TCRP
REPORT 84

Sponsored by
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Transit Administration

e-Transit: Electronic Business Strategies for Public Transportation
Volume 7

The Successful Adoption of Web-Based Collaborative Software

TRANSPORTATION RESEARCH BOARD
OF THE NATIONAL ACADEMIES

TRANSIT COOPERATIVE RESEARCH PROGRAM

TCRP REPORT 84

e-Transit: Electronic Business Strategies for Public Transportation

Volume 7

The Successful Adoption of Web-Based Collaborative Software

CFAR
Philadelphia, PA

SUBJECT AREAS
Public Transit

Research Sponsored by the Federal Transit Administration in Cooperation with the Transit Development Corporation

TRANSPORTATION RESEARCH BOARD

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TRANSIT COOPERATIVE RESEARCH PROGRAM

The nation's growth and the need to meet mobility, environmental, and energy objectives place demands on public transit systems. Current systems, some of which are old and in need of upgrading, must expand service area, increase service frequency, and improve efficiency to serve these demands. Research is necessary to solve operating problems, to adapt appropriate new technologies from other industries, and to introduce innovations into the transit industry. The Transit Cooperative Research Program (TCRP) serves as one of the principal means by which the transit industry can develop innovative near-term solutions to meet demands placed on it.

The need for TCRP was originally identified in *TRB Special Report 213—Research for Public Transit: New Directions,* published in 1987 and based on a study sponsored by the Urban Mass Transportation Administration—now the Federal Transit Administration (FTA). A report by the American Public Transportation Association (APTA), *Transportation 2000*, also recognized the need for local, problem-solving research. TCRP, modeled after the longstanding and successful National Cooperative Highway Research Program, undertakes research and other technical activities in response to the needs of transit service providers. The scope of TCRP includes a variety of transit research fields including planning, service configuration, equipment, facilities, operations, human resources, maintenance, policy, and administrative practices.

TCRP was established under FTA sponsorship in July 1992. Proposed by the U.S. Department of Transportation, TCRP was authorized as part of the Intermodal Surface Transportation Efficiency Act of 1991 (ISTEA). On May 13, 1992, a memorandum agreement outlining TCRP operating procedures was executed by the three cooperating organizations: FTA, The National Academies, acting through the Transportation Research Board (TRB); and the Transit Development Corporation, Inc. (TDC), a nonprofit educational and research organization established by APTA. TDC is responsible for forming the independent governing board, designated as the TCRP Oversight and Project Selection (TOPS) Committee.

Research problem statements for TCRP are solicited periodically but may be submitted to TRB by anyone at any time. It is the responsibility of the TOPS Committee to formulate the research program by identifying the highest priority projects. As part of the evaluation, the TOPS Committee defines funding levels and expected products.

Once selected, each project is assigned to an expert panel, appointed by the Transportation Research Board. The panels prepare project statements (requests for proposals), select contractors, and provide technical guidance and counsel throughout the life of the project. The process for developing research problem statements and selecting research agencies has been used by TRB in managing cooperative research programs since 1962. As in other TRB activities, TCRP project panels serve voluntarily without compensation.

Because research cannot have the desired impact if products fail to reach the intended audience, special emphasis is placed on disseminating TCRP results to the intended end users of the research: transit agencies, service providers, and suppliers. TRB provides a series of research reports, syntheses of transit practice, and other supporting material developed by TCRP research. APTA will arrange for workshops, training aids, field visits, and other activities to ensure that results are implemented by urban and rural transit industry practitioners.

The TCRP provides a forum where transit agencies can cooperatively address common operational problems. The TCRP results support and complement other ongoing transit research and training programs.

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The members of the technical advisory panel selected to monitor this project and to review this report were chosen for recognized scholarly competence and with due consideration for the balance of disciplines appropriate to the project. The opinions and conclusions expressed or implied are those of the research agency that performed the research, and while they have been accepted as appropriate by the technical panel, they are not necessarily those of the Transportation Research Board, the National Research Council, the Transit Development Corporation, or the Federal Transit Administration of the U.S. Department of Transportation.

Each report is reviewed and accepted for publication by the technical panel according to procedures established and monitored by the Transportation Research Board Executive Committee and the Governing Board of the National Research Council.

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Cassie Solomon-Gillis, Senior Manager at CFAR, was the principal investigator. The other authors of this report are Linda May, Ph.D., Senior Manager at CFAR; Chatham Sullivan, Psy.D., an Associate at CFAR; Belinda Chiu, Research Assistant at the Fletcher School of Law and Diplomacy, Tufts University; and Brenton Burke, Research Assistant in Organizational Psychology at Rutgers University. The report was completed with the meticulous assistance of Beth Latham, Tim Riley, Zoë Schlesinger and Jamie Sims at CFAR.

Great thanks are due to several people who participated from the case study organizations. At Raytheon, Rusty Peterson and William Baker were especially generous with their knowledge and time. Kristine Fallon and Mike Poynton from KFA and Paul Gross at the Chicago Transit Authority greatly strengthened the report and candidly shared their experiences. Pradip Mehta at the Port Authority of New York and New Jersey made sure that the information in the report was comprehensive and clear. Thanks are also due to all the study participants who shared their wisdom and advice about the adoption of web-based collaborative software and organizational change.

FOREWORD

By Gwen Chisholm-Smith
Staff Officer
Transportation Research Board

TCRP Report 84: e-Transit: Electronic Business Strategies for Public Transportation documents principles, techniques, and strategies that are used in electronic business for public transportation. *TCRP Report 84* is being published in multiple volumes; *Volume 7: The Successful Adoption of Web-Based Collaborative Software* presents case studies of three organizations that have successfully used web-based collaborative software: the Chicago Transit Authority, the Port Authority of New York and New Jersey, and Raytheon. This report may be used by transit managers, program and project managers, engineers, general contractors, construction managers, designers, financial managers, and intelligent transportation systems professionals.

The Internet and other new information and communication technologies are revolutionizing the way services are delivered and organizations are structured. Electronic business processes change the ways organizations operate and conduct business. Opportunities to lower transaction costs and improve efficiency have changed relationships between transit agencies and their suppliers and customers, and electronic business processes are likely to change industry structures in the long term. Portals for transactions in government-to-government and business-to-government marketplaces are offered through diverse organizations. Numerous transit agencies are preparing to offer customized itinerary planning and fare media purchasing over the Internet.

The declining costs of communications, data storage, and data retrieval are accelerating the opportunities spawned by the Internet and other information and communications technologies. Choosing and sequencing investments in technologies, processes, and people to reduce costs and increase productivity present challenges to the transit manager, who must weigh the costs, benefits, and risks of changing the ways services are delivered. To assist in meeting such challenges, TCRP Project J-09 produces a multiple-volume series under *TCRP Report 84*. The research program identifies, develops, and provides flexible, ongoing, quick-response research designed to bring electronic business strategies to public transportation and mobility management.

The Successful Adoption of Web-Based Collaborative Software is the seventh volume in the *TCRP Report 84* multiple-volume series. CFAR—the Center For Applied Research, Inc.—of Philadelphia, Pennsylvania, prepared this report. This report describes, through three case studies, how web-based tools have been used to assist with controlling and managing active and planned construction projects, including schedules and costs of the projects. The report also examines how web-based collaborative software has been used to help engineers share knowledge across varied programs and contracts and to create and enhance supply chain relationships.

Volumes issued under *TCRP Report 84* may be found on the TRB website at http://www4.trb.org/trb/onlinepub.nsf/web/crp. (Click on "Transit Cooperative Research Program" under the "Project Reports" heading.)

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e-Transit: Electronic Business Strategies for Public Transportation: Volume 7

THE SUCCESSFUL ADOPTION OF WEB-BASED COLLABORATIVE SOFTWARE

SUMMARY

Transit agencies face some of the most complex project management challenges, with large numbers of construction projects and intricate supply chain relationships. Transit agencies face these challenges in an environment made even more complicated by public oversight and bureaucracy. Web-based tools for collaboration are beginning to have a positive effect on productivity, knowledge management, communication, and community in many other domains, but these tools have been slow to take hold in the architecture/engineering and construction industries and in the transit industry in particular.

One of the problems with web-based tools for collaboration and with all online virtual communities and project groups is that most internal developers and consultants have focused too heavily on the technology and paid too little attention to the human element. One of the reasons for this is that the technology associated with this type of work far surpasses modern theories of social systems. So work with the social aspect of socio-technical design lags behind technological understanding. Even when the social aspects are given the proper attention, the research is often poor. This confluence of superior technology and poor social science contributes to many new technology failures in large organizations. A lot of money and time is wasted because the big ideas associated with web-based collaboration are poorly implemented.

The TCRP J-09 panel commissioned this in-depth study to identify three organizations that have successfully implemented web-based collaborative software. Our company—CFAR, a management consulting firm that is a spin-off of the Wharton School of Business at the University of Pennsylvania—conducted the research with an emphasis on what kinds of social interventions lead to successful implementation. The study advances the idea that "one size does not fit all" when it comes to the introduction of new technology and proposes at least two implementation styles that organizations can choose. Each approach will be effective if the choice matches the organization's particular circumstances and resources.

CHICAGO TRANSIT AUTHORITY

At the Chicago Transit Authority (CTA), a massive influx of federal and state funds to shore up the CTA's aging infrastructure was the impetus to move to online collaborative

software. Because part of the funding came from federal money, if the CTA did not use the funding, the CTA would lose the funding or risk nonrenewal the following year, so speed was of the essence. The CTA outsourced the capital program's construction management and was able to speed up the acquisition of new information technology. Strong leadership in the upper management at the CTA saw the potential of web-based project management tools. The program manager, URS, selected Kristine Fallon Associates (KFA) as a consultant to help the CTA select a web-based system, implement the system, and provide ongoing training and support for it.

Believing that if there is poor coordination in the design phase, the costs will escalate during construction, KFA looked for a system with strong design phase communication, collaboration, and document management capabilities in addition to these same capabilities for the construction phase. KFA ultimately chose Citadon's ProjectNet product, which is an application service provider (ASP). ASPs provide access to software that runs on the ASPs' computers. Customers pay for the use of the software. The CTA requires every construction manager, general contractor, and designer with a CTA contract to use the CTA's web-based project management system. Internally, this meant that the CTA needed to provide all employees on the capital projects with Internet access, and, externally, it meant that all construction managers had to bring in T-1 broadband lines to their construction sites.

Today, ProjectNet has over 800 users (nearly 900 users trained) from approximately 90 organizations, for over 50 different projects. The first construction project to use ProjectNet is still under construction, and it will be another year before the CTA can test the theory that the system accountability and auditability functionality will help them minimize contractor claims. However, there have been significant gains in productivity that can be reported to date.

The website implementation team could report on a couple of ProjectNet modules and quantify improvements that led to increased productivity and, thus, cost savings. One of these modules was the Request for Information (RFI) module. RFIs are a means of asking a question that needs an answer before work can proceed any further. KFA found that 9 months into the Douglas Blue Line Reconstruction project, CTA senior technical personnel were processing 260% as many RFIs per business day per person as, and responding in 18% less time than, those who were not using the web-based system on a comparable construction phase project that was managed without a web-based system.

CTA attributes the success of its implementation to several key factors: the fact that top management was fully behind the implementation of the web-based project management system and the enforcement of its use, the fact that the implementation team understood the CTA's business processes and dedicated support to make the system function smoothly, and excellent in-house training resources that tailored the training to individual roles.

PORT AUTHORITY OF NEW YORK AND NEW JERSEY

The Port Authority of New York and New Jersey (PANYNJ) has a 5-year, $8.7 billion capital budget and an engineering staff of 650 engineers, supplemented with approximately 600 outside consultants. PANYNJ houses its employees in 30 facilities in New York and New Jersey. In addition, four or five office sites now house the PANYNJ employees who used to work at the World Trade Center. On 9/11, the PANYNJ lost 84 employees in those offices. The attack has influenced the agency in other ways as well. Since 9/11, challenging fiscal constraints have forced a more rigorous prioritization of projects. There have also been significant increases in expenditures for security.

The agency has traditionally been conservatively managed when it comes to taking risks with data security. Since 9/11, that commitment has only grown. As a result, PANYNJ did not choose to use an ASP provider to host its collaborative software and data.

The case study focuses on the engineering department's use of Primavera's P3e and Primavision software to manage its portfolio of 600 active and planned projects, emphasizing the classic project controls: scheduling and cost. In addition to enhancing project control, the engineering department and chief operating officer needed a system that would help the agency prioritize among the 600 projects that it had in various stages of development. The PANYNJ wanted to move from a stand-alone solution to an enterprise solution so that working across units would be more integrated. Most important, the system needed to strengthen the cost controls on the agency's capital projects.

At the PANYNJ, a team of managers in the engineering department led the agency to the selection and implementation of various technologies, including Primavera Expedition and P3e software. Implementation was evolutionary and took place over several years.

The PANYNJ studied what others in the industry were using and found that over 90% of the engineering and construction industry and the top 400 contractors used Primavera Scheduling. The department decided to also use Primavera. P3e had a very robust cost control module, could be customized to the agency's needs, and was flexible enough to integrate with its existing systems, including SAP, a common material requirements planning (MRP) software.

Primavera's P3e functions as a kind of umbrella system that incorporates other software. To accomplish the systems integration with other departments, there are extensive monthly downloads, from both the budgeting system and SAP, which provide actual costs into P3e.

The PANYNJ determined that only some people in the engineering department would need to be fully trained on P3e. These people are called "power users," and they are technical resources for the department's 120 project managers. Project managers themselves are described as "casual users" and see a higher-level interface called Primavision.

The agency uses Primavera Expedition software to track its shop submittals and RFI turnaround time for all projects with budgets of $3 million or more. For example, all submittals flow through the agency's project managers, who are responsible for disseminating the required information to Expedition specialists who enter the tracking information into the Expedition system.

The philosophy behind the engineering department's approach was not to exhaustively redesign its processes formally, but instead to test the water with pilot projects. The engineering department thought carefully in advance and sought input about what the project managers needed from the system, but the department also wanted to avoid a lengthy redesign process before it could begin to introduce the technology.

Today, the PANYNJ has 200 projects in Expedition and has processed 50,000 submittals and 6,000 RFIs. Any project over $3 million is now tracked in Expedition to improve and log the submittal and RFI processes. In 2002 and 2003, the PANYNJ measured its turnaround time for processing RFIs and submittals and saw a 20% reduction in turnaround time.

Although the hierarchy and approval structure at the PANYNJ is essentially unchanged since the adoption of this technology, there have been two significant shifts. The first is in the way that broad access to the information enables a much more collaborative decision-making process. Just as significant has been the way project managers have embraced their role as financial managers as well as engineers. Joe Garcia, a member of the engineering department's financial services group, which works in a decentralized

way in each of the line departments, has seen a "really big leap" since Primavision has been implemented.

RAYTHEON

Raytheon today is a global defense and aerospace systems supplier with 77,500 employees worldwide and $18.1 billion in sales for 2003. Raytheon operates in 70 countries.

In the late 1990s, Raytheon faced several challenges. It needed to consolidate four separate companies that it had begun to acquire in 1997, and it needed to integrate the efforts of employees working across different time zones and geographic locations. The urgency to create a more unified and collaborative Raytheon culture came from the plummet in its stock price from $70 per share to $17 per share and the stock market decline. It became clear to Raytheon leaders that there was a need to change the "old Raytheon," which was noted for its traditional, hierarchical structure, into a "new Raytheon" that was more fluid and capable of collaborating and learning across many diverse boundaries.

Raytheon's approach to create a more collaborative culture included three elements: (1) the companywide adoption of a Six Sigma culture change program in 1999, which helped to create a common language and culture across the four newly merged companies; (2) Raytheon's choice of low-cost web applications like e-Room and Quickspace to support collaboration; and (3) the introduction of a community-of-practice model, which enabled Raytheon to share best practices across organizational boundaries. The study examines one of these communities, the Raytheon Integrated Logistics Community of Practice (RILCOM).

The Raytheon case exemplifies the idea that it is possible to start with the social aspect of change and then bring in the technology to support it. Because technology is more adaptable and less fragile than group structure, technology is often best designed around the group and not the other way around. Raytheon began by re-engineering work processes and then proceeded to build the technology around the new processes.

Raytheon Six Sigma was mandated from the top and spread throughout the entire company over a 2-year period after selected pilot experiments were conducted. It was a customized version of Six Sigma that helped the "new Raytheon" develop a common language. Raytheon focused on winning the support of its middle managers for the program, believing that middle managers are typically the slowest to adopt change because they are often the most overloaded. Raytheon Six Sigma designed and delivered an extensive 6-week training program; 1,400 employees have received the training. Raytheon has also qualified 13,000 people as Raytheon Six Sigma specialists, approximately 45% of Raytheon's employees.

Raytheon had already been exploring desktop collaboration tools. This software needed to support a wide range of teams—from a small number of employees putting together an event somewhere in the country or developing a PowerPoint presentation to huge, multiyear programs such as a missile program that involved thousands of employees from different businesses.

Raytheon sent a few of its members to research and rank the top solutions that were compatible with Lotus Notes, the system it was already using. As part of its selection criteria, Raytheon decided that it was going to spend "zero dollars developing something" and leverage its existing software license. Raytheon also wanted a tool that would require no training at all, believing that if people needed to go to a 4-hour training course, it would slow down adoption of the technology considerably.

QuickPlace and eRoom were chosen because they were intuitive and easy to use. These tools allow all team members on a project to view each other's changes, comments, and

suggestions. It also allows project collaboration to happen 24/7, thereby reducing costs, misinterpretations, and time.

QuickPlace and eRoom enhanced the culture of sharing that Raytheon Six Sigma was promoting. Simplifying the complexity of the work, these tools have a chat room function that enables people to talk in real time about their ideas, suggestions, and comments on a particular project. The tools allow immediate revisions in one place and keep all comments and changes. These products allow team members to tweak the work, and everyone can see who made the changes and why without having to email a document back and forth. Because others can take a look at changes prior to finalization, team members must be comfortable and willing to work in real time. The web-based format also allows members to easily interface with the program.

The dissemination of this technology has been very gradual and incremental. Raytheon believes that it is offering people a tool—an opportunity for people to use something—but it has to be something they want to use. One Raytheon employee stated in an interview,

> If you force it on them, you have to have an infrastructure to make it stick—a training platform to create experts and specialists, force people to come back and get new elements of the training because it drives the performance of the company. If you force it on them, you're back to needing to do lots of training.

Raytheon believes it is still in the "early-adopter" phase of technology introduction of its collaborative software, with only about 1,000 users.

Raytheon believed that it was critical to share knowledge across the company to gain a competitive advantage. Raytheon embarked upon a benchmarking study to understand how other best practice companies deployed their knowledge management activities, and Raytheon decided to create more formal "communities of practice" to learn about and share best practices across the company. The company worked closely with the American Productivity and Quality Center in Houston and licensed its community of practice methodology for use within Raytheon. One important lesson learned about creating successful electronic communities is that it is important to build the relationship among members up front. Members need the opportunity to develop the foundations for their work and their relationships before they go online, and they need the chance to have face-to-face contact several times throughout the year.

The study examines two communities of practice—(1) an informal community at Raytheon Missile Systems that helps engineers share knowledge across different Raytheon programs and contracts and (2) a formal community devoted to streamlining Raytheon's supply chain relationships, RILCOM.

STUDY CONCLUSIONS

Keys to Success

Choose the Right Model of Implementation

In our experience, successful adoption requires a certain forcefulness or passion in the organization because change is difficult. Without a driving force of considerable strength, it is unlikely that the innovation will overcome initial resistance to it and take hold.

To describe the adoption of new technology, we have developed a nonlinear model to complement the more traditional project management planning tools and models (see Figure 1). The nonlinear model reflects what we see in these case studies—that implementation is a distinctly nonlinear process where many things happen simultaneously. By focusing on the implementation phase of technology adoption and "thinking backward"

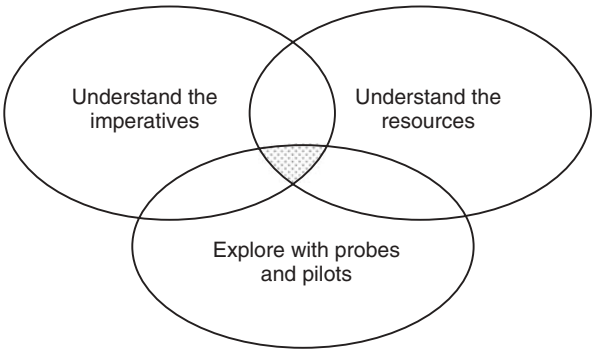

Figure 1. Our nonlinear model for adopting new technology.

toward the planning phase, this model is designed to help organizations think through what is driving their technology strategy and which approach to implementation will be successful for their particular situation. In deciding on an approach to implementation, organizations need to consider all three aspects of the model:

- Understand the imperatives:
  - Speed: How fast do we need to make the change?
  - Comprehensiveness: Does the entire organization need to change at the same time?
- Understand the resources:
  - Where is the leadership for this effort coming from?
  - What kinds of training resources are available?
  - What kind of technical support resources are available?
- Explore with probes and pilots:
  - Should we engage in process redesign before we begin?
  - What are we learning from pilots?
    - Technical challenges
    - Social challenges

Table 1 applies the nonlinear model to consider the differences between two kinds of implementation, "Mandated Change" and "Opportunity to Change." We define Mandated Change as change sponsored by the top leaders of the organization to be implemented fairly quickly and broadly, if not universally. In this type of implementation, change is required; it is "my way or the high way." To be successful, this kind of implementation requires deep commitment from the leadership, good resources for training and technical support, and the willingness to enforce the change. The Chicago case and aspects of the Raytheon case exemplify this type of implementation. The "Opportunity to Change" implementation, by contrast, can find its sponsorship in different departments of the organization. This type of implementation is opportunistic and takes advantage of other changes that may be occurring in the organization. This type of implementation is more organic, may require fewer resources for training and technical support, and introduces change more slowly. The PANYNJ case has elements of this kind of implementation model, as do some aspects of the Raytheon case.

Respect the Principles of Socio-Technical Design

Our approach to studying web-based technologies and the impact they have on organizations is through a socio-technical lens—that is, how technology impacts the flow

TABLE 1 Application of nonlinear model

Aspect of Nonlinear Model	Mandated Change	Opportunity to Change
Imperatives		
Speed	Fast	Can be slower
Comprehensiveness	Many people at once	Selective or phrased participation
Resources	**Higher**	**Lower**
Leadership	Top leadership enforcement	Top or middle leadership, attraction is high
Training	Many resources, formal training	Limited resources, less training required
Technical support	Many resources, much dedicated technical support	Limited resources, less technical support required
Probes and Pilots		
Process redesign	Extensive, upfront redesign	Incremental, learning-based redesign
What are we learning? • Technical challenges • Social challenges	Overcome technical challenges with resources, resistance may be high, enforcement required	Gradual technical refinement, lower resistance, attraction

of information across functions, levels, and organizations and the "social" side of roles and responsibilities.

Socio-technical design theory posits that organizations should design their technical and social systems concurrently and that people who work in these systems should participate in their redesign. Over the past few decades, practitioners and scholars have learned how new technology challenges old organizational designs and role relationships. Technical innovation produces socio-technical development one way or another. Organizations that anticipate and plan for the social consequences of new technologies are more capable of using these technologies to their fullest.

Typically, managers align social systems to technical ones through a process of linear rather than concurrent design. In other words, they design the technology first and then think about the design of the social system afterward, if at all. While this helps managers create an orderly implementation plan and project schedule, it frequently produces significant unanticipated costs and consequences. Time saved at the beginning by decomposing the tasks into their technical and social components is lost at the end when the two types of components don't mesh. Managers then call these problems implementation problems rather than problems in the design process.

Research and practice highlight at least four principles of socio-technical design that are relevant to thinking about how to introduce new technology:

- Identify the divergent interests that different users have. Don't work under the assumption that there is only one paradigmatic user.
- Let people who will work with the new technology participate in building the social system that will work with it.
- Focus on the system for delivering a new technology, as well as the technology itself.
- Do not over-design the implementation; use a minimum of critical specifications.

This report examines each of these principles with illustrations from the three cases.

Pay Careful Attention to the Boundaries of the Online Community You Are Creating

Web-based collaborative tools are essentially tools that enable you to move information across boundaries more easily—different companies located in different time zones around the globe in Raytheon's case, across 30+ different sites in New York and New Jersey in the case of the PANYNJ, and among CTA managers, architects, designers, engineers, and contractors in the field in Chicago. So we look to understand the theoretical underpinnings of boundary theory to help us recognize what is working, why, or what we can do about what is not working.

Many online communities lack sufficient boundaries. In a project management environment, this can lead to disorganization, ambiguous roles, and leadership problems. Chapter 5 defines a group boundary and explains how you can recognize when that boundary is too loose or too tight and what kinds of problems are associated with each condition.

The Benefits of Web-Based Collaborative Tools

The three case study systems all experienced certain benefits from web-based collaborative software. All three are enthusiastic about these benefits, even though the implementation is new enough that the benefits are difficult to quantify. The software provided

- Enhanced productivity,
- More accurate information to decision makers,
- Enhanced speed for information exchange,
- Role enhancement for project managers, and
- Enhanced accountability throughout the system.

The Barriers to Implementation

The three case study systems experienced different barriers to implementation of the web-based tools, including

- Reluctance to give up paper and wet signatures,
- Reluctance to locate data off-site,
- Difficulty in agreeing on a single process to be followed,
- Difficulty scanning documents and reading oversized documents that have been scanned on a regular-sized computer screen,

- Difficulty supporting a web-based system with users who are not part of your own organization (e.g., contractors and subcontractors in the field), and
- Reluctance to show work in progress to peers.

Best Practices

The study identifies certain best practices from the experience of the case study organizations. Each of these best practices is expanded upon in Chapter 8:

- Think carefully about what kind of implementation model will be successful for you.
- Notice where there may be opportunities to introduce collaborative software in the midst of other systems initiatives.
- Think of technical support people as change agents who can advance your agenda.
- Don't overcustomize the product.
- Think creatively about process redesign.
- Use pilot experiences and early forays.
- Think carefully about your criteria for selecting a pilot site.
- Focus your implementation efforts on the middle managers in the organization.
- Don't train every user on all aspects of the new technology; instead, differentiate the training by role.
- Keep training simple for the majority of users.
- Plan to offer a refresher training course after 3–6 months.
- Don't underestimate the technical challenge that may arise with the scanning of documents.
- Align the evaluation, incentive, and compensation systems to support the adoption of new technology.
- Recognize the problems of microcosm and temporary groups.
- Make a long-term commitment to the technology in order to push through the initial resistance.

CHAPTER **1**

INTRODUCTION

The projects and activities that transit agencies manage are increasingly complex. They may involve multiple organizations and a variety of departments and staff within these organizations. Some of the most complex of these projects are major construction projects that typically involve the agency and its prime contractor, the contractors' subcontractors, multiple architects and engineers, third parties such as utility companies, and other organizations such as local, state, and government oversight agencies. Contract changes and claims can be frequent and contentious.

Transit agencies are not alone in struggling with these issues on construction projects. Historically, the architectural, engineering, and construction (A/E/C) industry has been plagued by inefficiencies, cost overruns, and interparty disputes. Communication and coordination problems are inherent in these projects because of the projects' complexity and the often fragmented processes they involve. Scott Unger of Constructware writes that the following facts all negatively impact productivity:

- Changes are a standard part of the building process, but cannot be predicted.
- Many parties can initiate a change in the process.
- A change often impacts a substantial number of parties.
- There are few consistent methods for notifying impacted parties of changes.
- Impacted parties often are not made aware of changes in a timely matter, if at all.[i]

Construction projects have unique needs for the large volume of communication that needs to flow rapidly between widely dispersed parties. In most settings, information is a basis of power and authority, and it is often difficult for information to flow between management levels, among individuals, and across organizations: "The vast majority of project participants get their information the old-fashioned way: from phone calls, fax transmissions, word-of-mouth and written monthly reports. This type of decentralized information flow contributes to disputes, delays and claims."[ii]

Web-based tools for collaboration can provide functionality that diverse participants need to more efficiently exchange project information, thereby minimizing misunderstandings and miscommunications. The web is beginning to affect productivity, knowledge management, communication, and community in many other domains.

If we think of construction projects as a series of supply chain management problems, it makes sense that some of the same kinds of boundary problems that plague supply chain dynamics also contribute to conflict and inefficiencies in construction projects.

In supply chain management projects, the problematic boundaries appear both within the organization itself—for example, between the maintenance group that needs a part and the procurement group that orders it—as well as outside of it. Problems with information flow also occur on the boundaries between the agency and its suppliers and between primary suppliers and the companies they in turn rely upon to provide them with parts. Like construction projects, supply chain issues exist in a complex network of many players, and it is not always clear who should or can initiate the implementation of technology that might transform the entire system on behalf of its participants.

The objective of this research is to understand the use of real-time integrated electronic technologies that enable collaboration on and management of complex projects involving multiple organizations and individuals. This research studies the experiences of three organizations: the CTA, the PANYNJ, and Raytheon.

Each of these case study sites applied web-based collaborative technologies to address pressing business needs, yet they did so in three completely different ways.

BENEFITS OF WEB-BASED PROJECT MANAGEMENT

According to Kristine Fallon, of Kristine Fallon Associates, Inc., web-based project management is particularly helpful in situations where teams and documentation are scattered across multiple physical locations. Fallon's assertion is supported by M. Barnes in his keynote speech to the 16th IPM World Congress. Barnes claimed that web-based project management systems allow entire project teams the following:

[i] Unger, S. "The Trend Towards an Internet-Based Communication Standard in the A/E/C Industry." Constructware (January 2002), p. 2. http://www.constructware.com/common/downloads/standardization_white_paper.pdf

[ii] Ibid, p. 5.

> Real-time access to a single source of all project information via the Internet, a personal computer and a web browser. All project participants have access to the latest and most up-to-date project information, no matter where they are physically located.[iii]

Web-based project management systems allow for faster and easier exchange of information, which, in turn, allows project participants to create, view, upload, and download project data from any personal computer with an Internet browser and an Internet connection. Stakeholders are not restricted to one physical location. Using computer-based technology can increase productivity throughout the design and construction phases, providing easy access to project information, while also providing for accountability (who is also responsible for what and when it is due) and auditability (who did what and when they did it). Implementing an Internet-based system is also less costly than other alternatives. Baecher notes that web-based tools are quickly replacing traditional methods of managing the tasks of large engineering projects.[iv]

Particular areas that are ideal for web-based management tools include

- Automation of design of construction business processes,
- Document management,
- Online bidding and procurement,
- Material management,
- Contracting and pricing,
- Scheduling collaboration, and
- Cost control and estimation.

Among the many benefits of web-based project management are the following:

- Streamlining of communications:
  - Constant, real-time interchange of communications;
  - Anytime, anywhere access to project data;
  - Reduction of communication paths and miscommunication;
  - Documentable and searchable communication;
  - Instantaneous communication across all projects;
  - Decreased response time to all project participants;
  - Accountability for content and timely response;
  - An easy-to-use, single web-based interface for all participants; and
  - A shared calendar for individual appointments and for team meetings.
- Document and forms management:
  - Complete sets of project specifications and drawings accessible to everyone,
  - A central clearinghouse for all official project documentation,
  - Document security and integrity,
  - Knowledge management, and
  - Custom security permissions to control access-sensitive data.
- Faster cycle time:
  - Automated and controlled work flow,
  - Comprehensive tracking of time-sensitive items,
  - Automated notifications to project participants, and
  - Increased productivity.
- Cost management:
  - Overhead reduction by eliminating unnecessary resources and redundant work,
  - Real-time visibility for better decision making,
  - Standardization,
  - Ability to fix errors and make adjustments instantaneously,
  - Quick identification of problem areas,
  - Integration of project expense and labor costs,
  - Prediction of project costs, and
  - Budget planning and project monitoring.
- Overall supervision:
  - Automated reporting of business processes,
  - Alignment of project priorities with overall company strategy, and
  - Optimization of existing intellectual property and company assets.

Many of these benefits were realized in the three organizations studied.

WEB-BASED PROJECT MANAGEMENT AND THE CONSTRUCTION INDUSTRY

Hendrickson and Au argue, "The greatest stumbling block to effective management in construction is the inertia and historic divisions among planners, designers and contractors."[v] The relatively high level of fragmentation of specialties—architects, engineers, state and federal oversight agencies, construction managers, general contractors, and community organizations—makes good communication and coordination even more important.

Construction projects in the transit industry are full of inefficiencies. According to S. Sunil, 15% of projects are over budget and delayed.[vi] Unger argues that the lack of accurate and timely information exchange is a root cause of cost-plus contract change orders and delays during design and

[iii] Barnes, M. "A Long Term View of Project Management—Its Past and Its Likely Future." UK: Cornbrash House (June 2002). www.pmforum.org/pmwt02/papers02-07.htm

[iv] Baecher, G. "The Project Environment." Foundation Knowledge. Accessed October 9, 2003. gbaecher@eng.umd.edu. www.foundationknowledge.com/Briefings/WBPMKMProjectenvironment/main.htm

[v] Hendrickson, C., and T. Au. "Project Management for Construction: Fundamental Concepts for Owners, Engineers, Architects and Builders." www.ce.cmu.edu/pmbook

[vi] Sunil, S. "Construction e-Project Management." http://www.projectmanagement.com/pm/article.cfm?ID=127864.

construction. Internet-based applications are ideally suited to solve communication and coordination problems.[vii] Because one project is often composed of many individual subprojects, a schedule change in one element has a ripple effect on all the others, resulting in low levels of productivity, particularly when compared with other industries.

Because communication and document management typically make up one-third of the cost of a construction project, using web-based project management tools can potentially result in 10–15% cost savings and a return on investment (ROI) of 300%.[viii]

As a whole, the construction industry has been slow to take advantage of collaborative technology, however. Unger believes that this is due to the "silo" nature of the projects. Individual project teams may use client server–based project management software to manage their day-to-day work, but few use complex platforms that allow for application sharing and links between the primary workplace and remote worksite.[ix] Construction IT administrators point out that their "number one problem is attempting to link dozens or hundreds of jobsites over the course of a year to their corporate network. They either have an enormous IT budget, or they do the job poorly."[x]

However, many believe that as companies see significant benefits to these collaborative systems, large contractors will set the standard and "push these tools out to their business partners."[xi]

The need for innovative project management tools has implications beyond the individual project. The Business Roundtable said the following in the Construction Industry Cost Effectiveness Project:

> The creeping erosion of construction efficiency and productivity is bad news for the entire U.S. economy. . . . The price of every factory, office building, hotel or power plant that is built affects the price that must be charged for the goods or services produced in it or by it. And that effect generally persists for decades. . . . Too much of the industry remains tethered to the past, partly by inertia and partly by historic divisions.[xii]

THE INTRODUCTION OF NEW TECHNOLOGY

Many models exist to explain how organizations take up technological innovations, and most of these models are linear and highly rational. They often begin with some kind of needs assessment, progress through design phases and process redesign, and move on to implementation and testing and lessons learned. These phased models are useful in the way that they structure and impose order on what can often be a chaotic and distinctly nonlinear process. These classic project management models are very helpful in creating a roadmap to guide project managers and organizations through the process.

We have developed a nonlinear model to describe the adoption of new technology (see Figure 1 in the report summary). This model is designed to complement the more traditional project management planning tools and models. It reflects our experience that implementation is a distinctly nonlinear process where many things happen simultaneously. By focusing on the implementation phase of technology adoption and "thinking backward" toward the planning phase, this model is designed to help organizations think through what is driving their technology strategy and which approach to implementation will be successful for their particular situation. In reality, the adoption of new technology is rarely a linear process. Table 2 shows the questions to ask for each of the aspects of the nonlinear model.

TWO STRATEGIES FOR IMPLEMENTATION: WHICH ONE IS RIGHT FOR YOU?

We propose that two distinct approaches to implementation are illustrated by the case studies in this report: Mandated Change, which is change that is pushed into the organization by leadership from above, and Opportunity to Change, where change is pulled by opportunities that exist in the system and leadership acts as a guide and promoter of the changes it wishes to see. To be successful, Mandated Change requires heavy initial investments in formal training programs, technical support, and the commitment of the system's leadership. Mandated Change is well suited to organizations that need to introduce technology very rapidly or with total compliance across the organization. In order to succeed, the leadership must be willing to enforce the change. For example, at the CTA, contractors needed to adopt ProjectNet if they wanted to work on the CTA's capital projects. To be successful, Opportunity to Change needs consistent leadership that can provide a vision of change across a longer span of time. Opportunity to Change is well suited to organizations that have more time to create evolutionary change and gradual adoption. Each approach carries different risks. With Mandated Change, which is pushed from above, you are more likely to encounter higher levels of social resistance. With Opportunity to Change, there is the danger that the change effort will dissipate and not take hold.

No one approach to implementation fits all settings. Rather, there is danger in not accurately diagnosing what you need and what you have and pursuing one kind of implementation with resources that are better suited to another. To choose wisely, it is first necessary to understand the differences

[vii] Unger, S. "The Trend Towards an Internet-Based Communication Standard in the A/E/C Industry." Constructware (January 2002), p. 1. http://www.constructware.com/common/downloads/standardization_white_paper.pdf

[viii] Sunil, S. "Construction e-Project Management." http://www.projectmanagement.com/pm/article.cfm?ID=127864.

[ix] Unger, S. "The Trend Towards an Internet-Based Communication Standard in the A/E/C Industry." Constructware (January 2002), p. 4. http://www.constructware.com/common/downloads/standardization_white_paper.pdf

[x] Ibid.

[xi] Ibid., p. 11.

[xii] The Business Roundtable, "More Construction for the Money, Summary Report of the Construction Industry Cost Effectiveness Project" (January 1983), p. 11.

TABLE 2 Questions to ask to determine implementation approach

Aspect	Questions to Ask
Understand the imperatives	• Speed: How fast do we need to make the change? • Comprehensiveness: Does the entire organization need to change at the same time?
Understand the resources	• Where is the leadership for this effort coming from? • What kind of training resources are available? • What kind of technical support resources are available?
Explore with probes and pilots	• Should we engage in process redesign before we begin? • What are we learning from pilots? – Technical challenges – Social challenges

between the two implementation approaches and the imperatives that are driving the introduction of a new technology.

UNDERSTAND THE IMPERATIVES

Organizations move toward the adoption of new technology in response to a variety of imperatives, and sometimes these strategic choices are implicit rather than explicit. In our experience, successful adoption requires a certain forcefulness or passion in the organization because change is difficult. Without a driving force of considerable strength, it is unlikely that the innovation will overcome initial resistance to it and take hold.

In the planning phase, organizations need to ask two questions:

- Speed: How fast do we need to make the change?
- Comprehensiveness: Does the entire organization need to change at the same time?

These two questions together make up what socio-technical design calls "felt need," which captures the power and passion that drive organizational change. As Fred Emory said in an interview, reflecting on the organizational change projects that composed his career, "May I just say that every project I've mentioned has been started under conditions of crisis . . . 'felt need' used to be a favorite phrase of ours at Tavistock. Unless there is a felt need, nothing is going to happen."[xiii]

Many people refer to imperatives for change as "burning platforms"—that is, natural or engineered crises that force change. In Chicago, the CTA faced a burning platform when it received $2.2 billion in funding and faced an explosion in the magnitude of its construction activity. At Raytheon, the imperative for the Six Sigma initiative came from the need to integrate different parts of the newly formed company. The burning platform was Raytheon's stock price. Later, Raytheon adopted a more evolutionary style of implementation when it saw opportunities to share knowledge across its various divisions and projects. At the PANYNJ, the felt need came from a clear sense of opportunity, as many departments began to move toward new technology and leadership recognized a chance to integrate efforts. There is no "one size fits all" answer for the successful adoption of new technology; each of the successful organizations we studied chose a different method that was well suited to its particular circumstances.

Before making choices about what kind of implementation will be successful for your organization, it is important to understand the felt need that is driving the change.

UNDERSTAND THE RESOURCES

To make an informed choice about implementation, the organization will need to answer several questions:

- Where is the leadership for this effort coming from?
- What kind of training resources are available?
- What kind of technical support resources are available?

The key question to ask when considering different models of implementation is, how fast does the company need to make a change? Where there is a burning platform, implementation often needs to be very fast and involve many people in a short time. In this case, you will need a leadership-driven, Mandated Change implementation model. Leadership will have to be willing to enforce the change to overcome the initial resistance, and training and technical support

[xiii] Fox, William M. "An Interview with Eric Trist, Father of the Sociotechnical Systems Approach," *The Journal of Applied Behavioral Science*, Vol. 26, No. 2, p. 271.

resources will need to be significant. Where opportunities draw the company forward into new technology, successful implementation can be more organic and evolutionary. Committed leadership is also necessary in order for this model to succeed, but it can be more influential and less directive. We call this approach an Opportunity to Change implementation model.

How do these two different approaches to implementation—Mandated Change and Opportunity to Change—show up in the case studies that follow? At the CTA, there was an urgent need for fast adoption of new web-based technology, and so they were successful with the Mandated Change implementation approach. At the PANYNJ, leadership recognized a series of opportunities to introduce collaborative software and led the organization in a more gradual and organic Opportunity to Change model. The Raytheon case provides examples of both models of implementation. Facing a crisis in its performance and stock price, Raytheon executives mandated the adoption of a Raytheon Six Sigma program, which succeeded in knitting together four new companies into the "new Raytheon." Then company executives recognized an opportunity to share knowledge formally and informally across programs and adopted two technologies to facilitate learning: a tool (web-based collaborative software) and a social structure (communities of practice). Raytheon has used an Opportunity to Change approach to encourage the adoption of these two innovations.

The key concept to understand when thinking about how best to introduce new technology is what William Ibbs describes as "suitability." This means that there is no "one size fits all" solution in project management, in implementation model, or in product selection. It means that a mature organization will be able to discern which of these tools is most appropriate for which challenge and at which time.

Each of these approaches to implementation—Mandated Change and Opportunity to Change—has implications for how much training is necessary and how it is approached. For example, using the Opportunity to Change approach, Raytheon consciously selected a product that would require no formal training at all and instead would rely on attraction and ease of use to disseminate throughout the company. At the CTA, however, with its mandated implementation of web-based technology in a short time frame, a formal training program was designed and delivered to everyone who would be working with the new technology.

EXPLORE WITH PROBES AND PILOTS

Regardless of what kind of implementation approach is used, all of the case study organizations learned from pilot experiences, or early forays that helped them to test the new technology initially. These initial forays were a rich source of learning that helped the organizations to adjust their approach based on experience. Learning typically answers questions:

- Should we engage in process redesign before we begin?
- What are we learning from pilots?
  - Technical challenges
  - Social challenges

Another question in the case study organizations was how best to handle process redesign. Conventional project management wisdom holds that formal process redesign should always precede the adoption of new technology in order not to "automate junk." But it is also the case in real practice that the work of process redesign can take place at the same time as early forays. The PANYNJ, for example, was very clear that it was interested in capturing obvious process redesign gains without engaging in a complete overhaul of its work processes. Once PANYNJ had implemented the new project management tools on a project, it understood more clearly what kind of process changes needed to be made, and then it made them. At Raytheon, the focus was on information sharing and knowledge transfer, with the assumption that this would in turn lead to changes in process as different parts of the company learned about and adopted best practices.

In Chicago, they encountered a technical challenge with scanning. The CTA discovered that contractors and subcontractors had a difficult time initially scanning documents into the web-based system because they didn't have the proper scanning equipment or the equipment was not set up properly. Raytheon faced a social challenge: engineers were wary of using a collaborative product and sharing work-in-progress with their colleagues.

The nonlinear model for adopting new technology can be "read" in the way it is described here, with one phase coming before another and each feeding into the next. But in reality, everything often occurs simultaneously. For example, at one point in Chicago, the imperative of speed changed the plan to do more detailed process redesign; instead of doing the detailed process redesign, provisional steps were put into effect. Or the learning from pilots will feed back into the design of the solution and lead to a change in the software product itself, as it did at the PANYNJ.

Part 1 of this report features the three case studies that illustrate the nonlinear model and the two methods of implementation.

THE THEORY YOU NEED

Our approach to studying web-based technologies and the impact they have on organizations is through a socio-technical lens—that is, how technology impacts the flow of information across functions, levels, and organizations and the "social" side of roles and responsibilities.

Socio-technical design theory posits that organizations should design their technical and social systems concurrently and that people who work in these systems should participate in their redesign. Over the past few decades, practitioners and

scholars have learned how new technology challenges old organizational designs and role relationships. Technical innovation produces socio-technical development one way or another. Organizations that anticipate and plan for the social consequences of new technologies are more capable of using these technologies to their fullest advantage.

Typically, managers align social systems to technical ones through a process of linear rather than concurrent design. In other words, they design the technology first and then think about the design of the social system afterward, if at all. While this helps managers create an orderly implementation plan and project schedule, it frequently produces significant unanticipated costs and consequences. Time saved at the beginning by decomposing the tasks into their technical and social components is lost at the end when the two types of components don't mesh. Managers then call these problems implementation problems rather than problems in the design process. In reality, the initial work pays off at the end.

In many organizations, the social system may be partially addressed during a process re-engineering. How extensive that process re-engineering is, how intentional, who participates, and how they participate are all choices that will somehow be made. Socio-technical theory encourages us to think of process re-engineering as the broad questions, "How will we get the work done?" and "Who will do what?"

Web-based collaborative technology creates information-intensive environments. In Chicago, for example, senior technical personnel were able to process 260% as many RFIs per business day per person as, and respond to them in 18% less time than, those not using the web-based system on a comparable construction phase project that was managed without a web-based system. Access to so much information changes workers' roles: it stimulates workers to develop new skills, but, equally important, workers in an information-intensive environment think about their work differently—the time horizon of their work changes. Workers develop the ability to think more systematically, to look at relationships between trends and variances; they increasingly take up new roles as planners as well as fixers. This was the case at the PANYNJ, where project managers who were able to became adept at cost control on their projects.

In an interview, Robin Cody at the Bay Area Rapid Transit (BART) system described the way the agency conducted a quick pilot of a web-based technology and allowed vendors to submit invoices—many hundreds of pages and pieces long—electronically. Different managers at the agency could then distribute the invoices electronically for approval. Cody described the pilot as follows:

> We brought it up in a week or so. We didn't do much formal training and had no time to change our business practices. . . . We were basically taking a nice product out of the box, dumbing it down to match our old manual methods—and even then it had benefits. . . . If I had the time to do it right, we would spend the time up front, defining the end game—canvassing the vendor as well as the agency vetted, "What do you need to do your business," and then built the product around it. We mapped our current practice—we would want to go back and challenge that. The upfront work would have paid off at the back end.

Socio-technical design theory posits that participative methods are essential in designing a social system to complement the new technical system. In BART's case, Cody knows that he would have wanted to re-design the processes by including the vendor, the manager, and those who need to work with and approve the invoices.

In the field interviews, it seemed clear that people are "fluent" in speaking the language of process re-design. They have all had some, or extensive, experience in examining the "what" of people's jobs and how information flows through a system. It is less clear that they speak the language of "role" and its implications. These questions may sound like, "What sort of work will I do now?" "What am I responsible for?" "What kind of authority do I have if I see a problem occurring?" "How should I interact with others on the project?" "When is something 'my business'?" Sometimes the answers are not clear because no one is asking or trying to answer these questions. However, this role change can be expected to occur when new information-intensive technology is introduced. Sometimes the answers are not clear because the impact of the new technology on roles is difficult to anticipate.

Part 2 of this report discusses several different theories that we believe are especially helpful in thinking about social systems and their re-design:

- Boundary theory—underbounded and overbounded groups and their problems,
- Selected socio-technical design principles, and
- Social resistance theory.

Each chapter of Part 2 illustrates the theory with examples from the case material.

PART 1:
THREE CASE STUDIES

CHAPTER 2

CHICAGO TRANSIT AUTHORITY: MASTERING THE INTEGRATION OF DESIGN AND CONSTRUCTION

OVERVIEW

The CTA is the nation's second largest transportation system. The bus and rapid-transit rail system serves Chicago and 40 surrounding suburbs. On the average weekday, 1.5 million riders travel 1,900 route miles and 289 miles of track.

The CTA was created as a public body in 1945 as a result of chronic financial problems among private companies that had previously operated the transit service and had been continuously in and out of bankruptcy. The CTA began operations in 1947, but the majority of its physical infrastructure was built between 1892 and 1920.

In 1971, the federal government began a program to fund the renewal of public mass transportation systems. The state of Illinois established a program to assist the CTA to meet requirements for nonfederal matching funds; finally, in 2000, federal and state funds for capital projects to shore up the CTA's aging infrastructure became available. The deteriorating infrastructure and slow trains needed major rehabilitation. As former CTA Executive Vice President of Construction, Engineering and Facilities, Jack Hartman, said of the Douglas Branch of the Blue Line, "If we didn't do this, within a year or two we'd have to shut the whole line down." The focus of the CTA's capital improvement program (CIP) is to build and rehabilitate facilities to extend their life by four decades. According to Hartman, one of the CIP's goals for achieving this was to "further the use of technology, particularly in the area of online communications, collaboration and project management."

With an initial capital improvement budget of $2.2 billion for the next 5 years, there was a massive influx of resources. The CIP was created under the direction of CTA President, Frank Kruesi, and Executive Vice President of Construction, Engineering and Facilities, Jack Hartman.

In this chapter, quotations without attribution were taken from interviews with CTA employees or people who have worked with the CTA.

UNDERSTAND THE IMPERATIVES: SPEED IS OF THE ESSENCE

The $2.2 billion in transportation funding that the CTA received was far more than it had the internal resources to manage. The organization was not adequately staffed, and it did not possess the resources appropriate for the scale of the project. Because part of the annual funding came from the federal government, the CTA needed to use all of the funding or risk nonrenewal of funding the following year.

The CTA's in-house professional construction and management services were already extremely busy, and the scale of design and construction was about to explode—70 projects ranging from less than $1 million up to approximately $500 million. To appropriately manage the CIP, the CTA needed to augment its staff. In 2000, the CTA hired a program management team composed of 13 firms and led by URS Construction Services. The program management team spent the first year with the CTA in an intense planning process, culminating in a program master plan. A matrix organization, the team of "insiders and outsiders" became so integrated at the CTA that the lines between owner, consultant, and subconsultant blurred significantly with respect to getting the job done.

The CTA Board of Directors established four quantifiable goals for the CIP team:

- 80% of the funds committed within 5 years,
- Majority of benefits realized within 5 years (construction underway),
- Progress toward bringing the system to a state of good repair, and
- Equitable distribution of benefits throughout the CTA service area.

In addition to bringing additional resources to the agency, outsourcing program management enabled the CTA to speed up the acquisition of new information technology. The program managment team could move more quickly with its own procurement than CTA could with public procurement, allowing program managers to get things up and running for the CTA and themselves more quickly.

The CTA wanted to achieve transparency to improve credibility with funding authorities and the public at large. Traditionally, integrating the Project Management Oversight Contractors (PMOCs) into the project had been problematic, especially when the PMOCs were geographically dispersed. At the CTA, the PMOC team was trained on the web-based

project management system so that team members could have access to all capital information from anywhere in the country via the Internet.

Additionally, the CTA was committed to achieving ISO 9001:2000 quality registration, which required

- Correct versions of controlled documents available in a single location,
- Prevention of unintended use of obsolete controlled documents,
- Maintenance of records providing conformity to quality requirements, and
- Legible records that were readily identifiable and retrievable.

WHAT KIND OF PROJECT MANAGEMENT TOOL DO WE NEED?

Jack Hartman, the former CTA Executive Vice President of Construction, Engineering and Facilities, pushed for a web-based approach to project management. He strongly believed that this web-based, collaborative approach would be necessary if the CTA were to manage its capital projects successfully. Hartman kept informed of emerging technology and explored web-based project management tools. In the end, this led him to require the program manager to implement a web-based project management system for the CIP. URS selected Kristine Fallon Associates, Inc. (KFA), to join the program management team and charged KFA with the selection of a web-based system as well as with implementation of the system and ongoing training and support for it and all of its users.

The Importance of Design

KFA spent its first two months performing a CTA needs analysis. As Kristine Fallon stated, it is "important to really understand the source applications and classic problems in communications and look for products that can solve them." The project management team quickly realized that it needed a tool that could support both design and construction phase business processes equally.

In an interview, Kristine Fallon explained why it was so important to include design in the solution:

> Design quality controls your construction costs. While the construction phase is where the lion's share of the total project costs are expended, poorly coordinated design drawings are what lead to contract change orders and additional expense in the construction phase.

KFA likened the cost structure to a "creeping slope"—illustrated in Figure 2. As the design phase moves into construction, the project costs increase but the ability to control them decreases. Therefore, you want to identify problems as early in the process as possible, where your ability to influence them is still high. If there is poor coordination in the design phase, the cost will escalate during construction. Thus, the system selected had to have strong design phase communication, collaboration, and document management capabilities, with the same capabilities for the construction phase *plus* the automation of construction phase business processes.

The system would also need to meet three key goals as defined by KFA. The goals came to be known as "the three A's":

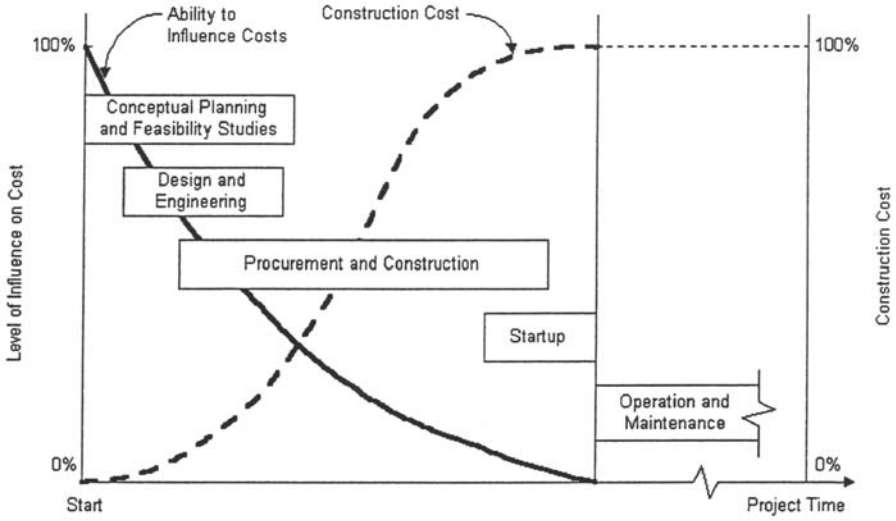

Figure 2. Ability to influence construction cost over time.[a]

[a]Hendrickson, C. "Project Management for Construction: Fundamental Concepts for Owners, Engineers, Architects, and Builders." PA: Carnegie Mellon University, 1998. http://www.ce.cmu.edu/pmbook/

- **Access.** Project information is accessible to authorized project team members from virtually anywhere with a personal computer, browser, and Internet connectivity.
- **Accountability.** The system tracks who is responsible for what task and when the task is due or overdue.
- **Audit trail.** The system logs who did what and when they did it.

Choosing an Application Service Provider

KFA believes that "If it's not part of your core business, don't do it." KFA recommended Cephren, Inc. (which later merged with Bidcom, Inc., to form Citadon, Inc.), based in San Francisco, because Cephren had a track record with large construction projects and because its web-based project management system, ProjectNet, supported design phase document management as well as the construction phase document and business process management. Citadon is an application service provider (ASP). ASPs provide access to software that is hosted remotely and that is accessed by the customer via the Internet. Customers pay a subscription fee for the use of the software.

Benefits to using an ASP are as follows:

- **Reduced cost.** Since the ASP provides hosting, data storage, backup, and disaster recovery for the system, no expensive on-site management information systems (MIS) staff needs to be hired by the customers. Also, the customers only pay for the capacity they use as they use it. In-house systems must be sized to accommodate estimated future needs.
- **Unlimited users.** Citadon's licensing scheme for ProjectNet allows for unlimited users. The CTA pays only for active projects on a project-by-project basis and for additional storage if needed. KFA believes that a license that allows an unlimited number of users to access the system is preferable to licensing schemes that charge "per user" (or per number of users). Limiting the number of users who can access the system vitiates the system's effectiveness.
- **Product updates.** The ASP pushes software to the user via the Internet, allowing software product updates to occur transparently. KFA believes that this is particularly beneficial to large companies and public agencies where deployment of software updates by internal MIS staff can be problematic and costly.
- **Scaleability.** An ASP provides capacity on demand. The customer does not need to worry about accurately projecting needs or planning procurements.
- **Redundancy, backup, and disaster recovery.** All services are provided by the ASP. The customer does not need to procure, configure, support, or maintain the system.
- **High reliability.** ASPs provide high levels of system availability. As Jack Hartman said, "Since Citadon uses Exodus [the Internet data service company that is now Cable & Wireless], the same Internet data facility that MasterCard, Sun Microsystems, MSN and American Airlines uses, it wasn't hard for me to convince our staff about the reliability and security of such a service."[i]

Some people are wary of ASPs because ASPs are not platform independent, but most web-based project management systems are not platform independent, either, requiring a Windows desktop. In addition, KFA believes that in-house systems are more expensive to support and maintain than ASPs are.

UNDERSTAND THE RESOURCES: COST VERSUS BENEFIT

KFA believes that it is important to tie the cost of the ASP solution to the program's overall value. For example, the cost of using ProjectNet over the 5-year life of the CIP was approximately 0.1% of total construction costs—roughly the cost of hiring a single senior-level manager for the 5 years.

ProjectNet allowed for some customization of the business process, but customization was limited. ProjectNet functionality was based on best practices for design and construction and was thus a more "out of the box" approach. Though somewhat limiting, the implementation team saw value in this "out of the box" approach because it would save time in implementing the system. System implementation takes more time the more complex the product is and the more customization it allows. A high degree of product customization also is more likely to result in more errors and miscommunication of requirements. A good "out of the box" solution contributes to a good system implementation, allowing everyone to benefit from the technology more quickly. Citadon's next-generation tool—Citadon CW (Collaboration Workspaces) allows for much greater business process customization.

ProjectNet works both like an electronic file cabinet and like a series of logs that allows team members real-time access to project information—from design drawings and bid documents to requests for information (RFIs) and submittal packages. ProjectNet allows the ability to search, sort, and filter project information based on the user's preference. For example, one team member may want to view all open RFIs, while another may want to view only open RFIs that are overdue, while yet another may want to view only RFIs that pertain to a specific section. Having all project information organized in one place allows project participants to collaborate in their own styles based on their roles on the project.

[i] Cyon Research Corporation. "Cyon Research Study Analyzes Web-Based Project Management Implementation at Major Transportation Agency." 2002. http://www.cyonresearch.com/press/?20020826.

WHAT KIND OF IMPLEMENTATION IS SUITABLE?

At the CTA, time was of the essence because the agency needed to move aggressively forward with its CIP, which was orders of magnitude larger than anything the CTA had attempted in the past. The CTA did not have the option to consider a more gradual, incremental implementation of the new technology. Under these circumstances, the implementation and transition to ProjectNet needed to happen quickly and comprehensively. Therefore, compliance with its use needed to be mandated from top-level management and rigorously enforced.

The CTA requires every company with a CTA contract to use its web-based project management system. "In terms of propagation of system use, having the owner in control is very helpful. We can and do require everyone—construction managers, general contractors, and designers—to use the system. Without access, you are off the project."[ii]

Today, ProjectNet has over 800 users (nearly 900 users trained) from approximately 90 organizations for over 50 different projects. Two key facts proved important for successful implementation: (1) that top management was fully behind the implementation of the web-based project management system and the enforcement of its use and (2) that the implementation team understood the CTA's business processes and procedures.

The project management team, particularly KFA, understood the importance of a good product roll-out for the successful adoption of the new system. Meetings were hosted by top-level CTA and program management personnel for all Construction, Engineering, and Facilities Department employees. The meetings stressed the importance of adopting the new way of working toward realizing the CTA's goals—failure was not an option.

Within 4 months of procurement of Citadon's services, the project management team had its first construction phase project website up and running—the Douglas Blue Line Reconstruction Project, one of the largest capital projects in the program. ProjectNet was next used for the design phase of the Ravenswood Brown Line project and is currently being used on the Dan Ryan Red Line Reconstruction project. It took the CTA about 2 years to fully adopt the technology as part of its culture. During this time, many CTA procedures that were not clearly defined before ProjectNet was implemented were re-evaluated and revised to incorporate the way the web-based system was being used.

EXPLORE WITH PROBES AND PILOTS: PROCESS REDESIGN

KFA clearly understood the importance of streamlining procedures at the outset of system implementation and then automating them using the system's features and functionality. KFA found that although this technology might not transform a process itself, it could aid in streamlining the process workflow.

Concurrent with the implementation effort of ProjectNet, the CTA engaged in a commitment to achieve ISO 9001 quality registration for their Construction, Engineering, and Facilities Departments. This commitment required documentation of all CTA and CIP management procedures. However, the ProjectNet implementation was on a much faster timetable.

To understand how procedures would need to change with the adoption of the new system, KFA planned to understand the CTA's current procedures, document them, and then adapt them to indicate how ProjectNet should be used to support these procedures. KFA went through each defined business procedure, met with key stakeholders, and solicited feedback until all were in agreement on how the process should work on ProjectNet. In cases where procedures were ill defined or nonexistent, KFA took the lead in meeting with stakeholders to define them. Having key stakeholders involved in defining the process resulted in stakeholders buying into using the new tool the way it was meant to be used. The Website Implementation Team then wrote detailed work instructions on exactly how team members were required to use ProjectNet to do their work. These instructions became the ProjectNet Web-Based Project Management User Manual, the basis for training. According to Kristine Fallon, "If you introduce a new tool and don't show people how to get their jobs done, they'll each use it in a different way."

However, key stakeholders could not agree upon all ill-defined or nonexistent procedures. The more complex procedures, typically requiring contract changes and the routing of paper for multiple hand-written, or "wet," signature approvals, rather than electronic signature approvals, were not readily adaptable to the ProjectNet environment. These types of workflow processes have tended to remain in hard copy and offline. When documentation has been finalized, it is scanned and uploaded to the project website for record. Thus, the access, accountability, and auditability that ProjectNet provides are lost on these business processes.

Mike Poynton, program management's website manager (and employee of KFA), stated the following in an interview:

> While trying to document a business process, such as who may create a proceed order, to whom it may be forwarded for review, and by whom the proceed order is closed, I met with several key stakeholders, all of whom gave me a different story. There would be 10 of us in the room, I would diagram the process and someone would say "No, that's not the way we do it!" Consequently, we went through three revisions of the ProjectNet User Manual. It took us months to create, review and revise flow diagrams of the many CTA procedures . . . it was extremely tedious, time consuming and frustrating. Eventually we were faced with the imminent notice to proceed with the construction phase of the Douglas Blue Line Reconstruction project. Some procedures were still in

[ii] Ibid.

> flux—we punted on getting procedures approved and went on our instinct and professional experience so that we could get the project up and online.

Some things changed dramatically at the CTA as a result of the implementation of the web-based technology, but many others did not. While RFIs and submittals were being resolved and processed more quickly and efficiently, the processes themselves were nothing new. "We didn't invent new processes for submittal and RFI reviews . . . we're building things the way we built them 100 years ago—the only difference is that the information is being routed and exchanged on a website via the Internet."

It should also be noted that the system has not fundamentally changed the approval hierarchy that was in place before it was implemented. "The people who have the final say still have the final say. The hierarchy is the same. You might have 10 people making public comments on an RFI, and in that sense it's more democratic, but the final resolution is still made by the boss."

UNDERSTAND THE RESOURCES: ROLE-BASED TRAINING

Training was tailored to the team member's role on the project and was focused on the process rather than on the technology. The staff was trained on how to do their own jobs using ProjectNet, rather than on how to use all of its features. The philosophy behind this approach was to help people to recognize that ProjectNet was a different tool for them to use to get the same job done, but more quickly and efficiently with less miscommunication. KFA offered initial training tailored to various design and construction phase project roles. For instance, there were classes targeted toward design architects and engineers, construction managers and general contractors, subcontractors, oversight agencies, contract compliance, and so forth. Training focused on using ProjectNet as it pertained to each person's roles and responsibilities on the project.

Introduction to ProjectNet training is offered both as a hands-on course and as a computer-based training course on CD-ROM. The computer-based training, which is preferred over the hands-on course, can be completed at the trainee's pace and on his or her own time, taking approximately 3 to 4 hours. The CD-ROM includes quizzes that trainees must complete for each chapter. Upon completion of the introduction course, trainees are invited to complete an advanced, role-based class, as described above. In the initial 2 years of ProjectNet's implementation, KFA recognized a need for more follow-up and refresher training because people didn't always absorb all of the information the first time. Productivity refresher training is available on a regular basis, concentrating on the most frequently asked questions regarding the use of ProjectNet. A class on document scanning is also offered.

Though it took a while for people to stop relying so much on paper copies, users attested to the fact that the more they used ProjectNet, the easier it became to do their jobs, as participants gradually realized that the benefits of using the system far outweighed the drawbacks of having to change. As one of the Brown Line design engineers put it, "What's different now is you don't live and die by the fax machine. I haven't used a fax machine for 3 years." Even people who had never used email adjusted because of the existence of excellent training and support and because of top-level management's commitment to this way of doing work.

UNDERSTAND THE RESOURCES: WHAT'S MISSING AT CTA?

Though the CTA Construction, Engineering, and Facilities Departments have largely adopted web-based project management, the CTA has not been able to integrate the tool throughout the entire organization. Some departments still cling to wet-signature approvals and a paper-based system. This is especially true of the Field Memo, Proceed Order, and Change Order processes for which no CTA or program management procedures exist. The ProjectNet "Issues" module, however, is being used in parallel with the paper process by the construction manager to track the progress of wet-signature approvals, with some success. Any business process that directly affects the project budget is still very slow because of the wet-signature approval paper process associated with contract changes, which does not completely leverage ProjectNet's accountability and auditability. Business processes involving wet signatures rather than electronic approvals are typically offline processes that, once completed, are documented on paper, scanned, and uploaded to the project website.

SOCIAL RESISTANCE TO CHANGE

The implementation process was not easy. The project management team faced some information technology issues, a tight schedule, and resistance to adopting ProjectNet; the team learned a great deal about both technology barriers and corporate culture's resistance to change.

Technical Challenges: Internet Access

The CTA's commitment to giving all CTA users access to the system meant that the CTA needed to commit to giving almost everyone Internet access from his or her desktop. The CTA had traditionally resisted giving all CTA employees Internet access. The program manager had to push the CTA hard to give users email accounts and Internet access so that they could access their project websites and communicate with each other.

Additionally, the issue of getting contractors and subcontractors online to use the system became problematic. Kristine Fallon said,

> A contractor comes in and sets up an office near the construction site and chooses a place where they can park trucks, not a place with great Internet connectivity options. We had to bring in T-1 lines . . . contractors are about caring for their trucks, not caring for their PCs . . . we had to make sure that everyone had the right technology and make sure that hardware and software requirements got written into contracts so that general contractors and construction managers were clear on exactly what they needed to use ProjectNet.

Technical Challenges: Scanning Documents

The reality of design and construction is that each phase still heavily relies on paper documents, regardless of whether team members use an electronic, web-based system. Because paper cannot be uploaded to a website, anything that was not created electronically in the first place needs to be scanned and uploaded to the project website. Document scanning proved to be a larger problem than expected.

It was discovered rather quickly that people did not know how to scan documents properly, nor did they know what kind of scanner was appropriate for professional document scanning. People were scanning black and white documents on $150 flatbed scanners, one page at a time, at 800 dpi in full color, resulting in wasted staff hours and enormous file sizes (8 MB per page rather than 35 KB per page). This manifested itself in user frustration at long upload times for creators of the files and long download and view times for the other project participants who were trying to access the uploaded information via the project website.

To address this issue, KFA created a "How to Scan" training course that went over scanner settings and offered recommendations on what types of professional document scanners were best suited for the type of work being done. Subsequently, recommendations for document scanners were included in both the ProjectNet User Manual appendix and contract documents so that designers, general contractors, and construction managers could budget for the equipment and get started quickly after their notice to proceed. Recommendations for the outsourcing of scanning—especially for large-format scanning—were also included in the training curricula.

Social Challenges: Adequate Support

The CTA acknowledges that this system requires dedicated support and excellent in-house training resources to function smoothly. As one user put it,

> Managing the website is a full-time job for a full department. Without our three people who make up the Website Implementation Team, it would be chaos, impossible. You need to have your website management available. How does it change the way contractors do things? The CTA has dedicated web guys, and the contractor has dedicated web people, but our web guys function de facto as the contractors' web guys, too. They've never gone out to the Blue Line contractors' office and found a computer properly configured yet.

Social Challenges: Resistance

Psychological and cultural barriers to the adoption of web-based project management were also evident. Initially, CTA personnel resisted the ASP concept of having electronic data hosted on servers physically located outside of the offices of the CTA, rather than on servers located within the walls of the CTA. To counter this obstacle, KFA had to educate these people and prove to them that, in fact, it was better for the websites to be hosted by the ASP because redundancy, backup, and disaster recovery for the system were provided by the ASP. Additionally, support of the ASP approach by the executive vice president sent a message to concerned employees that the executive vice president trusted the system and that this was the way the CTA would manage all of its design and construction projects in the future.

The contractor work philosophy also affected the initial adoption of the system. As one contractor said, "construction folks would rather build a computer than use one." For the general contractors, the initial training seemed overwhelming. The CTA contractors talked about the initial attraction of ProjectNet for all that it professed to do, but it quickly faced two key "panic" issues. First, even though the hardware and software requirements and the scanner recommendations were written into the contract documents, the CTA contractors had not budgeted properly for the requirement that they use the web-based project management system. Second, contractors generally admit, with good humor, that they are not technologically savvy. Even though the contractors understood the CTA requirement to use the web-based system, they admitted that for the first project, they didn't quite understand the challenges of using the system. This barrier is common with initial roll-outs. The subsequent projects have shown greater success because general contractors gain experience and the Website Implementation Team implements solutions to problems that arise.

However, in the CTA case, the executive vice president and program management enforced the discipline from the top down. The executive vice president showed that the CTA was serious about change and that people needed to conquer psychological, cultural, and technology barriers. For example, a 50+ year old field superintendent who had never used a computer or mouse was trained and not only learned the system, but became one of its most enthusiastic and frequent users.

Initially, people resisted the much higher level of accountability that the new system provided. With ProjectNet, it is easy to see (or for others to see) how many RFIs a team mem-

ber has opened and how quickly RFIs or issues are dealt with. This gives the organization valuable metrics for measuring productivity. It also makes the system transparent. For example, the president of the CTA, Frank Kruesi, wanted to be trained on the system. While the trainer was with him in his office, they went through an RFI example. Looking into the system, the president chose an RFI that had been created that day and that had been commented on and resolved within 2 hours. He was able to see what every person who "touched" the RFI did and when they did it. Having seen the results of the system on his desktop computer, he became convinced of its power. With time, however, team members began to realize that the accountability had benefits for them, too, because the system not only allowed others to see what they were doing, but it allowed them to keep track of what others were doing, making accountability a two-way street. As one Brown Line architect described it, "People like being able to eavesdrop on other people's work—it's a peer pressure, self-policing environment—improving quality and responsiveness. Everyone can see what everyone is doing and they're talking about it. It's like living in a small town."

Technically, subcontractors to the general contractor are not required to use the web-based project management system because there is no contract between the subcontractor and the CTA. However, the KFA approach to implementation was to provide benefits to *all* project participants using the system. Therefore, KFA created a subcontractor training curriculum and special areas on project websites where the general contractor and some of its subcontractors adopted the system immediately. Some contractors—particularly the small shops—did not use the system at all. Not having every single subcontractor on the system has not appeared to adversely affect the construction phase because the general contractor is responsible for coordinating its subcontractors regardless of whether they use the web-based project management system.

There will always be people who resist training and adoption of new technologies. For example, while the majority of the construction manager's team uses ProjectNet, some team members still go back to using the fax machine. Doing so may cause miscommunications because the communication is not happening within the web-based system where all the other team members are communicating and collaborating.

EVALUATION: THE DOLLAR VALUE OF SPEED

Early in the construction phase of the Douglas Blue Line Reconstruction project, the program manager sponsored a partnering meeting with the project's key stakeholders. One of the mandates that came out of that meeting was to implement a web-based project management system. Not all participants initially supported the mandate.

Although there were cynics, most participants believed that the partnering meeting really helped the contractors embrace ProjectNet more fully as they realized that the tool could aid in reducing construction claims later. The first construction project that used ProjectNet—the Douglas Blue Line Reconstruction project—is still under construction, and it will be another year before the CTA can test whether the system accountability and auditability functionality will help the CTA minimize contractor claims.

Additionally, many contractors and construction managers believe that the higher quality of easily retrievable information available to them on the project website and the speed at which the information, such as an RFI, is processed will result in fewer misunderstandings and contract change orders. Socially, having the Website Implementation Team personnel in the contractors' offices to support them may also help to create an ongoing collaborative relationship. Thus, partnering meetings become the point of departure for a relationship that is constantly being reinforced.

Benefits from web-based project management tools are not easily measured because they are not necessarily quantifiable. Many of the benefits, such as providing designers and contractors with both a central clearinghouse on a website and immediate access to more information than they would typically have otherwise, are difficult to measure in dollar savings.

By 2002, 699 users from 65 companies had been trained and were using ProjectNet. Before the end of the 5-year contract, KFA expects the number of trained users to increase to 2,000.

KFA believes that speed and quality drive cost savings. ProjectNet focuses on quality and efficiency, which in turn help to control costs. As stated previously, mistakes made during the design phase of a project will adversely affect the construction phase of the project, resulting in costly change orders. With web-based project management systems, the entire project team has ready access to project data. Survey feedback from users indicates that access to information is the greatest benefit provided by the system.

Increased Speed and Productivity

The Website Implementation Team could report on a couple of ProjectNet modules to quantify increased productivity and, thus, cost savings. One of these modules was the RFI module. RFIs are a means of asking a question that needs an answer before work can proceed any further. KFA found that 9 months into the Douglas Blue Line Reconstruction project, CTA senior technical personnel were processing 260% as many RFIs per business day per person as, and responding in 18% less time than, people who were not using the web-based system on a comparable construction phase project that was managed without a web-based system. This increase in efficiency translated into a savings of $152,000 per year, or $760,000 for 5 years, as a result of decreased time spent by senior engineers processing RFIs. It also

reduced cycle time and eliminated multiple iterations in work processes.

Storage Costs

ProjectNet also saved the costs of physical document storage. The Website Implementation Team estimated that the CTA would require approximately 1,200 square feet of dedicated paper document storage for its capital projects. The fact that this space was no longer required saved the CTA approximately $24,000 per year, or $120,000 over the program's 5-year duration.

Other measurements of success are evidenced by the CTA's gaining ISO 9000:2001 registration. ProjectNet enabled the CTA to meet the ISO registration criteria for document management and retrieval. This ISO 9000 registration for the agency's quality management system for engineering and construction operations gives the CTA greater competitive standing among other transit agencies vying for federal funding.

Awards

In 2003, the CTA won the Richard H. Driehaus Public Innovator in E-Governance award for its implementation of ProjectNet, and the FTA has publicly announced that the CTA's approach should be replicated by others. KFA received the 2002 Illinois Road and Transportation Builders Association Technology Advancement Award for contribution to technology improvements in transportation design and construction. The case study was presented at the American Public Transportation Association's 2003 Rail Transit Conference in San Jose. In 2004, KFA and the CTA were recognized by *Constructech Magazine* for the successful use of advanced technology to improve business performance. The CTA was awarded the Gold Award in the Transportation Category for the execution and use of Citadon's ProjectNet for the CTA's 5-year, $2.2 billion CIP. KFA received the Technology Enabler Award for its contribution to the successful implementation and continued support of the ProjectNet project management and collaboration system.

CHAPTER **3**

PORT AUTHORITY OF NEW YORK AND NEW JERSEY: MASTERING PROJECT CONTROL

OVERVIEW

The PANYNJ has an $8.7 billion, 5-year CIP. Though many people think first of New York's bus system when they think of the PANYNJ, the authority's scope is much broader. There are different "line units":

- Aviation (four airports, including John F. Kennedy [JFK], La Guardia, and Newark);
- Tunnels, bridges, and terminals (TBT), including the Lincoln and Holland tunnels and the George Washington Bridge and the PANYNJ Bus Terminal;
- Ports at Newark and Elizabeth, New Jersey; and
- The PATH subway system connecting New York and New Jersey and the Downtown Restoration Program (which includes the restoration of train stations at the site of the World Trade Center).

The PANYNJ supports this massive span of operations with its 5-year, $8.7 billion capital budget. Its engineering department has a full-time staff of 650 engineers, supplemented with about 600 outside consultants. The mission of the engineering department is to support this capital program with most of the work done in-house. The engineering department awards and supervises 100–150 contracts per year.

The PANYNJ houses its employees in 30 facilities in New York and New Jersey. In addition, four or five office sites now house the PANYNJ employees who used to work at the World Trade Center. On 9/11, the PANYNJ lost 84 employees in those offices. The attack has influenced the agency in other ways, as well. Since 9/11, challenging fiscal constraints have forced a more rigorous prioritization between projects. There have also been significant increases in expenditures for security. The agency has traditionally been conservatively managed when it comes to taking risks with data security. Since 9/11, that commitment has only grown.

This case study will focus on the engineering department's use of Primavera's P3e software to manage its portfolio of 600 active and planned projects, emphasizing the classic project controls—scheduling and cost. All 600 projects in the engineering department are managed with Primavera's P3e Enterprise cost and schedule management software.

DESIGN THE SOLUTION: WHAT KIND OF PRODUCT DO WE NEED?

A leadership team composed of Deputy Chief Engineer Peter Zipf, Assistant Director of the Capital Program Bill Radinson, Manager of Project Controls Pradip Mehta, Assistant Chief Engineer Achille Niro, and Manager of Engineering Financial Services Joe Garcia, among others, strongly believed that technology could enhance existing work processes and provide a tool to manage information through a project's life cycle. This team guided engineering services' move toward technology-enhanced collaboration. The team's selection and implementation of various technologies, including Primavera Expedition and P3e software, took place over several years. Although the team did not foresee all of the issues involved with selecting and implementing the technologies, it successfully managed the change. In an interview, Peter Zipf said, "We were naive. But it all worked very well."

As various departments performed technology self-assessments, it became clear to the team that the many different initiatives taking place at the agency represented an opportunity. Zipf said,

> Our goal was to keep the momentum going and keep progressing. We weren't mature enough to just adapt the technology to suit us. We needed to break our effort down into unique critical components. We myopically looked at several initiatives and then one day they all were able to be integrated. CAD [computer-aided dispatch], scanning, project scheduling, document control—there were several hot things going on. Within the agency, we were also moving towards SAP and PeopleSoft and it all lined up to create a great time to take advantage.

Gradually, the PANYNJ adopted an agencywide network that was accessible via a web-interfaced intranet.

Zipf encouraged a free-form discussion of users from various divisions to discuss which existing systems worked, which ones needed replacement, and which ones needed enhancements. In the discussion, the PANYNJ learned the importance of using off-the-shelf technology. Joe Garcia said,

> Go for off-the-shelf as much as possible and get the best product in each class. Get the stuff that most people use rather than some homegrown concoction. It may not technically be the

best for you, but if it is what everyone else is using, then you are much more likely to find support.

The team decided that its new project control system would have to be able to integrate with the team's existing technologies.

UNDERSTAND THE IMPERATIVES: A MUCH GREATER NEED TO MANAGE CONSTRUCTION EXPENSES AFTER 9/11

The PANYNJ has always emphasized fiscal accountability. Achille Niro described the agency as follows: "We are not a not-for-profit; we're a public-sector service provider but we are self-sustaining financially. We don't get money from the government so we have to make money from our own services." From the mid-1990s on, there has been ongoing analysis to find out where the projects go wrong. The issues would be familiar to any transit agency—cost management, scope management, and, most of all, scheduling. Initially, the agency did not have comprehensive scheduling; it had one system for design and another system for construction.

Achille Niro told us the following:

> Timing became the crucial element—the longer it takes, the more we lost income and business opportunities, and the costs continue to escalate. We bond our projects, so financially we have to stop that clock. We would constantly reinforce the message, "The greatest engineering job that is not completed in time renders little benefit. Great design and great construction delivered a year late is not good." This was our message.

The need to transform the PANYNJ's talented technical engineers into informed business people accelerated after 9/11. Pradip Mehta said,

> After 9/11, there was more pressure to say, "We can't afford to continue at this rate of spending" because revenues dropped, and revenues support the Port Authority's Capital Improvements Program. There were also significant new demands on the budget: heightened demands for security at all Port Authority sites and a need to integrate the approach to security across the agency.

In addition to enhancing project control, the engineering department and chief operating officer needed a system that would help the agency prioritize the 600 projects that it had in various stages of development.

For years, the department had been moving in fits and starts toward a robust and integrated environment that would be mature enough to support web-based collaboration. It began in the late 1990s, when it was discovered that some systems were not Y2K compliant. At that time, the agency made a commitment to build up the agency's network. The engineering department introduced Livelink for electronic document management. This small step created a much more robust network and encouraged other divisions to do self-assessments about how technology might enhance their work, such as scanning drawings. The self-assessments, in turn, led to many different initiatives happening at the same time within different areas.

The PANYNJ wanted to move from a stand-alone solution to an enterprise solution so that units would be more integrated. Most important, the system needed to strengthen the cost controls on the agency's capital projects.

Financially, the existing system did not allow project managers to understand what was happening with costs on their projects. The old process to understand expenses on a project involved the project manager sitting down to compare separate spreadsheets, code by code, between the budgets in Excel and the actual charges from the finance office's SAP system. Most PANYNJ project managers are responsible for 10–15 different projects in various stages of development; the hard copies of these reports might run to hundreds of pages. Checking within each expense category might require the input of several different managers. Only the most egregious discrepancies were addressed; then the project manager initiated an SAP investigation with finance to understand the charge. Joe Garcia said, "It was pretty tedious, and a lot of people didn't do it. . . . We had horror stories about people coming to us [and saying] . . . 'I have a $60,000 project—little one—but I have $90,000 in miscodes!'" Project managers either spent a great deal of time struggling with the system to understand the costs on their projects or didn't bother to understand it at all.

Given the new financial pressures on the agency, engineering services needed a solution that could integrate and enhance the project control processes.

Selection: Primavera's P3e

The engineering department recognized that it didn't make sense to choose a scheduling package that was different than the construction package. The department wanted something that could take the PANYNJ from inception of a project to closure. The departmant also wanted something that could be integrated with SAP and something that the construction and engineering industries were comfortable with and had already embraced. This would make interfacing with one another easier. The team also recognized that P3e had a very robust cost control module that it could use to provide the cost control information to project managers in a palatable and practical manner. This was one of the driving factors behind the selection of P3e.

The PANYNJ studied what others in the industry were using and found that over 90% of the engineering and construction industry and the top 400 contractors used Primavera Scheduling. The department decided to use Primavera. Primavera could be customized to the agency's needs and was flexible enough to integrate with the agency's existing systems.

Figure 3 illustrates how the PANYNJ uses its Primavera software in concert with other software packages to orchestrate the management of its projects.

The PANYNJ Chose to Keep Its Data In-House

Rather than using an ASP, the PANYNJ houses everything internally with a sophisticated backup system. The department trained both Primavera experts and the agency's own technology services department to manage the network and supervise the data security. However, because the PANYNJ already had existing server infrastructure and a robust intranet system, it wanted to use what it already had. Further concerns of keeping the data in-house because of the owner-centric philosophy of the agency and security concerns made in-house servers the more attractive option.

Data Are Downloaded into P3e

Primavera's P3e functions as a kind of umbrella system that incorporates other software. To accomplish the systems integration with other departments, there are extensive monthly downloads from both the budgeting system and SAP. The downloads integrate actual costs into P3e. These downloads are broken down by actual costs, costs by each stage (e.g., design, program management, and construction management), costs by division (e.g., engineering and architect), costs by function (e.g., mechanical and electrical), and costs by employee who charged the codes.

Role-Based Reporting

Scheduling and cost information is entered into Primavera's P3e system. This information is tightly regimented—only the information that each project manager needs to do his or her job is given. For example, each project manager sees only information relating to his or her projects.

The PANYNJ determined that only some people in the engineering department would need to be fully trained on P3e. These people, called "power users," are technical resources for the department's 120 project managers. Project managers are described as "casual users" and see a higher-level interface of P3e called Primavision. Zipf said, "Primavision is a superb project control tool. Project team members can come into the environment and find schedules, and we set up reports that enable them to find information." Primavision makes a lot of data available to project managers to determine trends, but project managers cannot go into the system to make changes. Achille Niro said,

> We made a conscious decision that project managers should not be experts on P3e; their role is to manage the projects. Let's provide technical experts to help them crank out any scenario the project manager needs, but let us give some executive summary–level data as well as detail to the project manager that he or she can easily access and use.

Power users, such as project control engineers, use P3e extensively and are trained to understand the nuances of scheduling mechanics and its other modules. These users can update and maintain the information.

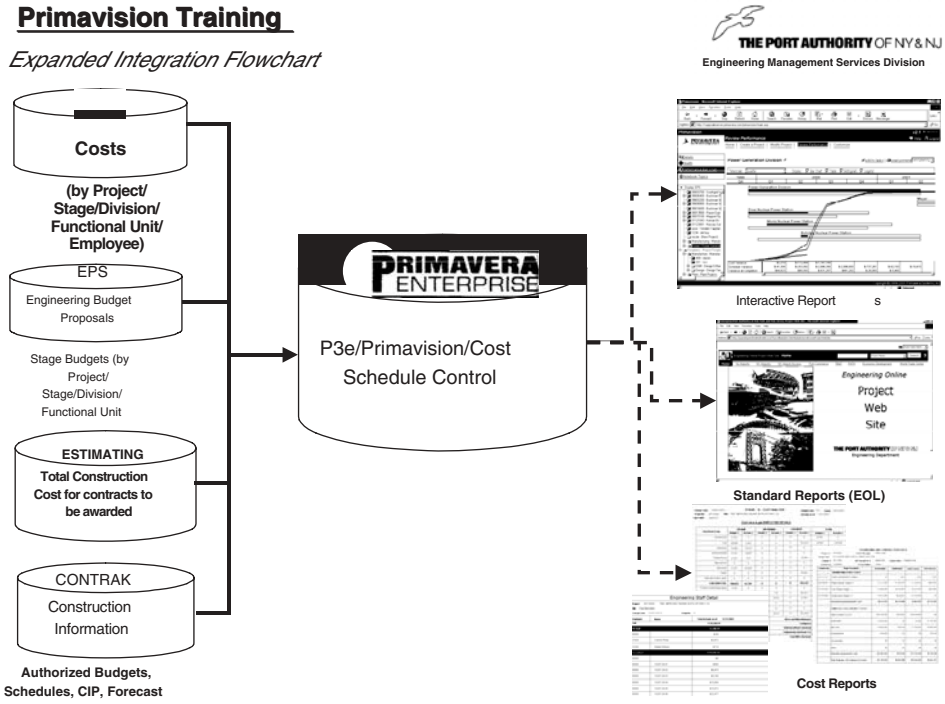

Figure 3. Expanded integration flowchart.

Casual users use Primavision, the "window" into P3e. The idea is not to overwhelm the casual users with too much detail, but to give them a visual way to access the data that would help to facilitate their decision-making processes. However, casual users cannot change the data. This restriction helps to maintain the integrity of the information. Consultants, who have been assigned to a particular project and essentially become an extension of the PANYNJ staff, also have access to Primavision.

Training on Primavision takes only 1 hour. There is often a refresher session after 3 or 6 months.

UNDERSTAND THE RESOURCES

The PANYNJ's engineering department did not set out to reengineer its processes when it implemented Primavera's P3e and Primavision, but it did need to think very carefully about what information needed to be presented to the project managers. Rather than give each project manager an SAP license, which would have been expensive and would have flooded the project managers with too much information, the department instead downloads some summary and relevant detail information into P3e once a month. This information then "rolls up" further into Primavision. Joe Garcia said,

> We were very careful not to overburden P3e with all the financial information at the level of every journal entry. We reflected those costs and schedule parameters that drive the project management decisions. If you need more detail, you can always go get it from SAP.

The engineering department recognized that real-time integration would be not only complicated, but also expensive to maintain. With such a dynamic link, any changes would require modification into the system. Because SAP is currently on a client server, monthly downloads are more appropriate than a dynamic link. P3e has monthly interfaces with existing systems that are not now web based, including SAP (actual costs), ConTrak (construction management system) and EPS (Engineering Proposal System). The department is exploring the use of hyperlinks between Primavision and project drawings posted on the intranet.

The highly trained project control specialists (i.e., power users) also became change agents. Joe Garcia said, "It was a great vehicle to introduce this stuff. It's his [Mehta's] change agents, stationed right next to the project manager's. There is no better way to do it."

To integrate the system into the agency's existing technology, the PANYNJ took great care to understand what information from System A needed to be downloaded to System B. The engineering leadership team's project-mapping process allowed the team to configure only the essential information that would enhance project managers' ability to make decisions.

The agency uses Primavera Expedition software to track its shop submittals and RFI turnaround time for all projects with budgets of $3 million or more. For example, all submittals flow through the agency's project managers, who are responsible for disseminating the required information to Expedition specialists, who, in turn, enter the tracking information into Expedition. Once the information is in the system, the shop submittal log and the RFI log can be printed out at any time. The system will show who has opened the RFI log and looked at it, where an answer has been given, and where an answer is still pending. Pradip Mehta said, "You can clearly see who is holding it up." Once a week, the resident engineer meets with the contractor and reviews all RFIs and shop submittals to confirm which ones have been answered and which ones are not yet answered.

EXPLORE WITH PROBES AND PILOTS

The philosophy behind the engineering department's approach was not to exhaustively redesign its processes formally, but instead to quickly test the new technologies with pilot projects. The department thought carefully in advance and sought input about what the project managers needed from the system, but the department wanted to avoid a lengthy redesign process before introducing the technology. Pradip Mehta said the following about the technology:

> We had to make sure we configured it in a way that was easy for [users]—we didn't have formal committees but continuous informal feedback from diverse small groups. We felt the danger of a committee of 50 people—we didn't want to detract from our vision because we knew what we wanted. We wanted to avoid elaborate review processes driven by formal committees. It would take a long time to get everyone to agree.

The PANYNJ created a pilot using Primavera's Expedition starting in 2000 for an $82 million parking lot construction project at Newark Airport. In that job, the PANYNJ had 450 RFIs and 3,500 submittals. Four months into the work, the agency had a claim from a contractor for an extension of 3 months because the contractor claimed the agency was delinquent in answering RFIs and submittals. Because of the Expedition software, the department was able to provide a rebuttal to the claim in 2 days, demonstrating that the department was not the cause of the delays. The claim was withdrawn by the contractor.

The engineering department took an organic and evolutionary approach to introducing P3e to gain greater acceptance from users. Its implementation model uses pilot projects to validate benefits and gain acceptance from staff. When selecting pilots, the department's leader thought about which people would be good at offering constructive feedback. The

leader chose to focus on the middle managers in the agency, believing that they had the institutional power.

Rather than redesign processes completely prior to implementing a pilot, the PANYNJ allowed itself to learn from the experience of the pilots, which in turn led to changes. For example, after implementing Expedition, the engineering department was able to see that the initial delay in the submittal and RFI process was because of the project managers, who had lengthy submittals and drawings languishing on their desks. In response, the department retrained three support people, and then hired two more, to become document distribution specialists. They helped the project manager route the shop submittals and eliminate the delay. As Peter Zipf said, "The construction industry will always be paper. The issue is how you distribute it."

Today, all PANYNJ projects with budgets of $3 million or more are tracked with Primavera's Expedition to improve and log the submittal and RFI processes. This totals about 200 projects, involving 50,000 submittals and 6,000 RFIs. The total is independent of the Primavera P3e Enterprise, which is used to do scheduling and cost management for all 600 of the PANYNJ's projects.

Pradip Mehta supports the 20-60-20 rule, which says that 20% of the people in a given organization are optimistic about accepting change, 60% are skeptical but open-minded, and 20% are pessimistic. Given this distribution, it would be a waste of time and money to convince the pessimists. The idea, therefore, is to implement change organically by targeting the 20% of potentially early adopters and enlisting their help with a pilot project. Once the early adopters have had a positive experience with the new technology, they will then appeal to the 60%. Mehta explained, "We didn't spend too much time trying to attack the 20% pessimists. We did attack on the 60%-skeptical middle ground—did some pilots with people there—they are now the salesmen for us."

It is a firm part of the PANYNJ's approach to implementation that experience is more important than analysis. Pradip Mehta said,

> Put a system out there, and it will illuminate the facts, and it will help you. You have to make a very careful, intelligent decision to what degree you're going to solve your business problems—I knew that if I had to wait to solve our work order tracking problems, [the new technology] would have taken me 3 more years to implement. You have 10 different entities involved! It is what it is. Just put it out there and get everyone to see the problems—otherwise we'd still be sitting here with our process flow charts.

The PANYNJ's gradual implementation began with P3 in 2000 and then shifted to P3e in July 2002. From July to October 2003, the PANYNJ brought Primavision to its casual users such as project managers, functional leads, and line department project managers. There are currently more than 350 users.

Gradual Adoption

Achille Niro said,

> If you are an outside contractor, we do have certain requirements, but we don't require that you be online because that would be too restrictive. That is a pretty bold position for a public agency to take. We can easily put down a mandate and force everyone. . . . [But] to make it a directive would shut out a lot of people's ability to work for us, and I don't think policywise we would be able to support that. Even with the larger and more sophisticated organizations. . . . In my view the construction industry has been very slow to embrace technology.

The next phase is to move to an extranet and integrate it with Expedition to enable outside consultants to readily access information via the web. Because the data are stored on the PANYNJ's own server, the PANYNJ must deal with firewall issues.

The Transformation of the Project Manager's Role

Although the hierarchy and approval structure at the PANYNJ is essentially unchanged since the adoption of this technology, there have been two significant shifts. The first shift is in the way that broad access to the information enables a much more collaborative work process. Achille Niro said the following about broad access:

> What it does is open up the whole process to the entire team, so you get collaboration. Multiple people have input to the situation and quickly resolve differences in opinions, whereas previously, it took a longer time and you might miss someone's input. Now we have team-based communication—much more open and collaborative.

The second and more significant shift has been in the way project managers have embraced their role as financial managers as well as engineers. Joe Garcia, a member of the engineering department's financial services group, which works in a decentralized way in each of the line departments, has seen a "really big leap" since Primavision has been implemented:

> I've seen steady improvement over time in the amount of information engineers have regarding financial performance and a steady improvement in attitude. The old attitude has been "I'm engineering, my job is to get the project in on time, don't bother me with financial details." Financial information was just so hard to find. Even though they thought they didn't have to think about this stuff, they do. Too often in the past, they had to find out the hard way they didn't have the money.

Roles have been enhanced with tremendous workflow improvement. The hierarchy is the same, but P3e has given

engineers and project managers more time and information to identify and fix problems rather than handling paper and finding numbers. With an enterprise solution, the focus has shifted from administrative detail to forward-thinking analysis across the board. The shift is representative of a mature organization.

Project managers have not changed in their decision-making abilities, but their roles have been enhanced. Before Expedition was implemented, for example, project managers were responsible for copying and distributing shop submittals to functional unit leaders. Because of their other responsibilities, project managers did not always have time to do the actual distribution, thus holding up the entire process. The agency recognized that the project managers needed help, and once Expedition was implemented, the agency refined this process. The agency hired Expedition specialists (ESs) and document specialists for support. Each unit has an ES who enters the submittals. The ES monitors and follows up on these documents so that the documents don't get lost, as had happened before. An ES typically monitors about 30–40 construction projects within one program. Large engineering programs also have document specialists who do the actual distribution of documents. Because the specialists have now taken over the responsibilities of entering, distributing, and following up, the project manager can now look to where the submittal is and easily find out where the delay is and contact that particular department or individual.

SOCIAL CHALLENGES: RESISTANCE TO CHANGE

One of the major advantages of a web-based collaborative system and the reason such a system enhances productivity and speed is the increase in accountability. However, like a double-edged sword, this aspect of the system can also cause fear in some people. Because the system is so transparent and because upper-level managers have access to look across all of the projects, people can feel that there is a "big brother" aspect to the system. Joe Garcia, acknowledging this dynamic, said, "The project managers have no excuses. The data is all out there. There is nothing to hide behind. Now you have to look at it or someone else will."

Another social challenge is that people who were raised in a paper-based world traditionally feel more secure with paper and less secure with electronic documents. Achille Niro said,

> We have not yet reached the maturity where we do everything online. Part of that is due to the fact that the system isn't fully built out and part due to a cultural thinking shift—a level of comfort that our people still need to touch and feel paper. That's the barrier that we are starting to hit. How do you get them comfortable and convince them that this is more efficient for them?

For the most part, however, because the PANYNJ has used an evolutionary and incremental approach to implementing the system and relied on the power of pilot programs to reach out and convince people of the value of the new technology, resistance to the system has been minimal. For the most part, the word of mouth from people who have experienced the changes has been very positive.

LINE DEPARTMENT'S PERSPECTIVE

The majority of this case study deals with the implementation of collaborative software in the engineering department. However, the line department that manages the operations of the facility and oversees the capital program used the software differently. Assistant Director of the capital program Bill Radinson said,

> The line department's role is one of oversight and strategic planning for the agencywide capital plan. Its role is to coordinate the capital plan and to make the decisions about which investments take precedence. . . .
>
> Even though the Port Authority is a financially self-sustaining organization, it is accountable to many external stakeholders, including the governor offices of New York and New Jersey. Many of the investments have large implications for other potential developments that the team must take into account. Many of these priorities have been determined by strategies set years ago. For example, the political decision that New York and New Jersey's ports would become a hub on the East Coast has had major implications for terminal configurations and developments.

Because of these pressures on the agency, the agency has historically placed more focus on cost management than scheduling issues; it has continuously refined the process by which projects are developed. This process includes a careful initial cost estimation based on historical data and experiential knowledge from different line units and the engineering department. The initial costs are made up of many assumptions and often require going back to historical tapes (e.g., actual construction costs from past projects, now archived) over the last 10 years for data. This information is not easily accessible, however. With a move toward building an agencywide estimating discipline, the operations team has recognized the need to coordinate this information and make it easily accessible in one place. Moreover, the team understands that its project investments are not discreet but must be treated as a portfolio of assets. To get a fuller picture of previous investment decisions, project costs and schedules, and investment flows and to make proper investment allocation decisions for such a diversified portfolio necessitate easily accessible and coordinated information.

Integrating P3e with SAP with the cost control module enabled the PANYNJ to prioritize projects. In engineering, budgets are done in four stages: (1) conceptual design, (2) preliminary design, (3) detailed design, and (4) construction. With P3e, the engineering department can take a holistic

view of the all the proposed budgets and see how many budgets are in each stage. While the projects in Stage 4 (construction) are too far along to be canceled, those in Stage 1 may be able to be adjusted to save costs.

Not every project that the operations team oversees is solely made up of engineering services. Many of the projects require outside approvals, which requires the team to create a master schedule, which may include, but is not limited to, engineering service schedules. The operations team recognizes that it lacks a robust technological tool to create and maintain such a master schedule. Currently, the closest thing to such a tool is an in-house mainframe system developed in 1990 called CapTrak. CapTrak captures actual cost breakdowns of projects, total spending, and current actuals by month and year, but does not provide a way to holistically examine and compare actual costs with schedule-dependent estimates across a portfolio of projects. Given the schedule limitations of CapTrak, some line departments are using P3e to do overall master planning of their capital program. Bill Radinson said,

> Seeing the success of using applied technology to enhance business performance by the engineering department, [the operations team] is currently seeking the next generation of technology with EPMS [enterprise project management system] to get total costs, estimated costs, and project schedules into one place. This would not only include projects that involve engineering, but would also include those that need external approvals from outside stakeholders. The system would be integrated with engineering's P3e system.

Unlike the engineering department, which mapped its workflow and sought out technology that could enhance the existing processes, the operations team has been working to change its business processes to make it easier to go from the current information system to an enterprisewide system that incorporates everyone. Currently, there are many redundancies because information exists in several places. The operations team recognizes that the processes are far more complex than they need to be because everyone tries to generate the same information.

The difference in approach from the engineering department reflects the complexity of the agency. Within the line operations, convincing five different line units that they face similar problems and would benefit from a more streamlined work process is difficult, particularly because streamlining the process will change people's roles. However, the team wants to take advantage of the momentum created by the engineering department with applied technology and convince new departments that, with appropriate workflow redesign and an enterprise solution, technology, too, can improve workflow, transparency, and ability to manage a portfolio of investments. The line operations department will take lessons from the engineering department and will continue to search for ways that technology and business intersect.

EVALUATION: THE VALUE OF PROJECT CONTROL

Zipf has asked the leadership team to think about quantifying the cost savings. In 2002 and 2003, the PANYNJ measured its turnaround time for processing RFIs and submittals and saw a 20% reduction.

The PANYNJ also believes that its project managers are able to be much more analytical now. Achille Niro said, "We're already achieving benefits—better information for intervention. Better accounting. Certainly a heightened level of information. That part of the investment alone makes it worthwhile."

AWARDS

In 2003, the department won the Primavera Excellence Award for Outstanding Achievement in the Engineering Industry for its strength of vision, demonstrated commitment to industry leadership, overall system configuration and integration with other in-house systems, scope and breadth of system implementation, and added business value. Given this industry recognition, there are many outside organizations like the state of New York's Metropolitan Transportation Authority (MTA), Keyspan, Johnson and Johnson, Wyeth Pharmaceutical, La Farge (a French conglomerate), and Amtrak that have visited the PANYNJ's premises to review the PANYNJ's Enterprise implementation.

CHAPTER **4**

RAYTHEON: RE-ENGINEERING THE SOCIAL SYSTEM

OVERVIEW

Raytheon is a global defense and aerospace systems supplier with 77,500 employees worldwide and $18.1 billion in sales for 2003. As an industry leader in defense and government electronics, space, and information technology; technical services; and business aviation and special mission aircraft, it provides integrated mission systems for defense and nondefense needs. Established in 1922, Raytheon is now present in 70 countries.

In the mid-1990s, the defense and aerospace industries began to consolidate as defense budgets were cut drastically. Raytheon began to acquire companies in 1997 and ultimately merged with E-Systems, Texas Instruments, Hughes Aircraft, and Beechcraft. Together, these companies made up "the new Raytheon." As one Raytheon supply chain manager explained, "Each company had a corporate office, each one of the companies had several different businesses—each made up of previous acquisitions and divestiture, each one of them probably had one or two legacy systems in each zone." For example, the new company had 69 different purchasing systems. It also had four distinct cultures, databases, and corporate languages.

UNDERSTAND THE IMPERATIVES: WHAT KIND OF PROBLEMS ARE WE TRYING TO SOLVE?

Compounding the problem of consolidating these businesses, Raytheon's stock price dropped precipitously from $70 per share to $17 per share, and shortly afterward the stock market declined. This was their "burning platform." There was a clear need to change the "old Raytheon," which was noted for its traditional, hierarchical structure, into a "new Raytheon" that was more fluid and capable of collaborating and learning across many diverse boundaries.

Another problem that Raytheon faced was that team members typically worked across different time zones and geographic locations. Getting face-to-face meetings was sometimes nearly impossible. Because many projects had tight time constraints and were complex, team members needed a better way to get quick answers and reduce the potential for miscommunication and mistakes.

UNDERSTAND THE RESOURCES

The Raytheon case study contains three distinct components:

- The companywide adoption of Raytheon Six Sigma, a change that was mandated top down by chief executive officer (CEO) Bill Swanson, which helped to create a common language and culture across the four merged companies.
- Raytheon's choice of low-cost web applications rather than enterprise solutions to support these efforts.
- The adoption of a community of practice model, which enabled Raytheon to share best practices and collaborate across organizational boundaries. This chapter specifically examines the experience of Raytheon's supply chain management team, which evolved from the Logistics Council to become Raytheon Integrated Logistics Community of Practice (RILCOM).

The following sections describe these components in detail.

The Companywide Adoption of Raytheon Six Sigma

A Raytheon Leadership Forum was called in January 1999, and its participants decided that Raytheon Six Sigma would affect all company procedures. Over the next 2 months, Bill Swanson flew around the globe to reach 56,000 employees on three shifts. He himself was trained as a Raytheon Six Sigma specialist. At one meeting, union workers in the front row challenged Swanson, and he threatened to "go six rounds" in the parking lot with anyone who did not believe how passionately he believed in the importance of Raytheon Six Sigma to the company's future. Later, a videotape about Raytheon Six Sigma was made with Swanson at the beginning donning boxing gloves and repeating his commitment to the program.

Clearly, the implementation of Raytheon Six Sigma was mandated from above. In addition to creating the boxing videotape, Raytheon tied Raytheon Six Sigma goals to the performance evaluation of all of the company's top executives.

Even with this degree of top-level commitment, Raytheon Six Sigma was not implemented everywhere at once. Initially, Raytheon Six Sigma was implemented in selected pilot areas

that were handpicked to make sure that the people involved were flexible enough to take up the new processes and language and make them successful. Then the successful results of these efforts were widely publicized during the first year of the program. This handcrafted approach at the beginning helped to ensure better acceptance, and, by the second year, the program had started to pick up momentum. By the end of 2000, Raytheon Six Sigma was fully deployed at different levels of maturity throughout Raytheon.

Raytheon also focused particular attention on winning the support of its middle managers, believing that middle managers are typically the slowest to adopt change because they have the most work to do. Also, middle managers have a harder time justifying collaborating with people in other businesses. Whereas senior leaders are compensated for how well the corporation does, middle managers are rewarded for how well their own businesses do.

Raytheon customized Raytheon Six Sigma for Raytheon's particular method of work. One Raytheon employee said,

> Each company had its own flavor of process improvement—one of them even had Six Sigma already. But we had the same language problem, so we said, "Whoever had Six Sigma before, erase the slate—it's Raytheon Six Sigma." So rather than calling people "Black Belts"—old Six Sigma terminology—we call them "Experts."

Raytheon also hired consultants to help design a 6-week training program tailored for team members to understand that the new corporate strategy from the merger meant a commitment to enhanced learning and the sharing of knowledge.

Raytheon Six Sigma set a unified standard across the division and readied Raytheon for collaborative work processes.

Raytheon's Choice of Low-Cost Web Applications

Simultaneous with the advent of Raytheon Six Sigma and communities of practice, Raytheon's CIO recognized the need to adopt collaborative software to enable teams to work together across geographies. One Raytheon employee said, "We were going to have a need for desktop collaboration anyway—the whole world is going that way—the need for these tools is common, as people are working more geographically dispersed but need to collaborate as if they are in the same building." This software needed to support a wide range of teams—from a small number of employees putting together an event somewhere in the country or developing a PowerPoint presentation to huge, multiyear programs such as a missile program that involved thousands of employees from different businesses.

Raytheon sent a few of its staff members to research and rank the top solutions that were compatible with Lotus Notes, the system that Raytheon was already using. The staff decided to spend "zero dollars developing something" and instead to leverage Raytheon's existing software license. The staff also wanted a tool that would require no training at all, believing that requiring people to attend an hour-long training course would slow down adoption of the technology considerably. One Raytheon manager said,

> We needed one enterprise system, but when we looked at the price tag, it was upwards of half a billion dollars. We had just spent $7–8 billion buying these companies and did not have the cash to put into a common system. We had to find a different way to collaborate that would allow us to work around all these different systems. We are just now implementing a common financial system and next will implement an enterprise planning system.

QuickPlace and eRoom were chosen because they are intuitive and easy to use. They also required the purchase of only one corporate license. Raytheon understood that people had little time to take additional training. One Raytheon employee said, "These products were simple enough that when someone says, 'I don't have time to learn something new.' You can say, 'You just have to go on it and start using it—you'll make a mistake or two, but it doesn't blow up.'"

QuickPlace was the first solution Raytheon used, but Raytheon is now replacing QuickPlace with eRoom. With both systems, the user enters a collaborative space that is described as a "virtual room." The user can bring other tools into the virtual room, such as Primavera scheduling software. The collaborative software will track revisions, assign time and date stamps, and note who made the revisions. One Raytheon employee said, "The beauty of this environment is that you can collaborate asynchronously. . . . You can basically crunch on something around the clock if you are collaborating with Europe and Asia."

QuickPlace and eRoom also provide chat room features if two or more users happen to be online at the same time, with no time delay.

The dissemination of this technology has been grassroots, very gradual, and incremental. Raytheon believes that it is offering people a tool—an opportunity for people to use something—but the users have to want to use it. One Raytheon employee said,

> If you force it on them, you have to have an infrastructure to make it stick—a training platform to create experts and specialists, force people to come back and get new elements of the training because it drives the performance of the company. If you force it on them, you're back to needing to do lots of training.

Technical Challenges and Social Challenges

With the grassroots campaign style of implementation, there have been very few technical problems because the software itself is so intuitive. In fact, Raytheon managers believe that one of the lessons they can share is that if you are

trying to enhance learning and knowledge sharing between people, you want the simplest tools that the least technical person can use, not complicated tools that only the most technical person can use. Complexity is a barrier to adoption.

One Raytheon executive reflected on the different methods of implementation that Raytheon used, including the mandate from the top that Raytheon Six Sigma received and the more gradual approach being taken with eRoom and collaborative communities of practice:

> It is effective to legislate what you want to have happen—change can happen very quickly, if I have a billion dollar program and a lot of subs [subcontractors] want to participate on it—it's the only way they're going to do business on my program. We haven't done that yet. When you don't legislate it, you have to live through the pace and be willing. . . . We decided to make eRoom a grassroots activity—more cultural adaptation and less resistance—and the result is that it has less of an impact to the organization. But the change is less likely to be rejected with the strategy we're following now.

This same employee later said,

> Raytheon believes that the best way to disseminate this tool is by having people drawn to its ease and the value it can add. It's not a corporate strategy to drive communities of practice but to develop a technology and an ease of being able to use it—if they don't have a reason to use it, it won't work—it's easier than e-mail.

The main problem with adoption has been the occasionally frustrating pace with which the old engineering culture takes up the flexibility of a more collaborative culture. Engineers want to be very precise and very sure of themselves before they answer a question, so the act of putting something "half baked" into a collaborative system and allowing others to help shape it can be very, very difficult. One Raytheon employee said,

> Some people don't like to show an unfinished product—they won't even contribute in a meeting because it will look like they don't have a well-formed thought—they want to wait until the end and then critique it. . . . That's how you know [the collaborative system is] starting to work, when people feel comfortable [making suggestions], and you don't take anything personal when people reject your idea.

Evaluation

Raytheon believes it is still early in the adopter phase of technology introduction; only about 1,000 people use its collaborative software.

QuickPlace and eRoom allow all team members on a project to view each other's changes, comments, and suggestions. They also allow project collaboration to happen 24/7, thus cutting down on costs, misinterpretations, and time.

QuickPlace and eRoom enhanced the culture of sharing that Raytheon Six Sigma was promoting. As mentioned before, these tools have a chat room function that enables people to talk in real time about their ideas, suggestions, and comments on a particular project. It allows immediate revisions in one place and keeps all comments, changes, etc. These programs allow team members to tweak the work and allow everyone to see who made the changes and why without having to email a document back and forth. Because others can look at changes prior to finalization, team members must be comfortable and willing to work in real time. Being web based also allowed the programs to easily interface with members. The programs' simplicity fit the technical needs of team members, making sharing and collaboration easy, accessible, and practical.

The Adoption of a Community of Practice Model

Raytheon needed a mechanism to support collaboration across all its boundaries—across the newly merged companies, across geographic and time differences, and across different functions. Raytheon decided to develop a collaborative process as well as a technology—in effect, to redesign its roles and processes first before venturing into a new, enterprisewide IT system. The company worked closely with the American Productivity and Quality Center (APCQ) in Houston and licensed its community of practice methodology for use within Raytheon. Contact information for APQC is in Appendix D, Vendor Choices.

What are communities of practice? They are well known by anthropologists as one of the oldest elements of organizational life, defined as "groups of people who share information, insight, experience and tools about an area of common interest."[i] Communities of practice have traditionally been part of the informal structure of organizations, forming spontaneously as people seek help, solve problems, and develop new ideas or approaches. Many people believe that spontaneous communities of practice are the real vehicles through which technical knowledge spreads in organizations. However, if you try to reproduce these communities by sharing data or documents, you will invariably discover that the real value in knowledge management lies in sharing ideas and knowledge that are not documented and hard to articulate. This type of knowledge is called "tacit knowledge"[ii] and has usually been shared in person, often by watching someone do something or listening to someone think through a problem. One Raytheon CIO said,

> Communities of practice existed long before we had any of these [technology] tools—what I saw happen, we always had communities of practice—pods of software experts, and

[i] Wegner, Etienne. *Communities of Practice*. Cambridge University Press, 1998.
[ii] Polanyi, Michael. *Personal Knowledge*. University of Chicago Press, 1958.

> mechanical—that came together around paper-based documents. Then the technology came along. After the intranet was introduced we saw all these great tools to help us work more geographically dispersed and we said, "What do we do with them? Gee, how can we apply them? Can we share the tacit knowledge?

Raytheon embarked upon a benchmarking study to understand how other best practice companies deployed their knowledge management activities and communities of practice. One of the critical success factors Raytheon learned is well documented: face-to-face group contact is necessary throughout the year if the community is to be successful online. The standard seems to be anywhere from one to four meetings a year. One to two times a year seems to be a minimum. One Raytheon employee said,

> The reason you need face-to-face contact with these groups is what you're after is building trust. If I don't trust you, I don't care what you say. That social networking is the first level of trust—I can call you on Monday morning at 11:00 a.m. and you will answer the call and give me your undivided attention. And I'll respond when you call me, too. The second level of trust is—does that person really know anything? Can I trust the data that they give me? There are really only two levels of trust that need to be built.

The need to supplement electronic collaboration with personal contact is well established. In his article, "Knowing in Community: 10 Critical Success Factors in Building Communities of Practice," Richard McDermott describes the work of Shell Oil's Turbodudes community, which is devoted to sharing technical information about a particular geological structure, turbidites. The Turbodudes are able to meet weekly and use a coordinator who helps them to stay connected to one another. McDermott notes that communities thrive on trust:

> Contact—and the social connection and obligation that comes with it—is the key to ongoing community success. The coordinator of one of our most vibrant global communities said, "This is all about relationships. People don't really contribute to the community because it is good for the company. They do it because I ask them to." Successful coordinators visit community members, . . . they keep the community energy up by building one-on-one relationships among community members strong. The Turbodudes' coordinator tracks the number of people who attend meetings and has found that the strongest predictor of high attendance is how much time he spent the previous week walking the halls. Successful coordinators build and maintain these personal connections outside official community meetings.[iii]

Raytheon communities of practice can be either informal or formal. The two have quite different expectations and requirements, as summarized in Table 3.

[iii] McDermott, Richard. "Knowing in Community: 10 Critical Success Factors in Building Communities of Practice." Community Intelligence Labs (CoIL), 2000. http://www.co-i-l.com/coil/knowledge-garden/cop/knowing.shtml

An Informal Community of Practice: Raytheon Missile Systems

At Raytheon's Missile Systems (RMS) in Tucson, Arizona, engineers are assigned to various programs, each with its own separate contract. Although the engineers are located in the same Raytheon location, that location has 12,000 employees, so it was as if the engineers lived in separate worlds. After the knowledge management leaders at Raytheon completed benchmarking work, they shared what they had learned with the RMS vice president of engineering, who got enthusiastic about finding a way for engineers to share knowledge across these programs. He appointed a steering committee and told the members, "This is important. I need you to work on this." One Raytheon employee explained that if two engineers in different programs are both trying to solve problems with fuses,

> In RMS, these people don't even know the other ones exist, let's introduce them to one another. The output should be that we have old gray beards, sharing knowledge on fuses, with new engineers that can barely spell "fuse," and that will help us share our core knowledge as we bring new people on.

Initially, the vice president of engineering appointed six people who had passion, knowledge, and interest to lead the charge. Because they had content knowledge about different engineering areas, they had a good feel for where Raytheon needed to share knowledge to gain competitive advantage. They started by creating some pilot groups that they thought would be successful. Because these groups are informal communities of practice, their membership is open—one Raytheon employee said, "Come if it's fun, if you're getting anything out of it." Good leadership of an informal community of practice is less about being a project manager and more about being an excellent facilitator. The community of practice leader needs to let the community lead rather than directing it.

One barrier that Raytheon discovered as it began to put together the RMS communities was that engineers are accustomed to charging their time to a specific contract rather than to overhead. One Raytheon employee said,

> We are a company of projects, and our projects come directly from contracts, and that's very bureaucratic. How do you get out of your silos when that's not a contract requirement? You can execute your contract, you just can't do it as well or as rapidly. . . . We're very bureaucratic in each program, and this is a horizontal overlay across programs and across businesses.

The company had to establish clear ground rules that made it easy for people to attend community of practice meetings. Engineering leadership suggested that the groups meet at noon and provide pizza and soda for these meetings. It was difficult initially to draw attendance into these meetings and help the engineers get outside of their project orientation.

It is more difficult to measure the success or progress of an informal community of practice because of the absence of a concrete deliverable. Raytheon measures participation and

TABLE 3 Formal versus informal communities of practice

Variable	Formal Community of Practice	Informal Community of Practice
Purpose	Create bottom-line impact	Create social network
Expectation	Produce deliverable	Share knowledge
Leadership Skills	Directive, project management based	Facilitative, influence based
Membership	Closed membership—by invitation only	Open membership—anyone can show up
Sponsorship	Must be formally sponsored	May be formally sponsored

also surveys those who attend to see how they feel about the community. One Raytheon employee said, "Are we doing good? Are we doing bad? You have to keep your finger on the pulse to see if the patient is still alive."

A Formal Community of Practice: Raytheon RILCOM

One of the most promising areas for consolidation between the four companies of the new Raytheon was consolidation of suppliers, which numbered 44,000 across all the different businesses. The engineers are in charge, and they all have their favorite suppliers. Although the companies had merged, the databases remained separate, and there might be the same part inventoried in four different places.

Initially, Raytheon formed a logistics council with representatives from each of the businesses. This group focused on spend leverage but had very limited cross-business knowledge sharing. One manager said,

> We had limited cross-business sharing—didn't talk about our processes, stayed stove-piped, didn't standardize our processes. We were fragmented, we have these different businesses—players on the team kept changing. At the enterprise level for logistics, we didn't have a common focus, no one to lead. . . . We were communicating as this organization, but we were still just stove pipes. Everyone was still thinking, "I'm only going to do what is good for my business."

Then, in 2003, Raytheon transformed its logistics council into RILCOM to adopt a one-company strategy for the logistics organization. Business representatives were still included, along with knowledge management champions, subject matter experts, and peer assistants. In fact, the hierarchy didn't change, but a new leader of the group was brought in, George Ellis. Ellis had no staff of his own but reported instead to the corporate staff, and, under his leadership, the group broadened its mandate to include a wider definition of logistics enterprisewide.

The RILCOM team began with the baselining process that was critical to understanding what the company spent and where the opportunities could be realized. Next the team identified best practices from all its businesses and asked, "If we replicate these best practices across all of our businesses, what will the impact on the bottom line be?" This questioning created a solid business case for the enterprisewide changes that the RILCOM team wanted to recommend. Individual business leaders saw the value of the team more clearly once these impacts were quantified; team members could then much more easily get permission to do RILCOM's work during paid business hours, which raised the status of RILCOM membership. By analyzing the payback data, the team was able to identify two projects it wanted to focus on in 2003–2004:

- **Powertrack.** This project converted 38 different freight payment methods to one standard web-enabled process and eliminated multiple and manual processes.
- **Mtrak.** This project, which is a web-based self-service inventory system, automates and simplifies manual processes and makes material and property assets visible to internal customers. This solution has drastically reduced material losses and freed up logistical resources.

RILCOM holds quarterly face-to-face meetings as a result of its belief that communities of practice need this time together in order to create the strong relationships that build trust. The group has weekly electronic meetings and even has its own mascot, Lonnie, one of the logistics leaders who dresses as a hobo and rides to their meetings on a bicycle, claiming to have no web access or telephone access at all.

The RILCOM team was recently invited to present its experience in partnership with the American Productivity and Quality Center at Supply Chain World.

EVALUATION: INCREASED USE OF COLLABORATIVE TOOLS

Adoption of Raytheon Six Sigma has continued to drive the performance of the company. Raytheon currently has 675 certified Raytheon Six Sigma experts, and 1,400 employees have received training. By 2004, an estimated 13,000 full-time people were qualified as Raytheon Six Sigma specialists. Raytheon Six Sigma has become the way that people think about work and processes at Raytheon.

The enterprisewide adoption of Raytheon Six Sigma suggests that Raytheon has been transformed from a hierarchical organization to a collaborative organization. As word has spread, more businesses within the company are using QuickPlace and eRoom. Without top management forcing the products on employees, adopters have recognized the value of the tools through experience and sharing with peers. The increased use has led to easier facilitation of information sharing, improved efficiency, and increased speed of work. QuickPlace and eRoom are proving to be elegant solutions that did not require a great deal of investment, training, or customization.

There is also increased use of the communities of practice, which is indicative of the growing norm for people to share knowledge. Currently, Raytheon estimates there are 65 formally sponsored communities of practice and about 65 more that are not yet registered. The company believes it may eventually have up to 1,000 communities.

PART 2:
THE THEORY YOU NEED

CHAPTER **5**

BOUNDARY THEORY—UNDERBOUNDED AND OVERBOUNDED GROUPS AND THEIR PROBLEMS

Web-based collaborative tools are essentially tools that enable you to move information across boundaries more easily—different companies located in different time zones around the globe in Raytheon's case, across 30+ different sites in New York and New Jersey in the case of the PANYNJ, and between CTA managers, architects, designers, engineers, and contractors in the field in Chicago. Boundary theory can help us recognize what is working, why, and what we can do about what is not working. The boundary theory in this chapter is from Clayton Alderfer's "Consulting to Underbounded Systems."[i]

Boundaries regulate transactions between a human system (i.e., a group) and its environment; in simple terms, they determine what gets in and what stays out of the system. The concept has its roots in biology, but has been applied by social scientists to define systems and groups. In this context, boundaries are the defining characteristic of a group of people. Without boundaries, talking about "groups" is meaningless.

Boundaries can be physical, such as geographic distance or the architectural layout of a building that separates two departments, or they can be psychological. For example, crossing into a new group can make an individual feel out of place or unsupported. Or reading highly technical material can be difficult if one is not familiar with the jargon of that field. In both of these examples, there is a psychological boundary that separates the individual from the group with which he or she is interacting. According to Alderfer, "Psychological boundaries tell more about the 'here-and-now' of a system, but their condition is harder to detect than physical boundaries—especially to an outsider."

In cellular biology, the ease or difficulty with which foreign objects move in and out of a cell is called "permeability." An optimum degree of permeability means that the cell can take in what it needs to function and release what it needs to release without difficulty. If its outer membrane is too permissive and lets in too much, the cell can die. The cell ceases to function because its boundary no longer works to differentiate it from the larger environment. But a cell also dies when its outer membrane is too restrictive and causes the cell to lose the ability to take in important parts of its environment. The cell will miss out on essential metabolites and "starve to death." Success depends on taking in neither too much nor too little, on preserving a fragile balance.

When a group's boundary with its environment is too restrictive, social scientists describe it as "overbounded," whereas groups whose boundaries are too permissive are called "underbounded." Another simple way of thinking about this is that overbounded groups have boundaries that are too tight, so it is difficult for the groups to take in people or thinking or information from the outside. Underbounded groups have boundaries that are too loose, so the groups are not able to keep the turbulence of their environment at bay. When a group's boundaries are not functional or balanced, the result is a variety of "symptoms" that are much easier to identify than the actual boundaries themselves. These symptoms are deeply familiar to most people because at one time or another most people have belonged to a group with dysfunctional, imbalanced boundaries. And each of these conditions—too rigid and too loose—carries a distinctive threat for the system. Alderfer writes,

> The primary threat to underbounded systems (too loose) is that they will become totally caught up in their environmental turbulence and lose a consistent sense of their own identity and coherence. The primary threat to overbounded (too rigid) systems is that they become closed off to their environments and lose the capacity to respond adaptively to environmental changes. Thus, being extremely underbounded is a greater threat to a system's survival, especially in the short run, than being overbounded.

Groups that are underbounded or overbounded have different problems that have different solutions. In order to determine whether a group in trouble is underbounded or overbounded, one can look at several indicators. Alderfer has identified several variables whose values will be quite different in underbounded and overbounded systems (see Table 4).

HOW TO RECOGNIZE AN UNDERBOUNDED GROUP

The following characteristics are typical of underbounded groups—in other words, where boundaries are too loose and

[i] Alderfer, Clayton. "Consulting to Underbounded Systems." Chapter 11 in *Advances in Experiential Social Processes*, Vol. 2, eds. C. P. Alderfer and C. L. Cooper. New York: John Wiley & Sons, Ltd. 1980, pp. 269–278.

TABLE 4 Properties of overbounded and underbounded systems

Variable	Overbounded Systems	Underbounded Systems
Goals	Goals clear, priority unequivocal	Goals unclear, priorities equivocal
Authority	Monolithic	Multiple and competing
Economic conditions	Minimal, short-term stress	Impending economic crisis
Role definitions	Precise, detailed, restrictive	Imprecise, incomplete, overlapping
Communication patterns	Difficulties with openness when people meet	Difficulties in determining who can and should meet
Human energy	Constrained, blocked	Diffuse, exhausting
Affect/feelings	Positive inside, negative outside ("We're great, you're terrible")	Negative inside, negative outside ("We're terrible and so are you")
Intergroup dynamics	Task groups dominate	Identity groups dominate
Time span	Long	Short
Cognitive work	Single theory ideology	Multiple theories or no theory or ideologies

Source: Alderfer, Clayton. "Consulting to Underbounded Systems." Chapter 11 in *Advances in Experiential Social Processes* Vol. 2, eds. C. P. Alderfer and C. L. Cooper. New York: John Wiley & Sons, Ltd. 1980, p. 278.

the group or system is in danger of being swamped by the chaos in the surrounding environment:

- **Goals.** In order to be clear, goals need two qualities: they need to be clearly stated, and they need to be supported by a consensus. Underbounded systems have neither clarity nor consensus about their goals. People in these groups may experience their group as floundering without a sense of direction.
- **Authority.** Larry Hirschhorn, at CFAR, has conceptualized all leadership as the management of the group's boundaries, which in turn promotes the work of the whole system. In underbounded systems, the authority may be fragmented and unclear. People in these systems may ask, "Who is really in charge?" "Who is responsible for doing this work?" "To whom can I turn to clarify my job?"
- **Economic conditions.** Economic crisis can have a profound effect on psychological boundaries. Systems that have healthy boundaries when they are prospering will often transform into underbounded systems when their territory or economics are threatened. Or underboundedness may itself cause financial problems. A group that is unable to organize itself may miss opportunities or waste resources. People in underbounded groups may be worrying about their job security or about their compensation, making it even more difficult to focus on the work.
- **Role definitions.** For individuals in an underbounded group, the clarity and expectations of their roles tend to feel fragmented, conflicted, and isolated. There may be conflicting demands on individuals coming from different sources, or there may be a lack of explicit performance expectations. People in these groups often wonder how their contributions will be evaluated, if they are working alone, or what they are supposed to focus on.
- **Communication patterns.** Communication has to do with the way in which valid information is given and received in order to do the work. In an underbounded system, it is even difficult to determine who should talk with whom or to organize a meeting that gets everyone together. Once an exchange of information actually takes place, it may be characterized by withdrawal or outbreaks of simultaneous talking. There may be a great deal of conflict simmering just below the surface.
- **Human energy.** In underbounded systems, people's energy may feel fragmented and diffuse. It may be difficult to harness energy and effectively channel it toward the group's goals.

- **Affect/feelings.** Overall, the balance of the feelings in an underbounded system is less positive than it is in an overbounded system. The system may be facing (or feel that it is facing) an imminent threat. People often feel a lack of confidence in themselves and in their leader, and there may be feelings of futility. Members of underbounded groups are often very stressed because they spend a great deal of their time organizing the chaos that surrounds them. In times of systemwide change, members of underbounded groups are likely to fear the dissolution of their group. Promoting the discovery of positive feelings in an underbounded system may allow people to see that they do share common concerns and that they are able to control the chaos that is threatening to overwhelm their system.
- **Intergroup dynamics.** Underbounded groups tend to experience less conflict between task groups (e.g., maintenance, purchasing, engineering, and marketing) than between identity groups (e.g., age, gender, race, and ethnicity). This may make it difficult to achieve a sustained sense of direction.
- **Time span.** Underbounded groups tend to have a short time perspective. Some organizations are capable of planning and thinking ahead, and others are more short term oriented. This may be the result of external threats in the environment making underbounded groups unsure about whether they will be able to survive.
- **Cognitive work.** People in groups and organizations need a rudimentary theory to explain what they experience in organizations. Without it, they would be overwhelmed by confusion and not know how they should behave. Underbounded systems may have no unifying theory at all, or they may have multiple theories that compete with each another.

HOW TO RECOGNIZE AN OVERBOUNDED GROUP

Being a member of an overbounded group is often a lot more pleasant than being a member of an underbounded group. But, by definition, overbounded groups have problems, too. They are too rigid, too impermeable, and, although these characteristics may initially feel comfortable for the group's leaders and members, the characteristics make the group too vulnerable to changes in the environment and too difficult to collaborate with. This type of group is not optimal, either. Overbounded groups have the following characteristics:

- **Goals.** Overbounded groups and systems tend to boast an unequivocal clarity about their goals and priorities. In order to increase the rigidity of a group's boundary, increase the clarity of its goals and priorities.
- **Authority.** Authority in overbounded groups and systems tends to be centralized and hierarchical. Most resources are controlled by a single source, usually at the top of the organization. These organizations are characterized by a unity of purpose, direction, and control.[ii] Therefore, to increase the strength of a group's boundary, leaders need to exert a directive style of authority.
- **Economic conditions.** Overbounded groups are likely to be facing smoother economic conditions. When economic conditions are favorable, the group's territory and technology may improve and it may able to keep members and attract new members.
- **Role definitions.** Expectations in overbounded systems tend to be precise, detailed, and restrictive. People in these groups may feel confined and constrained and experience a lack of creativity and stimulation, especially at lower levels of the organization.[iii]
- **Communication patterns.** When information is not being given and received as needed to do the organization's work, then the communication in a system is considered suboptimal. The clear roles established in overbounded groups establish clear communication links between people and groups. Getting people together on a regular schedule is usually not difficult. However, in overbounded systems there is a strong tendency to withhold information or to distort it in order to present one's own position in a favorable light. Bad news is withheld, especially from authority figures.
- **Human energy.** In overbounded systems, people often feel that their energy is confined and that it is difficult to release it for work. If boundaries are tightened further, the effect is to further restrict the available energy. The feeling in an overbounded group is that this is not an environment that welcomes individual creativity.
- **Affect/feelings.** This characteristic is particularly complex for an overbounded group. On the one hand, the feeling in an overbounded group is generally quite positive. The future looks rosy, the group's goals and priorities are well understood, the leadership is in control, and people's roles are clear. However, this positive feeling can often be the result of repressive forces, which discourage people from voicing any criticism or negative feelings. Members of overbounded groups are likely to feel that things are the way they are and cannot be changed. Internal criticism is muted in an overbounded system, and, as a result, a negative affect is directed outward at other groups. This may make it difficult for an overbounded group to collaborate with others, to share information or take in information across its boundary,

[ii] Gulick, L., and Urwick, L. *Papers on the Science of Administration*, 1937. As cited in Alderfer, Clayton. "Consulting to Underbounded Systems." Chapter 11 in *Advances in Experiential Social Processes*, Vol. 2, eds. C. P. Alderfer and C. L. Cooper. New York: John Wiley & Sons, Ltd. 1980, p. 271.

[iii] Argyris, C. *Personality and Organization*, Harper and Row, 1957. As cited in Alderfer, Clayton. "Consulting to Underbounded Systems." Chapter 11 in *Advances in Experiential Social Processes*, Vol. 2, eds. C. P. Alderfer and C. L. Cooper. New York: John Wiley & Sons, Ltd. 1980, pp. 269–278.

or to experience the growth that depends on understanding the power of dissent. In times of systemwide change, members of overbounded groups will tighten their boundaries as much as possible to the point of becoming wary of outsiders.

- **Intergroup dynamics.** Overbounded groups are more likely to experience conflict on the task boundary, such as when people from one department clash with people from another department, than on their identity boundaries (e.g., race, gender, and ethnicity). One way to loosen the boundary around a group that is too rigid is to encourage people to come together in their identity groups so that they can experience their similarities outside of their department or task groups.
- **Time span.** Feeling relatively secure, it is easier for overbounded groups to take a longer time perspective than underbounded groups.
- **Cognitive work.** Overbounded groups are much more likely than underbounded groups to have a single unifying body of theory or ideology that members are expected to master. This may be invoked as "the company line," which influences everything and is introduced to new members. If the group is too rigidly bounded, it may make it difficult for the organization to experiment or adopt innovation.

CONSTRUCTION: AN EXAMPLE OF MULTIPLE BOUNDARIES AT WORK

Because boundaries describe a relationship between a group and its environment, it is sometimes necessary to look at more than one group to figure out what is going on. You may need to look at two groups interacting where one has more rigid boundaries than the other. You may need to consider why a group may be underbounded when it exists inside a company or agency that is generally overbounded.

To understand how groups in a system affect one another and how boundary theory applies, let's look at the example of a construction project. According to Scott Unger of Constructware, "historical inefficiencies, cost over runs and interparty disputes often characterize the building process."[iv] Typically, these problems occur on the boundaries between groups—between architects and designers, between contractors and their subcontractors, or between contractors and the owner or agency.

The new trend to create partnering events at the beginning of a large construction project is an attempt to create a new system whose members are all the participants on a particular build. Three or four days may be devoted to a meeting at which everyone agrees on a common vision and purpose, vows to work collaboratively, and gets to know one another. If this work is done well, participants may emerge feeling terrific about their new partners, but it is all too easy for the effects of a good partnering session to wear off long before the project is complete. Why do these effects wear off?

Imagine that each participant has a primary membership in his or her own firm—whether architect, transit agency engineer, or lighting designer. The build creates a temporary system where all participants come together for work—much like a task force in a corporation that cuts across different divisions or departments. The boundary around this new group is quite a weak one compared with the boundaries of the primary groups. The original, primary groups claim most of the individuals' allegiance, and the primary group cultures dictate how the individuals behave on the new team. Figure 4 shows these boundaries at work.

It is easy to imagine that the new "partner" group on the build will face many of the challenges associated with underbounded systems: conflicting priorities, multiple and sometimes competing authority, overlapping role definitions, diffused human energy, short time perspectives, and multiple ideologies with no unifying theory to hold them together.

The social system of a transit construction project will be made up of several subgroups with varying levels of boundary permeability. A classic problem in construction projects is the lack of communication between one group and other groups in the project, causing someone to act on a false assumption and leading to waste and delays. Another way to think about this example is to imagine information as an object that must transfer from within one group across the boundary to another. In order for this information to be transferred, an exchange between the group members must be arranged. If information is not passed on or is misunderstood, there is a flaw in the exchange process.

In an ideal construction project, groups will have all the necessary information and understand what information all other groups need and when they need it. Consequently, the groups will freely give important information to everyone who needs it when they need it. When a web-based knowledge management technology is applied to that ideal project,

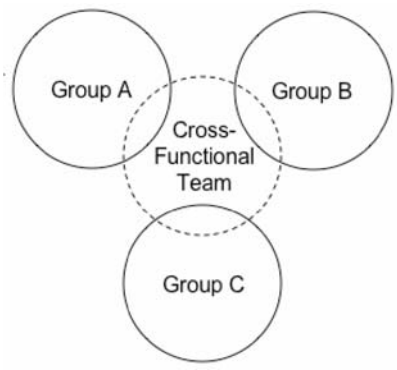

Figure 4. Multiple boundaries at work.

[iv] Unger, S. "The Trend Towards an Internet-Based Communication Standard in the A/E/C Industry." Constructware, January 2002, p. 1. http://www.constructware.com/common/downloads/standardization_white_paper.pdf

groups will give and take from the web constantly, thereby creating an up-to-date and complete information archive of the construction project.

In a less-than-ideal world, however, problems can still exist when groups do not give information in a timely manner or do not give it at all. If the subgroups within the social system of the transit construction project are all overbounded, they will have trouble knowing what information other groups need at what time. This trouble is not due to incompetence or indifference toward the other groups on the project, but is a simple lack of familiarity with the members of other groups and their expectations. When the common membership in the social system of the construction project is emphasized over membership in the different subgroups, the boundaries of each of the subgroups will loosen and information will begin to get where it needs to go. However, because of the inherent temporary nature of the social system created for construction projects and the more permanent nature of the subgroups involved in the projects, emphasizing common membership in the social system is easier said than done.

Web-based knowledge management technologies are sometimes thought of in terms of easing the process of communication between groups that have common goals or tasks. When you use the theoretical framework about boundaries and groups, however, you attempt to create a new group that includes all of the people who need information about the project and who are trained to use the new web-based technology. Technology is the communication enabler of this new group of all decision makers on a project. This new group spans across all the subgroups of the system by including a few key members of each. If any of the subgroups are overbounded, then members of those groups will be less likely to contribute to the project's knowledge. They will be the "hold outs." Old familiar communication breakdowns will take on a different form through the use of technology.

At the same time, using web-based collaborative software can help a temporary system like a construction project to strengthen its boundaries. Implementing new technology to help carry information across group boundaries is not enough by itself. To be successful, the social system needs to be evaluated and possibly changed to make sure that the boundaries of the groups are neither too loose nor too tight to exchange information. For example, if the group can't work together productively and you believe that it's because the construction team needs to have stronger boundaries, you can recommend a more directive style of leadership for that group, or you can physically move the group so that it works more closely together, or you can arrange for the group to spend time together face-to-face to help the group establish personal trust. You might examine the reward system to make sure that the group was rewarded for collaboration instead of for protecting the interests of individual companies.

Changing the social system at the same time you change the technological system is the primary idea behind sociotechnical design and is discussed further in the next section.

A HYPOTHETICAL TRANSIT CASE: SUPPLY CHAIN CONFLICTS

To illustrate the point, let's examine a hypothetical case set in a large, metropolitan transit agency.

The director of purchasing is frustrated. Despite many attempts, he or she cannot convince the maintenance department to produce reliable forecasts far enough in advance. Maintenance in turn sees the director as unresponsive. When maintenance workers need a piece of equipment, they know that it can take more than 24 months to produce it. If purchasing can't manage its supplier relationships better than that, they figure, why should we knock ourselves out creating more elaborate forecasts for them? The director of purchasing has several times suggested that he or she place one of the purchasing employees in the maintenance division to learn more about the way maintenance works and to bring back early intelligence, but each time the director of purchasing suggests this, he or she is rebuffed by maintenance. The director of purchasing would also like to have more influence over the suppliers' projections and wonders if it would help to have someone "on the ground" working directly at the supplier site. Perhaps he or she needs to pull together a task force, with representation from maintenance, purchasing, and some of the suppliers? But that's the last thing anybody wants—another committee and set of meetings to attend.

In boundary terms, it makes sense that purchasing very likely has looser boundaries as an organization than maintenance does—after all, purchasing must interact with all of the departments at the transit agency, as well as all of the suppliers. It couldn't do its job if it had rigid, impermeable boundaries that did not permit information to flow easily. Maintenance in this case has a much more rigid boundary—it doesn't like the idea of letting an outsider into the department, and it is very regimented about the way it wants information to flow out. Maintenance organizations often enjoy strong, hierarchical leadership, clearly defined roles, and strict protocols—this develops naturally as a way of working when the cost of error is perceived to be very high. (Think of the difference between the tight norms that a cardiac surgeon establishes for what is "right" behavior in the operating room versus a general practitioner seeing patients in the office.) An overbounded maintenance organization would try to suppress or expose weaknesses in any information that wasn't favorable to maintenance.

What may happen if the director of purchasing puts together a task force that includes representation from purchasing, maintenance, and suppliers? To be successful, the task force will need to counteract many forces that work to make the group underbounded, chaotic, and disorganized because these forces can make it hard for the group to accomplish its task. The task force may need to establish clear authority for its work from someone at the agency who is higher up than either purchasing or maintenance. This sponsor will need to be clear about the group's purpose and goals and hold the group

accountable. People serving on the task force will need to have clearly defined roles for their contribution to the work. A clear meeting schedule and group membership will have to be established, and members will have to undergo training or adopt a new unifying theory for their work, or "common language."

Can this group come together as a virtual, web-based collaborative group and satisfy some of these criteria? The answer is a qualified "yes" if the group follows the best practices outlined later in the report.

AN ACTUAL BOUNDARIES CASE: RAYTHEON SIX SIGMA

In this study, Raytheon provided the clearest example of what happens when a company lacks a unifying framework. After the merger of the four companies, there were competing ways of working and talking and much unproductive conflict. Alderfer writes, "Usually the multiple theories are associated with the various warring groups whose conflict keeps the system in constant turmoil. Finding a means to deal with the theoretical differences also reduces boundary permeability and aids the system to establish a greater sense of wholeness."

The four original companies were the primary groups in the system, and the "new Raytheon" that encompassed them had far weaker boundaries. Membership in one's original company defined one's reaction to others. For example, a best practices database was originally developed at Texas Instruments. Texas Instruments thought everyone would be thrilled to have the new database, but nobody looked at it but Texas Instruments. The new Raytheon was an underbounded group at the beginning, with the economic crisis to prove it.

Think about the way that Bill Swanson worked to impose Six Sigma on the organization in a very authoritarian, top-down way. He flew around the globe to meet with almost every Raytheon employee to emphasize the importance of the initiative. Many middle managers were trained; in fact, becoming a Six Sigma expert was encouraged for promotion. The impetus behind this Six Sigma reform was economic crisis; the stock price had plummeted from $70 a share to $17 a share, another characteristic of underbounded systems. Thinking was necessarily short term. Rather than continuing to allow the situation to continue to unravel, Swanson and his team took steps to impose a unifying framework on Raytheon. In boundary terms, they simultaneously

- Clarified goals and priorities,
- Asserted clear top-down authority,
- Imposed clear role definitions on managers (Raytheon Six Sigma training and language), and
- Improved the negative feelings of self-doubt in the system.

All of these actions served to tighten the boundaries around the new Raytheon and weaken the boundaries around the four original companies. Swanson and his team succeeded—at the time of this writing, Raytheon's stock price was $37.23.

WHY TO STUDY BOUNDARY THEORY

If you are looking at a struggling group, it helps to understand the theory underlying some of the things you are seeing, because the theory will help you decide what course of action to take to correct the problem. For example, there is a great deal of rhetoric in business texts that urges managers to "empower their employees." A common strategy is to bring many levels together to brainstorm vision and strategy for a unit or organization. But many of these ideas are based on research in the organizational behavior literature, where the study of overbounded systems is more prevalent. For overbounded systems, breaking down barriers to communication and pushing decision-making power down in the organization are generally helpful ideas. However, if you are dealing with a group or a system that is underbounded, applying these same concepts can be disastrous. Dealing with overbounded groups always requires loosening the boundaries, and dealing with underbounded groups always requires tightening the boundaries. For underbounded groups, it may be more useful to create a strong leadership structure that consults with the team but retains the authority over strategy, mission, and vision. The classic tools of project management—setting internal deadlines, monitoring them, and seeing deliverables—may be much more appropriate.

CHAPTER **6**

PRINCIPLES OF SOCIO-TECHNICAL DESIGN

The principles of socio-technical design are based on two foundational ideas:

- Organizations should design their technical and social systems concurrently.
- The people who work in these systems should participate in the system redesign.

Fred Emery, one of the founders of socio-technical design, said, "The simple truth is that organizations harnessing the mental power of all their employees outperform organizations that have brilliant leadership yet fail to harness the mental power of all their workers."[i]

Research and practice highlight at least four principles of socio-technical design that are relevant to thinking about how to introduce new technology. First, identify the divergent interests that different users have. Don't work under the assumption that there is only one paradigmatic user. Second, let people who will work with the new technical system participate in building the social system that will work with it. Third, focus on the system that will deliver a new technology, as well as the technology itself. Fourth, do not overdesign the implementation; use minimum critical specifications. Let us briefly examine each of these principles.

IDENTIFY THE DIVERGENT INTERESTS THAT DIFFERENT USERS HAVE

In designing new technologies and their organizational supports, we need to take account of the variety of users who interact with the technology. Designers are frequently counseled to find out what the user wants, but most often there are different user subgroups whose needs and interests may conflict. A good designing process takes an up-front account of these competing needs so that the resulting design optimally resolves the tensions and differences between groups of users. The design embodies a consensus. Thus, for example, maintenance technicians and operators in many settings typically have different information needs from a series of displays. The operators (when they are at a console in a factory or in the conductor's cab of a train car) want systems-level data that highlight the links between all the relevant components; maintenance technicians want more in-depth, below-the-surface data on particular subcomponents. In designing the circuitry, memory banks, and displays for components, designers may need to take account of these different needs so that the resulting informational capacity of the component can reasonably satisfy both groups. Moreover, when the components are designed with participation from both groups, each group and the designer develop a deeper appreciation of the others' needs and interests. The design process itself has integrating effects.

LET PEOPLE WHO WILL WORK WITH THE NEW TECHNICAL SYSTEM PARTICIPATE IN BUILDING THE SOCIAL SYSTEM THAT WILL WORK WITH IT

Participative methods are essential in redesigning a social system that complements the new technical system. In an interview with CFAR Principal Larry Hirschhorn, Harold Salzman described a study of the design of machining cells in an aerospace factory. The findings from the study showed how effective participative methods are.

In the study, a design team containing machinists and other professionals made a storyboard with the proposed layout of cells, hung it on a wall of the shop, and invited machinists to suggest improvements to the basic placement of machine tools and the flow of parts. Machinists proposed changes on such issues as the bunching of tools at workstations, the type of tools to be used (e.g., hydraulic versus electrical), and the nature of certain operations. Rotating off and on the design team, machinists reviewed proposed vendors and helped select new equipment.

Salzman reported that when the machining system came up online, workers were in much closer proximity to each other than before. They informally cross-trained one another, several decided to take math courses at a junior college to "trig" out problems, and they participated actively in a post-implementation suggestion system, sometimes doubling their income by participating in the cost savings resulting from their suggested improvements. Thus, a participative design process can not only create an effective technical system but

[i] *Participative Design*, by Fred and Marrelyn Emery, adapted by Robert Rehm from *Participative Design for Participative Democracy*, a Tavistock anthology, edited by Eric Trist and Hugh Murray, Vol. 2, The Socio-Technical Perspective.

also stimulate a process of continued learning and improvement. This is critical to workers' ongoing success as they transform from fixers to planners.

FOCUS ON THE SYSTEM THAT WILL DELIVER A NEW TECHNOLOGY, AS WELL AS THE TECHNOLOGY ITSELF

In her study of the dissemination of an expert system designed to help sales representatives configure computer systems, Dorothy Leonard-Barton found that many sales representative rated the program poorly because other competing programs overloaded the computer networks that transmitted program data to local terminals.[ii]

Because the sales representatives didn't understand that the configuration program competed with others for space on the network, the representatives attributed the slow response time that they got from the expert system to the expert system itself. In other words, they confused the technology with the system for delivering it.

In Chicago, the CTA found that one of the earliest problems of implementation was the way that subcontractors in the field were using their scanning equipment. Using their equipment to scan drawings into the system was especially difficult for subcontractors. The CTA staff and consultants went into the field to check the equipment, sometimes determining that the scanner wasn't heavy duty enough to do the work, sometimes setting up the equipment for people in their trailers, and sometimes training people on the proper use of the equipment. The CTA staff and consultants then issued detailed guidelines for what types of scanning equipment should be purchased. Without this elaborate technical support, the success of the whole web-based system was in jeopardy. People would likely have attributed the failure of the system to the new collaborative technology rather than to the scanning equipment that was necessary to deliver the collaborative technology.

As the above two examples suggest, new tools can be used and new technologies can be managed only if the context surrounding the tool, its delivery system broadly described, is redesigned or reconfigured. Component designers may take great pride in a particular module, technology, or tool, but users rarely distinguish between the component and the system that makes the component useable. This will be no less true of subway car operators and riders. When prototyping the social system to match the technical system, we design the tool or technology and its delivery system concurrently. In this way, both the design and the resulting rise of new tools and technology are optimized.

DO NOT OVER-DESIGN THE SYSTEM; USE A MINIMUM OF CRITICAL SPECIFICATIONS

Eric Trist, one of the founders of socio-technical theory, said,

> When you come to designing something new, you don't know what to do. When you've got change in a technological process and in the social process accompanying it, you can't lay it all down in the beginning. You can't program it and detail it. So we came up with the idea that you should only decide those things that, at any particular time and phase, have to be decided. You leave everything else open. . . . You specify the least that you have to, and then you get on with that, and that produces the next set of problems, and you fill in the next. . . . This is a critical truth because things are over designed and they have to be undone.[iii]

Whenever an organization chooses to pilot a new approach, it is acknowledging its debt to this idea that some things can be learned only through experience. With the introduction of new technology, it is rarely possible to know all of the challenges you will face and all of the effects it will have, even with meticulous planning on the part of knowledgeable people. We believe it is a best practice to create pilot projects and early forays to learn from experience before trying to broadly implement new technology. If early participants can be recruited into the process as learners and improvers, you will have the benefit of their experience and encounter less resistance.

The PANYNJ case exemplifies this idea. The leadership there consciously set out *not* to over-design the implementation of new technology. While the leaders solicited input from many groups, they did not put together a formal process redesign team, believing that such a team would slow down progress. Instead, the leaders instituted a pilot project. Once there was experience with the technology, the leaders began to shift roles and create new roles to reflect what they had learned. This in turn changed their work processes.

Pradip Mehta explained it this way:

> Put a system out there and it will illuminate the facts and it will help you. You have to make a very careful, intelligent decision to what degree you're going to solve your business problems—I knew that if I had to wait to solve our work order tracking problems, [the new technology] would have taken me 3 more years to implement. You have 10 different entities involved! It is what it is. Just put it out there and get everyone to see the problems—otherwise we'd still be sitting here with our process flow charts.

[ii] Leonard-Barton, Dorothy. *Wellsprings of Knowledge: Building and Sustaining the Sources of Innovation*. Harvard University Business School Press, 1995.

[iii] Eric Trist in "An Interview with Eric Trist, Father of the Socio-technical Systems Approach," by William M. Fox in *The Journal of Applied Behavioral Science*, Vol. 26, No. 2, 1990, pp. 259–279.

CHAPTER **7**

SOCIAL RESISTANCE THEORY

When the introduction of new technology disappoints or fails, it is often attributed to resistance on the part of workers who are still attached to the old way of doing things. That resistance may take active forms, as when someone with some authority in the organization questions the value of the technology or flatly refuses to use it, but many times it takes the form of passive resistance. The psychological term "resistance" is in wide use in the culture, but in order to effectively respond to it, we need to understand it. Unless otherwise noted, the social resistance theory in this chapter comes from Robert Graham's classic article, "Understanding the Benefits of Poor Communications."[i]

RESISTANCE MAY BE RATIONAL

One perspective is to take a broader and more systems-oriented view of resistance and why it may be occurring. Graham argues the following:

> From the literature on innovation theory (and from common sense) we know that the criterion of acceptability of an innovation is the conviction on the part of potential recipients that the innovation will, in sum, contribute more importantly to the satisfaction of a network of wants and needs than to their frustration.

Graham further points out that different people and groups within an organization have different interests, and, therefore, "With many innovations it is often true that the needs and wants of one group of people will be satisfied while those of another group will be frustrated. That is, one person's solution can often become another person's problem."

As management consultants, we often hear individuals in organizations attribute the organizational problems to "poor communication." The underlying belief seems to be that if only communication could be improved or even made perfect, there would be no conflict. In his article, Graham draws on the earlier work of psychoanalyst Charlotte Kursch to suggest that nothing could be farther from the truth. When someone is calling for better communication, it is possible that one or more of four erroneous assumptions are at work:

1. **Poor communication is a result of faulty technique.** In reality, the problem may be the message rather than the technique.
2. **Better communication will reduce strife and conflict.** It is sometimes the case that more clarity only serves to underscore conflict and bring it out into the open. Where people or groups are conflict averse, they may rely on poor communication to obscure their differences because they lack the skill or the courage to deal openly with them.
3. **When conflict continues for a long time, lack of communication must be one of the basic problems.** Graham points out that "During any prolonged conflict there is usually plenty of communication but just not much agreement." Graham further says that "clarity has the disadvantage of tying the executives' hands and limiting flexibility in dealing with contingencies as they arise." One seemingly rational remedy would be to identify the particular motive or anxiety that was contributing to the stalemate, so that the benefits of clear communication are seen to outweigh the benefits of poor communication. However, any experienced consultant or manager will be able to think of examples when that approach has not sufficed.
4. **It is in everyone's interest to attain clarity.** In reality, it is often in the interest of one or both parties to leave the situation fuzzy. Graham claims that fuzzy communication provides the following benefits:
   - Minimizes impact of poor planning (do not let others know you do not know what you are doing),
   - Permits faster decision making and minimizes objections,
   - Preserves the freedom to change your mind,
   - Allows you to say two things at the same time,
   - Allows you to say no nicely,
   - Helps you avoid confrontation and anxiety, and
   - Helps minimize opposition and criticism.

In the case of the first and second erroneous assumptions, the answer is to first diagnose accurately that the resistance is quite rational, although it may not be publicly expressed. Improving the communication technique and getting the message clearer in cases like these will not only *not* improve the

[i] Graham, Robert. "Understanding the Benefits of Poor Communications." *Interfaces,* Vol. 11, No. 3 (June 1981), pp. 80–81.

situation, but it may exacerbate long-existing or suppressed conflict in the system.

The remedy is to acknowledge that some resistance is rational and use a negotiation framework to address the different motivations and interests of the groups or departments. Dismissing the resistance as bad or irrational will ignore the underlying conflicts it reflects. It is helpful to consider an alternative stance on conflict: Conflict is an opportunity to make progress on business outcomes and relationships and to strengthen the organization's capacity. Conflict is often less about personalities than about the system. In this frame, conflict can actually be seen as an entry point for productive and creative work on business issues. Can conflict be acknowledged in a nondestructive way? Yes, if you adopt a negotiation framework.

It is helpful to look at underlying forces that may be at work when we encounter resistance.

FORCES THAT UNDERLIE RESISTANCE

Edgar Schein[ii,iii] believes that there is an inherent paradox of learning: Anxiety inhibits learning, but anxiety is also necessary if learning is going to happen. He distinguishes between two types of anxiety: "learning anxiety" and "survival anxiety." Learning anxiety comes from being afraid to try something new for fear that it will be too difficult, that we will have to change old habits, or that we will look stupid attempting something new. Schein believes that you can't talk people out of their learning anxieties and that these anxieties are the basis for resistance to change. Survival anxiety, however, is the realization that in order to survive, we will have to change. Schein believes that it takes survival anxiety to push people to the point where they are willing to take the risk to change. He argues, "The basic principle is that learning only happens when survival anxiety is greater than learning anxiety."

You can increase survival anxiety by threatening people with loss of jobs or valued rewards. This is the basis for motivation behind top-down (i.e., mandated) change programs where everyone from the CEO on down needs to "get with the program" or risk the loss of his or her job. However, the use of survival anxiety as a motivator also has some drawbacks. If corporate change efforts come and go, this type of message can make workers cynical. In response to the next change program, they may sink into even deeper passivity.

As another approach, Schein argues that you can decrease learning anxiety by creating a safer environment for unlearning the old way and learning the new way. The creation of psychological safety, however, is very difficult when a company is downsizing or reorganizing. During these times, people are fearful about their future and their jobs.

Schein believes that real change does not begin until the organization's survival is threatened in some way. This threat creates high levels of survival anxiety and learning anxiety. The remedy, Schein suggests, is for the CEO and top executives to be willing to acknowledge their own vulnerabilities—first to share the risks they feel from the environment and the dangers they face. By acknowledging their own vulnerabilities and placing the imperative and the threat outside of the organization, the leadership can simultaneously create survival anxiety and a safer learning environment. This kind of survival anxiety is linked to forces outside the organization, to the "burning platform" rather than to a simple top-down mandate, which is the organizational equivalent to "because I say so." Survival anxiety can lead to what Schein calls "transformational learning," but only if the CEO and top executives are willing to acknowledge their own vulnerabilities first. Schein advises, "If leaders really want workers to learn new things, they have to educate them about economic realities in a way that makes their messages credible."

One of the barriers to creating effective communities of practice or other forms of web-based group interaction is that openly discussing problems, sharing half-baked ideas, or thinking aloud in public doesn't come naturally to most of us. As one community member said, "It's hard to talk about your problems in front of a lot of people you don't know."[iv]

In frustration, a senior executive at Raytheon complained, "Some people don't like to show an unfinished product. . . . It's like a personality defect. What would a psychologist call this? Some of these guys won't even contribute in a meeting because it will look like they don't have a well-formed thought—they want to wait until the end and then critique it."

It is particularly difficult for professionals (physicians, engineers, lawyers, etc.) to jump in and collaborate at the beginning of a thinking process, and it is easier to wait until someone else has formed a "straw man" product that they can critique.

Larry Hirschhorn, CFAR Principal and author of several works on organizational behavior,[v] believes that when people are afraid to look incompetent in front of others, the

[ii] Coutu, D. L. "The Anxiety of Learning" (Interview with Edgar Schein), *Harvard Business Review*. March 2002.

[iii] Schein, Edgar. "Three Cultures of Management: The Key to Organizational Learning," *Sloan Management Review*. Fall 1996.

[iv] McDermott, Richard. "Knowing in Community: 10 Critical Success Factors in Building Communities of Practice." Community Intelligence Labs (CoIL), 2000. http://www.co-i-l.com/coil/knowledge-garden/cop/knowing.shtml

[v] Hirschhorn, Larry. *Beyond Mechanization: Work and Technology in a Postindustrial Age*. MIT Press, 1984, 1986.

Hirschhorn, Larry. *Managing in the New Team Environment: Skills, Tools, and Methods.* Addison, Wesley, Reading, 1990.

Hirschhorn, Larry, and Carole K. Barnnett. *The Psychodynamics of Organizations*. Temple University Press, 1992.

Hirschhorn, Larry. *Reworking Authority: Leading and Following in the Post-Modern Organization.* MIT Press, 1997.

Hirschhorn, Larry, P. Noble, and T. Rankin. "Socio-Technical Systems in an Age of Mass Customization," *Journal of Technology and Engineers Management.* Vol. 18, 2001.

most basic emotion underlying their reluctance to contribute is shame. "Shame," he said, "is about deficits—the opposite of pride—when people fear their response is a reflection of their competence and self-worth, they feel inadequate, they will hold back."

The remedy, he suggests, is to make some collective acknowledgment of the difficulty of the task ("Hey, no wonder we're having difficulty doing this—it's hard") and fostering an environment of trust and feedback.

Richard McDermott goes a step further and orchestrates meetings so that senior members of the community who are well respected ask for help from the group. After several events like this over the first few meetings, it becomes easier for others to start asking for help openly.

The climate of evaluation can contribute to the problem. In a good authority system, you have both a system of evaluating performance and a system for containing the anxiety about evaluation. The boss communicates when you will be evaluated, and it is not every minute, every second. In a good system, there is a sense that evaluation will be fair. In a loose and disorganized authority system, people will be more anxious about evaluation. It may seem that it is coming from many different groups and in many different settings. This fearfulness about evaluation will in turn create barriers to collaborations, which involve taking risks.

Professionals often work in organizations that are, by their nature, more diffuse and loosely structured (e.g., physicians in a medical center or attorneys in a private practice law firm). These environments can create the kind of evaluation climate that makes people less willing to take risks for fear of appearing foolish in front of their peers.

Finally, there may be an identity piece that contributes to the anxiety about collaboration. Engineers, for example, are trained to be very precise in their knowledge and judgment. As one executive at Raytheon put it, "As an engineer I was trained to think four or five steps past anything I was willing to say out loud and nine or ten steps beyond anything I would commit to paper." The training to be so conscientious makes sense when you think about the potential consequences of failure. In this sense, engineers are trained like physicians, to rely on the power of their own judgment to make life or death decisions and to stand by their decisions once ventured.

PART 3:
CONCLUSIONS AND BEST PRACTICES

CHAPTER **8**

CONCLUSIONS AND BEST PRACTICES

THE BENEFITS OF WEB-BASED COLLABORATIVE SOFTWARE

All three cases experienced certain benefits from web-based collaborative software. All three were enthusiastic about these benefits even though the implementation is still new enough that the benefits are difficult to quantify. The software provided the following:

- **Enhanced productivity.** In Chicago, on the Douglas Blue Line Construction project, CTA senior technical personnel were able to process 260% as many RFIs per business day per person with the implementation of web-based collaborative software. At the PANYNJ, project managers were able to audit the expenses on their projects in a much more thorough and consistent way. At Raytheon, employees can work on a project 24/7 as it travels around the globe.
- **More accurate information to decision makers.** All three organizations reported that although decisions may be made by the same people in the hierarchy as before, the web-based tools created an opportunity for more people to see the information and to give input about it to decision makers. We can assume this leads to higher-quality decisions and fewer unpleasant surprises.
- **Enhanced speed for information exchange.** The CTA has been able to quantify that its RFIs are processed 20% faster with the web-based collaborative software. At the PANYNJ, RFIs have been processed 18% faster. These gains in speed translate to reduced delays in construction, which, in turn, translate into cost savings.
- **Role enhancement for project managers.** In Chicago, people appreciated the opportunity to have input into many new decisions. At the PANYNJ, easier access to cost information has begun to turn project managers into able financial managers.
- **Enhanced accountability throughout the system.** In a web-based system, everything is time and date stamped, and the whole system is transparent. Anyone looking in can see the status of an RFI or change order request and can see where the delays are. Initially, this transparency is what people are afraid of, but once the system is operating, they come around to appreciate the heightened accountability. This accountability is equally shared across workers, managers, and outside contractors.

THE BARRIERS TO IMPLEMENTATION

The three case study systems experienced different barriers to implementation of the web-based tools, including

- Reluctance to give up paper and wet signatures,
- Reluctance to locate data off-site,
- Difficulty in agreeing on a single process to be followed,
- Difficulty scanning documents and reading oversized documents that have been scanned on a regular-sized computer screen,
- Difficulty supporting a web-based system with users who are not part of your own organization (e.g., contractors and subcontractors in the field), and
- Reluctance to show work in progress to peers.

BEST PRACTICES

The following best practices were gleaned from the case studies:

- **Think carefully about what kind of implementation model will be successful for you.** Table 1 in the summary applies our nonlinear model to consider the differences between two kinds of implementation, “Mandated Change” and “Opportunity to Change.” If widespread change must happen quickly and you choose to take a Mandated Change approach, then you must have committed leadership at the top of the organization that is willing to force the terms of the change on others. You will also need adequate resources for excellent training and dedicated technical support. If you have the luxury of more time, you may be better off with the Opportunity to Change approach, which was exemplified by the PANYNJ and Raytheon. This approach encourages “pull” for the new ideas from within the organization. It, too, requires leadership, training, and technical support, but it relies on attraction rather than enforcement and can be highly successful at circumventing resistance.

- **Notice where there may be opportunities to introduce collaborative software in the midst of other systems initiatives.** For example, when the PANYNJ saw many departments taking up new technology and the new intranet, the PANYNJ seized the opportunity to introduce collaborative software.
- **Think of technical support people as change agents who can advance your agenda.** For example, in Chicago the KFA technical people would go to contractors' offices to set up their computer systems and troubleshoot. The presence and support of the KFA technical people served to strengthen the collaborative relationship between the CTA and its contractors. At the PANYNJ, the power users who were fully trained on P3e worked side by side to support the engineering department's 120 project managers. These technical power users became powerful change agents in the system.
- **Don't overcustomize the product.** All of our case study organizations argue in favor of using an off-the-shelf technology initially and then tailoring the system more after the initial adoption phase. There are trade-offs between speed and customization. All three organizations advise against engaging in a long, drawn out process of trying to get agreement on a customized product. Instead, they suggest using an off-the-shelf application to limit the input of users. Initial implementation of something that is "good enough" is preferable to a long process that may activate long-standing differences between groups.
- **Think creatively about process redesign.** Sometimes an urgent deadline will enable you to do "good enough" process redesign before the new technology is implemented. Or sometimes the experience of working with the new technology in a pilot location will highlight problems in the system that you can address with a process change.
- **Use pilot experiences and early forays.** These initial efforts will capture lessons learned about process redesign and about the technical challenges you will need to address. The PANYNJ's lesson fits here: "experience is more important than analysis." Pilots and early forays help you learn and improve the technical system and work processes, validate the benefits of taking up the new technology, and gain acceptance for the new technology.
- **Think carefully about your criteria for selecting a pilot site.** Select a site with people who can be flexible and open to change and who have credibility in the organization. The pilot experience must also have marketing value; therefore, you need to select a site where you are confident of success. Once the pilot is established successfully, these early adopters can help spread the word that the new technology is helpful. The pilot site participants will therefore also need to be good "sales representatives" for the new technology and communicate its benefits with enthusiasm to people who haven't tried it yet.
- **Focus your implementation efforts on the middle managers in the organization.** Both Raytheon and the PANYNJ believe that middle managers have the most power, the most work, and possibly the best perspective, linked as they are to the strategic view of the top executives and the operational wisdom of the workers. Middle management's acceptance and feedback are crucial to success.
- **Don't train every user on all aspects of the new technology; instead, differentiate the training by role.** CTA training represents a best practice; not only did the CTA differentiate the training by role, it also trained people on how to do their work with the new technology, rather than just training them on the software itself. The goal was to have every user using the tool in the same way. The PANYNJ used the same principle in a different way by thinking about what kinds of information workers with different roles would need to see in order to do their jobs. The PANYNJ gave workers with each role different levels of information and access accordingly. Information technology can fail because people are overwhelmed with data. By differentiating data for people and determining what people do and don't need to see or know, you can help them to turn all the data into information that is relevant for them.
- **Keep training simple for the majority of users.** In every site, we heard that initial training was kept as simple as possible. Raytheon exemplifies this approach by choosing a web product that requires no training at all and can be learned with simple experimentation. Training on Primavision for casual users at the PANYNJ takes 1 hour. At the CTA, the initial training is a little longer, but can be done online at a person's convenience with a training CD-ROM.
- **Plan to offer a refresher training course after 3–6 months.** Once people begin to actively use the new tool in their work, they will have a much better idea of what they need to know, and their questions will be more informed. If you retrain them at this point, they will become much more powerful users of the technology.
- **Don't underestimate the technical challenge that may arise with the scanning of documents.** This is often the weak link in the implementation of knowledge management systems and collaborative software systems. Either provide additional training around this feature, as the CTA did, or designate and train specialists to handle paper flow, as the PANYNJ did.
- **Align the evaluation, incentive, and compensation systems to support the adoption of new technology.** This is particularly important if you are moving quickly with a Mandated Change model. At Raytheon, although it was not explicitly stated that managers needed to take

the Raytheon Six Sigma training, the message was clear: get on board with this effort to advance in your career at Raytheon. In Chicago, the commitment to ProjectNet was clear for contractors—getting on the system was a requirement of working on the capital program.

- **Recognize the problems of microcosm and temporary groups.** When you create a group that cuts across different organizations or departments, you create a microcosm group for the purpose of doing a particular piece of work. In the case of a construction project, this temporary system may last for years and become quite stable. Organizations create these groups for many good reasons—they facilitate knowledge sharing, they can come together to accomplish a particular piece of work, and they can be more creative than the traditional divisions of the hierarchy. To be effective, these groups need to have clear purposes, clear authority for their work, clear deliverables that they are held accountable for producing within a clear time frame, a good base of face-to-face interaction before you ask the team to be effective online, and two to four face-to-face meetings each year to maintain the connection.
- **Make a long-term commitment to the technology to push through the initial resistance.** The collaborative tools are so good and generally easy to use that if you stick with them for a year or two, even the people who resist in the beginning will be won over as converts. It will take time, so in order to succeed you need a long-term commitment to bringing the technology into the organization and adequate resources to support it.

PART 4:
APPENDIXES

APPENDIX A
PROJECT MANAGEMENT MATURITY MODELS

Project management maturity models promote the idea that some organizations have more fully developed approaches to project management than others. This allows organizations to gauge themselves against a standard, diagnose their weaknesses, and plan their own development. Models developed by Harold Kerzner[i] and Kwak and Ibbs[ii] can gauge an organization's project management maturity level. The Berkeley Management Process Maturity (PM^2) Model by Kwak and Ibbs is similar to Kerzner's, but starts the organization from a point of general ignorance of project management, whereas Kerzner starts the organization from a point with a basic knowledge.

KERZNER'S FIVE LEVELS

Kerzner designates five levels of project management maturity:

1. **Common language.** At the initial level, the organization begins to recognize the importance of project management. It has basic knowledge project management. Assessing whether you've reached this level involves evaluating the degree to which the organization understands the fundamental concepts.
2. **Common processes.** At this level, the organization attempts to use project management by developing appropriate processes and methodologies. It realizes that if processes of one project can be replicated to another, the entire program can be managed more easily. As these processes are implemented, the organization also begins to realize the need to understand behavioral changes and expectations. Assessing whether you've reached this level involves evaluating the effectiveness of the common processes.
3. **Singular methodology.** At this level, the organization recognizes the value of a singular methodology over multiple ones to achieve project control and synergy. The organization is committed to the development of this methodology. Assessing whether you've reached this level involves evaluating the adoption of a singular methodology and the level of commitment.
4. **Benchmarking.** At this level, the organization has proven its commitment to project management. To understand how best to use these tools, it uses benchmarking to compare its practices with recognized leaders. This analysis helps to determine how integrated the key success factors are. Assessing whether you've reached this level involves evaluating how structured this benchmarking effort is.
5. **Continuous improvement.** At this level, the organization recognizes the need for continuous evaluation and analysis and implements any necessary changes from the benchmarking efforts. Assessing whether you've reached this level involves evaluating the extent to which your organization implements change.

BERKELEY MANAGEMENT PROCESS MATURITY MODEL

The Berkeley model also designates five levels of project management maturity:

1. **Ad-hoc.** At this level, project management procedures are very basic. There are no formal processes or guidelines. Project management either is not used or is used inconsistently. The organization is isolated by projects, which are dependent on individuals for success.
2. **Planned.** At this level, projects are planned and executed by individuals, though management processes are partially controlled by managers. Still, project management procedures are informal and incomplete. The organization is more team oriented, but is still inefficient because it does not attempt to control projects beyond the individual.
3. **Managed.** At this level, project management tools are partially formal. There is some data collection for trend analysis and management. The organization is team oriented and works to integrate cross-functional teams for more structured planning and control.
4. **Integrated.** At this level, project management procedures are formal and information is documented and quantitatively measured. The organization has strong teams that can conduct multiple-project planning and control. Integrated project management tools are fully implemented.
5. **Sustained.** At this level, the organization is fully committed to project management processes and works to continuously improve the system. Data are collected for this purpose, and innovative ideas are pursued. The organization has dynamic and fluid project teams.

[i] International Institute for Learning, Inc. "Kerzner's Five Levels of Project Management Maturity." http://www.iil.com/project_management_training/kerzner_five_levels.asp

[ii] Kwak, Y. H., and C. W. Ibbs. "Project Management Process Maturity $(PM)^2$ Model (Berkeley PM Maturity Model)." Department of Civil Engineering, University of California at Berkeley. www.ce.berkeley.edu/~ibbs/yhkwak/pmmaturity.html.

APPENDIX B
RETURN ON TECHNOLOGY

"Even though non-financial benefits do not have standard metrics, they are important because of IT's potential to impact business performance and the organization's mission."[i]

DEFINITION OF RETURN ON INVESTMENT

Return on investment (ROI) is a measurement of the net income an organization is able to earn with its total assets.[ii] It is

$$\frac{\text{Net profits after taxes}}{\text{Total assets}}$$

For the construction industry, the calculation of ROI must take into account the rate of return for each year of the duration of the project. Typically, "the ROI is different from year to year, with a very low value at the early years and a high value in the later years of the project."[iii]

ROI AND IT

Part of the reason for the failure of integrating information technology (IT) solutions is that appropriate value is not placed on cost-efficiencies.[iv]

What are you getting in return for what you are spending? Traditional benefits are financially driven, i.e., cost reduction and revenue increases. With IT projects, however, many of the benefits are nonfinancial. These include shorter cycle times and increased and accurate information.[v]

A number of software packages are available to help calculate ROI for the IT industry, such as InterWorld and ROInow.

Understanding the benefits requires more than calculating immediate costs and benefits, but should also take into account the entire life cycle of the project and beyond.

OTHER MEASUREMENTS

In addition to ROI, there are other methods for measuring net income:

- Net present value: project value and cost added to expected future value.
- Internal rate of return: the return a company would get if it expanded or invested in itself.
- Payback analysis: the time it will take to recoup an investment.

Net present value allows the owner to plan over a longer period of time. "The net present value (NPV) of the estimated cash flows over the planning horizon is the discounted value of the net future value (NFV) to the present. A positive NPV for a project indicates the present value of the net gain corresponding to the project cash flows."[vi]

Internal rate of return (IRR) "gives the return of an investment *when the capital is in use* as if the investment consists of a single outlay at the beginning and generates a stream of net benefits afterwards. However, the IRR does not take into consideration the reinvestment opportunities related to the timing and intensity of the outlays and returns at the intermediate points over the planning horizon."[vii]

Payback period "refers to the length of time within which the benefits received from an investment can repay the costs incurred during the time in question while ignoring the remaining time periods in the planning horizon."[viii] This can be used as a secondary measure.

TRANSIT AND ROI

Construction projects in the transit industry are inherently long-term investments, so costs and benefits cannot simply have the short-term picture in mind.

There are typically three approaches to facility investment planning:

1. Need or demand driven,
2. Design driven, and
3. Finance driven.

Another issue to consider for the transit industry is whether the facility is publicly or privately owned. Private ownership typically requires a higher rate of return than public ownership. Further, private ownership generally looks at returns as monetary revenues. On the other hand, "public agencies often

[i] Resource Management Systems, Inc. www.rms.net
[ii] Ibid.
[iii] Hendrickson, C., and T. Au. "Project Management for Construction: Fundamental Concepts for Owners, Engineers, Architects and Builders." http://www.ce.cmu.edu/pmbook/. Accessed October 2003.
[iv] Sunil, S. "Construction e-Project Management." http://www.projectmanagement.com/pm/article.cfm?ID=127864.
[v] Resource Management Systems, Inc. www.rms.net
[vi] Hendrickson, C., and T. Au. "Project Management for Construction: Fundamental Concepts for Owners, Engineers, Architects and Builders." http://www.ce.cmu.edu/pmbook/. Accessed October 2003.
[vii] Ibid.
[viii] Ibid.

consider *total* social benefits in evaluating projects. Total social benefits include monetary user payments plus user's surplus, external benefits, and non-quantifiable factors. Generally, total social benefits will exceed monetary revenues."[ix]

FINANCIAL ROI

Ibbs and Reginato point out that in project management, the use of financial and nonfinancial metrics that matter most to individual companies "typically deteriorate into mass exercises in measuring for the sake of measuring."[x] As a ratio rather than an absolute number, ROI can help to clarify the "fuzzier" areas.

NONFINANCIAL ROI

The "60% solution" concept suggests that most organizations only recoup 60% of potential value. Merkhofer argues that having a value model helps to understand the organization's decision on project choices. Such a model can help decrease value losses that occur mostly because of errors in decision making and weaknesses in business systems.[xi] This model should be a top-down approach and offer the ways that the project creates value and helps to make intelligent decisions. It can also help to estimate day-to-day value in cost, time, and product.

Particularly in the public sector, "financial metrics, quite simply, don't capture all of the organization's true objectives."[xii] Rather than looking at traditional shareholder value, examining stakeholder value may be more appropriate. In the transportation/construction industry, value to the employees, suppliers, customers, and community are all important. Though metrics do not have to be financial metrics, they should be observable—"that is, characteristics of projects or project outcomes that can be observed and measured in the real world."[xiii]

[ix] Ibid.

[x] Ibbs, W., and J. Reginato. *Quantifying the Value of Project Management*. Project Management Institute, 2002, p. 12.

[xi] Merkhofer, L. "Choosing the Wrong Portfolio of Projects: And What Your Organization Can Do About It—Introduction." Project Management Wisdom. www.maxwideman.com/guests/portfolio/intro.htm

[xii] Merkhofer, L. "Choosing the Wrong Portfolio of Projects: And What Your Organization Can Do About It—Reason 3." Project Management Wisdom. http://www.maxwideman.com/guests/portfolio/reason3.htm

[xiii] Merkhofer, L. "Choosing the Wrong Portfolio of Projects: And What Your Organization Can Do About It—Metrics as 'Observables' and the Clairvoyant Test." Project Management Wisdom. http://www.maxwideman.com/guests/portfolio/observables.htm

APPENDIX C

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* The Transportation Research Board of the National Academies, the National Research Council, the Transit Development Corporation, and the Federal Transit Administration (sponsor of the Transit Cooperative Research Program) do not endorse products or manufacturers. Trade or manufacturers' names appear herein solely because they are considered essential to the clarity and completeness of the project reporting.

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Abbreviations used without definitions in TRB publications:

AASHO	American Association of State Highway Officials
AASHTO	American Association of State Highway and Transportation Officials
APTA	American Public Transportation Association
ASCE	American Society of Civil Engineers
ASME	American Society of Mechanical Engineers
ASTM	American Society for Testing and Materials
ATA	American Trucking Associations
CTAA	Community Transportation Association of America
CTBSSP	Commercial Truck and Bus Safety Synthesis Program
DHS	Department of Homeland Security
FAA	Federal Aviation Administration
FHWA	Federal Highway Administration
FMCSA	Federal Motor Carrier Safety Administration
FRA	Federal Railroad Administration
FTA	Federal Transit Administration
IEEE	Institute of Electrical and Electronics Engineers
ITE	Institute of Transportation Engineers
NCHRP	National Cooperative Highway Research Program
NCTRP	National Cooperative Transit Research and Development Program
NHTSA	National Highway Traffic Safety Administration
NTSB	National Transportation Safety Board
SAE	Society of Automotive Engineers
TCRP	Transit Cooperative Research Program
TRB	Transportation Research Board
TSA	Transportation Security Administration
U.S.DOT	United States Department of Transportation