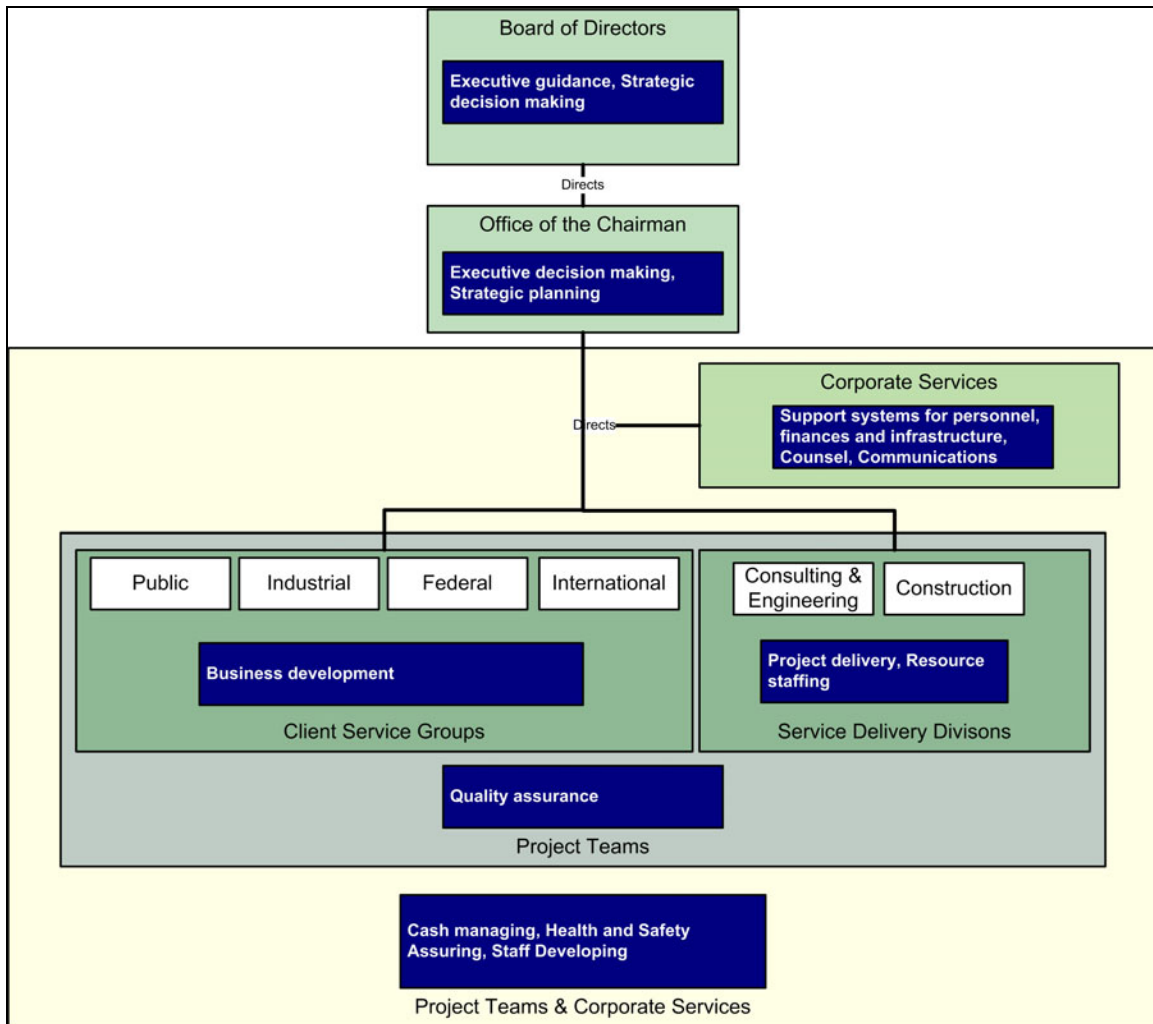


Figure 4.5: Functional decomposition of CDM

4.4.3 Concept and the Concept Definition Process

The concept of this organization is a “global consulting, engineering, construction and operations firm committed to exceptional client service to improve the environment and infrastructure”(CDM Corporate Communications, “About CDM: Values and Vision,” 2006; Martino, “Interview with Richard Fox,” 2006) This concept allows the firm to expand services and capabilities beyond the previously limiting concepts of “US based water engineering firm” and “environmental services provider” to incorporate any infrastructure projects anywhere in the world.

Strategically this concept is a logical outgrowth from the civil engineering structure on which the firm is based. Providing global infrastructure services takes advantage of

worldwide growth and enables CDM to operate efficiently in markets where US based water resources calculations would not be needed or cost effective.

It is challenging to the firm to create or acquire local offices in the region where work is needed. A matrix structure that enables project teams leveraging local rates to be competitive in global markets wins otherwise impossible contracts in places where labor rates are low but skill levels are high. CDM's policy of developing strong client relationships and making the CSM a trusted advisor to the client delivers value in any region of the world, and for any infrastructure related services CDM has the capability to deliver.

4.4.4 Form

4.4.4.1 Element Structure

The elements of the organization are the groups and the connections between them that combine to make up the firm.

Organization and jobs

- The corporation is headed by the Board of Directors who provides direction to the Office of the Chairman (OOCH) (see Figure 4.4 on page 49).
- Technostructure functions (as defined by Mintzberg and discussed in Section 3.1.1, page 20) and support staff are delivered by the Corporate Services groups, listed in Figure 4.6.

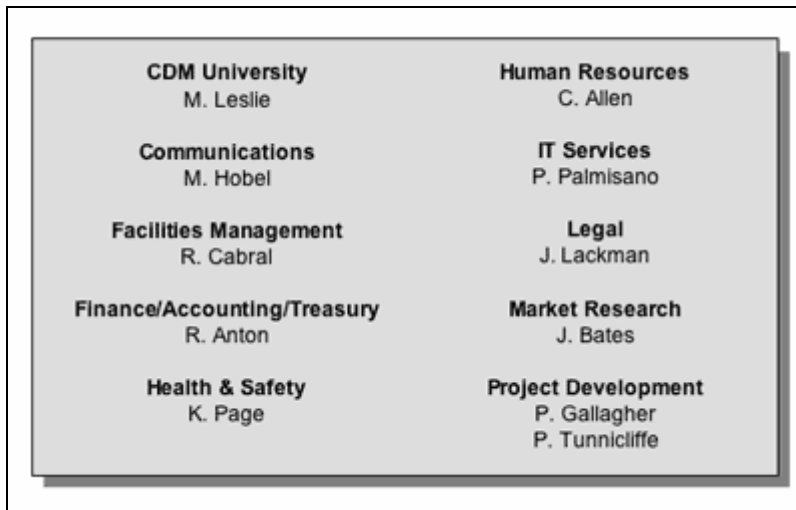


Figure 4.6: Corporate Services

Project opportunities are found and executed by two groups working together in a matrix structure, as illustrated in Figure 4.7:

- The Client Services Groups (CSG) completes client services and sales. CSG is organized into four service units: Public, Industrial, Federal and International
- Services are rendered by the service delivery divisions, consisting of the Consulting and Engineering Division (CED) and CDM Constructors Inc. (CCI).

CDM Inc., CDM Federal and CDM Constructors Inc.

The firm was previously divided into a number of smaller companies: CDM Inc., CDM Federal Programs Corp., and CDM Constructors Inc. The matrix organization integrates these firms, but there are a number of institutional barriers to this change.

At one time companies that worked on Federal projects had to keep their project information completely separate from CDM employees working on other consulting projects, because of different overhead and other billing rates, and to avoid conflict of interest. All CDM Federal data was on separate systems, and each of the three companies had separate financial and project management systems as well as different processes.

Although the matrix structure and federal regulations changes have enabled centralized systems and processes, the changes take place slowly. At this time, there are still separate financial tracking systems for client data, financial tracking, and project performance evaluation.

This document will focus on CDM Inc. processes, systems and architectural elements, and it will assume that CDM Federal Inc. and CDM Constructors Inc. will continue to merge systems with CDM Inc.

Matrix

Client Services Group

Client Services Group is responsible for client relationship building, proposals, and project negotiations. Designed to “setup and win projects from clients,”(Martino, “Interview with Scott McClelland,” 2006) they are measured on their ability to win project contacts and complete projects to client satisfaction.

Construction and Engineering Divisions (CED)

The CED provides resources for project execution. The divisions consist of the pooled resources of engineers/technical experts and scientists (E/T/S) selected from the group to complete project teams. The structure is designed to provide geographic flexibility, but it does not always work out. Because E/T/S often work on more than one project at a time, they often cannot leave the region where they are working to go to another area, although the creation of virtual teams is becoming more common to enable remote work.

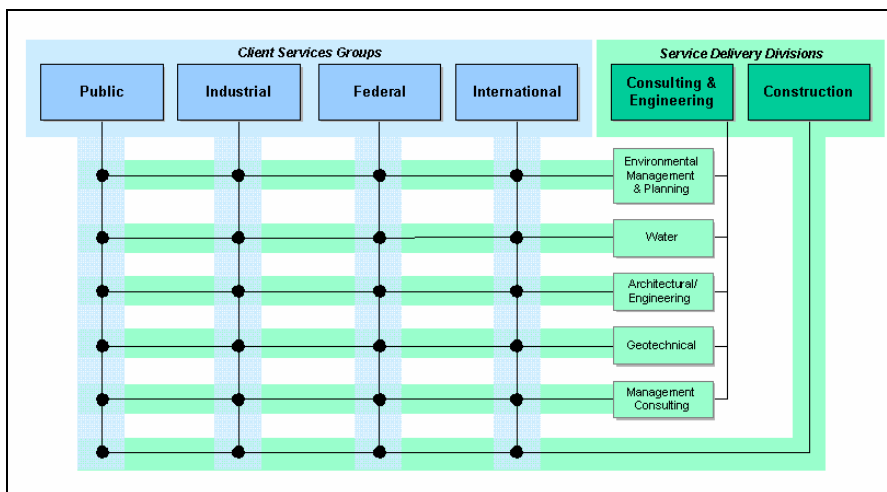


Figure 4.7: Matrix structure of CDM

Chart from the CDM intranet (Corporate Communications, 2006).

The matrix structure was implemented company wide in 2004. The reorganization represented a significant change from the previous regional structure. Under the regional structure, projects benefited the local office. The more work won in a region, the larger the office technical staff became, which led to specialization in offices and competition between offices, which were effectively small businesses within the firm. The matrix structure changed that, so that employees from anywhere in the firm may be assigned to a project. When a CSM signs a contract with a local client, E/T/S staff from any location within the organization may be assigned to execute the project. This change has been grounds for some conflict, and has caused a few people to leave the firm.

4.4.4.2 Disciplines

The discipline groups consist of 19 coordination groups for employee communication of expertise. They are composed of employees interested a single technical or administrative discipline (employees may enroll in as many Disciplines as they wish). Each Discipline is broken down into a number of (1-20) sub disciplines, which can be narrowly defined. In a “matrixed” firm, where an employee may be the only member of their discipline assigned to a project, the groups provide a convenient method for sharing of technology, techniques, and resources between members of the same discipline.

The discipline web site is a portal site that functions as a collaboration platform for the groups. Each discipline “page” on the site has a library, discussion forum, event calendar, feature article section, and RSS feed. The content of the site is created and populated directly by members of the discipline, and subsequently managed by the leaders of the discipline and sub disciplines. Some of the sites are highly utilized by active communities.

4.4.4.3 Roles

Eligible employees have roles designated in Corporate HR software. The roles are managed by HR and the CTO’s office, and are used by IT systems for filtering people assigned to project roles in project management software. They are typically equivalent to project team roles, as shown in this sample list:

- AM – Area Manager

The Area Manager is responsible for ensuring that the project has the resources necessary to complete the project to the satisfaction of the client, and profitably for CDM. It is an oversight role, which confirms schedule and cost, as well as smoothing access to resources.

- CSM – Client Services Manager (or Client Officer CO)

CSMs “sell” services from all the CED groups. CSMs are typically engineers who have shown a propensity for client relationships in addition to their technical excellence. They have a background in a specific discipline, but must now represent all engineering and

technical capabilities offered by the firm. Corporate communications, Discipline groups, and Group Leaders are called upon to assist CSMs as they represent techniques with which they may not be personally familiar.

- PMX – Project Manager at levels X=1,2,3,4

The PM's responsibilities include scoping projects, getting the right resources for the project at the most cost effective levels from CED, and managing project execution. Twenty-one classes and tests are required to achieve the rank of PM1. The highest level expert Project Manager at CDM is a PM4, who spends much of his/her time managing programs and training new PMs.

- QM

A single employee in each business unit fills the QM role, with responsibility for ensuring that all Quality Management procedures are followed on every project. QMs form a group of highly expert engineers with training in quality management and CDM QMP.

However, some roles are equivalent to corporate titles:

- VP - Vice President
- Pres - President
- CEO – Chief Executive Officer

The above roles determine user privileges in CDM custom applications. Project roles, such as Project Manager, can only be held by employees who have completed the mandatory PM training at CDMU. Divisional or Area Managers must confer other roles upon the employees.

4.4.4.4 Corporate Services

The corporate services groups include technical and support staffs, who typically address enterprise related issues and concepts. The majority of their work is not project related, but provides infrastructure services that support all projects and project related efforts.

On occasion, members of administrative groups participate in project work. An example: A writer from Corporate Communications recently worked on a master planning effort for Peachtree deKalb International Airport, where project stakeholder involvement is crucial. It required his skills at creating stakeholder communications in the form of newsletters to community leaders, and a project web site.

Corporate Communications

Corporate Communications consists of writers and graphic artists who provide public relations, marketing materials, and internal company communications. They manage the company internet site and all marketing brochures and publicity for the firm.

Office of the General Counsel (OGC)

The OGC is responsible for managing company liability and exposure. This group consists of lawyers with expertise in civil infrastructure contracts and litigation.

Human Resources

Human Resources is responsible for staff retention, benefits, and assistance with staffing. The HR group works with managers throughout the firm to find talented staff at both experienced and recent graduate levels. The group manages all company benefits, including employee medical and dental insurance programs, and employee reimbursement accounts for personal and family related expenses.

Information Technology

The IT department provides computers, data and voice networks, and administrative software systems to the organization. New projects within IT are evaluated and approved by the “6 Chiefs” Committee, which acts as the management committee for the department. Members of this committee are the CAO, CIO CTO, CFO, and two Executive Vice Presidents, who meet quarterly to set priorities, budgets, and identify which projects to pursue.

CDM University (CDMU)

CDMU provides a number of essential communications tasks for the firm. They offer three schools of training sessions classes, both live and online. The Business School trains project managers and other project leaders to perform their roles the “CDM way. An employee cannot be a PM or PL without the required number of classes to earn training certification from CDMU. The Technical School offers specific technical courses for staff requesting additional training. Field personnel often ask the Technical School for training in up and coming new technologies from CDMU’s Personal Development School provides training for individual growth within the company, and for ethics and sexual harassment training sessions required annually for all employees. All employee training records are maintained in a Learning Management System (LMS), which reports on compulsory training attendance to supervisors and managers.

Finance/Accounting/Treasury

The Finance/Accounting/Treasury departments manage CDM’s finances and investments. This includes tracking project payment, accounts payable, and all other money related aspects of CDM. The work is accomplished using Oracle Financials, Oracle HR, and interfaces to financial service providers.

Facilities Management

The Facilities Management group ensures that CDM’s numerous offices and project trailers are operational. This group provides services to most CDM divisions and business units.

Health & Safety

The Health and Safety provides guidelines and training services to all company units and divisions, and reviews the plans of all projects that require employees to be on site.

4.4.4.5 Centers of Excellence

Centers of Excellence is a recently developed CDM concept intended to provide knowledge repositories and pooled resources that “minimize wheel reinvention” (Martino, “Interview with William Howard - CDM Architecture Topics,” 2006). Two new Design/Build Centers, large, well-equipped design spaces, will enable teams to collaborate effectively and share information as their projects progress. The Discipline portal is a Microsoft Sharepoint based solution structured to facilitate technical disciplinary communications and knowledge sharing. Document libraries in the portal provide universal access to relevant “Go-Bys,” standards, and the Quality Management Process documentation. Forums, announcements, and email lists provide intra-discipline communications to employees with a single discipline or subdiscipline, but may be disconnected from others geographically, or because they work on different projects.

4.4.5 Processes

As James Champy stated in an interview, you must “design processes to fix what the structure doesn’t do”(Martino, “Interview with James Champy ,” 2006). Overall, this firm requires eight main processes to run the business (there are two subdivisions of staffing, which is shown twice on the chart below). These include project delivery processes and corporate services, as shown in Figure 4.8. The chart’s background is divided into the three major organizational divisions, and processes are shown overlapping divisions that contribute to process completion.

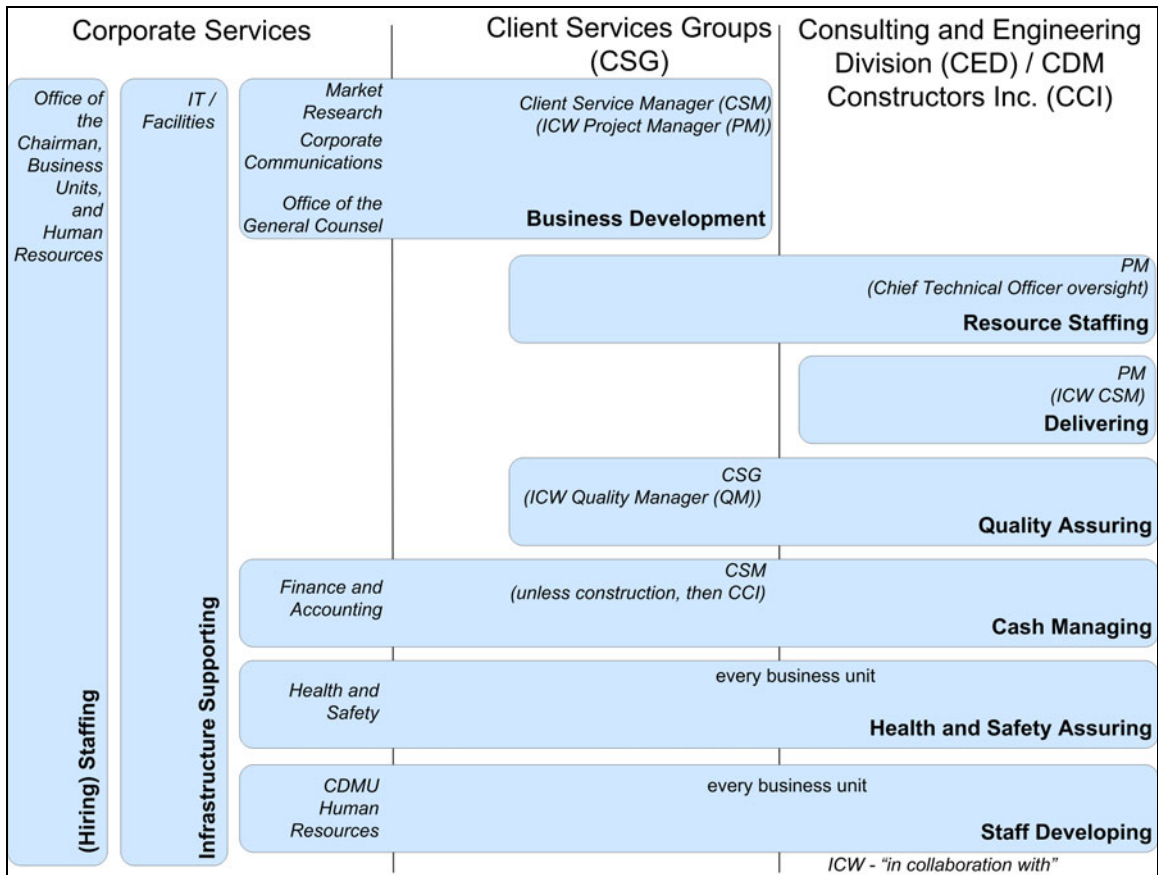


Figure 4.8: Major business processes of CDM Inc.

The firm’s business is to repeatedly execute profitable projects that meet regulations and professional standards, and satisfy CDM’s clients. The organization has created a number of procedures and guidelines, which the CSM and PM must use during business development and project completion. They are documented in the “Quality Management Process Manual No.1” (QMP-1) (Chief Technology Officer, 2004). The major elements are shown in Figure 4.9.

CDM’s work has no single formalized methodology because the project work is customized for every contract. Nevertheless, there are knowledge management initiatives, best practices documents, Quality Management guidelines and design centers that provide the structure for sharing lessons learned on previous projects. The Discipline web site attempts to provide a portal structure for knowledge sharing between members of a single discipline and sub discipline, and to create a network of professionals with similar skills who can benefit from others’ experience.

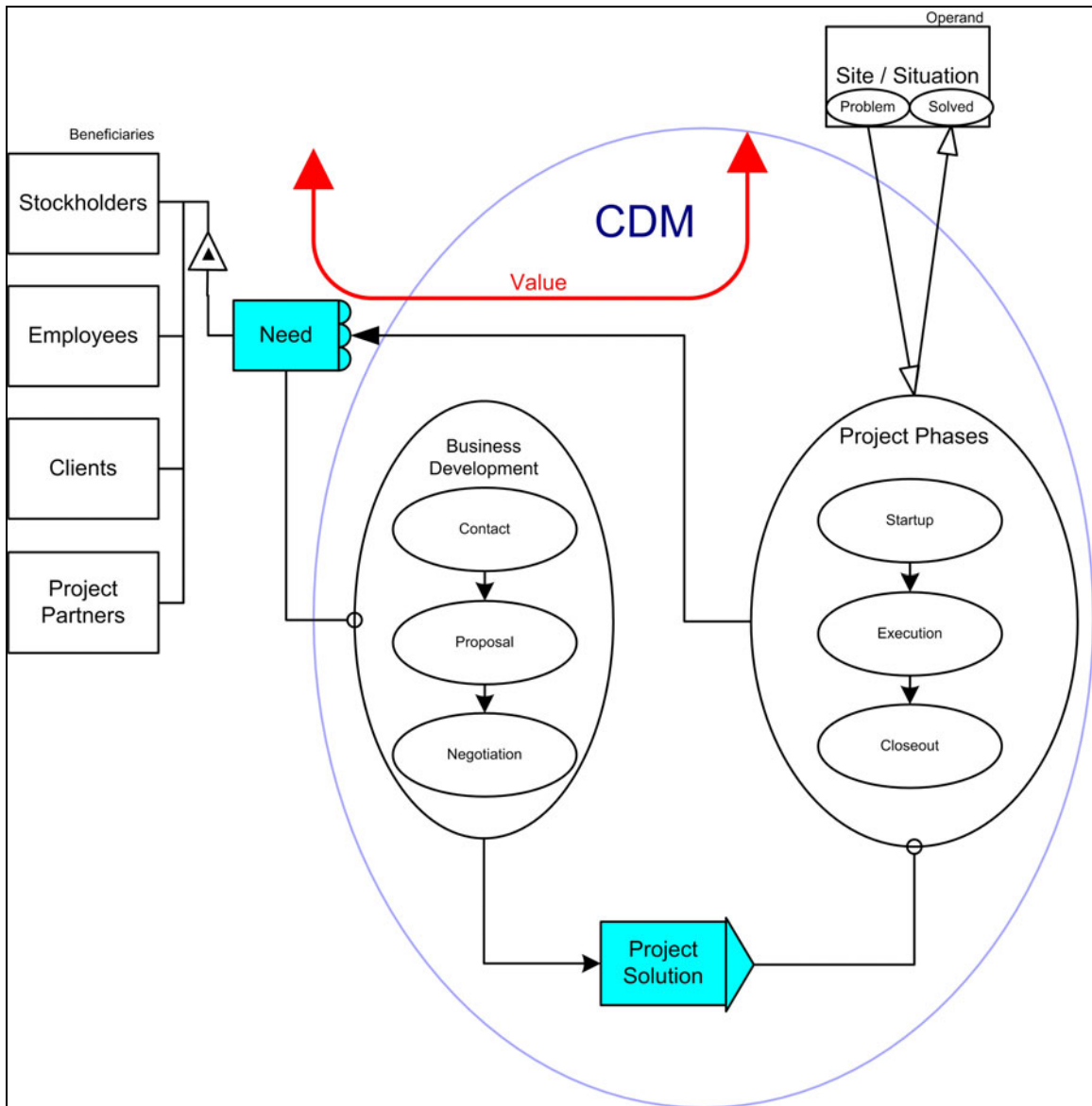


Figure 4.9: Design project process sub-processes

4.4.6 Business Development

At CDM, selling is more about relationship building than getting contracts signed. The Client Services group is rewarded for bringing in large contracts, but it is acknowledged that the satisfaction of a client on a small job brings work back to CDM in the long run. The Client Services Manager (CSM) is responsible for activities and client communications throughout the project.

Figure 4.10 shows a zoom into the Business Development process, which includes the internal sub-processes. The corporate systems of Oracle Client Relationship Management

Software (CRMS) and Timberline Estimating software are tools used outside the process to share information and support various sub-processes. The number of connecting arrows showing interactions running both ways between the processes in this phase of the project shows how tightly integrated every step of this part of the process is.

The CDMWins Session consists of a number of closely integrated tasks. As shown in the DSM matrix (Figure 4.14) on page 74, these tasks are almost entirely dependent on one another for information. For this reason, at a CDMWins session, a team of key project players evaluates information related to the project at one setting. Preparation for the session starts well in advance of the RFP. Important decisions are made at the meeting, e from Go/Stop determination of whether CDM will pursue the job at all, to scope, schedule, staffing, and Health and Safety coordination definitions to be used for the project proposal.

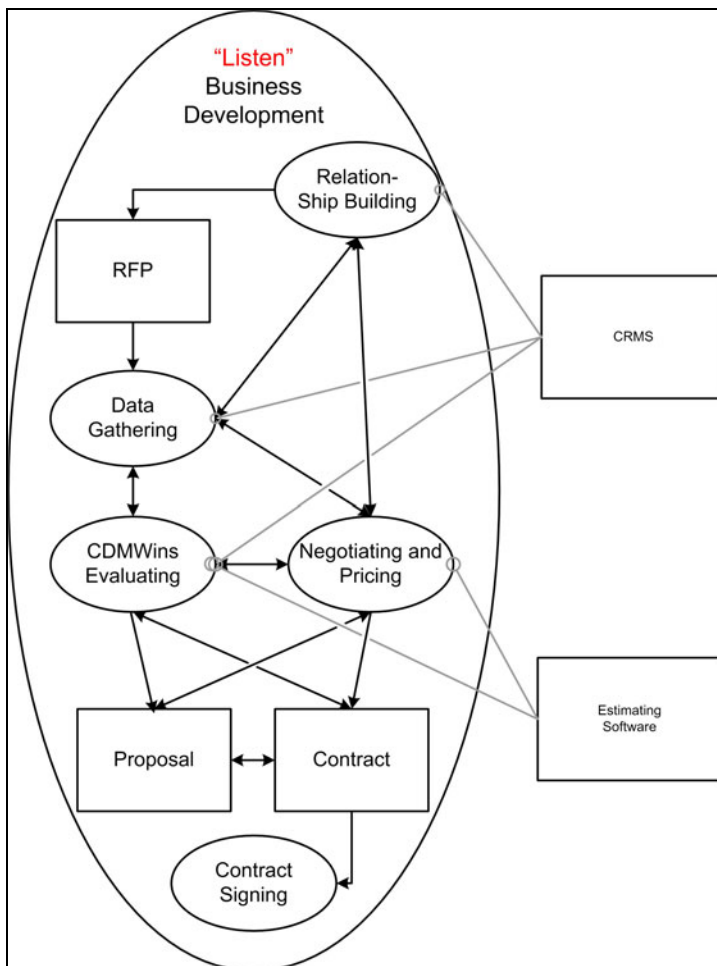


Figure 4.10: Business Development processes and client service value delivery

4.4.6.1 Project Startup

In the project startup phase, contracts have been signed, and people are beginning to work on the project. At this point, the project has been handed off to the other side of the organization, the Consulting and Engineering Division (CED). There can be a “fuzzy line between the axes of the matrix” (Martino, “Interview with Scott McClelland,” 2006) meaning that occasionally there are PMs within the Client Services Groups who might manage the project. This stage consists of “getting people on board to flesh out the problem and talk about a solution”(Martino, “Interview with Bruce Conklin,” 2006).

The Electronic Project Management Plan (ePMP) application assists the PM with gathering and communicating the information required by the Project Management Plan, and getting the required approvals from the CSM, PM, and Quality Manager (QM), and any other that might possibly be required.. License servers ensure that software used on the project is properly licensed for use by CDM. The DSM has highlighted process and we can see there is some iteration necessary to complete it, but since many decisions were made back in the proposal’s CDMWins session, the processes are fairly straightforward.

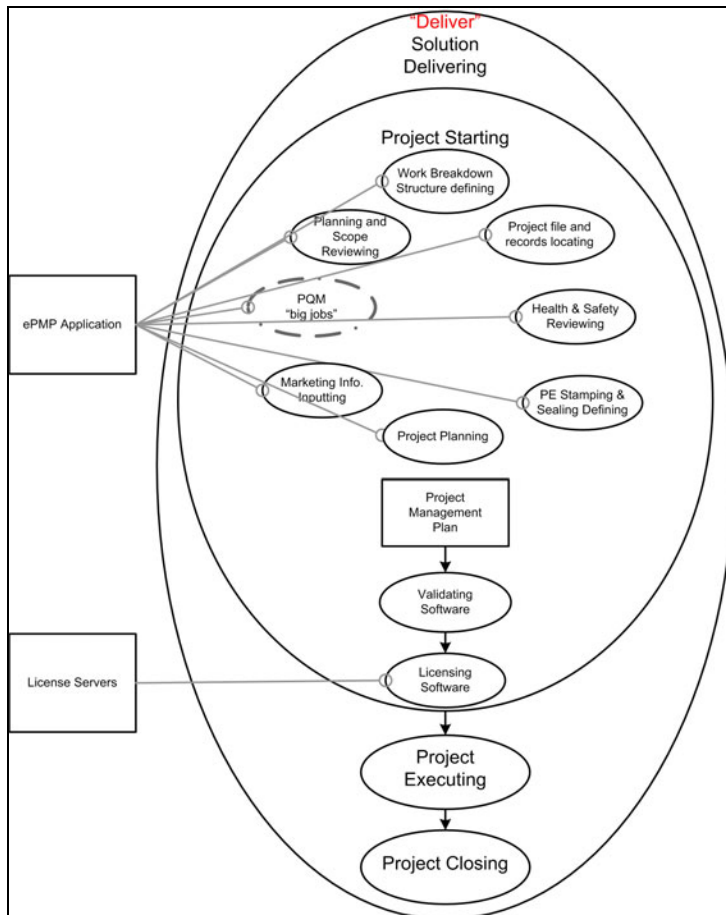


Figure 4.11: Project startup processes

4.4.6.2 Project Execution

Project execution entails all processes necessary to complete the project work and deliver the final product to the client, and consist of a number of sub-processes and elements which must be completed. However, not every process or element is necessary for every project. A project may not require Geotechnical work, Surveys or Construction Drawing if it is a Management Consulting engagement.

Project Execution is primarily directed by the PM, who manages daily activities of the E/T/S and subcontractors. Every project must comply with the Quality Management Plan (QMP-1 for all CDM Inc. projects except for construction), which requires the involvement of a number of other experts as listed below (Chief Technology Officer, 2004):

- The Client Service Manager (CSM), also referred to in some business units as the Client Officer (CO) (or the Manager of Client Service [MCS]), is responsible for “the long-term relationship between CDM and the clients assigned to him or her” (Chief Technology Officer, 2004 1-4). The CSM works with the PM to ensure that the project has appropriate resources, quality and schedule.
- Project Manager (PM) is responsible for the scope, quality and schedule of project delivery.
- Lead Practitioner (LP) is responsible for Quality Assurance (QA) in compliance with the appropriate QMP manual and the Project Quality Management (PQM) plan and to be an advisor, technical reviewer or technical or business mentor to the team.
- Quality Manager (QM) is a designated member of each business unit. He/she has the authority to declare a “time out” for a project and, if necessary, delay contract deliverables if QMP requirements have been breached. This decision is made by the QM after consultation with the Unit President (UP), Division Manager (DM), the Regional Manager (RGM), or the Area Manager.
- Technical Review Committee (TRC) is a committee created to review a project or an aspect of a project. The QM must approve this group.

This phase of the project is heavily supported by IT systems, which primarily enable reports on project status and tracking of project financials so project status and the communication of project progress may be reviewed internally. External communication with the client, and client reviews, are often simplified by the using eRoom to share project files and information.

Cash management is considered one of the eight basic business processes of CDM and is crucial to ensuring payment for services rendered by the firm. Expenses related to project work are generally captured in Oracle Financials. Labor expenses come from the custom Timesheets application. Clients are particular about the way their invoices are submitted, so CDM provides a custom solution named Client Invoicing that allows the creation of specific billing formats to support every client need.

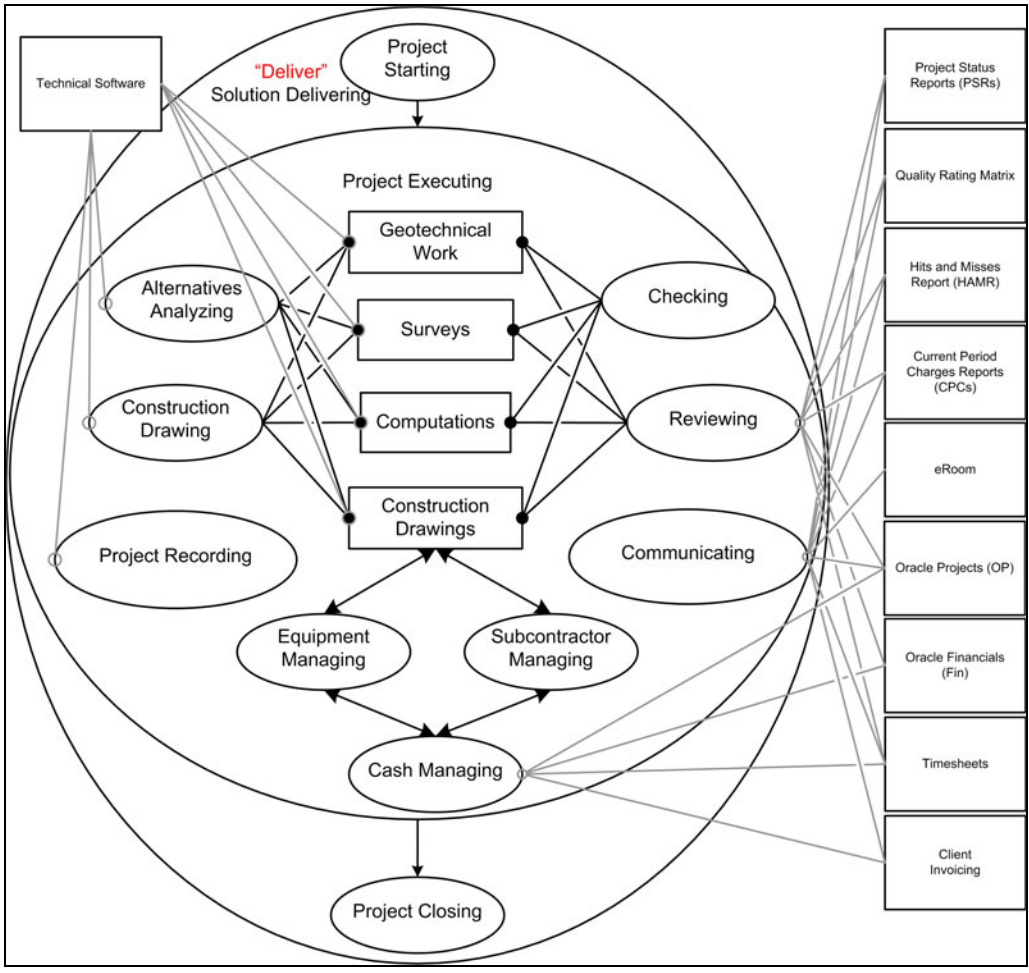


Figure 4.12: Project delivery execution phase processes

4.4.6.3 Project Closeout

Project Closeout is as important as Startup or Execution, but is often an overlooked procedure. All information related to the project must be archived by the PM and a project closeout form must be completed using the eCloseout application.

eCloseout aggregates information from previous phases of the project in order to simplify the closeout process. Document management within the application allows inclusion of project documents directly into the form. The InfoCenter librarians approve the form and are able to archive the project documents from this input.

The eCloseout also provides a mechanism for notifying OUCH that the project is complete and a Client Satisfaction Survey Questionnaire (CSSQ) may be sent for client feedback on the project. Marketing information is also gathered, some of it through eCloseout, information necessary for leveraging the knowledge gained on the project by finding future work of the same type.

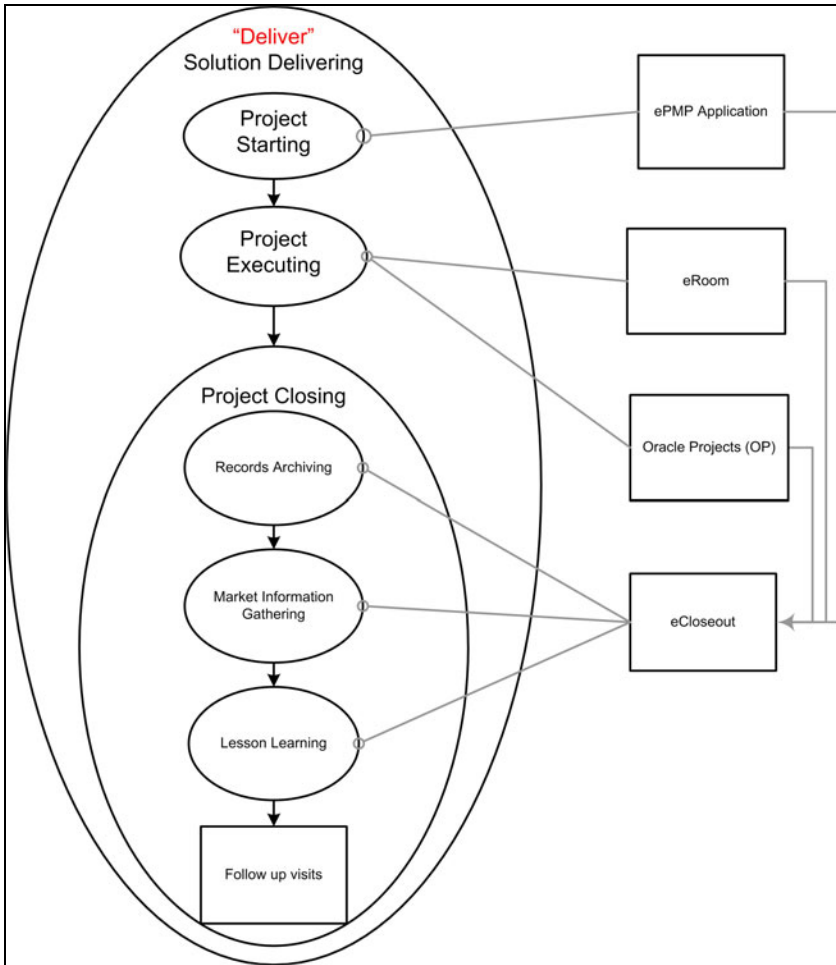


Figure 4.13: Project closeout phase processes and elements

4.4.6.4 Project Overview

The Design Structure Matrix (DSM) of Figure 4.14 shows each major task associated with the standard procedures of the QMP-1. The matrix shows the level of iteration necessary during the Business Development phase and again in the Project Execution phase. In Business Development, this issue has been identified and the CDMWins Session is required (or must be waived) to ensure information for each task is available.

In the Project Execution phase, the level of communication between all members of the project is very high. The tasks with the most iteration are the project activities of Geotechnical work, Surveys, Computations, and Alternatives Analysis; assuming that there may be rework required in the early tasks if the results indicate changes in the project alternatives. The same tasks may have to be reworked depending on findings during Reviewing, Checking, Equipment and Subcontractor Management, or Communications, however, the above are ongoing efforts, and their purpose is to flag needed rework early, so this indicates they are effective tasks.

Many tasks in the project feed information back to Relationship Building in a “generational loop”(Martino, “Meeting with Ed Crawley,” 2006). This information about project process and success will provide feedback to the client and to the CSM, and will provide the basis of the decision whether or not to work together again in the future on similar or different projects. It is an important process and must be carefully managed by the CSM.

Along the diagonal of this matrix, each task shows the name of an information system. This information is used to track in the information created by that task, or to facilitate the completion of the task.

4.5 Technology

4.5.1 Client Services Technology platforms

For a manufacturing oriented business, in which the return is based on the volume of product sold, great benefit is derived from standardizing on technology platforms. In a custom solution business like CDM, the investment in building each application is paid for by the client, and, in many cases, the client will support the solution after implementation. The incentive is not to standardize, but to provide the client with the best possible technologies for their particular application.

Still, there is also benefit to be had from the specialized knowledge related to certain methodologies and technologies. CDM has experts in a number of processes, people who leverage their expertise by consulting with the client to find the best specific solution to meet the client's needs.

CDM project work includes many types of technologies. They vary from alternative disinfection approaches like chloramines or ultraviolet light, trenchless technologies, which help install or rehabilitate underground water infrastructures without surface disruption, to integrated membrane solutions, which can convert brackish groundwater into safe drinking water. CDM also does much work providing information management systems to clients, frequently building custom integrated GIS and SCADA systems for facilities or municipality management.

Because of the variation in project types and clients, there is little overall platform definition.

4.5.2 Supporting technologies

The company's internal IT department consists of approximately 70 employees. IT is responsible for the design, implementation, management, and maintenance of all enterprise information services. This includes Management Information Systems (MIS), Infrastructure (Voice, Data, Hardware, Messaging, and Security), Collaborative Applications, and Desktop support.

Reporting to the CAO, and at one time focused on supporting the accounting department in their need to track financial data, Information Technology at CDM has been driven, over the last 14 years, by the need to provide the Project Manager with communications and tools for tracking project information and financials.

As the technical infrastructure has grown, a concerted effort has been made to keep the technical architecture of the firm simple and based on long term providers. Each desktop and laptop computer runs a standard version of the Microsoft Windows operating system (at this time the version is XP sp2). The department, as well, has always used LAN technologies that are closely aligned with Microsoft. The servers are either Microsoft server technologies (2003 servers), HP-UX (which is being phased out) or Linux. For this reason the IT infrastructure of the firm has remained relatively simple compared with the competition. Over the last few years, though, the number of servers, software applications, and new network communications mechanisms has driven the IT

infrastructure to deeper complexity. A network upgrade in 2005 increased network bandwidth and has enabled communications services like remote meeting, instant messaging and large scale file sharing.

CDM's needs in project lifecycle management are very specific and cannot be met with off the shelf software. Integration solutions have been built to report Oracle CRMS, Projects and Financials data, and to combine these data with custom software applications. A system of web applications has been designed and built to support planning from Business Development through Project Closeout and the final archiving of project documents.

The custom applications are built on a platform of Microsoft ASP.NET web development and communicate using web services whenever possible. Applications are delivered over the intranet to facilitate support and distribution of custom software. The web interface, and an adherence to a centralized repository for data, ensures that all project information can be communicated and is never lost on a single user's system.

In order to continue to support ever larger project management initiatives, CDM is also building a Program Management Portal that will enable programs consisting of multiple projects to be managed and monitored from a single interface.

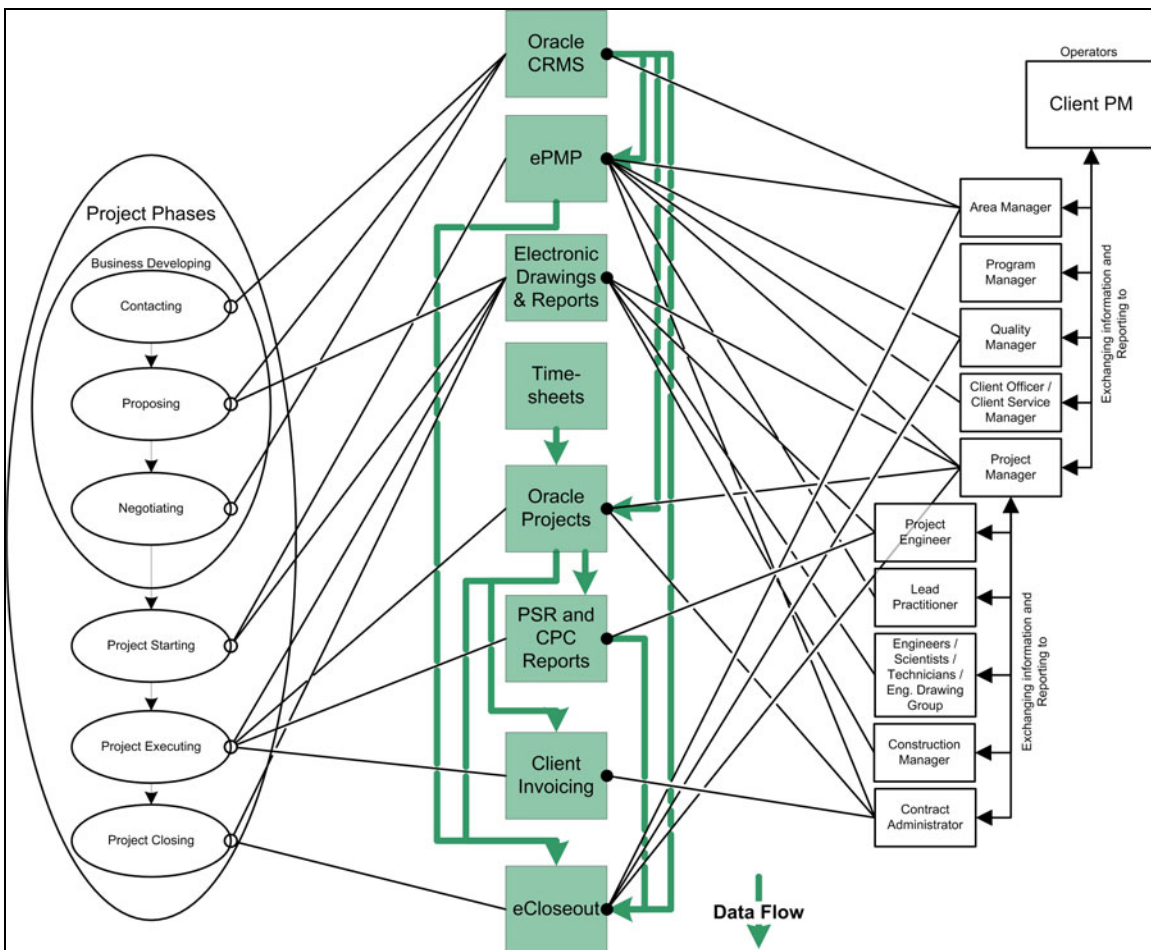


Figure 4.15: Data flow through IT systems during project delivery

4.5.3 Adoption of new technology

As a company of engineers and scientists, CDM employees are generally receptive to new technologies. However, change and progress can be difficult in an industry like civil infrastructure. Solutions are constrained by regulation and the very expensive risk of failure, which forces conservative solutions for all similar problems, when in fact the needs of the client may be very different.

Also, new technologies and processes are inherently riskier to project, schedule, and budget than known techniques. In order to use them, the client, the PM and the CSM must all agree that the risks are outweighed by the benefits when implementing a new system. The client must also be willing to share the risks with CDM to create an environment of collaboration.

4.5.4 Innovations

In the United States (US), a number of forces are contrary to innovation. Firms struggle to learn in a litigious society, where documentation of lessons learned can be used against the organization in court proceedings. (Martino, "Interview with William Howard - Communication of Innovative Ideas," 2006) Regulations limit the options in a number of engineering disciplines, forcing compliance through repeat use of existing technologies. (Martino, "Interview with Richard Fox," 2006) Although the firm solicits "Bright Ideas" through a corporate intranet web site, innovations in process and standardization are most likely to be implemented in this environment.

In its early years, CDM was known as a company of very bright, somewhat undisciplined engineers with innovative ideas, who were far ahead of the competition. The current company still depends on many bright engineers and other technical specialists, but their work is more likely to follow corporate and professional standards. As the firm's services have expanded, innovators are bringing new business opportunities into CDM from other disciplines like Management Consulting and Facilities Management.

4.6 Regulation

4.6.1 Regulation

Regulation is a big driver for the civil infrastructure industry in which CDM operates. Many treatment plant projects are necessary to bring older systems into compliance with updated laws. Often clients are under consent decree to complete mandated updates and rehabilitation. The downside is that clients are often "poor cities pounded by regulations into spending money on waste water treatment that no one sees. These projects are not politically popular." (Martino, "Interview with William Howard - Professional Societies and Regulation," 2006)

This is especially true in the northeastern US, where populations are not growing rapidly. States like California are more likely to expand their treatment plants due to an increase in population. The projects are more likely to be widely supported, both politically, and by the ratepayers in the community. CDM will work to find the right way for a community to reach compliance.

4.6.2 Standards

4.6.2.1 CDM Guidelines

Standards provide guidelines to employees while performing tasks and processes. They are well documented at CDM.

- Quality Management Process (QMP) manuals are accessible on the intranet in four versions, which vary depending on the nature of the project.
- Role specific standards documents are also available for key project player roles (CSM, PM, LP, QM). The documents outline team members' responsibilities and tasks. Also, the employees eligible to fulfill these roles must undergo standard CDM University (CDMU) training and certification in addition to their professional accreditations.
- Standard project sessions, like the PQM and CDMWins, have guidelines and forms that simplify data gathering and reporting as well as processes with facilitators trained to provide guidance.
- Every employee receives compulsory annual training in the ethical standards of the firm through CDMU.
- Each of the 19 technical discipline groups in the company have their own Discipline Portal, where they are free to post the standards and specifications pertaining to their field.

4.6.2.2 CDM Standards of behavior

CDM uses the professional codes of ethics from professional organizations as a guide for CDM's engineers/technical personnel and scientists' standards of behavior, primary benefits CDM derives from professional organizations. Compliance with the standards is important to the engineering profession and to public safety.

It can be difficult to establish behavioral standards that comply with laws, because they vary between countries and even between states. Professional Societies and Boards of Regulation for the profession set the bar on ethical behavior and provide training. The National Society of Professional Engineers has examples of ethical dilemmas related to conflict of interest, which clarify the engineering firm's responsibility to clients and employees.

4.6.3 Liability

CDM faces a number of types of liability including general liability, which is related to the risks of running any business with facilities and employees, and professional liability, which is negligence or gross negligence related to the professional work of the firm.

Negligence is the area where a firm like CDM has most of its exposure. Design and design/build projects can run into problems during the build phase, and when other contractors find issues they contend were caused by the work of CDM. At this point, the client might sue CDM for damages. In a typical design project, the firm may provide

500-700 drawings and approximately 2000 pages of specifications for a water treatment plant. There is a degree of error inherent in a work of that size that cannot be avoided; however, CDM is liable for damages caused by large errors.

Gross negligence is dire and would be very detrimental to the firm's future work. Gross negligence means the engineers on the project knew of errors in the work and left them in intentionally. The damage to the reputation of a firm which committed gross negligence would potentially be more damaging than the cost of a lawsuit.

The Office of the General Counsel (OGC) must review each contract, over a certain amount of money, signed by CDM. This is true of contracts with clients, subcontractors, and vendors. CDM's liability and that of other signing parties must be specified in the contract. CDM's work on infrastructure projects relating to hazardous waste, wastewater, water treatment, and other facilities brings many legal risks. CDM guards against potential liabilities through quality control via checking and validation, and contractual limitations on liability.

4.7 Legacy, Reuse and Supply Chain Issues

4.7.1 Company History and Legacy

Camp Dresser and McKee Inc. is a consulting, engineering, construction, and operations firm established in Cambridge, Massachusetts. A commitment to quality and integrity has built strong client relationships and grown the company from a three-engineer firm in 1947 into a worldwide corporation with 3,800 employees in the fall of 2006.

Founded as the a partnership of Thomas R. Camp, Herman G. Dresser, and Jack E. McKee, the company built a reputation as an engineering practice specializing in water supply and water pollution control. Since the 1960's, CDM has expanded geographically in domestic and international markets. Beginning in the 1980's, the firm diversified into hazardous waste management. Full service capabilities for design-build and construction now combine with CDM's expertise in other scientific, engineering, and management consulting services including the fields of transportation, operations, information management, and geotechnical services.

CDM operates within the Environmental Services and Construction industries markets worldwide. An initial innovator in water-treatment, the firm is differentiated from its large and small rivals by an excellent reputation for service. Projects range in size from small studies and reports for a few thousand dollars, to a wastewater treatment infrastructure redesign, to program management for all projects in a municipality. CDM is configured to handle thousands of projects worldwide each year.

The current architecture of this firm could facilitate a change from civil infrastructure to another identify if that were necessary. The matrix structure means that the Client Services Groups would begin to represent the new identity and the correct staff would be pulled from the Service Delivery Divisions for other types of project work. However, this would only work if the employee stockholders and other employees of the firm understood the need for, and the objectives of the change. Without complete support of

the employees, a company with such close ties between the customer and the employee resources would not change successfully.

4.7.2 Reuse

4.7.2.1 Knowledge Management

In a professional services firm like CDM, where the client's needs drive custom solutions, there is little "platform reuse," but at CDM there are existing systems and projects underway to provide knowledge management systems that facilitate knowledge reuse, especially related to techniques and processes.

An Electronic Document Management System (EDMS) to support all electronic project files and those that can be scanned is currently under development. Some of the challenges to this project relate to the difficulty of understanding the differences between electronic files and paper. Electronic files have little need to be identified by location, unlike paper, which is primarily identified by location in a traditional filing system. Still, in order to find the necessary documents in an EDMS, they must have thorough metadata libraries, which are difficult to enter and maintain.

CDM systems that facilitate the sharing of institutional knowledge are the:

- InfoCenter web site, library search, and online databases
- Marketing Information Retrieval System (MIRS), which includes technical information about projects completed by CDM, as well as marketing materials
- Discipline Portals, which are populated with technical field specific resources, references and discussions

4.7.2.2 Acquisitions

The architecture of CDM has developed over time. The firm's goals, functions and form are quite specific. Adapting them to include another firm must begin with the most basic of the organizational constructs – the core values. Once they are understood, the architecture can be adapted to include the new firm in the existing organization. When CDM acquires a new firm, the integration process related to goals, functions, and form takes a long time, sometimes years. However, the integration of the people into the culture and values of CDM is viewed as important and proceeds quickly. If there was not an initial culture match between the firms, they would not have been drawn together for the acquisition.

4.8 Platform Alignment

4.8.1 Services Delivery

The matrix structure of the firm is a platform that enables the organization to flexibly respond to changing project types and locations. It also allows the firm to create design centers, which serve project and clients in any geographical region from a centralized location with specialized tools, equipment and staff.

Process standardization in the form of the QMP manuals, professional standards, and discipline best practices provides a platform for project execution. Although the CTO, Lead Practitioners, and Discipline Leaders are careful to stress that the guidelines do not enable untrained staff to execute work, these guidelines ensure that staff use methods which are most likely to lead to quality work.

4.8.2 Knowledge Reuse

Most project work documentation and files are sent to archives for storage during project closeout. This represents a lost opportunity for any employee to reference previous projects to leverage their work and findings. The company is currently working to design a corporate Electronic Document Management System (EDMS), which provides relevant technical and process information from previous projects using search functionality.

4.8.3 Technology Platform

It was previously discussed that project work may be executed using the best technology for the specific application. However there is some expertise in certain areas, including software and techniques designed by CDM employees. CDM's industry leadership in these technologies provides a platform for executing projects and an opportunity to train other professionals in their use.

4.8.4 Information Technology Platform

CDM's IT structure is based almost entirely on platforms. This 70-person group must support over 4000 computers and 150 servers in nearly 100 offices worldwide, and software systems that provide company financial and project management support. Standardization of equipment and software simplifies support and enables rapid response when changes are necessary across multiple systems.

4.9 Lifecycle Plans

All phases of the lifespan of a system should be considered in the architecture. In the case of a client service organization, we are looking to see if the firm's architecture is robust enough to support each of these phases. The phases span the past, the present, and future of the company.

4.9.1 Design

This organization was designed based on core values and high level goals. In order to respond to changing global needs and opportunities, the company must also undergo regular reorganizations to meet strategic goals. These "reorgs" redesign the architecture of client service delivery.

Reorgs can be difficult for all units of the firm. Reporting structures change for employees in client services groups. Sometimes responsibilities and processes change as well, while, at the same time, the technostructure and administrative support units of the firm must alter their analysis, reporting, and monitoring systems to reflect the changed architectures.

To mitigate the impact of these reorganizations, the matrix structure of the firm is expected to allow senior management to modify and improve delivery of some services and capabilities without having a great impact on others.(Martino, “Interview with William Howard - CDM Architecture Topics,” 2006)

4.9.2 Operations and Support

This firm has had a proven ability to deliver services to clients to the benefit of stakeholders for nearly 60 years.

Support and operations groups are Corporate Services and are managed by the CAO. They ensure that primary system functions are maintained. Emergency contingency plans are in place to enable the organization to provide basic services and operations (accounting, communications) under most foreseeable circumstances.

The support and operations groups require different project and skill sets than CSG or CED. In general, they require processes which must be predictably repeatable. The work of CSG and CED groups require more flexibility in delivery in order to support changing client needs. Corporate service work provides a different kind of job satisfaction from knowing that internal clients are well supported, and enabled to support their external clients to the best of their abilities.

4.9.3 Change and Implementation

Alterations in organizational design often require changes to structures and processes within the firm in order to provide functions which meet updated goals.

At CDM, the execution of these changes can sometimes be problematic. An example: Implementation of the matrix structure caused a dramatic change to the corporate environment for members of CSG and CED. Another example: The increase in high bandwidth communications across the firm’s networks, necessitated by the matrix structure when members of a project team are communicating across distances instead of in the same office. Supporting this change required an expensive and risky network upgrade.

Implementation and operation are important considerations in a long lived organization like a client services consulting engineering firm. Without commitments to provide resources for the changes, and functions made necessary by organizational goals, they will not be achievable.

4.10 Architecture and Interface control plan

An organizational system is driven to change by both internal and external factors. The architecture of the organization must be responsive to change instigated by any opportunity, be it technical or business based.

Since the elements of the firm are business units, the firm’s interfaces are the borders between these units. The success of the business’s response to changes in architecture is based on the ability to communicate the purpose and objectives of the new goals to all the business units.

4.10.1 Control of architecture

The strategic apex, consisting of the Board of Directors, and the Management Committee of OUCH and the six Unit Presidents (four CSG, CED and CCI) defines CDM's goals and functions.

The goals are defined to achieve the basic mission; solving the client's needs while covering costs and delivering a profit. The objective of strategic decision-making is to balance acceptable risk with profit in opportunity and to balance the motives of the business (growth in changing markets) with the trust of clients.

The overall market of the firm is worldwide infrastructure services, for the most part public, but also private. Current strategies, defined in Strategy 2008, focus more on positioning the firm for the future than on specific markets.

To control the success of its strategies, CDM is implementing two-year re-evaluations of long-term strategic goals based on the results of annual business plans from the six units.

4.10.2 Corporate Interfaces

Corporate interfaces are bridged by the high level liaison devices, which communicate system functions as determined by the strategic apex based on the goals.

4.10.2.1 Initiative Champions

Each of the fundamental initiatives defined by the strategic goals has an Initiative Champion (IC). The ICs are responsible for the success of their goals. Progress is reviewed annually both individually and as a group.

IC's tools are the units or groups within which they operate. ICs are leaders (some Unit Presidents) within their groups, with management capabilities to implement the required functional changes to meet their goals. Success is measured based on the unit group's business plan performance.

4.10.2.2 Corporate Communications

Corporate Communications (CC) often communicates strategic initiatives within the company. CC does this using a number of different techniques.

Internal Communications:

30-40% of CC's work is internal communications. Brochures like "Strategy 2008" provide information about long-term goals and plans. Intranet web sites and HTML emails are often used to direct information related to corporate programs to employees.

External Communications:

About 60% of CC's work is external position and branding. CC defines and manages the company brand and creates "marketing communications," but not proposals. The group provides positive visibility outside the firm, particularly with the buyer and potential buyers of the company's consulting, engineering, construction, and operations (CECO) capabilities.

CC also helps support marketing strategy and direction by using press releases, internet web site case studies, and the CDMNews newsletter to showcase strategic initiatives and demonstrate company expertise. CC develops strategic communications where there is an identified need, perhaps defined by an initiative champion. CC works with the champion and CSMs or COs, if necessary. The group finds a solution and then works to create a brochure or an HTML eNewsletter that communicates the strategy. The work is often tied in with a conference presentation and an article about the project in CDMNews, and on the web site as a case study.

The company's organizational matrix can create difficulties with this procedure. Client Services (CS) knows the clients and what they need. When they need expertise, they contact technical experts in CED. For an outstanding technology, the CED experts might think that a brochure is necessary; however, the CS side must participate in the decision making process to help determine if there is a market for the technology or process. The technical expert is not aware of the marketability of technology.

CC uses a number of tools to accomplish the task of communicating a strategy. CDM is working to become a leader in Design/Build (d/b), so CC will write Press Releases about d/b projects, articles for CDMNews, and feature case studies and Viewpoint articles on the CDM.COM web site. Also, CC will participate in activities that showcase accomplishments and will convey the strategy with an externally facing brochure, advertising, and/or trade journal articles on the topic.

4.10.2.3 Company Intranet and Internet web sites

Intranet web sites

The intranet hosts such information as Technical and Administrative Career Paths, annual HR benefits selection, the HR jobs list, and Health & Wellness. The company intranet is a static internet site, which contains much old, out of date information that cannot be effectively managed in its current format. An ongoing initiative is attempting to find a technology platform that can address this need in the future. However, this project will also require significant changes to "harness business processes and authority to get good stuff in and good stuff out." (Martino, "Interview with Marlene Hobel," 2006)

Improving it would mean a fully functioning, well organized internal site, making CC more effective in communicating messages from OUCH, allowing improvements in the HR site, internal marketing sites and the Marketing Information Retrieval System (MIRS), which houses project summaries, technical capability information, and employee resumes, but contains information that is out of date and unreliable.

Internet web site

The CDM web site (<http://www.cdm.com>) was created and is managed by CC for both internal and external use. The site contains information appropriate for both audiences. Externally, the site is the "flagship marketing piece" (Martino, "Interview with Daryl Shepard," 2006) with the widest distribution of any marketing material. The site is crucial, establishing the CDM brand as a CECO firm that serves clients worldwide for potential clients and potential employees.

CDM.COM is used to position CDM as a unified, global company. There are no sections specific to any division, subsidiary, or geography. This is a CDM strategy, and it is as important for internal employees to know about it as it is for the external users of the site.

“The web site is becoming more known as a vehicle for marketing information.” (Martino, “Interview with Daryl Shepard,” 2006) Internally, employees are being educated to view the site as a viable marketing tool - inexpensive and fast. It shows qualifications of the firm and marketing information.

The site has received unsolicited feedback from magazine editors. Magazines have contacted the Webmaster with requests to feature relevant work in their publications. When this happens, CC may write an article or assist the magazine to write an article on a CDM project.

CC uses linkages between the newsletter CDMNews and CDM.COM to direct clients and potential partners to information about a particular topic, with the intention of driving existing clients to sites so they may learn about new devices, technology, or techniques.

4.11 Risk

The system architecture should be designed to mitigate risks. CDM faces a number of different types of risks, which are mitigated through quality controls and standards. These risks are managed through information sharing.

4.11.1 Legal liability

Legal liability is a risk on most client projects. Public projects often affect entire communities. Design project work can be problematic if the builder working from the designs runs over budget or schedule because of design caused delays. This may be considered negligence, and the client may sue the design firm to recover the damages. Legal liability is managed through careful review of all contracts by both senior management and the OGC.

Contracts are attached to ePMP project management plans electronically so that anyone reviewing the project can also view the contract. It is then easy for many people in the company to review the contract during the life of the project to ensure that specified parameters are met.

4.11.2 Health and Safety risks

Projects executed by the firm involve risk. The projects require work with hazardous materials and work with potentially dangerous equipment. CDM provides and requires Health and Safety training, and measures Health and Safety performance on projects for reporting back to clients. Liability is managed through careful contracts, supervision of subcontractors, and quality controls on project planning, design and execution.

Project level Health and Safety risks are evaluated at the planning stage in the ePMP application. A Health and Safety Manager must review and approve project description, scope and processes if CDM employees are to be working on site.

4.11.3 Project locations

Infrastructure projects take place in many areas where there has been recent conflict. CDM has been involved in rebuilding in Afghanistan after the war. CDM is also building schools in Pakistan, and working in Jordan and Lebanon (Martino, "Interview with William Howard - CDM Architecture Topics," 2006). In these areas, risk is mitigated for CDM employees and agents by providing security and any other form of protection that is necessary.

4.11.4 Risk of losing the trust of clients

Adapting to meet changing market conditions requires new services and capabilities. CDM's clients expect certain services and capabilities from the company's "brand." If it is perceived that CDM's services are being weakened by the pursuit of other markets, CDM could lose the trust of clients who no longer consider the firm a reliable source of expertise. Demonstrating capability in journal articles, professional presentations, and awards, and carefully maintaining existing client relationships mitigates this risk.

4.12 Architecture Conclusions

4.12.1 Organizational Analysis

A consulting engineering firm has many elements in common with a Professional Services Firm (PSF). Like a PSF, the consulting firm's primary resource is its people and the quality of their work. The reliance on people is direct because they provide value almost "real time" to the customer, in contrast to a product or manufacturing firm which has relatively few employees in contact with the customer, and whose products are perfected in bulk before being shipped to the consumer.

However, there are some ways in which this consulting organization varies from the traditional PSF. A senior partner manages a team of juniors and is only brought into client engagements at very high rates for short periods of time. In a PSF, leverage is a crucial method for growing the firm and increasing profitability. In contrast, an engineering consulting firm's more highly paid experts are somewhat leveraged in that they work fewer hours per project and turn standardized tasks over to junior engineers, but at CDM they continue to contribute specialized work at a moderately high utilization rate relative to other PSG senior partners, even at the most senior levels. These senior engineers are not able to demand the extremely high rates of a senior partner in a law firm or a medical specialist. (Martino, "Interview with Paul Camell," 2006) Another difference is that the senior engineers do not directly supervise the work of junior employees. The supervision of work is built into the quality management processes for each individual project and into overall company standards. Each project completed by CDM requires a highly tailored solution and approach.

Other important CDM characteristics are the drive to form solid client relationships and growth of the firm through an increase in services and capabilities (not just signing more work). The matrix organization of this firm is designed to support both functions with the flexibility to provide resources with appropriate technical skills when and where they are

needed by the client. This growth strategy through global flexibility corresponds to those recommended by Scott (see page 21)

4.12.2 System Architecture

The architecture is a thorough analysis of the organization. Because the author's experience is in IT, the description contains much information about IT systems and their integration into the organization, a tendency not detrimental to the document because of its use is intended as a framework for decision making related to IT projects. A more generic document would be useful to the organization for the education of incoming employees, or for the use of another division if that need were to arise

The architecture discussed in the preceding chapter is highly detailed and in depth. This document is appropriate for a study of the organization. However, most employees would not be expected to read a document of this type or format when attempting to understand the "big picture" of the organization. Appendix I contains a summary document employees would find useful as an overview of the organization or as a basic reference.

Chapter 5 Application of the Architecture to IS

An information system implementation is a large and risky project. The Standish Group estimated that in 1995 companies in the United States alone spent \$81 billion on software projects that would later be cancelled; projects that would be completed were predicted to overrun their budgets by \$59 billion (The Standish Group International, 1994). Although the basis of these numbers from the Standish Group 1994 study has recently been questioned (Glass, 2006), recent studies by the Standish Group show that 18% of IS projects are cancelled; 53% of the remaining projects are completed late or over budget, and only 29% are considered a success (Hartmann, 2006). Three major factors are attributed to the success of projects that complete on time and on budget:

- User involvement
- Executive management support
- Clear requirements or business objectives

The organizational system architecture (OSA) provides a framework for evaluating a proposed new or updated system to establish the value of the system and to gather information related to these three factors. This framework is based on the business analysis questions defined in Table 3.1, but is completed with details of the company regarding beneficiaries, needs, goals, value delivery functions, form and architecture.

Comparing the proposed system against this document provides insights into how it will contribute to the value delivery process or the achievement of the firm's goals. The OSA also offers a structure for identifying potential system users and executive managers whose processes and goals would be positively impacted by the new system. The details in the OSA also provide insight into the processes and functions which the new system should support, as well as system requirements information based on the new system's context within the firm; this includes integration points, platform alignment, regulations, liabilities, standards and risks.

In order to evaluate the value of the proposed system to the firm, it must be "projected" onto the OSA, accomplished by reviewing the system architecture document and identifying each portion of the model where the proposed system would affect the architecture.

In this section, an example proposed system is evaluated against the CDM system architecture. The proposed system is a corporate contact mail and email repository designed to replace an existing system. The new system enables management of mailing contact information in a single repository for the entire firm, with flexible query capabilities available to many administrators in various groups and divisions, excellent integration to mailing houses and targeted email capabilities. The system would facilitate the process of updating contacts for Client Officers (CO) and Client Service Managers (CSM) so that their contacts are maintained in a single location and available to COs and CSMs at all times while still remaining available to administrators for group emails or mass mailings when needed.

5.1 Information System Project Proposal

When initially proposed the system might only be an idea or concept. The idea could be a strategic function which requires IT infrastructure for network connectivity, communications, or centralized repository; or it could be a process previously handled in a manual or one-off manner, which becomes standard and must be implemented throughout the company and then automated.

During its proposal phase, the system is evaluated as if it were a new business proposition. The CIO presents a business case for the system to the six Chiefs' meeting (see section 4.4.4.4), which determines the priority for the system and whether it will be pursued.

In presenting the business case, the CIO communicates the role of the proposed system in the OSA of the firm. The issues the proposed system will resolve are made clear to the Chiefs, as well as defining who will benefit from its use. The proposed system must be understood in order to compute its value and "how this technology deployment supports the business processes," (Martino, "Interview with Peter Palmisano," 2006) or the functions and goals of the organization.

5.1.1 Communication device

The OSA document is a powerful communication device that can be used for discussing the value of a proposed IT system. The ability to reference a single document common to the entire firm, a document defining the project's goals, functions and processes, removes ambiguity in discussions.

The communication of the role of each IT system in the performance of the value delivery processes of the firm is a necessary foundation to discussions of process improvement, system upgrades, and new systems. The document will assist other managers to envision the interfaces between existing and new systems.

5.1.2 Proposed system value identification

Projecting the proposed system onto the architectural model allows a review of the OSA while considering the impact of the proposed system on each of its sections. The image in Figure 5.1 highlights and outlines the primary company elements affected as a result of "projecting" the proposed system onto the design project value delivery processes and sub-processes.

Core Values

The system must not conflict with core values in any way if it is to be considered further. In the example case, the proposed mailing list system supports the core values of shared commitment and team work and does not conflict with any of the core values.

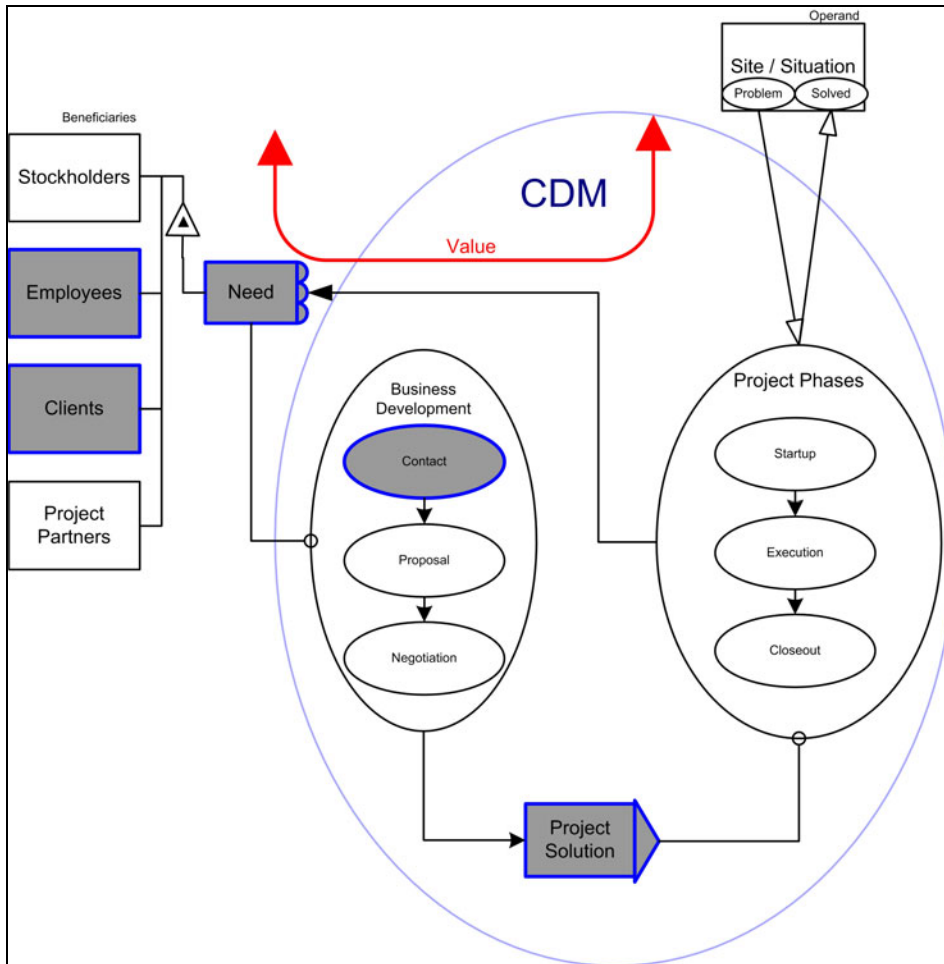


Figure 5.1: Value delivery processes with highlighted elements which are affected by the example application overlay

Needs

A system that requires company resources to implement and maintain must contribute to the value delivery processes of the organization or provide support for the functions which accomplish organizational goals.

The beneficiaries of the company include employees and clients.

Employees

Employees need stimulating work. The example mailing list system will remove problematic and redundant mailing management tasks required under the current system from the responsibilities of administrative personnel, COs and CSMs

- COs and CSMs will administer their own client contact information in a single location accessible from their company computers and company cell phones. That is convenient for them, and the information will be updated regularly to the central repository.

- Administrative support personnel will no longer have to compile and maintain mailing lists from COs and CSMs in the centralized repository.

Clients

Clients need solutions to their problems. CDM services and capabilities are increasing. Targeted mailings will expose clients to solutions they might not expect from the firm. Clients will receive mailings providing marketing information and event notices based on the client's market sector, geographic location, professional organization affiliations and other attributes. The new system provides categorization and query capabilities that enable targeted mailings and emails, so clients receive only relevant information.

Professional organizations

Professional organizations hold conferences which provide networking opportunities. The conferences are attended by professionals looking for information and contacts relevant to their needs. The updated mailing list repository will enable invitations to CDM events held at conferences to be sent to contacts of CDM who are likely to attend or who might benefit from attending.

Goals

The flexibility of the proposed system allows direct mailings about new services and capabilities and specifically provides for sending information to the clients who will be interested. This will support the company goal of providing full service by educating clients about firm abilities they might otherwise miss.

Requirements

CDM's requirements include the need for skilled professional employees, and CDM's past work is a selling point with professionals. Targeting experienced contacts of the firm with highly polished reports on successful projects and CDM's use of advanced techniques may encourage interest in the firm as an employer.

Context

The context of the firm includes its operating environment and market competition. The ability of the firm to expand its markets by informing clients about new services and capabilities will improve the company's position in its operating environments and markets and, thus, its context.

Architecture

The architecture of the organization includes the functions and processes which operate to achieve the goals of the firm.

Functions

CDM has high level goals delineated in "Strategy 2008" (see Section 4.2.4.1) which define strategic functions aimed at growing the firm. The proposed mailing list update project supports these functions by educating clients and potential clients about services and capabilities available from CDM. The goals are specific about increasing the volume of work provided to the four client sectors: public, industrial, federal and international.

The proposed system would increase the value of marketing and corporate communications by providing the ability to send specific mailings and emails to contacts in any of these sectors.

CDM’s operational functions include nurturing client relationships and “being the employer of choice.” Previous topics have discussed how the proposed system would support these functions by providing targeted information to clients, proposed clients and potential employees about the capabilities and experience of the firm.

Processes

The Business Development and Staff Hiring processes will benefit from this system as shown by projecting the system onto the CDM business development diagram in Figure 5.2.

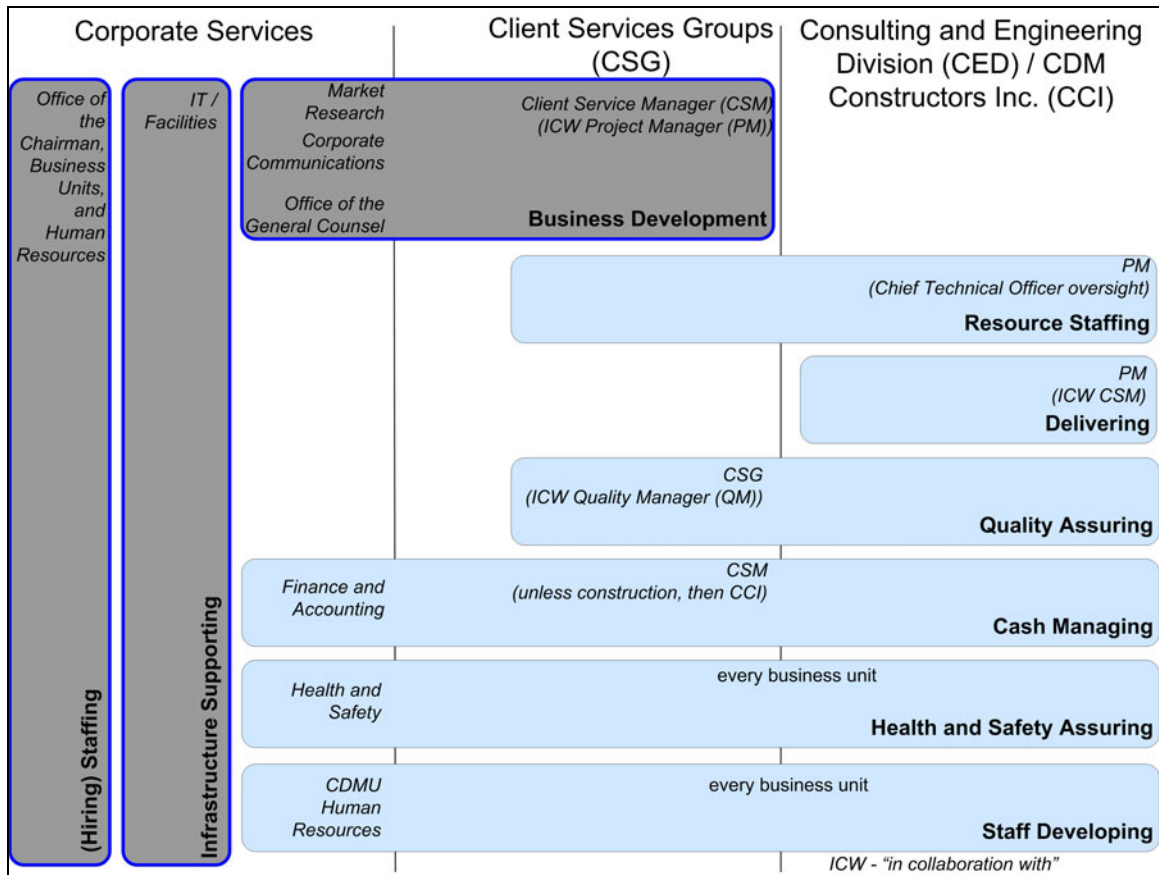


Figure 5.2: CDM business processes with highlighted processes affected by the example application overlay

5.1.3 Identification of executive management stakeholders

Executive managers with an interest in the project are most likely to be found among the executives within the groups identified by the affected processes which are shown as highlighted in Figure 5.2. These managers have an interest in processes necessary to the success of their group’s functions. The proposed system, if well defined, will enhance

their employees' performance and support the efficient execution of the process according to company standards and guidelines.

In the example mailing list management application case, the executives interested in the success of this project will be in Corporate Communications, Unit Presidents in charge of the Client Service Groups, Corporate Counsel, Human Resources, OUCH, and IT.

5.1.4 Identification of users

In the process of identifying the value of the proposed system, the architecture document reveals its user community. The processes highlighted in Figure 5.2 are the responsibility of various groups throughout the company. The proposed system will affect members of those groups responsible for accomplishing the relevant tasks within these processes.

In the example case of the mailing list management application the user community for the system will be drawn from members of Corporate Communications, Marketing groups within the Client Service Groups, Client Service Managers (or Client Officers), Human Resources, and IT.

5.2 Information System Project Startup

Once the proposal is approved and the stakeholders brought into the project the IT project team is created with employees from the IT groups:

- Networks, both data and voice
- MIS
- Collaborative Applications
- Desktop Support and Helpdesk
- Documentation and Training

The project team begins working with the stakeholders and other beneficiaries of the project to identify requirements. To be useful, the requirements must be a clearly stated "minimum set of independent requirements that completely characterizes the functional needs of the product in the functional domain. By definition each functional requirement is completely independent of every other functional requirement at the time the functional requirements are established." (Suh, 2001)

The OSA "gives context to make better decisions at the business analyst level." (Martino, "Interview with Christian Stanton," 2006) The group of stakeholders, beneficiaries and project team members use the OSA document as a model, discussing the organizational needs to be fulfilled.

The existing systems, roles and processes that will be impacted by the project are identified at this time. The OSA provides a framework for the analysis and helps to find links between project and existing applications and therefore establishing interface requirements for the new system. Without this framework "technical people miss connections and managers [of IT groups] are too busy to notice. Positioning staff members to think about this improves the systems and work." (Martino, "Interview with Peter Palmisano," 2006)

As the proposed mailing list management system is evaluated against the OSA, we find that a number of sections of the document are useful in contributing to requirements definition and system scoping.

5.2.1 System scope

The definition of the system limits and boundaries is as important as the identification of its capabilities. The proposed system must not be defined so that it will overlap the existing functionality of another system which is it not intended to replace.

Technology

The technology section of the architecture document provides information related to the systems existing within the organization and that support the value related processes. The proposed system may be aligned with or share resources, infrastructure, or data with one or more of these systems, but should not replace the functionality of that system unless replacement is the specific intent of the proposal.

If there is an intentional overlap between the functions of the proposed system and an existing system, it should be resolved to the satisfaction of the executive sponsors or the IT oversight board before the project proceeds further.

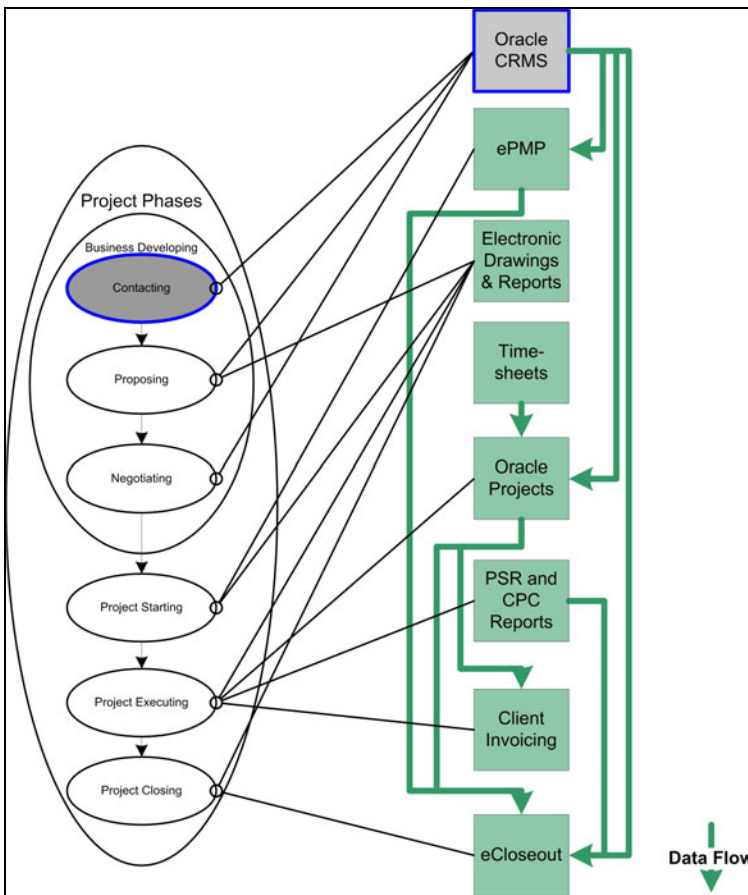


Figure 5.3: value delivery IT systems with highlighted process and system affected by the example application overlay

The example system has features in common with the Oracle Client Relationship Management System (CRMS) as shown in Figure 5.3. However, the new system was specifically requested as a response to a need not filled by the CRMS. The system definition will be scoped to specify which contact management capabilities will be features of the CDM Mailing List and which capabilities the CRMS will provide.

5.2.2 Requirements definition

The technology section of the architecture document provides platform and supporting technology information relevant to the definition of technical requirements.

The example system must be designed to fit within the IT infrastructure's intentionally simple structure. The system will be built using Microsoft web applications and web services where appropriate in order to maintain alignment with existing corporate custom applications solutions. It must be built to meet current web application development standards and guidelines.

Regulation

Functional requirements must include any applicable regulations. The regulation section of the OSA will provide structure for determining which regulations may affect the system. The system must be specified to provide support and reports on violations or potential violations.

CDM mailing list will be designed to provide clients with the assurance that their personal information will not be available to any groups outside CDM, and that they will be able to opt out of CDM's mailing list if they choose to do so. This level of privacy protection is a perceived regulation for a privately-held firm, but the company should still specify the system to respect the privacy of its clients.

Standards

The proposed system must be defined and scoped so that it does not conflict with CDM guidelines or standards. The system must support the firm's processes. These must be applied to the proposed system in both the functional and technical requirements specifications.

Liability

The liability section of the architecture specifies the types of liability the firm faces, and the processes and structures in place to manage their risk. Application requirements can affect both general and professional company liability. Review of this section will highlight features and functionalities that might be problematic. If the potential for liability is unclear, a member of corporate counsel should participate in a discussion to resolve any ambiguity.

The example mailing list management application does not expose the firm to an increased risk of general liability or professional liability. The list must be protected against theft and misuse by internal users or competitors, but with no financial data maintained in this repository, the legal risk is minimal.

5.3 Information System Project Design

System design involves specifying the system platform, architectures, processes and interfaces to be built into the new system. The OSA provides information useful to this process by showing other systems which are closely integrated, not only functionally, but in the user experience.

Two tightly functionally integrated systems (as defined by the system requirements) should have platforms and architectures which are compatible. Similarly, their user interfaces benefit the user when they are compatible. This simplifies use of the systems and creates a platform that simplifies maintenance and support of the closely affiliated systems.

As an example, the ePMP and the eCloseout systems are designed to pass project description information from the beginning of the project to the end. Project description and planning information is entered into the ePMP form by the PM at the start of the project. Much of this project information must be confirmed by the PM at the end of the project in eCloseout application, while also describing changes to the project and plan during project execution. The user of both of these systems sees the same or updated information in a similar screen layout and format. This simplifies the closeout process by giving the PM familiar forms to use for the validation of existing information, as opposed to an entirely new format. In addition, the development, maintenance and support of the eCloseout system benefit from similarities to the ePMP system because the technologies and platforms are the same.

The example CDM mailing list application does not closely align with any other application. Although it is complimentary to the CRMS application, they are not typically used in conjunction with one another and users will not experience any increased efficiency by attempting to share user interfaces between the systems. The data, though similar, is not the same, and data integration between these systems is not advantageous.

5.4 IT Management Comments

Other potential uses for the OSA related to IT system development and deployment were not researched in this work. It is possible that an OSA could provide a foundational framework for the documentation of systems for user training and support. Another possible use is to support the training of new employees. “This information is what we expect employees to learn during their first one to five years in the firm. However many employees aren’t exposed to this information and many don’t consider it part of their job. There is value in communicating the summary architecture of CDM.”(Martino, “Interview with Christian Stanton,” 2006)

However, concerns were raised about the benefits of detailing the company’s five year strategic goals set in the year 2003, which may not be reachable by 2008. When

communicating with employees, care must be taken to avoid the image of the system architecture as a political document. “Some of them will respond with a reality check ... [the document] must communicate the reality or lose the trust of employees” (Martino, “Interview with Peter Palmisano,” 2006). This concern could be mitigated by cautioning the reader of the architecture document that it is written to discuss the *design* of the system and that if goals are not being met, this document is intended to help determine the causes or contributing factors.

5.5 Example Application Conclusions

The example case, the CDM Mailing List contact management repository application, will benefit from having been evaluated against the OSA before the beginning of functional requirements gathering. The consideration that HR may benefit from the exposure of potential skilled employees was unexpected. Also, the risk of violating perceived regulation by emailing clients without providing them a mechanism for removing themselves from the email list, was not previously considered before the projection of this system onto the OSA.

The interviewed IT leaders found the OSA to be useful for tasks related to analyzing a proposed IT project or new subsystem. The document can support the following processes:

- The business case for the proposed subsystem by providing background for business value analysis
- Identification of stakeholders whose processes might benefit from the proposed subsystem by finding processes and functions affected by the subsystem
- Location of related systems which share features and/or functions and therefore contribute to subsystem architecture
- Definition of subsystem scope
- Specification of requirements for subsystem design
- Creation of unit test cases based on realistic use cases

Chapter 6 Conclusions

This thesis shows that system architecture is a useful tool for analysis of a consulting engineering services organization. An architectural framework is derived that enables analysis of CDM Inc. When this framework is applied to the example firm, the result is a powerful document, useful to the Information Technology (IT) groups within CDM in a number of ways, including communication and new system development:

6.1 *Organizational Documentation*

The organizational system architecture (OSA) describes the aspects of the organization that contribute to the fulfillment of its goals. This analysis provides a clear understanding of how CDM delivers value to its beneficiaries, and the elements and processes that contribute to its ability to do so.

6.1.1 Employee information

The OSA describes the entire organization in detail. Without an OSA this information is not always available or clear to the firm's employees. The OSA provides comprehensive information to employees in any department, helping them to better understand the context of the company. This understanding provides a foundation for decision making in all aspects of their work.

6.1.2 Communication

Because the OSA describes the goals, functions, elements, processes and structure of the organization, it provides a depth of information not typically contained in a single source. This single source provides a common foundation for communication of ideas related to the firm. The document is easily referenced for use in conversation and discussion.

6.2 *Information System Applications*

The OSA provides information for the three major factors identified by the Standish Group as common risk factors in project failure or cost overruns (Hartmann, 2006; The Standish Group International, 1994):

- User identification
- Executive management support
- Clear business objectives or requirements

Additionally, the OSA provides detailed information about the value the proposed system will provide to the organization.

6.2.1 Information system value

An experienced employee who is already aware of the details of the organization presented in the OSA will find it a useful framework which provides structure to the business analysis process. The value of the proposed system becomes apparent when the

contributions to the achievement of documented organizational goals or functions are identified.

6.2.2 User and executive stakeholder identification

The use of the OSA also enables a rapid but thorough evaluation of the proposed system against all groups operating within the firm. Executives responsible for groups whose functions and processes are affected may provide executive level support for the proposed system. These groups also contain potential users of the system who can contribute to the requirements definition process and further project phases.

6.2.3 Functional and technical requirements identification

Technical and additional functional requirements of the system are exposed by evaluating the architecture, technology, regulation, standards, liability, reuse, supply chain and risk specifications in the OSA against the proposed system.

Chapter 7 Appendix I: Architecture of CDM

Introduction

This document is a summary of the architecture of CDM. It includes information about aspects of the firm relevant to an understanding the organization at a high level. The model is organized as follows:

1. Stakeholders and their needs
2. Goals of the firm
3. Values and Functions of the firm
4. External Factors affecting the organization
5. Internal Factors affecting the organization
6. Major Processes
7. Connections between the firm elements
8. Risks facing the firm and affecting the success of the goals

This model is used to provide employees in Information Technology with an understanding of the beneficiaries, goals, functions, and form of CDM. Employees who have this information are well prepared to make decisions that affect the design and function of systems within the firm.

This work is based on information gathered during personal interviews with a number of employees of CDM during 2005 and 2006(Martino, “Interview with Bruce Conklin,” 2006, , “Interview with Daryl Shepard,” 2006, , “Interview with Lauren Courtemanche,” 2006, , “Interview with Marlene Hobel,” 2006, , “Interview with Paul Camell,” 2006, , “Interview with Richard Fox,” 2006, , “Interview with Scott McClelland,” 2006, , “Interview with William Howard - Professional Societies and Regulation,” 2006) .

What is CDM?

Camp Dresser and McKee Inc. (CDM) is a consulting, engineering, construction and operations firm established in Cambridge, Massachusetts. Its commitment to quality and integrity has resulted in strong client relationships and grown the company from a three engineer firm in 1947 into a worldwide corporation with 3,800 employees.

Founded as the a partnership of Thomas R. Camp, Herman G. Dresser, and Jack E. McKee, the company built a reputation as an engineering practice specializing in water supply and water pollution control. Since the 1960’s CDM has expanded geographically in domestic and international markets. Beginning in the 1980’s the firm diversified into hazardous waste management. Full service capabilities for design-build and construction now combine with CDM’s expertise in other scientific, engineering, and management consulting services including the fields of transportation, operations, information management and geotechnical services.

Why System Architecture?

“System architecture is an abstract description of the entities of a system and the relationships between those entities.”(Crawley et al., 2005) Communicating a system’s architecture through simplified models can assist in illuminating the innermost and outermost determinants of system operations.

CDM’s vision and concept

“CDM will be a global consulting, engineering, construction, and operations firm committed to exceptional client service to improve the environment and infrastructure.”(CDM Corporate Communications, “About CDM: Values and Vision,” 2006) CDM is a growing infrastructure firm with operations worldwide.

CDM Stakeholders and Their Needs

Table 7.1 lists the groups that benefit from the CDM organization. The stakeholders are important to the firm and must be considered as the beneficiaries of all CDM activities. Any actions that do not ultimately benefit these groups are not required for the success of the firm.

The needs of these groups are monitored by the Office of the Chairman. This group sends Client Satisfaction Survey Questionnaires to clients when projects close, sends annual surveys out to all employees and maintains a close relationship with the stockholders.

The Office of the Chairman communicates the needs of these groups through direct meetings with business managers and publication of employee survey results.

Stakeholder	Characteristics	Needs
Stockholders	Employee owned firm, titled employees own stock	Profit and growth
Employees	Highly skilled professional engineers, scientists, project managers, client service professionals and managers. Retaining and hiring are high priority activities, the employees of the firm are in direct contact with the firm's clients and must communicate as well as be technically skilled.	Stable employment Financial reward: financial stability, incentive to excel, investment return Opportunity for career growth: challenging work and Opportunity for personal growth: training others, developing professional standards Pride in work quality and effect
Clients	CDM will "use technical talent to find solutions that provide the client with a solution that goes beyond the singular need" (Martino, "Interview with Bruce Conklin," 2006) CDM's role may be to assist the client with defining the problem in addition to the solution. Clients also function as the operator of CDM by contracting CDM to complete project work.	Solution identification: regulation interpretation, project definition Project planning and management Project execution
Project Partners	CDM frequently partners with other professional engineering firms which can provide specific skills to a project.	Communications and knowledge transfer about project.

Table 7.1: CDM Stakeholders and their needs

Goals of the Firm

Specific Goals

Goals as defined by the Strategy 2008 5 year strategic initiative in 2003 are: (CDM Corporate Communications, 2003)

To bring CDM to annual revenues in excess of \$1 billion using increased capabilities, services and volume of work. This will be accomplished by:

- doubling our volume of core services for public clients
- doubling our volume of work for industrial clients
- tripling our volume of work for federal clients
- doubling our volume of work for international clients

while also maintaining paced growth to double our construction revenues

Objectives (Generalized Goals)

In order to serve its stakeholders, the firm has the following goals:(CDM Corporate Communications, “About CDM: Values and Vision,” 2006; Martino, “Interview with Richard Fox,” 2006)

1. Develop and maintain exceptional, trusted client relationships by:
 - a. Finding the right total solution to the client’s need: assisting with definition of the problem and facilitating client decision making
 - b. Setting standards for engineering: CDM standards and professional standards via professional society participation and educational support
 - c. Measuring client relationship success by Client Satisfaction Survey Questionnaires sent from the Office of the Chairman after each project.
2. Be the employer of choice by:
 - a. Retaining staff through stimulating opportunities for work
 - b. Hiring a skilled resource pool of experienced professionals and graduates
 - c. Measuring employee relationship success with a bi-annual Employee Survey
3. Provide full services to global clients by:
 - a. Remaining financially strong to ensure stability
 - b. Structuring the organization to provide increasing service capabilities to clients worldwide while balancing opportunity against acceptable risk
 - c. Confirm that all relevant services are available worldwide
4. Remaining privately owned to stay self directed and by:
 - a. Staying profitable
 - b. Keeping corporate focus on the growth and strength of CDM
 - c. Measuring ownership success through employee stock ownership interest

Value and Functions of the firm

The firm delivers value to clients by providing the “right total solution” (Martino, “Interview with Marlene Hobel,” 2006). This is the solution found after listening to the client’s situation, identifying their needs and understanding internal and external factors. CDM works with the client to find the solution that is best for the client and to help them to implement that solution. This may require CDM to provide services beyond traditional engineering. Clients face more decisions today than ever before, are frequently required to change internal processes, and are required to comply with court or government ordered regulations. Successful problem solving for the client and implementation of solutions is the value delivered by CDM.

The function of CDM is to achieve the goals stated above in order to fulfill the needs of the beneficiaries.

In order to fulfill the needs of CDM’s stakeholders (stockholders, employees, and clients) CDM’s functions are:

1. Growing the company’s annual revenues by
 - a. Increasing solution services for public clients
 - b. Increasing sales revenue to industrial, federal and international clients
 - c. Increasing construction revenues
2. Providing excellent service to clients to nurture client relationships
 - a. Supplying value with the “right total solution”
 - b. Encouraging repeat and new business
3. Marketing and advertising CDM’s services and capabilities
 - a. Providing internet, brochure, magazine, journal and advertising coverage of firm technologies and techniques
 - b. Presenting CDM projects and technologies to professional organizations, awards committees, and conferences to increase the firm’s prestige
4. Increasing the number of services and capabilities provided
5. Increasing the geographic and economic regions serviced by CDM
6. Growing service and support staff to support:
 - a. Capabilities and Services – bringing in subject experts to expand CDM’s capabilities and services, educating staff in new services and capabilities through CDM University (see page 110), university educations, and organization of technical discipline groups
 - b. Service volume - adding lower grade level staff to increase the volume of work that can be accomplished at lower rates
7. Operating efficiently:
 - a. developing processes that increase quality and efficiency
 - b. developing technology or incorporating appropriate technologies
 - c. integrating systems to support these processes and technologies

Factors external to the firm

Market

CDM operates in a highly competitive market of global civil infrastructure. The firm has built a reputation for skillful and innovative design and excellent client relationship building. However, design is becoming a commodity driving CDM to change market strategy.

New strategic marketing initiatives include: alternative project delivery (design/build for example), management consulting, and program management. These projects provide CDM employees to nurture client relationships as trusted advisors. These consultative projects will enable CDM to leverage its technically and managerially skilled resources in engagements which are more consultative than technical. These engagements are billable at a higher rate.

Competition

CDM operates in competitive industries. There is competition from both large firms and single consultant operations. Each region has its own competition as well as the global firms likely to be found bidding on jobs anywhere.

In these industries, firms are encouraged to “combine forces” and subcontract or partner on jobs in order to get the right set of skills. It is important to CDM to work closely with another firm on one project even though bidding against them on others.

Regulation

Regulation can drive business to CDM. Clients are forced to comply with regulation and have a need for consulting related to understanding regulations and the best solutions to meet them. The best solution may be to understand where the requirements do not apply. Confirming this to the client may not increase the value of the project, but will confirm CDM’s role as a trusted advisor and increase customer satisfaction. CDM will work with their clients to ensure that they comply with regulations in the “right way”.

Globalization

CDM has had a worldwide business practice since 1967. Global markets are challenging with issues related to business transparency in some areas and high levels of competition in others (esp. China).

Infrastructure projects in CDM’s areas of expertise (water, wastewater) proceed in many areas worldwide. CDM’s matrix structure enables the company to provide services anywhere, leveraging skills from almost any office without regional restrictions. In addition, using local rates in some markets is the only way to be competitive.

Factors internal to the firm

Organizational structure

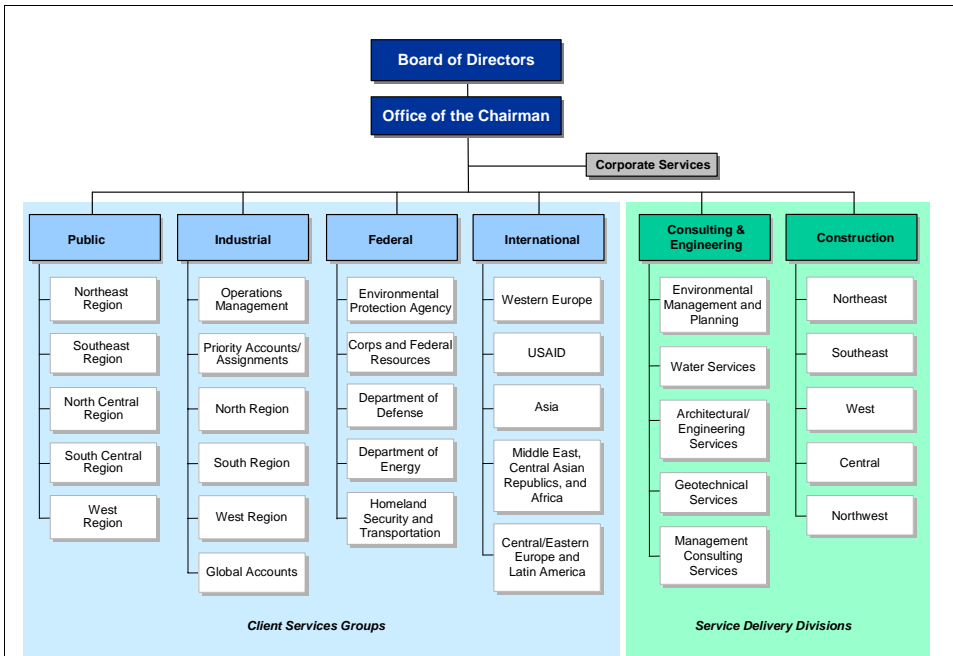


Figure 7.1: CDM's Organizational Structure

Chart from the CDM intranet (CDM Corporate Communications, "CDM Organization," 2006).

The Matrix structure

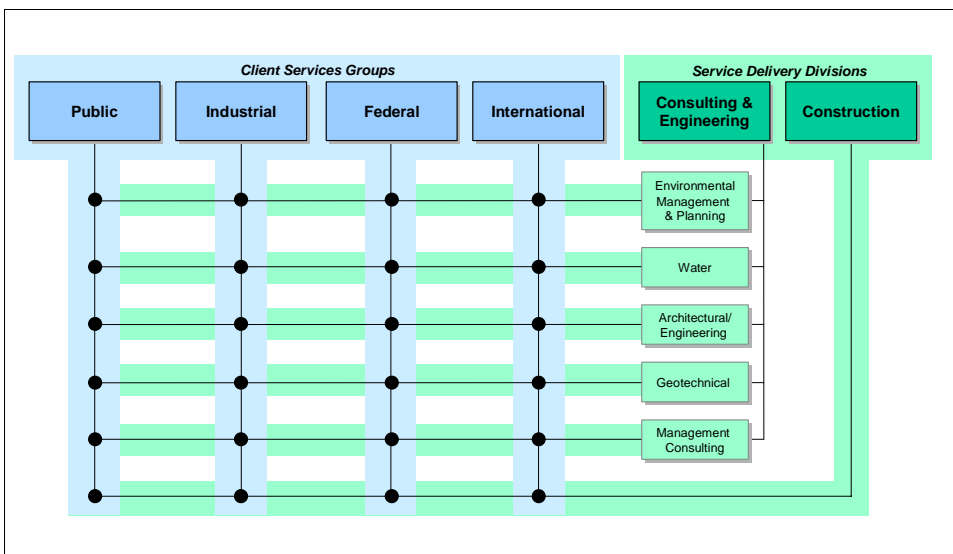


Figure 7.2: Matrix structure

Chart from the CDM intranet (CDM Corporate Communications, "CDM Organization," 2006).

How the matrix structure works

Business development is generally the responsibility of the four Client Services Groups (CSG) which are Public, Industrial, Federal, and International (as shown in Figure 7.1 and Figure 7.2). Opportunities are pursued by CSG in consultation with CDM Engineering and Consulting (CED) and CDM Constructors Inc. (CCI) for proposal and pricing support.

Projects are delivered by CED and CCI with client services provided by CSG client relationship experts.

CED is divided into 5 delivery groups:

- Environmental Management and Planning
- Water
- Architectural / Engineering
- Geotechnical
- Management Consulting

Purpose of Matrix structure

The matrix structure is intended to improve the firm's ability to put the most appropriate resources, its people, on projects where their skills are needed, despite regional position. Senior staff can be allocated more flexibly onto projects as their skills are needed.

Communication among matrix organizations

CDM has provided training to define the primacy structure within the matrix. Clarifying the decision making power within the matrix is intended to prevent conflict that can arise within and between matrix teams.

There has been little discussion of communication methods between the matrix organizations related to opportunities, resources and project work. There is no central project information based knowledge management structure within the firm.

Firm processes

The diagram in Figure 7.3 shows the eight basic processes of CDM that support client delivery and the business units that take or share responsibility for their success (Richard Fox, 2006). This is not a complete list of every process within the firm, but is a list of the major processes involved with providing services. The processes are named using the formal naming convention of system architecture in a noun – verb format.

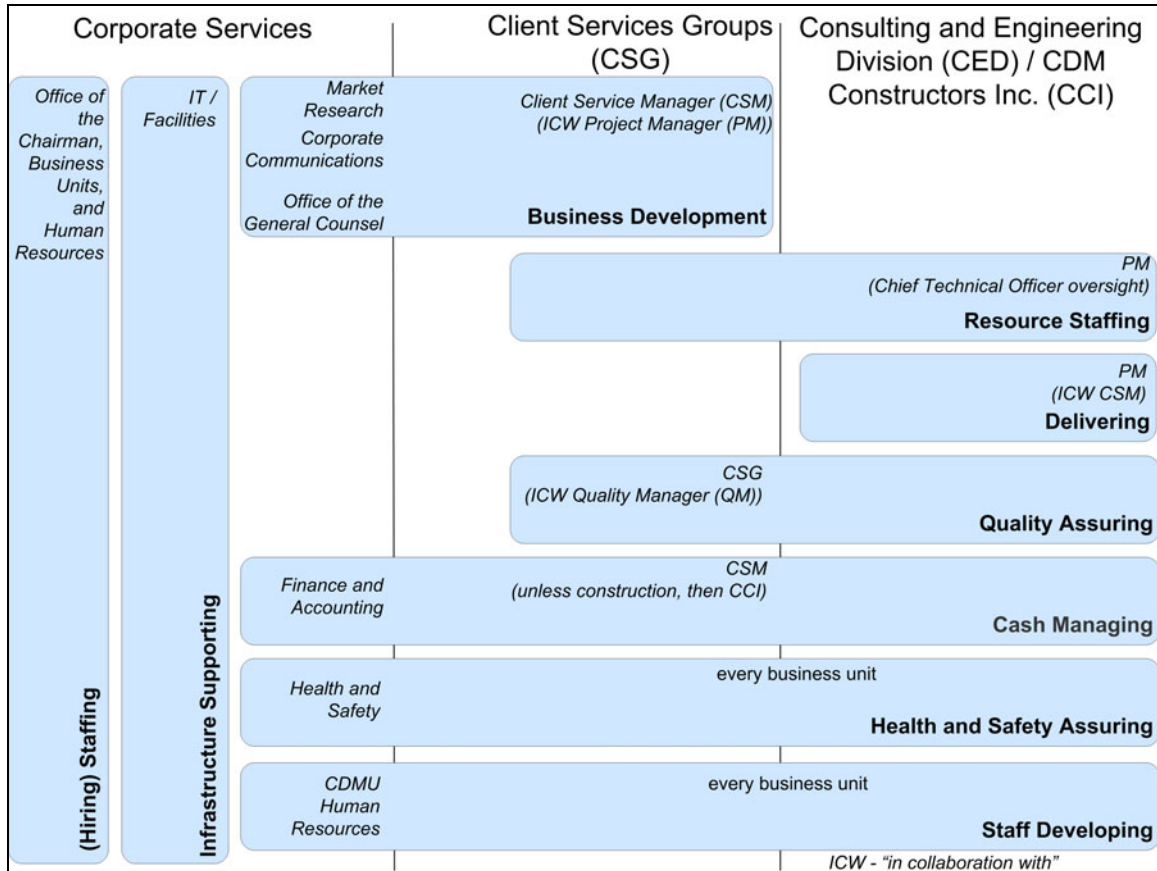


Figure 7.3: Business Processes of CDM

The processes that encompass the bulk of work at CDM are listed and described below. However, because the client relationship is paramount there are exceptional cases in many processes. The systems listed below are further defined in the section on Intra Project communications on page 113.

Developing Business

This process involves working with clients and potential clients to understand their needs, marketing CDM's capabilities and services, and winning projects. The activity associated with client relationships takes place mostly with CSG by Client Service Managers (CSM). Other groups that support the processes are Corporate Communications, Office of the General Counsel (OGC), members of market and proposal development teams from CSG and Consulting and Engineering Division (CED) or CDM Constructors Inc. (CCI).

Systems Involved (see page 113): Oracle Client Relationship Management (CRM), project estimation systems, Office software, CDM Web site (www.CDM.com), CDM Mailing List

Primary Artifacts: contract, proposal

Delivering Projects and Services

The process provides services and project results to the client. The process is overseen by the CSM, however the work is completed by the Project Manager (PM) and a project team most often from CED or CCI

Systems Involved: ePMP, Oracle Projects, Oracle Financials, Project Status Reports (PSR), Current Period Charges reports (CPC), PRISMView, Hits and Misses Reports (HAMR), technical software including CADD, Microsoft Office software, eRoom, and eCloseout, Timesheets

Primary Artifacts: planning documents, interim documentation, status reports, communications, drawings, calculations, project plans, design, permits, schedules, construction documents, reports

Staffing Project Resources

The process involves assigning appropriately skilled personnel to projects. It is the responsibility of the PM (with CTO oversight) and is likely to have started during the proposal phase of the project.

Systems Involved: CRMS workload estimation, local group leaders, Utilization Reports of goals and measurements

Primary Artifacts: none (staff resumes are included in the proposal)

Assuring Quality

During the entire lifespan of a project, from the PQM quality management workshop that kicks off a project, to the approval of project closeout form, the Quality Manager (QM) is involved and empowered to ensure that quality standards as set by the CTO are met. Quality is the responsibility of every member of the team, but the CSM has primacy on this issue.

Systems Involved: Quality Management Milestone reports from ePMP, Client Satisfaction Survey Questionnaire

Primary Artifacts: project artifacts generated during the QM milestone activities

Managing Cash

Contract Administrators use Client Invoicing to create custom invoices with current charges. The CSM ensures that billing and payment are timely. The Corporate Service Finance and Accounting supports the process.

Systems Involved: Oracle Projects, Oracle Financials, Client Invoicing, Timesheets

Primary Artifacts: invoices, payment records, Aging Reports, WIP reports

Assuring Health and Safety

The Health and Safety (H&S) group is a Corporate Service which provides guidelines to ensure safety on CDM projects whenever CDM employees are on site or at work. During a project, it is the responsibility of every business unit to ensure the safety of everyone on the job. Educational efforts provide H&S certifications and information via CDMU.

Systems Involved: LMS, CDMU, H&S vendor courseware, ePMP

Primary Artifacts: H&S guidelines available from the intranet site: CDMWeb

Developing Staff

CDM University training programs ensure that staff is educated in CDM methods and processes. There are mandated trainings required for PM and CSM certifications. Business, Technical and Personal training sessions provide opportunities for growth in many areas.

Systems Involved: Learning Management System, CDMU course delivery software

Primary Artifacts: LMS learning records

Supporting Infrastructure

The underpinning infrastructure of CDM consists of offices connected by communications networks carrying voice and data communications. The development, maintenance, and support of these networks and buildings are crucial to the ability of employees to work productively. IT network, systems and software decisions are the primacy of the Chief Information Officer (CIO).

Systems Involved: all network and telephone systems, server infrastructure, all offices

Primary Artifacts: none

Staffing (Hiring)

Hiring and retiring decisions are the responsibility of the hiring business unit and sometimes the Office of the Chairman (OOCH). The hiring manager works with CDM's Corporate Service Human Resources to find skilled professional resources.

Systems Involved: Oracle HR, BrassRing, CDM Web site (www.CDM.com)

Primary Artifacts: hiring contract, employment application

Firm projects

Systems for project planning and financial tracking are separate for CDM Inc. and the Federal group because of previous U.S. Government regulations. For this reason, data which includes all CDM projects is difficult to gather.

The charts shown in the figures below are based on ePMP project data gathered during the year 2005. Evaluation of year 2004, 2005 and incomplete 2006 data show that these percentages are relatively stable for CDM Inc. projects.

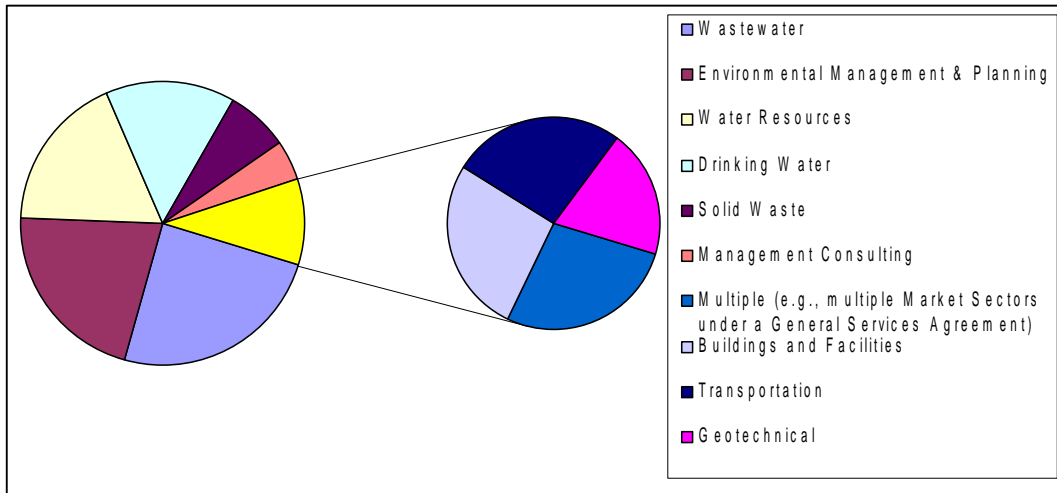


Figure 7.4: Number of projects by market type 2005

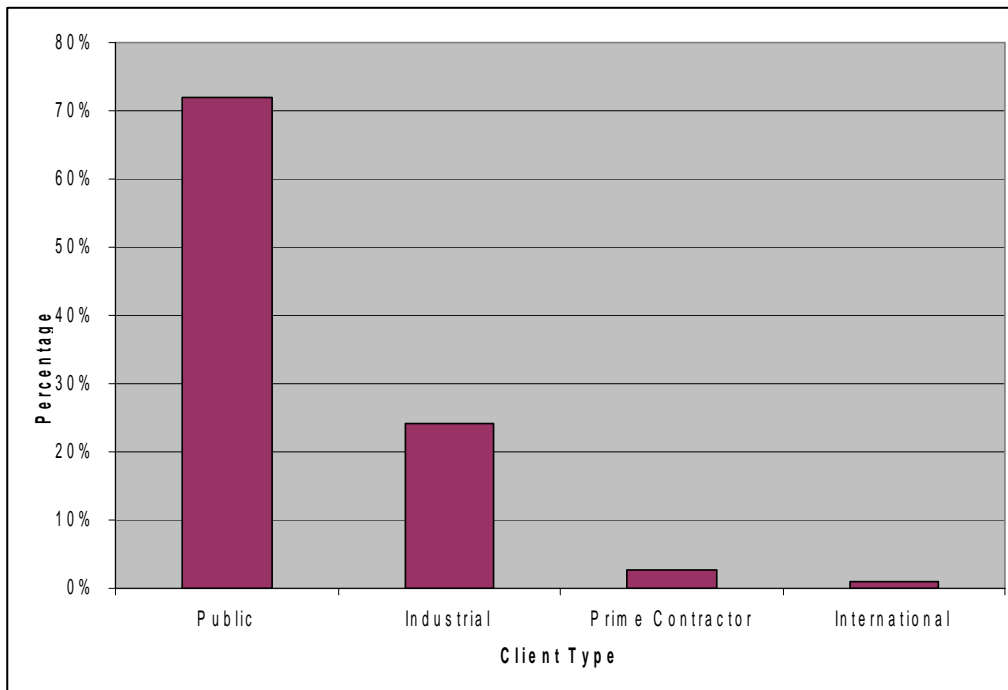


Figure 7.5: Number of projects by client sector 2005

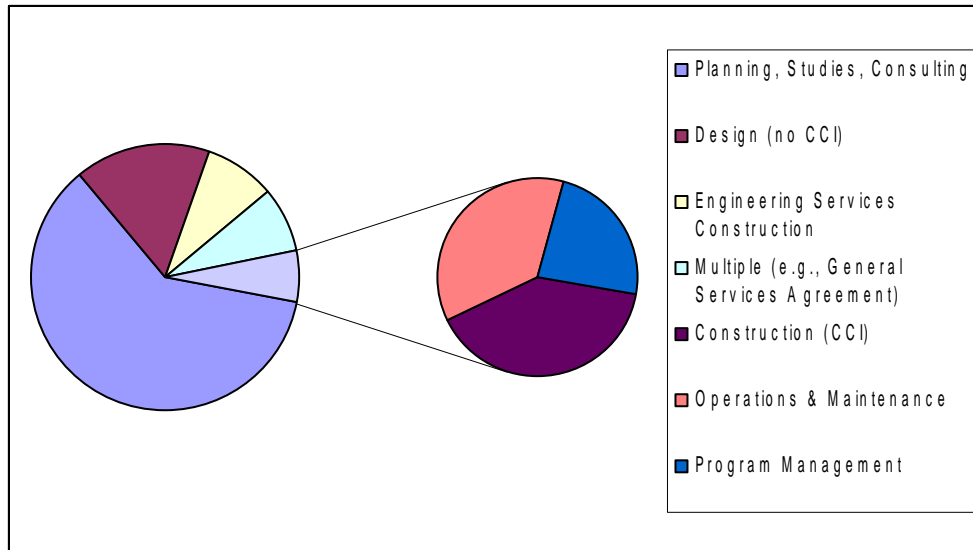


Figure 7.6: Number of projects by work type 2005

Organizational communication mechanisms

A professional service firm sells its knowledge, transferred among employees through communications. Resulting communications interfaces are the relevant interfaces within the organization.

Strategic communications

Strategic communications are delivered from the Strategy committee through two main channels:

- Strategic Champions within each unit responsible for representing initiatives within their business units.
- Corporate Communications, which delivers official strategic documents, regular strategic messages to the employees via the intranet, brochures and corporation-wide emailed newsletters.

Employee information

Dispatcher emails provide a mechanism for direct distribution of information: Inside/Online, CDMWins, and CDMNews

The CDM Intranet provides communication to employees on a daily basis.

Some business units provide their own intranet for communication at a unit level.

Discipline information

CDM has a practice area information-sharing structure, which provides employees with the opportunity to share information related to their technical or administrative discipline with peers in their fields. Employees self-select discipline groups and subgroups within

those disciplines. The resulting groups share technical knowledge, learning opportunities and standards information using an information portal.

Inter / Intra company communications

CDM capabilities information

CDM capabilities are represented to current and potential clients by the Client Service Managers.

Corporate Communications provides brochures and internet web site information on services and capabilities offered by the firm.

CDM technical abilities are also advertised through journal articles, conference papers, advertising.

Client information

Communication between CDM and clients is primarily the responsibility of the CSM.

Due to the nature of CDM's business, direct communication between the resource and client is likely during the project. Every employee must be able to communicate well and be knowledgeable about the project work, in addition to being technically skilled in their field.

Project information is frequently shared between CDM and clients using the EMC eRoom system. This application provides secure role-based access to project documents, basic schedules, and comment areas both inside and outside CDM.

Partner information

Communication between CDM, partners, and subcontractors is primarily the responsibility of the Client Service Groups in consultation with the Project Managers from CED or CCI.

Scheduling and project document information is frequently shared with these organizations through eRoom.

Intra project communications

eRoom provides an information sharing interface for many projects, and though not required for every project, is frequently used.

Oracle financials applications provide the backbone of enterprise information related to project management and relationship management.

- Oracle Financials –financial information and processes including: General Ledger, Accounts Payable, Accounts Receivable, Cost Accounting, and Purchasing
- Oracle Client Relationship Management (CRM) – provides opportunity pipeline, relationship and workload projections
- Oracle Projects – detailed project financial and progress tracking

Project data and status information is communicated to members of the project team and oversight using a number of custom reports and interfaces including:

- Current Period Charges Reports (CPC) - weekly text output report of project charges sent to key members of the project team
- Project Status Reports (PSR) – monthly status report updated by the PM and approved by the Project Director (PD) or Client Officer (CO) / Client Service Manager (CSM)
- Hits and Misses Reports (HAMR)– reports of project progress submitted by the PM when projects have outstanding positive or underperforming results
- Top Ten Reports – summary reports of the “ten most critical project-related problems, and actions for correcting them” summarized from the HAMR reports and submitted to Unit Presidents and then to OUCH.
- PRISMView – customized reporting interface for viewing project financial and management status summary information provided to employees involved with project management and administration
- Client Invoicing – custom invoice preparation from Oracle Projects records used by Contract Administrators for regular client billing
- Client Satisfaction Survey Questionnaire – client survey sent from OUCH after project close, responses made available to OUCH after completion

eApplications provide forms-based interfaces for gathering project information other than financial data. Each of these applications provides an interface for attaching documents to the project’s form.

- ePMP (Electronic Project Management Plan) –information required for creating a project in Oracle Projects, completed by the PM and approved by the project’s Area Manager, CSM, QM, H&S manager and the Office of the General Counsel
- eCloseout (Electronic Closeout Form) –form pre-filled with data from ePMP, Oracle Projects and Oracle Financials comparing planned to actual performance, completed by the PM at the end of the project, and approved by the CSM and QM. The final information is available to other employees and the Info Center

The InfoCenter is the CDM knowledge repository which stores and distributes (both physically and electronically) technical information regulatory information and CDM project files.

The company intranet web site provides access to standards and guidelines from Corporate Services, the business units and, through the Disciplines Portal, from the technical Disciplines.

At this time, there is no automated ability to combine documents from project files, eRooms, and eApps.

Risks and risk mitigation in the pursuit of strategy 2008 goals

Work volume increases

Increasing work volume increases the load on senior personnel. To some extent this is advantageous for CDM because there are a higher percentage of senior people in the firm than juniors and a high work volume will increase both exposure to new talent and their chargeable time (utilization). However, there will be more juniors to mentor and manage, providing less time dedicated to technical work for many senior people.

Communication limitations

The systems that CDM currently uses for communications rely on email and voice for person-to-person communication, and eRoom for document sharing. At the end of the project, the client typically receives a copy of all project artifacts.

As communication capabilities have increased, it has become important to provide clients and CDM employees with tighter integration. An extranet or project portal would enable the client to view project process, communicate with any member of the project team, or to view project status in “real time”.

Expanded internal communications would also better support the ability of the Office of the Chairman and Corporate Services to communicate important corporate information to employees. An internal portal could customize the interface by providing focused information according to discipline, functional role, or titled role, in addition to providing a foundation for an individualized view of work progress.

Problems caused by growth

As the work volume of the firm increases, the firm experiences “growing pains.” There may be staffing problems (see Inadequate Staffing below), space issues, or problems with training new staff.

- It is important that new staff are quickly brought up to speed on CDM’s expectations for client service and project quality.
- It is crucial that the CRMS workload predictions are used to determine staffing levels. If the predictions are not sufficient or accurate enough, a better solution must be found to give the business units and HR time to hire.
- Corporate Services groups do not typically grow as technical staff increases. Adding technical staff will increase the demands on corporate services to support many aspects of employee, equipment, and services delivery.

Inadequate staffing

In order to counter inadequate staffing problems, contracts must be carefully reviewed to ensure that CDM can provide the technical staff needed to complete the job. During the proposal stage of business development, staffing needs should be communicated to HR, along with the probability of needing people with specific talents.

Market fluctuations during capability expansion

It is possible that during the ramp-up to Strategy 2008 growth targets, there might be an economic slowdown affecting the ability to find work. If CDM staffing and growth is carefully gauged to reflect work already won or having a high probability of a win, the risk may be mitigated. Pursuing work worldwide makes a regional or slowdown less dangerous, because the economic performance of one region will have less effect on company performance.

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