ONLINE COLLABORATION AND PROJECT MANAGEMENT TECHNOLOGY: ITS VALUE AND IMPLEMENTATION PRACTICES

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Abstract

This paper summarizes the findings of a comprehensive research study undertaken at Harvard Design School by doctoral student Burcin Becerik and project investigator Professor Spiro Pollalis (the research team) in collaboration with five technology providers (the Sponsors) and their clients. The study seeks to validate and support statements that online collaboration and project management (OCPM) technology will positively contribute to the return on investment of architecture, engineering, and construction (AEC) industry stakeholders and their projects. The paper starts with a discussion of the need, challenges, and goals of this study and continues with an explanation of the best-suited evaluation method and data collection methods, which include nine comprehensive case studies, a survey, over one hundred interviews, and an aggregated data analysis. *Hard benefits* (tangible benefits) are a part of the research; however, a special focus is given to identification and measurement of *soft benefits* (quasi-tangible and intangible benefits), which are difficult to quantify and often hidden but whose value to the investors is enormous. The paper also examines the *industry practices* in implementation and use of OCPM technology and covers a wide range of *best practice* implementations by different industries for the construction processes. The research intends to capture different perspectives including those of *private and public owners, contractors,* and *consultants*. In addition, the paper explores the impact of these tools on the business processes and looks for evidence of increased and new values such as increased competitive advantage, improved market access, better customer relations, etc. The paper covers the project-level benefits as well as the benefits external to the project but internal to the organization(s). The benefits are documented and then measured utilizing both quantitative and qualitative methods and are summarized in the context of this research paper.[1]

1. INTRODUCTION

The architecture, engineering, and construction (AEC) industry operates in a project environment, where a collective achievement by a diverse team of participants is required. These team members represent different disciplines with diverse educational backgrounds and *even* with different goals. Successful completion of a construction project depends on accurate, effective, and timely communication, formation, and then exchange of critical information among these project team members. To make this happen, elements of the AEC industry have started to move away from traditional communication methods, which are typically time- and labor-intensive resulting in higher costs and inefficiencies, and have started to rely heavily on online collaboration and project management (OCPM) technology.[2]

Despite the benefits and the increase in use of OCPM technology, there is still a resistance from industry participants to adopting this technology in its *full capacity* and changing how work has traditionally been done (Björk, 2003). One of the primary motivators for the actors in the AEC industry to adopt new technology would be the opportunity for direct gains and benefits in their own operations. In order for the actors to realize these benefits, there must be a framework in place to measure the relevant costs and benefits associated with the OCPM technology investment. The problem of identifying and quantifying relevant information technology (IT) investment costs and benefits is neither new nor unique to the AEC industry. In fact, it is a global problem experienced in all types of business sectors and organizations (Hochstrasser and Griffiths, 1991), as many of the IT investment benefits fall into the soft (intangible) category and therefore lack the weight of clear revenue improvements. IT evaluation in construction is a particularly difficult, complex, and time-consuming process (Andresen et al., 2000), and the

[1] Please note that no gender bias is intended in this paper and that "he" is used everywhere in this paper only for simplicity.

[2] OCPM technology refers to any of various web-based (in which information generated by project team members is automatically saved to the OCPM solution on the web) and web-enabled (in which the Internet is used to connect directly to remote applications and self-hosted client databases) technologies that offer communication platforms, project management functionalities, and hosted collaboration spaces for capital construction projects.

problems associated with assessing its benefits and costs seem to be more acute than in any other industry (Marsh and Flanagan, 2000). The reasons for this are the industry's peculiar size and structure, its fragmented supply chain and undercapitalization.

Although there have been some initial efforts to calculate the value of OCPM technology, there are no valid results available today to spur industry stakeholders toward faster adoption. The metrics to measure the rather complex causal chain causing overall cost savings and quality improvements have only been sketched and reliable measurements with large enough data sets to isolate the effects of the learning curve or external factors are missing. In an attempt to bridge the need for an objective and comprehensive *OCPM technology value measurement*, Harvard Design School conducted research in collaboration with five OCPM technology providers (the Sponsors). The research team worked with the participating Sponsors and their selected customers *(1)* to understand the OCPM technology needs, implementation, and use and *(2)* to identify and measure the value proposition of both web-based (vendor-hosted) and web-enabled (self-hosted) solutions for construction project management, project delivery, and team collaboration as they are applied today. This paper summarizes the finding in three steps: by looking at industry practices in OCPM technology implementation and use; by identifying soft and hard (tangible, intangible, and quasi-tangible) benefits of this technology; and by evaluating the value of the OCPM technology in its real-life context.

2. STUDY OVERVIEW

The study conducted by the Harvard research team is based on actual project data analyses. The information is provided by the participating Sponsors (in aggregated data format), the investors[3]/users of the technology (in case study format), as well as other users and non-users of OCPM solutions. The information is used to measure and validate the value of OCPM technology. The data collection ran from November 2004 through August 2005. Sponsors of this study are (in alphabetical order): *Business Collaborator*[4] (UK), *Constructware*[5] (USA), *eBuild.ca*[6] (Canada), *Meridian Systems*[7] (USA), and *Primavera*[8] (USA). Besides providing information, the Sponsors were asked to provide feedback and to participate in discussions and interim meetings. The study takes hard benefits into consideration and also focuses on the future and long-term advantages of OCPM technology and looks at OCPM technology investment's impacts on organizational culture and work conditions (Van Grembergen, 2001). In other words, the characteristics of OCPM technology investments across the boundaries of individual organizations are also discussed and reflected in the study.

2.1.The Need

Leading-edge companies all over the world in all industries have increased their overall IT expenditures by double-figure percentages annually (Zee, 2002). Despite large investments in IT over many years, it has been difficult to determine where the IT benefits have actually occurred (Willcocks and Lester, 1999), if indeed there have been any. The lack of IT evaluation studies

[3] "Investor" in this paper is referred as "buyer" of OCPM technology.
[4] www.groupbc.com/
[5] www.constructware.com/
[6] www.ebuild.ca/
[7] www.mps.com/
[8] www.primavera.com/

reduces the motivation to innovate and translates into unfortunately missed IT business opportunities. The problem in construction businesses is that IT has often been implemented as an act of faith, without fully understanding how business values from investment can be shown (Baldwin et al., 1998). Investors feel sure that there must be benefits from keeping abreast of technological innovation but have neither been able to predict what these benefits will be nor been able to measure them after the investment has been made.

The lack of frameworks to measure the value of OCPM technology (Brynjolfsson, 1993)or inappropriate measures to determine the value of these tools (Keen, 1991) and resulting skepticism have caused strong resistance from industry participants to adopting OCPM technology in its full capacity. Although this issue has attracted much attention in both academic literature and the private consulting industry, little is known about what types of analysis are performed on technology investments in the construction industry, and there is no single study specifically focused on OCPM technology. The research reported here attempts to meet the need for an objective and comprehensive study of the return on investment in OCPM technology for AEC industry stakeholders.

2.2.The Challenges

In most cases construction organizations cannot afford *not* to invest in OCPM technology for competitive reasons, but economically they cannot find sufficient justification and evaluation to underpin the investment (Van Grembergen, 2002). The difficulties in measuring benefits and costs are often the cause for uncertainty about expected investments and therefore are major constrains on the investments (Van Grembergen, 2001). Several interesting problems interfere with the value proposition study. One of them is the time lag involved. OCPM benefits are usually derived long after the cost of the project incurred, and organizations need to go through a learning curve, so the benefits are sometimes not immediately obvious. Another problem is intangible benefits: these seem important but are not amenable to strict cash analysis and therefore lack the weight of clear revenue improvements. In addition, as the OCPM technology infrastructure becomes an inextricable part of the organizations' processes and structures, it becomes increasingly difficult to separate out its impact from those of other assets and activities. Moreover, there is a serious lack of collected and structured data. Similarly to other types of IT investments, it is extremely difficult to acquire data with regard to OCPM benefits and costs. Therefore, evaluation models conducted and marketed usually consist of various assumptions.

2.3.The Goal

The goals of this study are:

- To explore how OCPM technology investments have been valuable for the stakeholders of the AEC industry;

- To set examples of OCPM technology implementation (and use) best practices on the technical, organizational, strategic, innovations and alternatives levels;

- To provide senior management with a framework to measure potential benefits of OCPM technology, provide good stewardship of resources, and develop improvement strategies;

- To help bridge the communication gap between business executives and suppliers of OCPM technology by replacing opinions by facts;

- To enable an organization to compare the merits of a number of different investment projects competing for limited resources;

- To provide a set of measures which enable the organization to exert control over the investment (Farbey et al., 1999);

- To serve as a learning device to improve their systems, implementations, and capability by looking at several OCPM technology implementations.

By having a better understanding of OCPM technology's capabilities and functionalities, organizations can support their business objectives and provide for future business expansions. The research seeks to set examples for organizations to gain competitive advantage, to develop new business, to improve productivity and performance, as well as to provide new ways of managing and organizing (Earl, 1988) their projects and business processes.

3. METHODOLOGY

3.1. Evaluation Methodology

There is no industry standard for the definition of *investment value* in the IT area. Andresen's literature search identifies as many as 82 methods and there are, without doubt, many more as new methods are being developed continuously (Andresen, 2002). In his research, he categorizes these methods in three areas: financial methods, qualitative methods, and quantitative methods.

The early financial investment appraisal methods are primarily based on financial measures such as return on investment (ROI), discounted cash flow, internal rate of return (IRR), net present value (NPV), profitability index, cost benefits, payback period, and present worth. These methods, however, are found to be inadequate when used to evaluate IT investments because of their use of only one measure: the monetary value. They largely exclude the significant problem of risk, as well as costs and benefits that may be difficult to quantify (Brown, 1994). Those benefits which are intangible (soft) appear to be written off as unquantifiable and thus beyond any effective measurement technique. As a result, more complex methods have emerged, designed for evaluation of IT investments. Some of these are information economics[9] (IE) (Parker and Benson, 1988), return on management[10] (ROM) (Strassmann, 1990), and scalable systems software measurement and evaluation[11] (SESAME) (Willcocks, 1992). These complex methods are, however, rarely used in the AEC industry for a number of reasons: because of lack of awareness of the methods; because of the methods' large operation requirements; and because some critical problems are still not solved with these methods.

[9] IE seeks to identify and measure or rank the economic impact of the changes brought about by the introduction of the new system on an organization's performance.

[10] This metrics measures how technology is benefiting management decisions. ROM assumes that managers are the processors of all of a company's inputs and ultimately account for returns instead of capital investments or technology.

[11] The goal of SESAME has been to create a set of tools to study the performance of operating systems. IBM developed this method in order to provide a more flexible approach to cost/benefit analysis. Here the costs and benefits of an IT-based system are compared against an equivalent manual system. This method bases much of the assessment on user opinion, which may involve users more in the process of assessment.

In order to consider both quantitative and qualitative benefits, this study uses concepts from two evaluation methods: *measuring the benefits of IT innovation*[12] (Baldwin et al., 1998) and *information economics* (Parker et al., 1989). The goal is to demonstrate financial and non-financial impacts together to determine the (business) value of OCPM technology.

3.1.1. Benefit Analysis

Value is based on advantage achieved over the competition, and it is reflected in current and future business performance, which management should be willing to invest in (Parker et al., 1989). In other words, value is a function of keeping up with the competition and a major source of pressure justifying investment in IT. *Innovation* is often viewed as something undertaken by very few within the construction industry (Baldwin et al., 1998). Innovation creates new functions within the business domain. It changes the way the enterprise conducts its business. Innovative IT applications provide a vehicle to change business strategy, products, and services. *Cost* is defined as a measure of the amount of resources required to obtain a product or service (here, OCPM technology). *Benefits* take the forms of cost savings, cost avoidance, generation of new revenues, and intangibles. Three types of benefits are identified and have been used as the framework for this study. These are:

(1) Tangible benefits, the rate at which inputs are converted to outputs. These are quantifiable and measurable in monetary terms.

(2) Quasi-tangible benefits, the rate of actual outputs compared to planned. The focus is most often on improving the efficiency of an existing organization and processes that are quantifiable but difficult to measure. They are the ability of a program, project, or work task to produce a specific desired effect or result that can be measured. The quasi-tangible benefit group has some measurable elements, but not in monetary terms. Some examples of quasi-tangible benefits are: improved resource control, improved information availability, enhanced decision making, etc.

(3) Intangible benefits, the level of new outputs enabled. The focus is most often on improving the effectiveness and performance of the organization. Intangible benefits are neither quantifiable nor easy to measure but are the most important benefits for the investor in the longer term. Intangible benefits are the reasons for doing things that measurable benefits can't justify. Intangible benefits include: better risk management, gained market access, improved competitive advantage, etc.

Performing the right tasks correctly, staying consistent with the organization's mission, vision, and values, and supporting its goals and objectives – as well as providing an ability to measure all this – could be among investors' most important goals in deciding to implement an OCPM technology. The nature of modern business is such that, increasingly, senior managers are required to think beyond the direct tactical issues of tangible and quasi-tangible benefits, toward more strategic issues. Business performance, in its broadest terms, is a major strategic issue and one that OCPM technology has much to contribute to. A major argument of this study is that OCPM technology's benefits in construction extend beyond the tactical into strategic business performance improvement.

[12] The method considers three ways in which IT can improve investors' business: efficiency ("doing things right"), effectiveness ("doing the right thing"), and performance ("doing better things").

When considering the implementation of a new OCPM system, it is essential to understand whether the investors seek tangible, quasi-tangible, or intangible benefits, or a particular combination of these. In some cases, the focus is on *organizational-level benefits* rather than *individual project-level benefits*. In order to assess the value of OCPM technology, it is essential to identify and investigate real-life implementations. In order to do so, the research team worked closely with the OCPM technology providers, users, and investors, and identified potential benefits and values of OCPM technology as shown in Figure 1.

3.1.2. Cost Analysis

Cost is a measure of the resources required to obtain a product. The costs associated with IT are often perceived to be easier to estimate than the benefits, though Hogbin argues that this is rarely the case (Hogbin and Thomas, 1994). Identifying the costs related to an OCPM technology investment is challenging *first* because this is a sensitive issue for both the investors and the vendors. During data collection, some of the investors mentioned their desire not to publicly disclose the exact cost of their OCPM system: the costs associated are considered to be commercially sensitive due to some political and organizational factors. *Second*, there is no established structure for OCPM solution costs or cost structures. *Third*, a growing portion of the expenditures is invisible and therefore not (actively) managed by management.

Therefore, in this study the term "cost" is limited to the fees for licenses, ongoing maintenance (yearly service contract) fees, operating costs in terms of fees, implementation (installation and configuration), training, development, and customization (reengineering of business process to suit the solution, etc.) fees. Hardware costs, software costs (relational database software, additional networking software, etc.), overhead (electricity, toner cartridges, disks, etc.), staff and management resource costs (administration, marketing, procurement, dedication, employee training, etc.), indirect organizational costs (productivity losses during adapting to the system, procedures, guidelines, covert resistance to change, redesign of organizational functions, processes, and reporting structures, etc.) (Love and Irani, 2001) are not included in the study. Due to the sensitivity of the matter, some costs are given as a ratio to the overall project or program cost.

3.2. Data Collection

Four types of data collection methods were followed by the research team: case studies, a survey, interviews, and aggregated data analysis, each to some degree interlinked with the others. To define the linkage between the technology and business performance, some understanding is needed of the business itself, and of its structure, objectives, and interactions with customers, suppliers, and the rest of the economic environment (Parker and Benson, 1988). Therefore, the research team started with identification of the business cases in collaboration with the Sponsors. Potential benefits were identified and weighed. The assessment technique was selected according to the investor's focus on intangible, quasi-tangible, or tangible benefits or a combination of these. Realized benefits were documented by following the right methodology as discussed in the following subsections. Finally, the benefits/values were evaluated in close consideration of the initial goal of the investor as well as their impact on the business goals and performance.

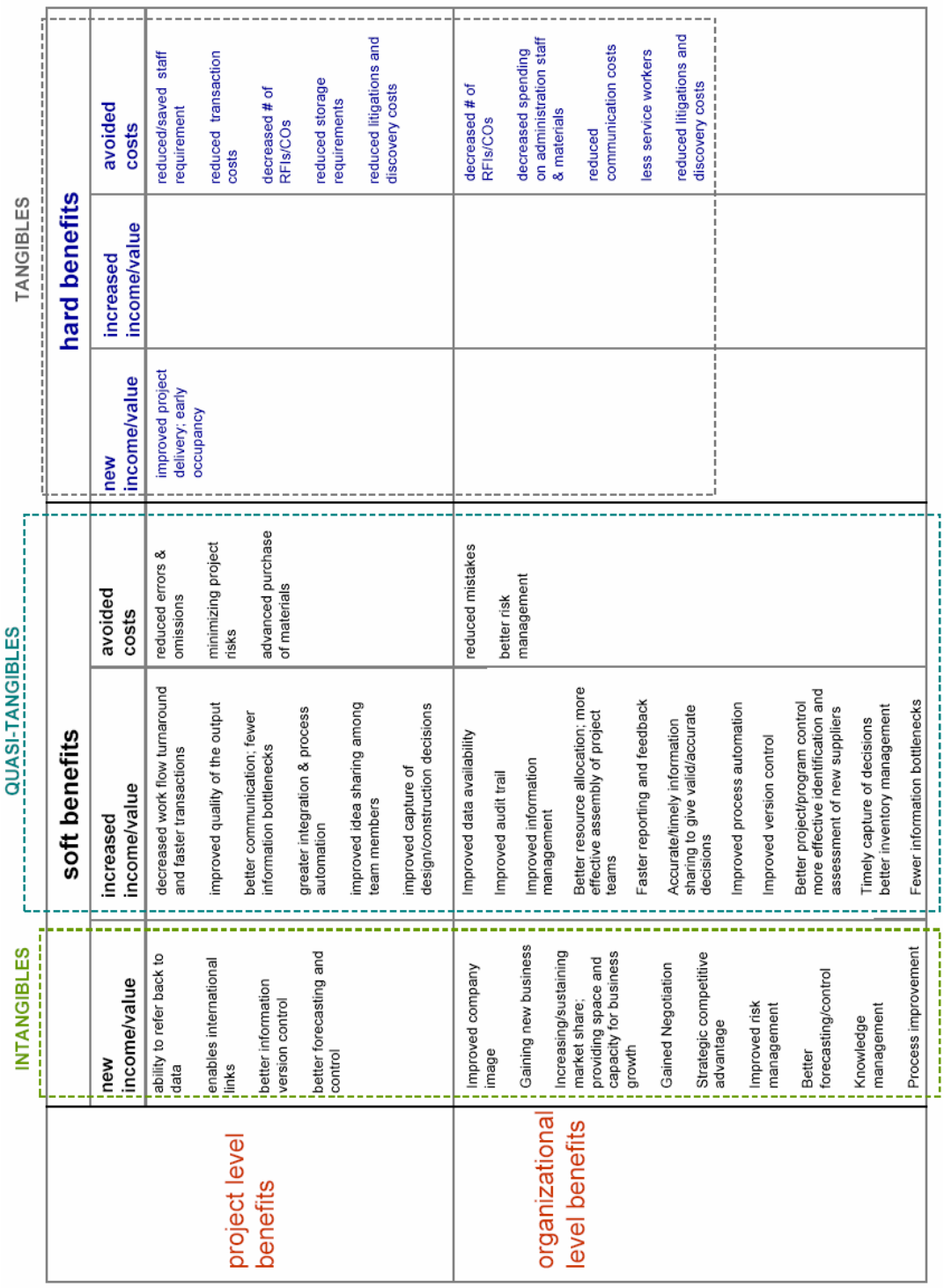


Figure 1. Tangible, quasi-tangible, and intangible benefits at the project and organizational levels

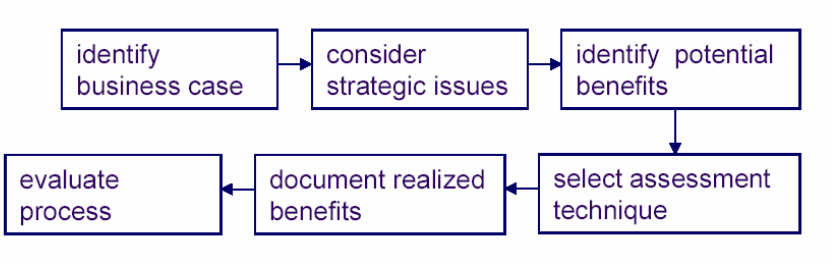


Figure 2. Research steps (modified after Andresen et al., 2000)

3.2.1. Case Studies

A highly appropriate method for satisfying the objective of the study is the *case study* method. The research team worked with the Sponsors to identify OCPM technology users and investors. As a result, a total of nine case studies were prepared as the basis of the study. While these organizations cover a range of industries (pharmaceutical, financial, construction, education, and manufacturing) and organizational structures, they still represent a reasonably homogeneous group in relation to the scale and complexity of their OCPM technology infrastructures and provide a rich source of data for development of the "best practice" sought. The names, locations, and business focuses of these firms are:

- Construction:
  - Kitchell Contractors, USA – *general contractor/construction manager*
  - Manhattan Construction Company, USA – *general contractor/construction manager*
  - P.J. Dick Incorporated, USA – *general contractor/construction manager*
- Financial:
  - Nationwide Building Society, UK – *public owner*
  - ITG Group*, UK – *private owner*
- Pharmaceutical:
  - TRM Healthcare*, USA – *private owner*
- Educational:
  - Indianapolis Public Schools, USA – *public owner*
  - Los Angeles Unified School District, USA – *public owner*
- Furniture manufacturing:
  - Inscape Corporation, Canada – *supplier*

Semi-structured face-to-face and phone interviews with senior company personnel including business and IT managers as well as the users of the OCPM technology (project managers and collaborators of the selected projects; engineers, architects, suppliers, etc.) were conducted in order to obtain different points of view. In addition, access to selected projects' OCPM solutions was granted to observe, review, investigate, and record issues in more detail. Other documentation acquired in various case studies includes items such as agendas, minutes, administrative reports, budgets, project statistics, and files.

* At the request of the investor, names of these organizations, their projects and participants were changed for confidentiality reasons.

Using these data collection methods, it has been possible to focus on the crucial issues of the research. It also helped to evaluate and compare data from the survey as well as from each interviewee, to clarify doubts, to ensure that the responses have been properly understood by repeating or rephrasing the questions, and to pick up nonverbal cues from the respondents (Sekaran, 2003). An overall structure to the interviews was given by a number of specific questions set up by the researcher before the interviews. Within this broad structure the interviewees were encouraged to talk about issues that seemed important to them (Burns, 2000). The main goal was to develop a framework based on the fit between theory and practice in the evaluation of OCPM investment in AEC projects. The complete interview protocol and specific questions include the purpose of the study, the issues that need to be further clarified and interpreted from the results of the questionnaire, the propositions being investigated, the operational procedures for getting data, the sources of information, and the questions and lines of questioning.

3.2.2. Survey

An electronic survey was designed and emailed to all interviewees to measure quasi-tangible benefits of OCPM investments. Each respondent received an identical list of possible benefits, phrased in exactly the same way, which they were asked to rank for their relevance to their own project. Errors resulting from the recording of responses by interviewers were thus reduced, and respondents were given the freedom to rank these benefits at their own pace. To get more truthful responses, it was guaranteed that the answers would be kept confidential. Personal appearance, mood, or conduct of the interviewer were not factors in completing the questionnaire. The survey covered several benefits that were brought into the conversation during the interviews. The aim of the survey was to uncover as much information as possible and to measure quasi-tangible benefits of OCPM technology investments. The responders were asked to rank the benefits on a scale of 1 to 5, where 5 is “very high,” 4 is “high,” 3 is “neutral,” 2 is “low,” and 1 is “very low.” The results from the questionnaire were also compared to the results from the case studies. The benefits that project team members were asked to rank were:

- Improved process automation (RFIs/change orders, automatic updating of master budget, etc.)
- Provided accurate and timely information to give valid/accurate decisions
- Enabled fewer information bottlenecks
- Improved information management
- Improved data availability
- Enhanced working within virtual teams
- Improved timely capture of design/construction decisions
- Enabled faster reporting and feedback
- Reduced personnel costs due to improved efficiency
- Enabled having complete audit trail
- Improved idea sharing among team members/within organization
- Improved project relationships with strategic partners
- Enabled better project/program control
- Enabled better resource allocation; more effective assembly of project teams
- Enabled better forecasting and control
- Improved quality of the output

- Minimized project/business risks
- Enabled advance purchase of materials
- Reduced delivery lead times
- Reduced errors and omissions
- Enabled better inventory management
- Enabled more effective identification and assessment of new suppliers
- Enabled faster launch to market due to faster delivery
- Improved public relations
- Enabled quicker response to project status and budget
- Improved information version control
- Reduced rework/data reentry

3.2.3. Interviews

Besides the interviews for the case studies, a number of interviews were conducted with industry experts and with OCPM technology users and non-users who didn't or couldn't participate in the case studies for confidentiality reasons or due to insufficient resources. A total of 102 interviews (including case study interviews) were undertaken with 82 industry stakeholders from December 2004 through July 2005. These interviews were undertaken in order to obtain opinions of investors and users from different industries and/or those who were utilizing or not utilizing OCPM technologies. The research team made observations and then compared the results gathered with the case study and survey results.

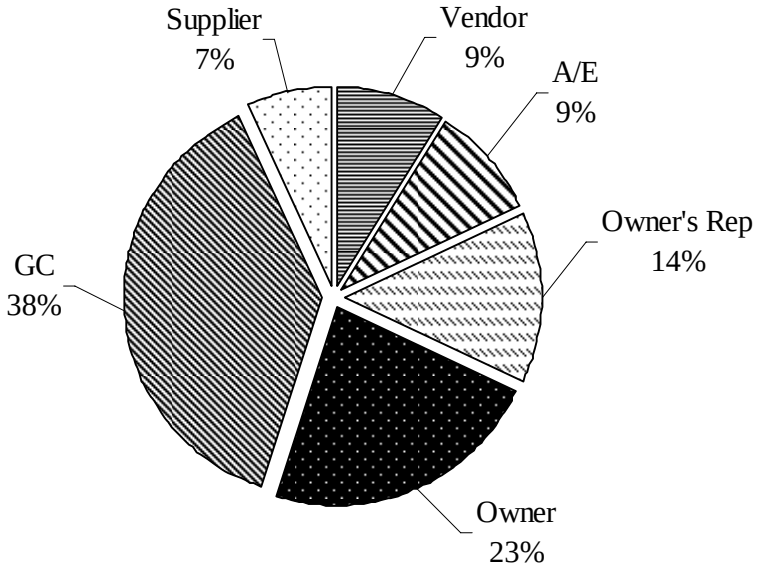


Figure 3. Backgrounds of the interviewees

3.2.4. Aggregated Data

Sponsors were asked to provide aggregated data from their databases. For each category of data, the team was able to analyze between 5,000 and 47,000 projects submitted by the Sponsors. The information asked was:

- Project type (retail, office building, industrial, educational, etc.)
- Project value (0-$1M, $1M-$10M, $10M-$50M, etc.)

- Project status (planning, design, bidding, permitting/approval, construction, close out, etc.)
- Number of clients, by type (subcontractors, consultants, general contractors, owners, CMs, etc.)
- Duration of use of OCPM solution (0-0.5 years, 0.5-1 years, 1-1.5 years, etc.)
- Type and percentage of entries in the OCPM tool (submittals, transmittals, drawings and specifications, documents, daily reports, correspondence, RFIs, submittals, meeting minutes, change order requests, etc.)
- Percentage of active users (define active as more than 10 logins per month)

4. INDUSTRY PRACTICES

4.1.Buyers and Users of OCPM Technology

The research shows that the major investors in OCPM technology are *large and mid-size general contractors,* and *long-term owners* whose core businesses are not construction but who need to keep and maintain buildings, such as banks, pharmaceutical companies, schools, and automobile manufacturers. Based on 46,500 projects, 67% of OCPM investors are owners, general contractors, or construction managers (Figure 4). Additionally, it is not a coincidence that investors in 5 out of 9 case studies are public and private owners, and in 3 out of 9 are general contractors and construction managers. The reason for this is the direct benefits these parties realize more than the other stakeholders. It is obvious that long-term owners are interested in having their buildings on time, on budget, with the highest possible quality. For some businesses such as manufacturing (e.g. pharmaceutical) and financial institutions (e.g. bank braches), it is crucial and very favorable to reduce project schedules, as each business day means additional revenue for these organizations. In addition, these investors consider details such the use of information created in design and construction phases in maintenance and operation phases.

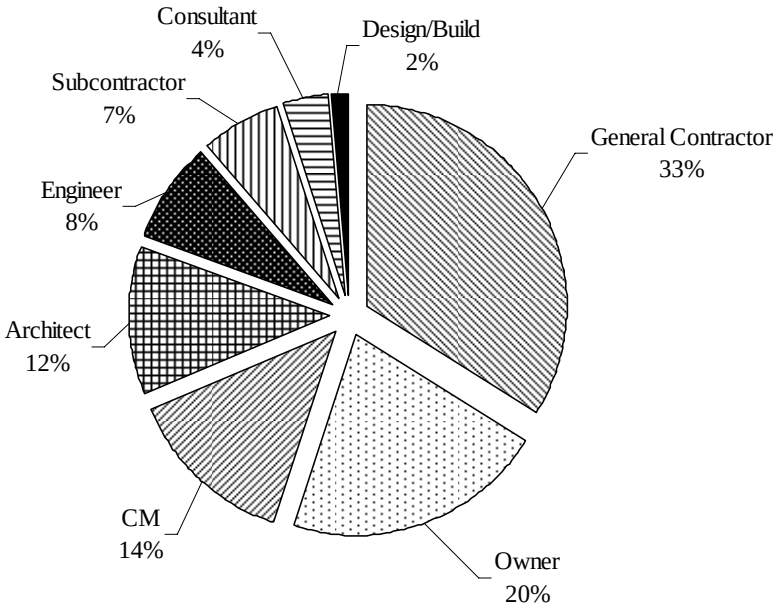


Figure 4. Clients of OCPM vendors by count, based on ~ 46,500 projects (Sponsors' aggregated data)

The profile of OCPM technology users changes depending on several factors including project type, team and power structure, and implementation strategy. However, owners, general contractors, construction managers, and architects/engineers are among the most active users of OCPM technology. Additionally, general contractors and construction managers are, typically, mandated to use the OCPM solution by the owner. Subcontractors are usually not amongst the most frequent users; in fact, they usually have limited access to the OCPM solutions for cost and security reasons. When they do have access, they rarely use the systems because most are not technology-savvy, usually the benefits miss them, and they are not permanent members of the project team.

4.2.Need for OCPM Technology

Execution of construction projects requires working with several parties including owners, general contractors, subcontractors, architects, engineers, consultants, and suppliers. The ultimate reason for investing in OCPM technology is to facilitate transparent and continuous communication with the entire project team as well as with the internal staff. Another good reason is to facilitate construction workflows such as requests for information (RFI), change orders, and submittals and to share construction documents such as drawings and specifications. Besides facilitation of team communication and construction processes, organizations aim to:

(1) *Create standards and certain policies:* Unify the project execution and enforce the teamwork among project participants while providing a structured way of managing projects' information,

(2) *Enable information availability and control*: Increase information visibility by centralizing all project information. This enables the ownership and security of the project information by maintaining a complete audit trail (eliminating the risk of data being lost and not knowing who did what when),

(3) *Improve project control and management*: Record all activities happening on construction sites to monitor and control every project in a timely manner from the main office, especially when there are several projects in the portfolio,

(4) *Gain competitive advantage:* Provide a better service to the owner and increase market share by building and maintaining relationships,

(5) *Gain efficiency:* Improve collaboration, review, and turnaround time with version control, smooth information flow, and dynamic routing of documents and notifications.

4.3.Selection Process

Investors follow different strategies to select their OCPM solution. In several cases, renewed agreements based on experience with the OCPM solution and provider were observed by the research team. The selection process is carried out by *consultants*, the owner's *project/program managers*, and/or the organization's *technology department*. The first issue to consider is whether to implement a *web-based* or a *web-enabled* solution, depending on firewalls, security, sensitivity, and resources (hardware/software/personnel costs). The second issue is the *stability of the vendor*, including responsiveness, company stability, system integrity, and the company's training availability.

Usually, the investors start by reviewing the well-known OCPM solutions on the market. With an increasing demand and common understanding, investors search for a product that would match their processes. They believe that the system needs to be closely linked to the overall business strategy of their organization. Several systems' functionalities are, usually, compared against the organization's multi-project requirements and control capabilities. Although the level of integration depends on the organization's needs, *customization*[13] and/or *tailoring*[14] are usually asked from the vendor as part of their services. The investor's team usually formulates a list of assessment criteria and prioritizes them. Sometimes, investors issue a request for quotations (RFQ) from the vendors. Some of the selection criteria are:

- Flexibility and usability,
- Customizability,
- Ease of use and learning,
- Features: document and process management features (built-in viewers, auditing and processes/documents supported, reporting, sorting and redlining drawings, version control, etc.),
- User interface: external email notification, client system/bandwidth requirements, intuitive "out of the box," content customizability on the personal level,
- System administration: multiple levels of security, audit trail, level of customization, the ability to browse external archives, broadcast messaging, etc.,
- Vendor stability: responsiveness, company stability, system integrity, training availability, etc.,
- Cost structure: both purchase and operation/maintenance costs.

Short-listed vendors are usually asked to give hands-on demonstrations of their solutions to clarify information. The investors usually ask additional questions and request vendors to walk them through some specific features during demonstrations. If the OCPM solution is customized, testing takes place on pilot projects. Regardless of an RFQ process, a demonstration, or a testing, the investors always rely on recommendations of past and current users of OCPM technology.

4.4.Cost Structure

The *cost*[15] is a sensitive issue both for the investors and the vendors. Some of the investors don't want to publicly disclose the exact cost of the systems. The costs associated with the developments, licenses, and training are considered to be commercially sensitive. There is no industry standard for OCPM solution costs or cost structures; there are several cost structures offered by the vendors.

(1) *Subscription base*: Based on memberships; there could be different kinds of memberships with different levels of functionality and access. Organizations can choose to subscribe

[13] Design and creation of software to meet a customer's specific needs; an application- or company-specific interface and/or database design.
[14] Process of making optional minor changes to defaults of software that is installed and configured on a system.
[15] Includes the development, levels of customization and/or tailoring, ongoing redevelopment (if any) costs of the solution, implementation, training, and maintenance fees.

on a monthly basis or prepay for an annual agreement and renew their agreement every year. This gives them flexibility based on work volume or whether they dictate the project management method used on a particular project.

(2) *License plus maintenance fee*: One-time user licenses are paid by the investor, maintenance and support fees are paid annually.

(3) *Negotiated fixed cost*: Corporate-wide agreement (enterprise license) negotiated with the vendor based on estimated number of users, customization level, etc. The contracts are either 3 or 5 years long with unlimited number of users, projects, and storage or a combination.

(4) *Exclusive business partnership agreement*: Fundamentally a *license re-sell* agreement. The investor acts like an agent of the OCPM vendor and gets a percentage of the sold fees.

If the owner is providing the OCPM solution, they usually cover the costs for the rest of the team, provide the tool, and mandate the use of it to all project participants. They believe this will enable them to realize problems early in the process and that they will be able to monitor the overall program in a more efficient way. If an AEC stakeholder brings the tool on board, they usually bill the cost to the owner.

4.5.Implementation Practice

Project teams increasingly realize the importance of allocating resources in OCPM solution implementation. For better buy-in, the investor purchases the rights to use the software and make it available to the entire team and provide training sessions for all. In successful implementations we notice a steering committee within the company – executives, project managers, secretaries, IT and accounting professionals – to oversee the implementation and use of the tool internally. This committee develops and reviews the implementation checklists and defines how the solution will be set up and used, how the business will be run, what features are going to be used and how. If the investor doesn't have resources to handle the implementation in-house, usually an implementation service from the vendor or recommended third party is purchased. Successful implementations need identification of an application sponsor, a champion (Castle, 1999), on a team and definition of the processes and procedures for the project. An early tactical step is to contractually mandate the training and the use of the OCPM solution for every participant.

Customization or Tailoring:

Depending on the needs of the investor, the OCPM solution might need to be extended and enhanced to cover the activities involved in the organization's projects from physical delivery to implementation management, with a continuous improvement loop built in. Sometimes the whole program management regime has to be reengineered. Although project workflows are documented as best practices, they aren't defined in detail and implemented truly in the organization's projects prior to standardization of the OCPM solution. In this case, investors usually work with the vendor and consultants to customize or tailor the tool according to their needs or (if applicable) modify the process to suit the technology.

Evaluation and enhancement:
In some cases, after customization of the tool the organizations go through a testing by implementing the tool on pilot projects and organizing workshops with selected users to refine the system. If this is the case, analysis and evaluation are given a key focus. This might continue throughout the system implementation as the processes themselves might change by the introduction of new technology. Early users and those who attend evaluation workshops significantly influence the system functions. In these workshops, procedures, templates, and types of data to work with are established. In some cases, the processes are created if the organization is not working under a process model. This involvement of the first users helps encourage the adoption of the system. Essentially, it gives the organization an advantage to overcome cultural difficulties by engaging the key users in the development process and by providing them a more efficient working method.

Training:
Training and getting users to "buy in" to the system is crucial for gaining financial and process benefits from OCPM technology investments. Typically, it is either the owner or the general contractor who brings the OCPM solution on board. On a successful implementation all stakeholders – including subcontractors – get training by the OCPM investor's personnel (if available) at least once, if not more. If there are no in-house resources available for training, investors use a third-party provider recommended by the OCPM vendors for training the team members. These training sessions are usually private one-to-one sessions with flexible schedules that accommodate trainees' schedules. There might be extended training, whether one-to-one or over the phone if the users have additional questions or if they are not comfortable enough to use the system. Weekly continuing education sessions are also available to the users via a free online meeting service provided by most of the solution vendors. Usually, the training costs are covered by the investor of the OCPM solution.

Administration:
The OCPM technology investor or the construction project usually has in-house administrators or assigned team members who are responsible for day-to-day operations, including the project's setup, administration, the tool's speed, etc., and they provide assistance to both internal and external users. The investor owns all the data at the end of the day. If the investor is the general contractor, typically they turn all project information over to the owner at project completion.

4.6.The Use of OCPM Technology
Projects use various modules. However, the most commonly used OCPM solution modules are the *document management* and *cost management* modules, including budget items, contracts, purchase orders, invoices, cost events, drawings and specifications, submittals, transmittals, daily reports, document and drawing logs, meeting minutes, and RFIs (Figure 5). Most projects use the OCPM solution to share cost information only in a limited way; usually, the cost-related information is for internal use. Most of the documents are created and transmitted electronically unless they are legal documents requiring signatures and/or stamps such as change orders, architect's instructions, shop drawings, etc. The traditional paper process is followed by the project teams (1) if the construction sites or all parties are not connected; (2) if the document size is too large to review through the OCPM solution, such as shop drawings, which are expensive to

scan and print and reviewing them digitally is difficult; (3) if the submittal is a physical object, e.g. a brick sample; and (4) if the team wants to have a backup record for internal reasons.

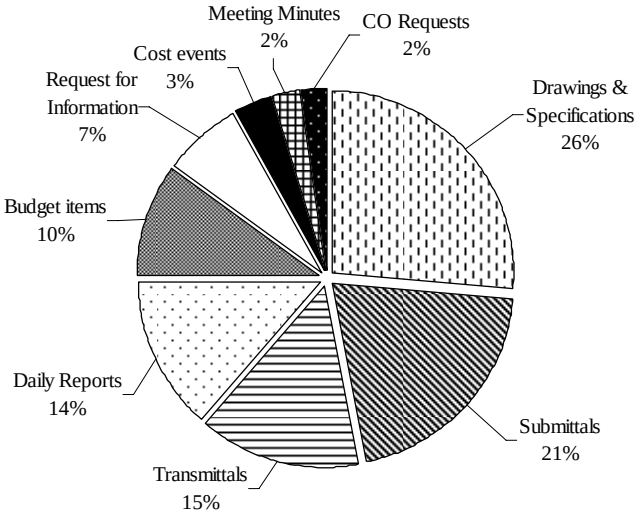


Figure 5. Types of entries and their frequency of use (number of projects using them), based on ~ 46,000 projects (Sponsors' aggregated data)

The construction team, especially general contractors, project and construction managers, consultants, and owners, are among the most frequent users of OCPM solutions. Based on data from 46,600 projects, the average number of users is 13.3 persons per project. 67% of the 46,600 projects have 20 or fewer users (Figure 6). Although there are some examples of subcontractors having significant participation, subcontractor participation is rare compared to the rest of the team members. Some owners leave the level of use to the project managers and team members, while others mandate the use of the tool by making it a requirement in the contract. Successful implementations are the ones in which the managers make it clear that if a document is not in the OCPM solution, it is not official and it doesn't exist.

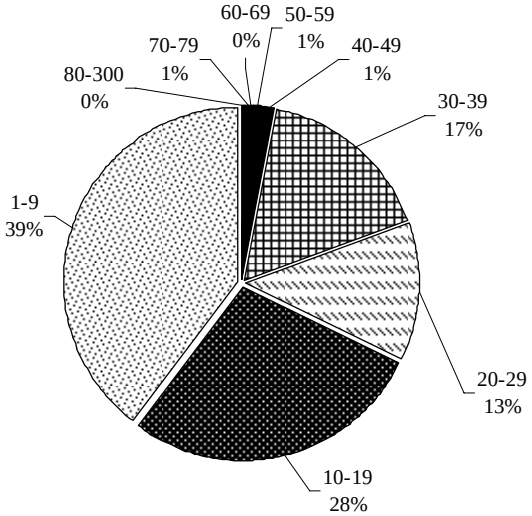


Figure 6. Active number of users per project, based on ~ 46,600 projects (Sponsors' aggregated data); the average number of users per project is 13.3 persons

Some investors have a certain dollar value threshold – e.g. $100,000 – to implement and use the solutions. Others use the tool regardless of the dollar value of the project or the number of participants. Average duration of use is 8.2 months, based on 5,700 projects' data (Figure 7).

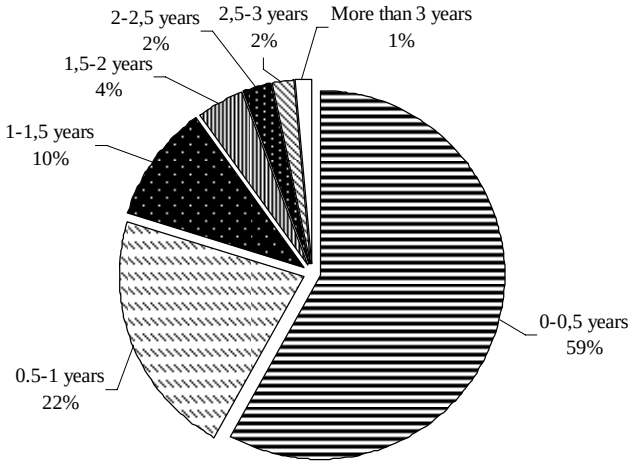


Figure 7. Duration of use, based on ~ 5,700 projects (Sponsors' aggregated data); the average duration of use is 8.2 months

OCPM solutions are used in most stages of projects but mostly in planning and construction phases. Out of 30,000 projects, 21% of the projects registered are in the planning stage and 49% are either in the construction or the close-out stage or already completed as of July 2005 (Figure 8).

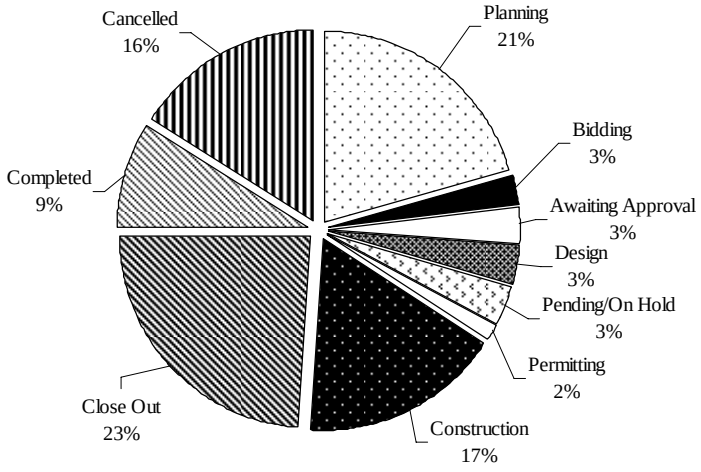


Figure 8. Project status, based on ~ 30,000 projects (Sponsors' aggregated data)

Besides the regular use of OCPM solutions for sharing information and for facilitating communication and construction processes, the research team observed some innovative ways of

OCPM solution use, which will be discussed in detail in the following sections. Some examples are the use of OCPM technology:

(1) *As a knowledge management tool:* To capture and then distribute business knowledge and strategy, project information, best practices, and experience gained from different consultants, suppliers, contractors, and projects;

(2) *As a business development tool:* To provide the OCPM solution as part of the organization's services in order to build long-lasting relationships with customers, increase the investor's negotiation power, and increase its market access;

(3) *As a forecasting tool:* To report and have accurate information. Used by some public entities. Categories for budget (current, pending, estimated, adjustments, projected) and commitments (original, approved revisions, pending revisions, estimate to complete, anticipated) are built to compare anticipated costs vs. projected budget so that the managers have a good track of what funds are available for each project and what has been spent to date in any given region/project.

4.7. Suitability of OCPM Technology

According to the interviews, case studies, and aggregated data analysis, it is evident that OCPM technology is suitable especially for multiple repetitive projects, for several reasons. Obviously, economies of scale is one of them. Having several projects in one system gives control to the owner; they can look across projects and compare very quickly, stop and divert something before it happens. In addition, this gives owners the advantage of reduction in construction management costs with the assumption that these systems will reduce the number of construction managers in a program and lower the transaction costs. The investor can learn from their mistakes as well as other peoples' experiences. In addition, the investor can have the leverage to set standards for repetitive projects such as renovations. Having several projects in one system also gives an advantage in negotiating the cost with the OCPM vendor and enables the investors to customize the solution according to their needs.

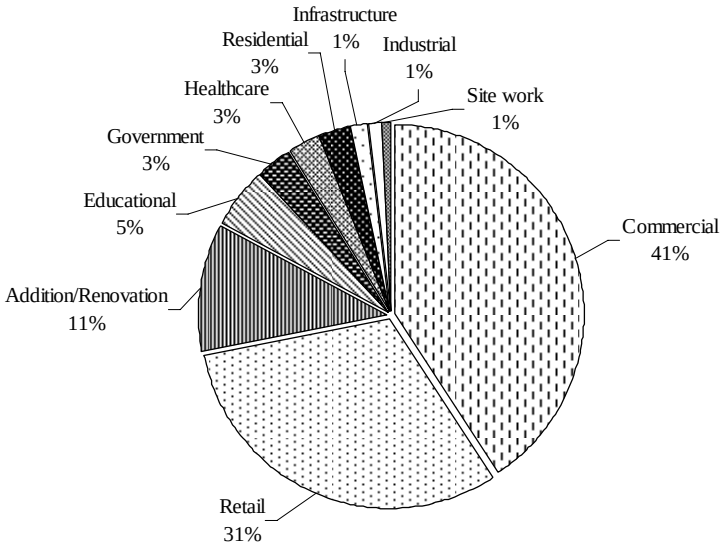


Figure 9. Project types, based on ~ 17,900 projects (Sponsors' aggregated data)

In addition to the advantage of having multiple and repetitive projects in one system, the research shows that these tools are used very extensively during the construction phase as opposed to the design phase. The reason for this could be the nature of design and construction. In the design phase, there are fewer players collaborating. Although these parties are quite advanced in using design related software, they have only touched the surface as it relates to using tools to improve productivity and collaboration. In construction, however, information needs to be in one place and controlling dissemination of the information is crucial for transparent communication and execution of work. There are many parties who execute orders and they are interdependent; the work of one depends on the other. In addition, having a complete record of the communication during the construction phase is advantageous in case there are any construction disputes.

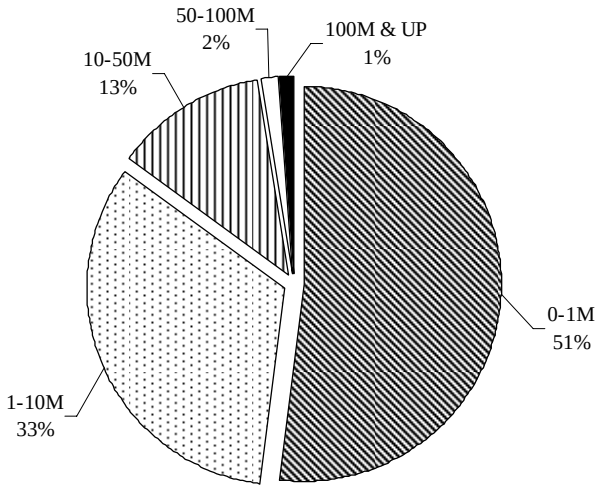


Figure 10. Project costs, based on ~ 10,000 projects (Sponsors' aggregated data); the average cost of projects is $7.3 million

4.8. In the Absence of OCPM Technology

The question: *"what would you lose if you didn't have the system in place?"* was asked to all interviewees. According to the top management, not having the system is *a major risk*. Those interviewed commented that without an OCPM system, they would lose:

(1) *The ownership of the data, and therefore an advantage in resolving disputes:* Interviewees mentioned several times that if they didn't have the OCPM solution in place, they would have to use hard copies and multiple technologies, which would result in disadvantages in resolving disputes because they wouldn't have records of the timing and sequence of things happening and who was involved. They would lose the ownership of the data, and if the project went to litigation getting the information from vendors and collaborators would be extremely hard, as unfortunately many have experienced before.

David Page, Los Angeles Unified School District's Facilities Information Systems' OCPM implementation leader, comments, *"The lack of communication in the project will create confutation and if you have confutation, you will have separation. If you have any of these three then you have a problem in the project. Separation creates the lack of communication so you get into the cycle. What you want to do is to break that cycle and make sure that everybody is getting the information they need."* And he adds, *"I would pay whatever the price is to use the system if*

we stop using it, because I believe it will save me in the long run. I have seen cases where one claim can save the entire system's costs. And I don't have any headaches. As a matter of fact, if they don't want to do that I might pay for the application out of my pocket."

(2) *The control of the overall program:* According to upper-level management, the greater value is the ability to manage a program's risk. The solution provides visibility and awareness to all parties inside and across the project team. Having knowledge of the contractors' progress helps the managers to control the projects better, especially when there are many projects and contractors in the portfolio. Knowing what your status is day-by-day is critical to ensure that your projects are on track and under budget.

Debra Kunce, program manager at Schmidt Associates, says, *"Our OCPM solution is a central point of information. From the owner's perspective, you can look across projects and compare very quickly. At some point we knew it would get overwhelming for communication among numerous parties, and we wouldn't be able to handle it. At that point these systems are priceless."*

(3) *The decision-making advantage:* The ability to get the information in front of the right people immediately has been very important for users and investors. In most construction projects, managers run into situations where there are disputes among the professionals and contractors. Having an OCPM solution in place provides the right information to evaluate the situations and to give the right decisions.

Michael Imbergamo, project architect of SmithGroup, confirms, *"The tool really helped us with the schedule. For example, there have been critical issues. We don't have to follow the normal way of processing the information. We are not tied to the individuals as we used to be in the past. The information is readily available with a couple of clicks."*

(4) *The efficient communication and coordination:* The ability to fast-track information in and out between contractors and subcontractors and have timely access to project-related information is very convenient with the OCPM technology. The system ensures that when a participant runs into a problem, at least one person from that company sees that issue the same day it occurs and responds to it immediately. The other team members are also able to notice that information within a couple of hours. This is very critical for keeping construction projects on time. Users think that without the OCPM solution they would lose the accountability and the accessibility of the information, which would result in mediocre communication and less trust between the collaborators.

Ed Costanza answers the question from the Kitchell Contractors' point of view: *"If we didn't have a system like this, we would be less efficient, and efficiency is critical when you're dealing with liquidated damages contracts. For us, this is the best system."*

(5) *The information accessibility and availability:* If project teams didn't have the system, the distribution of documents would be a problem, whereas with the OCPM solution the teams can do it in real time instead of needing 2-3 days to update technical documents, print, and send them. By implementing the system, project teams eliminate the whole distribution and administrative exercise. The ability to have a single reference point and depository for each project reduced the turnaround time for RFIs, submittals, and change orders. The information is available to everybody anywhere; there are no physical

boundaries or worries about transfers. If they didn't have an OCPM solution, the people would be less responsive because they would be less aware of the issues.

Steve Young, program manager of Indianapolis Public Schools, says, *"Frankly it keeps people honest, and that is difficult to quantify. I cannot say what my cost would be if I didn't have the OCPM solution, but the savings are sufficient for me to make the investment."*

Brett Pitcairn, project manager of P.J. Dick, comments, *"If we didn't have the system in the CMU project, we would lose our ability to maintain the tight schedule. It helps us to expedite compared to traditional methods."*

(6) *The ability to enforce workflow and data population:* Most importantly, if project teams hadn't implemented the system, they wouldn't have the work processes rethought and reengineered. They would lose the ability to enforce data population, and information management would be chaotic again.

Marek Suchocki, research and innovation manager at Atkins Management Consultants, says, *"Although the work was considered well understood, adoption of the OCPM tool provided an appreciation of the wider business process."*

(7) *The standardization:* Some teams achieved standardization throughout their projects by implementing an OCPM solution, which would not have been possible without a system in place.

Robert Harrison, support manager of Nationwide's OCPM solution, comments on what would have happened if they hadn't implemented the solution: *"We would lose time, quality, cost, ability to talk directly with a large number of people at any time, accessible record and data storage facility, performance enhancers, members' experience enhancements, technology and project management improvements, contractors' key performance indicators, and best practices capture."*

(8) *Individuals' time:* If the investors didn't have an OCPM system, the level of frustration would increase, the productivity would decrease, and therefore both teamwork and collaboration would lose operational capabilities. They would be spending more time using less fluent and more cumbersome ways of communication, and the project participants would be wasting their time working on different versions of the drawings.

Julie Ernzen, project engineer of Kitchell Contractors, comments, *"If I didn't have the system in place, I would have 10 times more paperwork. I would spend more time sending documents back and forth. The tool gives us an opportunity to work in a more structured way."*

Harold Heit, manager of project engineers at TRM Healthcare, says, *"We would be back where we were before implementing our OCPM solution. People would be looking at different versions of the drawings. We would be spending a lot more money to ship drawings all over the country. And we would be spending a lot more time because not everybody would be working on the issue from the same drawing."*

Jacquie Spencer, project coordinator of Inscape, comments, *"If we don't have the tool we will go back to extended response times because we will be dealing with overnights and time zones. Not having an OCPM system in place can slow down our process seriously."*

(9) *Competitive advantage:* In some cases, if the organization didn't have the system, they would lose an opportunity to increase their sales and enhance their relations with their customers. They would lose their responsiveness to customer needs and requests.

Dan Kennedy, sales analyst at Inscape, comments, *"Getting involved in the project sooner! This is one way that we can spark up in the conversation sooner. And this is extremely important for our sales."*

4.9.Success Factors

Successful implementation of a new and innovative technology in construction requires development of strategic implementation plans ahead of time (Betts, 1999). There are three cornerstones of a successful implementation: vision; commitment; and reengineering possibilities (Stewart et al., 2002). The success of OCPM solution implementation depends on the project manager's and the owner's willingness to use this technology. Having senior management heavily involved in the development effort helps overcoming hidden phobias, thereby reducing the resistance to changes.

The OCPM solution should be factored into the overall program plan early on. Business processes should be designed around the solution's capabilities or the tool should be customized to fulfill the organization's processes. The organization's corporate culture, planning and control style, organizational size, organizational structure (e.g. mechanistic vs. organic), and management style (e.g. entrepreneurial vs. conservative) should be considered. Evaluation of budgetary requirements, the study of time and organizational constraints, the elaboration of human resource issues, management and plan coordination, migration and diffusion are important factors to consider (Stewart et al., 2002). There should be proactive arrangements for training users and companies that will be executing the work. Successful implementations need clear definition of the processes and procedures and identification of an application sponsor (champion) on a team. An early tactical step is to contractually mandate the training and the use of the OCPM solution for all parties. Consideration should be given to the continual performance monitoring of the implemented OCPM technology over its life cycle. There should be performance measures and data collection strategies in place to get continuous benefits from the OCPM technology investment.

4.10. Plans for the Future

The study shows that the investors and users of OCPM technology are convinced that this technology contributes positively to their business and operations. At the same time, they are aware of changes they should implement. There are several trends developing currently in the industry. Some are:

(1) *Applications integration:* Integrating an OCPM solution with several applications including financial, contracting, purchasing, facilities management, assets management, enterprise content management and enterprise resource planning solutions. The organization's software should talk together and pull everything together under one database so there is no room for mistakes and data reentry;

(2) *Optimization:* A policy of having all official communication on a project go through the OCPM solution. Most of the organizations are rethinking their implementation and use of their OCPM investment. Therefore, investors are going through an optimization to extend

the use of their solutions. They are starting with the most-used modules and functions (in most cases this is the document management module) and they are expanding the use to several other modules (bid and cost management) as well as to more projects and users;

(3) *Benchmarking:* Using the OCPM solution to set benchmarks for future projects and performance;

(4) *Overcoming change and cultural barriers:* Continuously training the employees and the supply chain to use the system, make proactive arrangements, and provide a steady point of contact;

(5) *Knowledge management:* Revisiting the data on past projects; using the OCPM solution as a universally accessible reference library; eliminating loss of useful information created in design and construction once the project is over;

(6) *Making the OCPM solution a contract requirement:* Utilizing the OCPM technology as part of a contract requirement. Managers agree that the owners increasingly would like to know what tool the contractor will use to control a project. Therefore, contractors would like to increase the use of their OCPM tool modules in order to maximize their benefits;

(7) *Importing information from the OCPM solution to other applications:* For example, capturing and using the information generated during the management and execution of projects; attaching intelligent data as equipment changes in buildings; using the information as a reference for facility management; having electronic data and electronic access;

(8) *Developing communications specifications*: Formally documenting and contractually binding all parties on how to facilitate communication on a project: what modules will be used and how;

(9) *Reusing and reconfiguring the tool for future projects:* Using the OCPM solution and the information generated in other areas such as validation, capital planning, and facilities management;

(10)Bringing mobility to construction sites: Having portable devices that have a connection to the OCPM solution on the construction site to address issues directly, e.g. electronic requests for information.

5. OCPM TECHNOLOGY VALUE ASSESSMENT

5.1.Tangible Benefits

Of the three types of benefits (tangible, quasi-tangible, and intangible), only tangible benefits have a known financial impact on cash flow. OCPM technology investments are largely known and have traditionally been made for the generation of tangible benefits, which are based on direct financial project costs (Irani, 2002). These tangible benefits usually have an effect on operational efficiency. However, although these benefits are measurable and quantifiable, the savings overall to the project are hard to calculate without going through a series of assumptions. For example, traditionally the cost of sending a request for information (RFI) or a shop drawing is assumed by the sender. One might infer that the sender may be more willing to share information with an OCPM technology in place, since then they do not need to assume the cost. Cost savings (whether to print or not) is under the recipient's control with the OCPM system in place, which makes accurate calculations difficult as the savings differ from participant to

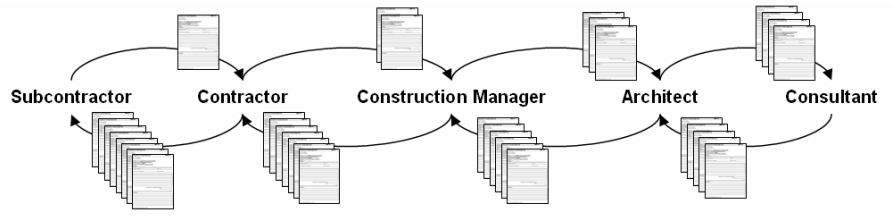
participant. After breaking down the efforts on the basis of the work functions affected by OCPM technology implementation in construction projects, the research team identified and focused on three specific job processes where dramatic savings become possible. These processes as discussed in the paper are: electronic request for information (e-RFI), electronic bidding (e-bidding), and electronic document transfer.

5.1.1. Electronic Requests for Information (e-RFIs)

Requests for Information (RFIs)

An RFI is one of many documents generated during the construction period. It occurs when a contractor, a subcontractor, or a supplier finds an unclear element or dimension in construction drawings, a conflict between specifications and drawings, or any question related to the construction site. The number of RFI documents varies from project to project. In small construction work, the number might range from 50 to 300. RFI documents are related to many parties. Therefore, they take time to generate and respond to. Sometimes not answering an RFI on time might cause delays in construction work. The average industry RFI turnaround time is around 14 days based on the information gathered through interviews, case study and survey analyses.

Questions asked have traditionally been sent by fax or in paper format to the construction/project manager or to the architect, depending on the procurement method. These questions are then passed to relevant parties. The party issuing the RFI, usually the general contractor or a subcontractor, has to wait for the answer, which might take a long time depending on the responding party. After receiving the answer, the construction manager or the architect passes the question file and attached answer information to the inquiring party with the name of the answering party, and the time and date it was received. Usually RFI documents are bound in three-ring binders, which occupy space. The responsible party has to look at all documents (specifications, drawings, etc.) and answer the question. While some of the questions might be easy to answer, some might take longer. In response to an RFI, a drawing or specification might be changed, modified, or the answer might cause a change order, which needs the owner's approval. The time needed to issue and answer an RFI is usually critical as it might affect the overall construction schedule.



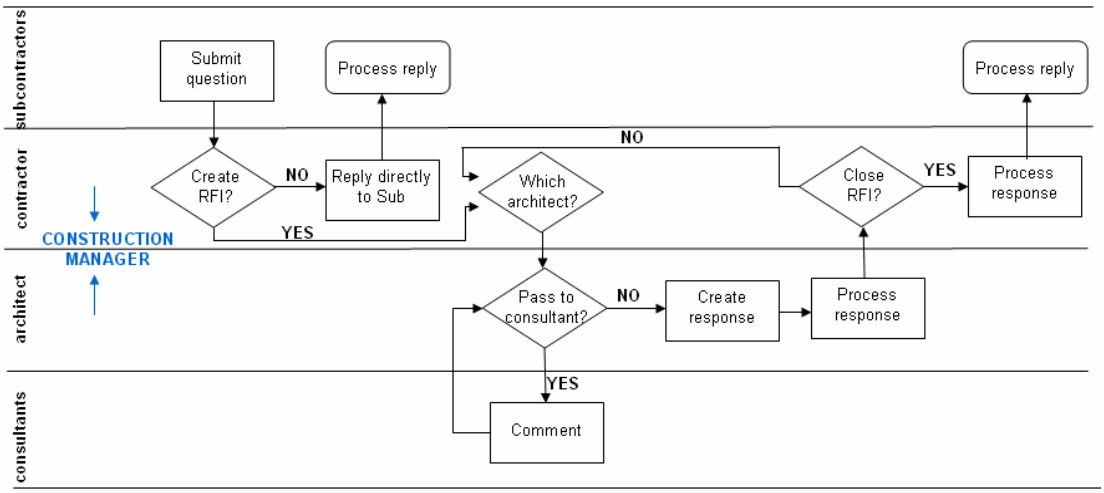


Figure 11. Lengthy and linear paper-based RFI process

Reasons for RFIs

- *Design intent and clarification:* Consultation with architect/engineer (A/E) for questions regarding the design intent in case clarification is required, there is insufficient or missing information, or there are errors, omissions, or conflicts in architectural drawings, specifications, structural drawings, etc.
- *Subcontractor information:* Access to any information that the contractor has about any of their subcontractors. Information about a subcontractor's activities at any given time.
- *Contract specifications and drawings:* Access to specifications or information regarding specifications, contract or shop drawings, and if necessary to personnel that can answer questions regarding the drawings.
- *Work package information:* Access to work package information, including scope of work, materials and equipment required, etc.
- *Means and methods:* Consultation when field personnel discover that an item cannot be installed according to the owner's plans or contractor's methods and/or an item cannot be found in the market as proposed or required in the specifications. Contractor's alternate proposal regarding construction execution method and/or model/size.
- *Guidance:* Consultation regarding a mistake made or a problem that has occurred on the construction site.

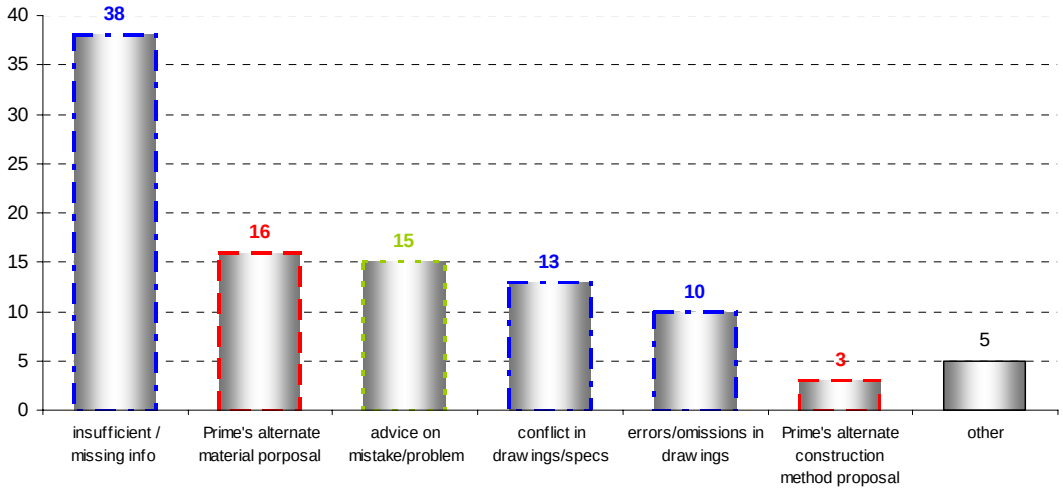


Figure 12. Reasons for RFIs in one of the construction projects

Problems with paper-based RFIs

RFIs are usually issued in paper form, sent by fax or handed in, and they take a long time to process. The time spent to answer a question is unpredictable. There is always a possibility that someone will forget to answer it or will lose the question. There are no mechanisms to track down which questions have been answered or not answered. There are no ways to accelerate the process. The parties who are answering a question have to go back and reexamine all relevant documents, which are in different formats and stored in different places. Project managers have to spend time managing RFIs, both the questions and the answers. The project manager has to manually attach the answers to the original questions, with other details such as who answered the question and the date and time of the answer. In addition, the project manager has to keep all records of RFIs even after the project is finished in case of claims. Although some large construction companies use stand-alone systems to manage RFI documents, these usually aren't fully integrated with other systems. Moreover, it is sometimes difficult to define who will answer the questions. RFI is a critical process, to which more attention should be paid by the construction staff.

e-RFIs

The RFI module is one of the most-used modules of the OCPM solutions. With the use of OCPM technology, the lengthy and linear RFI process can be shortened dramatically. These tools bring efficiency to the process by providing *automation* as soon as the sub/general contractor starts filling in the electronic RFI form. For example, areas such as the RFI number, the date the RFI is created, and the author's company and personal information are automatically filled in by the tool with the author's log-in information. This provides a complete *audit trail*. Contact information for all participants is usually built into the solutions in advance so that the person who issues the RFI can select the "corresponding company" and "corresponding person" from the contact list. This lets the system forward the RFI to the recipient's OCPM inbox and also send notifications to the recipient's email inbox. These tools also enable the author to

consistently use the same recipient and set the same review time.[16] In addition, the need for the RFI (confirmation, clarification, inconsistency, field condition, errors/omissions, site condition, etc.) and the discipline involved (architectural, civil, electrical, plumbing, structural, landscaping, etc.) could be selected from the built-in list. The author can type in his question, add notes (suggestions and comments), attach related drawings/documents/sketches, and mark the importance of the RFI, the RFI's impact on budget, schedule, and drawings, and whether that specific RFI record will require drawing updates.

The minute the RFI is posted, the recipient receives a notification in his email inbox indicating that there is an RFI he has to answer. The recipient can click on the link in the notification email or log in to the tool and view the RFI automatically. Then he can fill in the answer and reference/attach any specifications/drawings/documents/sketches. As soon as the recipient (responder) posts the document, the author receives a notification indicating that his question has been answered and is ready for viewing. Notifications are also sent to other users for RFI updates (such as project managers who need to review the RFIs). RFIs usually involve some form of collaboration with at least one other person. Some RFIs might require one answer or response from a single contact, while others may have to be redirected to several contacts before reaching the appropriate person who can answer the RFI question. Similarly if the recipient believes that the question should be answered by another party such as his consultant, he can forward the RFI to the appropriate person by selecting from the list. The whole process is done automatically and the history of all actions is recorded. The user can view either all RFIs in a project (if he is granted access) or those specifically assigned/redirected to him.

The solution could be set up in such a way that every RFI can go through e.g. the construction manager (CM), though other parties can also be copied. The reasons for having the CM at the center of communication might be as follows: (1) the CM reviews both questions and answers; (2) the CM becomes aware of the issues; (3) the CM knows the issues that involve more than one party, so he makes sure everyone affected is in the loop; (4) the CM always has the power to add, copy, or phrase answers in such a way that the parties will understand. The CM might be able to answer the question, depending on the nature of the RFI. In this case he would answer and forward a copy to the A/E. If the CM doesn't know the answer, he makes the contractor RFI into a formal RFI and forwards it to the A/E. The same path is followed for the answer.

Realized benefits of e-RFIs

(1) Reduction of RFI turnaround time: OCPM technology brings speed to issuing and answering questions as the process is very well automated. It enables team members to type in the question in an electronic form and to send the question to the relevant parties by just pressing a button rather than faxing, emailing, or mailing the documents back and forth. OCPM technology prevents any mail delay or risk of an RFI not being answered on time thanks to its real-time communication features and automated notifications. The interviewees agree that there is no comparison between paper and electronic RFIs. Electronic RFIs are much faster and they enable instantaneous communication. Jack Jones, the Carnegie Mellon University Collaborative

[16] Review time is the number of calendar days after the creation of an RFI by which a response needs to be received. This value automatically populates the date required.

Innovation Center project superintendent, comments: *"There is no doubt the tool improves the RFI process. We used to have 12 days turnaround time but now it is possible within hours."*

The average e-RFI turnaround time is 5.44 work days and 6.04 week days, based on 5,648 e-RFIs in 7 construction projects (Figure 14).

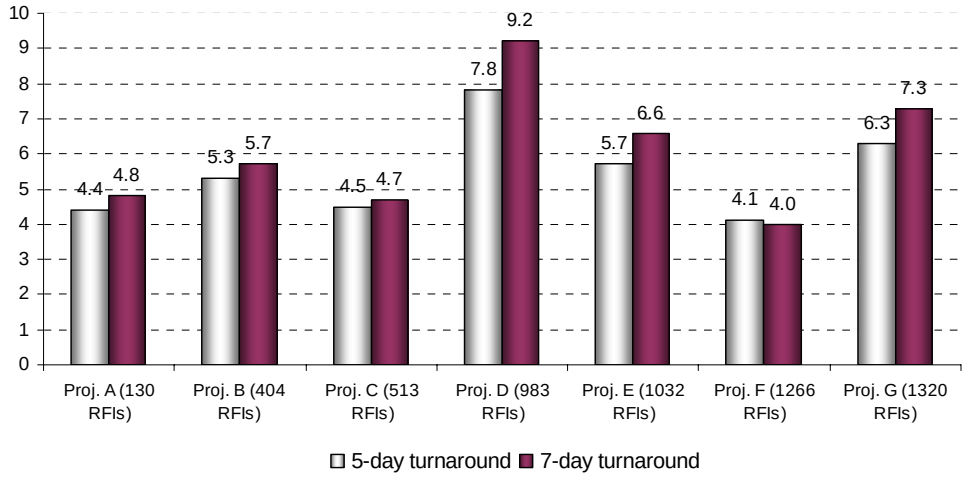


Figure 13. 5-day and 7-day turnaround time of 7 construction projects' e-RFIs

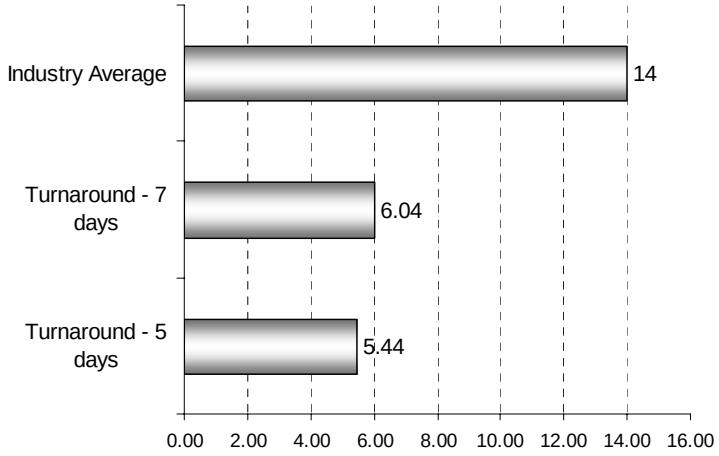


Figure 14. Electronic RFI turnaround time, based on 5,648 RFIs in 7 construction projects

According to the interviewees, OCPM technology is helpful in workflows when several parties need to be aware of the issues simultaneously. Depending on the issue, architects and engineers agree that they can send the answer back to the contractor or to the construction site literally within a minute. The process of answering an RFI also becomes very efficient. One of the construction administrators interviewed indicated that working on an electronic RFI would take him *5 minutes* instead of *45 minutes*. Reasons for increased efficiency in the e-RFI process are:

- All project information is at a central location, stored in a structured way. For example, construction administrators don't have to leave their desks and search folders for information;

- There is no faxing or illegible handwriting. One doesn't have to create a spreadsheet to list RFIs, do binders, and send them;
- These tools are web-based. One can just pull the information from one's computer, view it, issue it, and send it;
- The entire process is enhanced and controlled by instant notifications;
- Managers can be aware of pending RFIs by running reports on the status of RFIs.

This may reduce the number of administrative staff in an office, or the same number of staff can spend more time on other issues due to the efficiency gained. While these staff savings may not directly impact the investor (assuming the investor is the owner), one hopes that efficiency will impact future projects and their costs. For example the CM will be willing to negotiate a lower contract price because they know they will need to spend less time.

Dollar savings based on reduced time spent on answering an e-RFI:
We can estimate the savings with a basic calculation. Let's assume there is a project that has 807 RFIs addressed within a year in the construction period.

Number of RFIs = 807
Average salary of construction administrator = $48,000/year ($25/hour)
Time spent to process a traditional RFI = 45 minutes (75% of an hour)
[75%x25] x 807 = $15,131 annual expenses to process a traditional RFI
Time spent to process an e-RFI = 5 minutes (8.3% of an hour)
[8.3%x25] x 807 = $1,674 annual expenses to process e-RFI
45 minutes vs. 5 minutes (89% more efficient process gained by e-RFIs)

SAVINGS: $15,131 - $1,674 = **$13,457** annual savings per project
Assume that the office has 10 same size/duration projects within a year:
13,457 x 10 = **$134,570** per year for 10 projects

The above calculation takes the construction administrator's time savings into consideration. Therefore, it assumes that the administrator will be able to support more projects, which potentially can reduce the number of construction administrators required in an office. However, the savings of e-RFIs are not limited to one party's time savings. As mentioned in the previous sections, an RFI process involves several parties including contractors, architects/engineers, and construction/project managers. The calculation above could be extended to efficiencies gained by other parties.

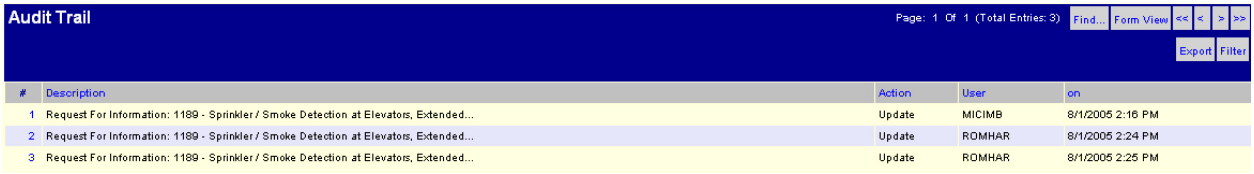
Dollar savings based on reduced RFI document printing, copying, mailing and faxing:
We know that the gains are not limited to time savings but also include reduced paperwork and transfer.

In all, we know there are 807 RFIs in our sample. Let's assume at least 400 of these RFIs have 2 pages.
Total number of pages = 407 + (400 x 2) = 1207 pages
Assume 80% of documents do not need to be printed and faxed when the e-RFI process is utilized:

1207 x 80% = 966 pages
Assume at least 3 different parties (A/E, CM, and GC) would print and fax 966 pages back and forth if the system wasn't implemented:
966 x 3 = 2898 pages of document
Assume printing cost $0.1 per page:
$0.1 x 2898 = $290 per project
Assume 50% of the documents were mailed before and they don't need to be mailed due to efficient electronic transfer, and that the mailing cost is $1 per envelope on average:
$1 x 50% x 807 = $404 per project
Total savings of printing, faxing and mailing per project:
290 + 404 = **$694** per project ~ **$6,940** for 10 projects

(2) Reduction in RFI numbers: There is no evidence that the OCPM technology reduces or increases the number of RFIs. However, it is agreed that these systems clear up the questions earlier in the process in a speedier manner. This prevents mistakes and solves problems early in the process. Some in the industry believe that the number of RFIs will increase since the OCPM technology makes it easier to ask questions. However, Brett Pitcairn of P.J. Dick Incorporated comments: *"RFIs are related to the quality of the documents. If someone has a question, he has a question. There is no correlation between the number of RFIs and the use of the system."*

(3) Audit trail: Interviewees agree that one of the most valuable benefits of e-RFIs is having a complete audit trail. Participants can easily track the dates when an RFI was submitted and returned. In addition, the history of who did what and when is traceable. Michael Imbergamo of SmithGroup, the architect of the Defense Intelligence Analysis Center project, says, *"If there is a discussion, it is very easy to find all related RFIs. If they are related, they are numbered as 5001a, 5001b."* Russell Triplett of Perkins+Will, the designer of the Barrow Neurological Institute Tower project, comments, *"When the contractor sends a question, we get an email saying there is a new RFI. I can answer or direct it to other people if necessary. It is a great tool for automating and tracking everything."*


Audit Trail

Page: 1 Of 1 (Total Entries: 3) Find... Form View << < > >> Export Filter

#	Description	Action	User	on
1	Request For Information: 1189 - Sprinkler / Smoke Detection at Elevators, Extended...	Update	MICIMB	8/1/2005 2:16 PM
2	Request For Information: 1189 - Sprinkler / Smoke Detection at Elevators, Extended...	Update	ROMHAR	8/1/2005 2:24 PM
3	Request For Information: 1189 - Sprinkler / Smoke Detection at Elevators, Extended...	Update	ROMHAR	8/1/2005 2:25 PM

Figure 15. Audit trail record of RFI #1189

(4) Enforcing timely responses: OCPM technology provides managers a list of overdue RFIs and may request prompt actions of related parties to maintain a timely construction process. In addition, it can send letters that advise a company that their lack of response to an RFI is causing construction delays. Additionally, the technology can warn that the owner may be notified via an official delay claim. Tony Teritehau, US Navy project manager, indicates, *"We can run reports for returned RFIs or more importantly for outstanding RFIs, which helps us to take timely measures."*

(5) Impact on overall schedule and budget: It is difficult to predict the impact of reduced RFI turnaround time on the overall schedule and budget. In our analysis of project RFIs, we came

across one RFI where an immediate response was required from one of the prime contractors. The question was about a connection detail showing how to anchor roof ladders into the hollow block. The question was asked on 10/28/2004 and the answer was required by 10/29/2004. The RFI was answered the same day it was asked, which prevented any delay in the construction sequence. The OCPM solution prevented any mail delay or risk of an RFI not being answered on time thanks to its real-time communication features and automated notifications. John King of J.J. Gumberg, Carnegie Mellon University Collaborative Innovation Center project developer, explains the necessity of the tool: *"These tools are critical to be on time. Our time frame for this project was very compressed in terms of meeting major goals. Without this tool, answering questions, getting information back and forth when people needed to, would be painful."* Michael McKay, TRM Healthcare's Methoda project manager, adds, *"Somewhere along the line, shorter RFI turnaround time should improve the construction schedule and reduce the costs if you are receiving hundreds of RFIs and reducing the turnaround time to 2 days."* However, interviewees also agree that the overall schedule of a construction project depends on several factors and that it is very difficult to prove the effect of reduced RFI turnaround time on project schedule.

5.1.2. Electronic Bidding

An essential stage in construction is the bidding process, during which the profit level is critically determined (Arslan et al.). The bidding process requires a great deal of time and effort. OCPM technology is increasingly used in the bidding process in order to reduce bidder query process costs and its onerous nature. OCPM technology reduces the demands of complex procurement processes by improving the efficiency, speed, and accuracy of the bidding process. E-bidding through OCPM technology is employed to facilitate the exchange of information, the submittal of prices in electronic format, and to manage the structuring and sharing of project information. The benefits of utilizing an OCPM technology in e-bidding are: enhancing time and cost saving for bid proposal preparation and reducing proposal litigations after the bid by having complete audit trail. E-bidding offers significant time and cost savings by reducing the paperwork, mailing, and copying. E-bidding also eliminates potential bidding errors through system checks and provides a reliable and quick information exchange medium among bidders. Easy and controlled access to archived data also increases the range of potential bidders. Comparison of price and technical data is much easier in the e-bidding process compared to the traditional bidding process. Moreover, the procurement process is brought to a standard format with the OPCM technology.

An example of e-bidding through OCPM technology and its positive impact on cash flow is presented below.[17]

Region 2 of the General Services Administration (GSA)[18] has a one-year subscription to an OCPM solution that includes a license for a 10GB site with up to 750 site members at a cost of $68,000 per year. Their site status as of June 2005 is 5+ GB of information stored with 500+ members involved in at least one project. About 80 members are GSA associates. The remaining members are either GSA customers or vendors, including A/E firms, general contractors, and subcontractors.

[17] Courtesy of Jay Burris of General Services Administration.
[18] www.gsa.gov

The following calculations reflect the base pay and benefits used for calculating the dollar value of time saved using the OCPM solution, as well as average values for direct costs:

Variables:
Engineer hourly rate: $37.00
Administrative staff hourly rate: $18.00
Printing 30 sets of plans (30 full-sheet pages) and specifications (200 pages) = $1,000
Overnight shipping of one bidding package: $15.00

Variables not included in cost estimating:
Normal print request and mailing varies between 30 to 50 packages, sometimes more for larger projects. Bidding amendments not included; average of two per bid sent overnight ($5) to prospective bidders: around 50 (estimated $6,000 additional cost)

Engineer administration time:
$37.00 x 6 hours = $222 x 8 projects = $1,776 x 6 project managers
= $10,656 (288 hours)

Contracting officer administrative time:
$37.00 x 6 hours = $222 x 8 projects = $1,776 x 4 project managers
= $7,104 (192 hours)

Administrative support time:
$18.00 x 8 hours = $144 x 20 projects = $2,880 x 6 project managers
= $5,760 (320 hours)

Total associate indirect costs: $10,656 + $7104 + $5,760
= **$23,520** (800 associate hours expensed)

Printing costs:
30 sets = $1,000 x 20 solicitations
= $20,000

Mailing costs:
30 sets x $15 (one box and one tube) = $450 x 20 solicitations
= $9,000

Total direct costs: $20,000 + $9,000
= **$29,000**

Direct and indirect costs associated with solicitations issued during one fiscal year (Oct - Sep): $29,000 (direct) + $23,520 (indirect) = **$52,520** in realized savings (for one Service Center – Syracuse Service Center)

GSA doesn't have another Service Center using the OCPM solution for bidding to the same extent, which would easily increase the realized amount of savings without any increase in cost. There are six Service Centers in Region 2 that have the same project load with similar efforts as described above. If all six offices used the OCPM solution to the same extent as the Syracuse Service Center, the estimated savings would be upwards of **$300,000** without an increase in the cost of the OCPM solution

Jay Burris of General Services Administration concludes, *"My description of how we save with the solution was based around the bid portion of our process. Any realized savings for the design review or project administration segments of a construction project only enhance our ROI. I usually quote a low $100,000 in savings that is realized over the cost of our OCPM solution. It does benefit me and I will continue to press to maintain this service as it saves the government time and money."*

5.1.3. Electronic Document Transfer

Ease of transferring documents, drawings, and specifications is definitely among the most important benefits of OCPM solutions. Budget items, contracts, submittals, transmittals, invoices, RFIs, daily reports, and meeting minutes are extensively used modules of OCPM solutions in construction projects. An example of e-document transfer through OCPM technology and its positive impact on the cash flow presented below.[19]

TRM Healthcare[20] (TRM) is a broad-based health care company that discovers, develops, manufactures, and markets products and services that span the continuum of care from prevention and diagnosis to treatment and cure. TRM calculated their savings from reduced FedEx costs in their international projects. As can be seen in Figure 16, the design review process requires the attention of several parties. What happens usually is that the designer/engineer prepares the drawings and sends them to TRM by FedEx for review. TRM professionals review the drawings and make changes and/or add comments, then send them back to the designer/engineer by FedEx again. The designer/engineer's team interoperates the comments and sends the final copy to TRM by FedEx, which is then sent to the construction site.

[19] Courtesy of Todd Wynne and Harold Heit of TRM Healthcare.
[20] The name of this company and the names of the people and organizations involved with this company were changed for confidentiality reasons.

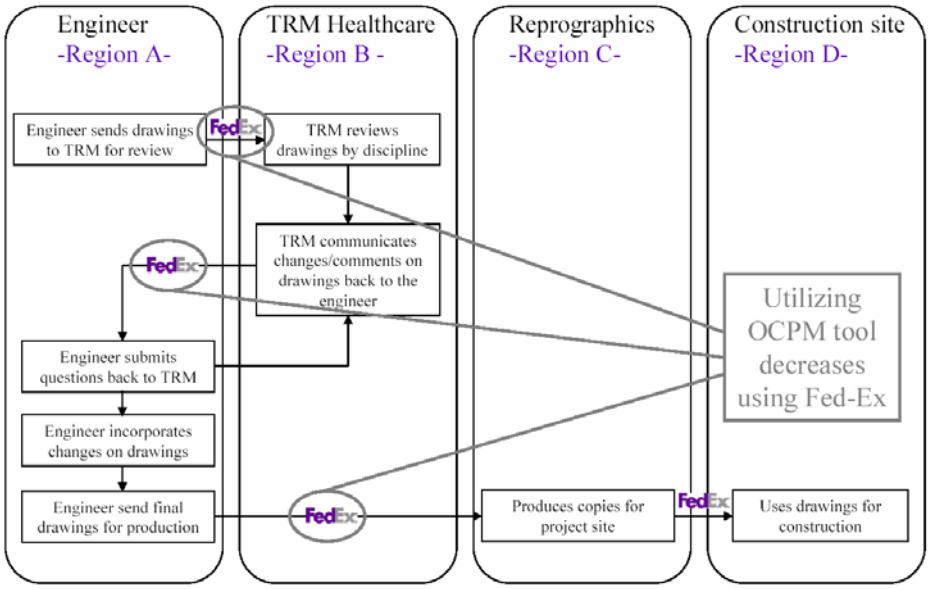


Figure 16. Drawing review process for an international TRM project

FedEx charges for 7 lbs between the destinations are stated below.

	Next day	2 day
Region A to Region B	$54.34	$11.55
Region B to Region A	$54.34	$11.55
Region A to Region C	$70.61	$17.54
Total	**$179.29**	**$40.64**

We will assume that a package of 50 drawings will weigh 7lbs. The number of drawings posted on the OCPM tool for this project is as follows, *with an estimate of how many packages would have been shipped* had the drawings not been posted electronically.

	# of drawings posted	# of packages shipped
2nd quarter of 2003	6742	134
3rd quarter of 2003	6271	124
4th quarter of 2003	5428	108

Let's assume half of the packages are sent by 2nd day shipping and the other half by next day shipping. Based on these assumptions, the savings are shown in Figure 17.

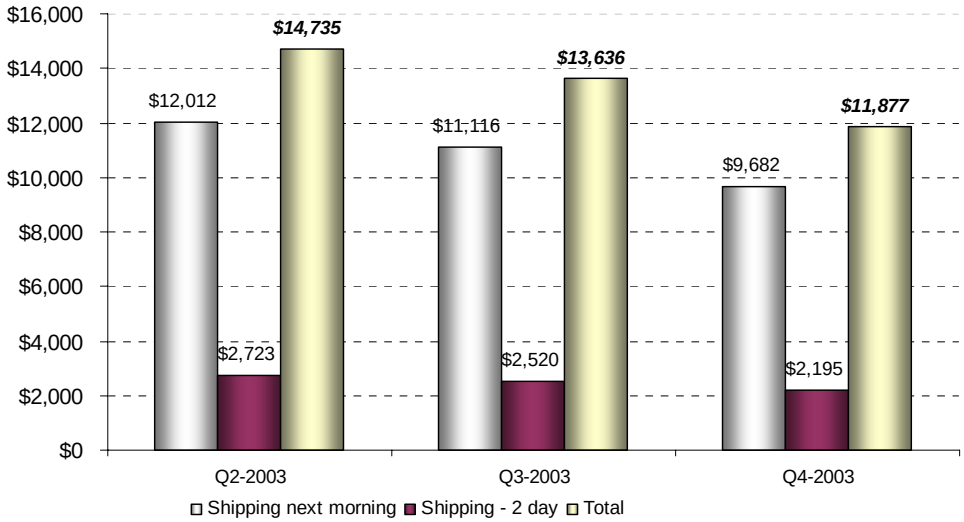


Figure 17. Estimated FedEx shipping charges

Total savings over a year and over three years for one project are as follows:

Total Savings:	
9 months	$40,248
1 year	$53,664
3 years	**$160,992**

We know TRM has 16 projects oversees that use the OCPM solution as of April 2005. If *we assume that at least 10 of these projects will have a similar design review process and that it will last for at least a year*, the savings will be around **$536,640** for 10 international projects.

Besides this specific example, let's assume that we have a project with a yearlong construction period where issues are addressed and documents are shared. The project has 5,000 documents (which is the average number of documents of 5 projects in Figure 18), including submittals, transmittals, meeting minutes, RFIs, drawings, specifications, etc. Estimating the reduction in printing and copying is a challenge, because most of the parties print the documents, either to have a record or back-up for internal systems or to communicate with upper management as they are not usual users of the tool. Brett Pitcairn of P.J. Dick comments, *"At some point they want to be paperless, but it is years away. There are still some executives who want to see information in paper and there are still some subcontractors who are not technology-savvy."* Therefore, we will assume that 50% of the documents are printed.

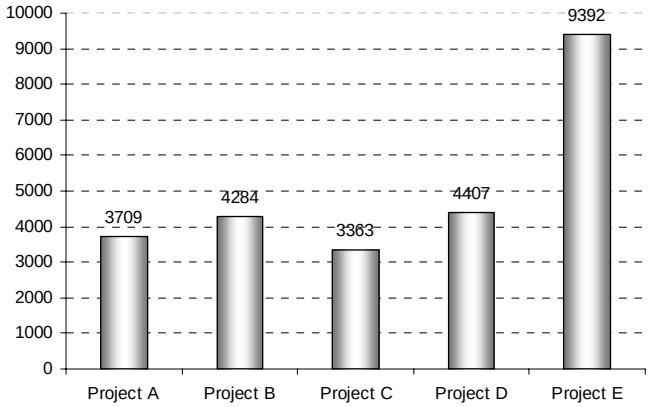


Figure 18. The number of documents stored in OCPM solutions of 5 construction projects

In all, there are 5,000 documents (we assume half are 1 page, the other half are 2 pages):
Total number of pages = 2,500 + (2,500 x 2) = 7,500

Assume 50% of documents do not need to be printed:
7,500 x 50% = 3,750 pages

Assume at least 3 parties would print if the system wasn't implemented:
3,750 x 3 = 11,250 pages of document

Assume cost of printing is $0.1 per page:
$0.1 x 11,250 = **$1,125** per project

Assume 75% of the documents don't need to be mailed due to efficient electronic transfer and that the cost of mailing is $1 per document:
$1 x 75% x 5,000 = **$3,750** per project

Total Savings:
3,750 + 1,125 = $4,875 annually per project

Assume that the office has 10 projects of the same size and duration within a year:
4,875 x 10 = **$48,750** annually for 10 projects

5.2. Quasi-tangible Benefits

Although efficiency savings are quantifiable in monetary terms, they are minor both from the investors' and collaborators' points of views. Steve Head, service support manager at Nationwide Building Society, comments, *"We focused on organizational-level benefits rather than individual project-level benefits. The reason for this is that business benefits rather than cost savings have always been more important for our organization. Performing the right tasks correctly, staying consistent with our mission, vision, and values, and supporting our goals and objectives have been among our most important goals in deciding to implement this technology."*

Like Steve Head, many managers are now appreciating the wider strategic implications of developing a robust and responsive technology infrastructure, yet this in turn presents businesses

with the dilemma of how to assess, quantify, and accommodate the implications of infrastructural investments within traditional methods of appraisal. Simple calculations present an attempt to quantify as much as possible. However, simple return on investment alone cannot present all factors that management must consider during the OCPM technology investment decision-making process. Some of the most-cited benefits of this technology fall into two groups. The *quasi-tangible group* has some direct measurable elements in benefits. The *intangible group* has only indirect benefits. Some examples of quasi-tangible benefits are: more timely information, improved planning, faster decision making, etc. These benefits focus on making organizational assets more productive through leveraging OCPM applications. In this section, the quasi-tangible benefits are presented based on the results of the interviews, case studies, and the survey conducted.

5.2.1. Benefits Ranking

Effectiveness is the ratio of achieved outputs to planned outputs. These benefits are not quantifiable, but are valuable. Besides interviews, an electronic survey of quasi-tangible benefits was designed and distributed via email to all interviewees to measure the improvement in a more consistent and less subjective way. The aim of the survey was to uncover as much information as possible and to quantify quasi-tangible benefits of OCPM technology investments. Each respondent received an identical list of benefits, phrased in exactly the same way in order to reduce errors resulting from the recording of responses, and the respondents were free to rank the benefits according to their relevance at the respondent's own pace. The survey covered several benefits that were stated during the interviews. The respondents were asked to rank the benefits 1 through 5 (where 5 is *"very high,"* 4 is *"high,"* 3 is *"neutral,"* 2 is *"low,"* and 1 is *"very low"*). Below are some effectiveness benefits as realized and rated by OCPM technology investors and users.

Rate	**Ranking**	**Quasi-tangible benefits**
37/38	4.35/5	Improved data availability
37/38	4.19/5	Enabled having complete audit trail
37/38	4.00/5	Improved information management
36/38	4.00/5	Enabled faster reporting and feedback
38/38	3.97/5	Provided accurate and timely information to give valid/accurate decisions
38/38	3.95/5	Improved process automation (RFIs/change orders, auto-updated master budget)
29/38	3.93/5	Improved information version control
37/38	3.84/5	Enabled better project/program control
36/38	3.61/5	Improved timely capture of design/construction decisions
37/38	3.57/5	Enabled fewer information bottlenecks
36/38	3.56/5	Enhanced working within virtual teams
32/38	3.47/5	Enabled quicker response to project status and budget
32/38	3.41/5	Improved quality of the output
28/38	3.29/5	Enabled better forecasting and control
35/38	3.26/5	Improved project relationships with strategic partners
30/38	3.20/5	Reduced rework/data reentry
34/38	3.06/5	Enabled better resource allocation; more effective assembly of project teams
22/38	3.05/5	Improved public relations
34/38	3.03/5	Reduced personnel costs due to improved efficiency

35/38	2.94/5	Improved idea sharing among team members/within organization
32/38	2.94/5	Minimized project/business risks
23/38	2.91/5	Enabled faster launch to market due to faster delivery
33/38	2.88/5	Reduced errors and omissions
23/38	2.87/5	Reduced delivery lead times
16/38	2.75/5	Enabled better inventory management
18/38	2.56/5	Enabled more effective identification and assessment of new suppliers
24/38	2.38/5	Enabled advance purchase of materials

Table 1. Quasi-tangible benefits: the number of people who rated the benefits (rate) and the average ranking for each benefit (ranking)

5.2.2. Top 10 Quasi-tangible Benefits

(1) Improved data/information/document availability:

OCPM technology helps the users to reach and search the project information globally. The technology provides a common archive for information that could be reviewed off-site and after hours by the collaborators. For example, when a team member travels and he is in a remote location or at home, there is no need to carry any computer or hard copies. Any authorized user can access the network and download the most updated project information wherever they are as the entire project resides in the Internet. Kim Verdier, document control manager in a TRM Healthcare project, indicates, *"The fact that I don't have to be on the site in order to do my function is great. I can take work home on the weekends or at nights just by having a computer at home."* The technology also ensures and forces the data population and provides a structured and easy way to store it. Adrian Wilson, the ITG project manager, comments, *"The tool is superb! It is very useful because all branch information is at one place and we don't have to create folders from scratch every time. Everything is in the library. If you send information regarding a certain branch, all the footnotes go to the library. That itself is a fantastic benefit. No matter where you are you can look at the project. The rest of the world sees it at the same time. I can go right now and use the information. If we were to send all of that information via email, we would lose track."* Michael Imbergamo, project architect of SmithGroup, indicates that the tool informs everyone about active development. He adds, *"I can go and take a look at the archive; what is open or active. I can find old but relevant information. It becomes a resource tool for all project members."*

(2) Enabled complete audit trail:

Having an archive of all project information as well as project communication and tracking the history of the documents posted (e.g. RFIs and submittals) have been identified as very valuable in case of any reviews or construction disputes. If an investor needs to prove a point, the OCPM solution would give him access to final documentation as well as the previous communication in a structured and credible way. Michael McKay, project manager of TRM Healthcare's Methoda project, says, "*I think having an archive of the entire communication is among the important benefits of the tool. We didn't have any claims or a major problem that we had to go back and resolve. But if we did, if a document wasn't there, it wouldn't be anywhere."* From the owner's point of view, having access to all project information is also very crucial. For example, although the owner doesn't usually get involved with the RFI process directly, they would have access to all modules and could track any RFI in case of any disputes. According to John King of J.J. Gumberg (the developer of the Carnegie Mellon University project), with 30 years of experience

in construction, it is hard not to have any unpleasant experiences during construction. He says, *"There are all kinds of things that can happen: litigations or weak memories. It is always good to have good record keeping. The Carnegie Mellon University project has been a very smooth project. But if there would be a structural problem 5 years from now, we would be able to go back and see if there were any questionable methods."* Dennis DiPalma of P.J. Dick asks, *"What if the key personnel who would solve the problem leave the company?"* Ed Costanza of Kitchell Contractors adds, *"We definitely have more documentation electronically than hard copies. We can build a catalog of documents in short order to argue a claim if needed."*

(3) Improved information management:
OCPM tools provide an extensive file management system with granted accesses or restrictions to particular project areas and folders. User actions can be simplified to allow the reading or creation of data with the minimum of difficulty. The users have the ability to imply the rules on folder naming, folder structures, and folder length. They can find the information from the database easily, and notification rules provide them with certainty of the activity. Mark Bittner, one of the area directors of Catholic Healthcare West, comments, *"It is very beneficial for related parties to have access to the same documentation via logs for submittal processing, RFI processing, change management processing, and meeting minutes."* Scott Grissom, project management systems coordinator at Rooney Holdings, comments on achieved standardization through OCPM technology, which saves time and brings consistency to their operations: *"Team members go from project to project and everything looks alike. They will be using the same system for each project they work on. They don't have to learn things over again. ... In the old days every project manager had their own ways; project to project things were changing."*

(4) Faster reporting and feedback:
Interviewees agree that the OCPM technology provides a faster and better way of working. Brian Killion, a senior project manager at Manhattan Construction Company, comments, *"The tool is saving time because everything is standardized. Take the meeting I was holding on Wednesday as an example. Before, I needed a certain amount of time on Tuesday and Wednesday to prepare for it. Now if I want, I can pull out some reports and understand where we stand."* Project teams are able to manage complex programs with decreased number of staff. They manage to be more effective as all of the external parties report through one system. Steve Young, the Indianapolis Public School's (IPS) facilities director, says, *"The tool has a very positive impact on our ability to manage the IPS construction program. We are experiencing more timely and efficient communications between the parties involved in the program, and that translates into lowered administrative costs, reduced risks, and improved accountability."* Increased speed and effectiveness of communication among the team players as well as within the executive team is another benefit. Project teams believe that their jobs' schedules have improved due to the quick turnaround of questions and easiness of information transfer. Sean Mathurin, team leader of design and specification support at Inscape, says, *"I can see who has done what in a project. So if someone says he has never received the drawing or the specification package from us, I can pull it out and prove that he had a look at it yesterday."*

(5) Enabled valid and accurate decision making:
OCPM technology facilitates faster decision making by enabling faster and more complete flow of information and speedier communication. Having a single source for the projects helps

managers with general management information – what projects they have in the system and the status of those projects – which was previously managed usually by databases where all project participants had to rely on somebody updating the information. Luis Hernandez, the acting director of facilities information systems at Los Angeles Unified School District, comments, *"There is a variety of benefits, but the greatest is organized construction information, therefore project visibility. This allows the division to effectively mediate issues of construction concern that could potentially lead to costs, legal costs, and impact."* OCPM technology also increases awareness. With the tool in place, project managers can easily realize any changes that would affect a project or a contractor. Moreover, they can easily realize the effect on the whole program by having a better view of the program's progress. Steve Head of Nationwide says, *"We now have an internal and external team who could previously only have coped with relatively low numbers of projects – now we estimate that with this tool in place we could considerably ramp up our activity with no loss of quality or loss of control."* John King of J.J. Gumberg agrees that the tool makes the job go as smoothly as possible: *"The information is available and understandable and makes the processes go efficiently. It is so much better than waiting for the telephone call. It makes the entire process more efficient."* He adds, *"The sooner you can get the information in front of the right people, the better you get them prepared for your next discussion as far as resolving a problem."*

(6) Improved process automation and standardization:
OCPM technology allows project teams to monitor and guarantee a certain degree of consistency in their projects. These tools guarantee that everyone is aware of the issues and everyone is informed about a proposed correction and agrees that it is acceptable. For example, issues brought up by the craftsmen and foremen are addressed and discussed during the design and construction using the OCPM solution communication. Scott Grissom, project management systems coordinator at Rooney Holdings, comments that he gets a lot of feedback that once the OPCM solution is up and running and all of the contacts are in the system, it is very easy to issue or answer an RFI or write meeting minutes. Users can link their RFIs to other documents; or with a couple of clicks the system can create the letter template for you. He adds, *"The increased automation and having all information in one place are what the users like the most."* Mike Parkinson, project manager of Manhattan Construction Company, adds, *"Web-based is great because we didn't need to catch up with the owner's computer system. We have consistency in the document appearance and format."*

(7) Improved version control:
In a construction project, it is important to make sure that all participants have access to the most updated documents to ensure that all parties are working from the same page. With the use of an OCPM tool, everybody can have access to the latest documents and files at the same time from anywhere in the world without waiting for the hard copies. Besides the cost savings from electronic document transfer, by utilizing OCPM technology the users can save an enormous amount of time – especially in international projects – by transferring and accessing drawings through the Internet. Ongoing availability of information when questions arise about a particular project has also been important to the team members. Marek Suchocki asks, *"If you have a dozen people working on the project, how can you be sure that all of them have the most up-to-date and relevant information? You cannot if you are doing it via emails or if you are mailing it and the*

drawings are sitting on the desk of somebody. With the tool, we are making sure that we are getting the correct information and we can see the previous history."

(8) Better project/program monitoring and control:
OCPM technology automatically tracks everything related to the project. The single database model allows team members to create reports and easily search to find the documents they need. In addition, the tool increases team member awareness through instant notifications and provides easy access to information for consultants. Having all project information stored in one centralized space helps the project managers to control the budget and the schedule more effectively. For example, project managers can easily analyze the effects of delays on the contract completion date. This involves hypothetically imposing the delaying event and carrying out a critical analysis to determine the new completion date. By performing a number of "what if" analyses and storing the results, the manager can prove the effect of delaying events. David Page of Los Angeles Unified School District comments, *"It is the small things that you don't see where the cost savings come in. For example, project managers don't have to go through everything; they just go to generate function. A meeting minute can take you half an hour to an hour. With this process, you just simply modify the items that are basically going on. The punch list, daily reports, meeting minutes. You are starting to save 30 minutes here and there, in total you are saving 2-3 hours a day, 2,000 hours of savings over the course of a year. If you have hundreds of projects, this is a substantial saving."* Karl Zook of Kitchell Contractors comments, *"The owner can look at the system and can tell if somebody is underperforming. It enables open communication and it is very beneficial to all parties."* Debra Kunce of Schmidt Associates says, *"It is a central point of information. From the owner's perspective, you can look across projects and compare very quickly. You can check how many RFIs and submittals you have and hopefully stop and divert issues before they happen."*

(9) Improved timely capture of design/construction decisions:
The ability to review multiple projects, wrapping many projects into one site visit and avoiding the need to revisit for each separate project, provides for more effective management. The interviewees also believe that the implementation of online approvals and comments in real time helps reduce the need for meetings and travel in many cases. Marek Suchocki of Atkins Management Consultants agrees: *"Being able to monitor multiple projects at the same time reduces the administration staff and provides better construction management."* In addition, an improvement in teamwork and professionalism is experienced through a positive attitude to utilizing OCPM technology from the entire project team. More effective management can be achieved with easy overall project management and control.

(10) Reduction in errors and wastage/fewer information bottlenecks:
Duplication of effort and wastage are key concerns on a construction project. OCPM technology gives all users certainty of information. The benefit isn't just having the correct version and having access to it but also having the ability to track the previous versions back and seeing who else has accessed or modified the information. Technology wastage has been addressed with a reduction in email and storage on personal computers. Michael Imbergamo, an architect from SmithGroup, confirms, *"The tool really helped us with the schedule. For example, there have been critical issues. We don't have to follow the normal way of processing the information. We are not tied to the individuals as we used to be in the past. The information is readily available*

with a couple of clicks." He adds, *"It brought efficiency to our processes. We only had weekly meetings and there were no surprises. Information was available to everyone."*

5.3. Intangible Benefits

Attempts to quantify intangible benefits in financial terms involve making assumptions and medium- to long-term forecasts in an environment that is very volatile (Milis and Mercken, 2004). These benefits are non-quantifiable in monetary terms, but represent soft return on investment or qualitative benefits. Business benefits rather than cost savings have been more important for the participating investors in most cases. Performing the right tasks correctly, staying consistent with the organization's mission, vision, and values, and supporting its goals and objectives have been among organizations' most important goals in deciding to implement this technology. Some performance benefits realized are: supply chain integration, process reengineering, gained market access, improved customer relationships, gained competitive advantage, performance measuring, knowledge management, and increased negotiation power. The intangible benefits realized in nine case studies are represented and discussed qualitatively in the following sections.

5.3.1. Knowledge Management

Data,[21] *information*,[22] and *knowledge* are terms that are often loosely used. Knowledge is information that is contextual, relevant, and actionable. It indicates recognition of the intellectual property rights that any organization owns (Sun and Howard, 2004). Knowledge is tied to the experiences, many years of work, completion of several projects, and it mainly resides in peoples' minds. For knowledge to be used for organizational success, it should be recognized as a form of capital, and must be exchanged between people and organizations. Managing knowledge assets can be a challenge, especially in the AEC industry where short-term working contracts and temporary coalitions of individuals can inhibit knowledge sharing.

Knowledge takes two forms: *tacit*[23] and *explicit.*[24] Explicit knowledge is the very factual information such as telephone numbers, details of previous contracts for a particular client, methods of repairing a common fault, etc. Tacit knowledge is widely celebrated as a vital element in improving competitiveness in an organization (Egbu and Botterill, 2002). It is increasingly being recognized as a vital organizational resource that provides competitive advantage. To make use of tacit knowledge for competitive advantage, it needs to be articulated and utilized by companies and their partners. This has compelled academics and practitioners to discuss the way in which knowledge can be managed; thus while knowledge management (KM) is fairly new to the AEC industry, it is emerging as a significant concept in management science.

OCPM technology provides a framework for creating, discovering, capturing, storing, transmitting, and reusing knowledge to gain competitive advantage. For example, determining who has what experience on past projects and providing ways of getting these people together

[21] Data is collections of facts, measurements, or statistics.
[22] Information is organized or processed data that is timely and accurate.
[23] Tacit knowledge is a cumulative store of experiences, mental maps, insights, acumen, expertise, know-how, trade secrets, skill sets, understanding and learning that an organization has (Sun and Howard, 2004).
[24] Explicit knowledge can be captured and stored and used without reference to others (SUN, M. & HOWARD, R. (2004) *Understanding IT in Construction,* London, Spon Press.).

with the others who need that knowledge. In other words, it provides a way to convert the tacit knowledge to explicit knowledge in order for it to be shared and utilized by others. The role of OCPM technology in KM is an essential consideration for any company wishing to manage their knowledge assets. The impact of IT could have a positive influence on KM applied to the construction process (Bush, 1999). The areas of this impact can be defined as: automating, informational, sequential, tracking, analytical, geographical, integrative, and intellectual.

Case Study:
After having the OCPM solution in place for their project and program management and realizing the benefits, Nationwide Building Society (Nationwide: UK's fourth largest mortgage lender and eighth largest retail banker) requested additional functionalities and space from the OCPM solution provider to facilitate KM. The goal was (1) to capture the knowledge that already exists within the organization and among wider groups involved in Nationwide's projects and (2) then to distribute business knowledge and strategy, project information, best practices, and experience gained from different consultants, suppliers, contractors, and projects. With their OCPM technology for KM (named TeamRoom) Nationwide not only aimed to capture comments and observations but also aimed to capture the knowledge in the spatial context of construction projects for purposes of understanding and delivering it to the right person at the right time [Informational].

Communities for special-interest areas and projects are built into the tool. As of March 2005, there were 15 different communities based on specific projects or special-interest subjects. With TeamRoom, one can open a discussion and have a chat room addressing questions and answers, and capturing people's ideas and experiences for future benefit. In TeamRoom, one can find agendas, project and contact information, etc. [Automating]. TeamRoom's communities include special interest groups, discussion rooms, news and event arenas, and a library where the participants can post documents. A participant can find all community members' names and contact information in TeamRoom [Automating]. The tool also provides useful links and a search engine. Participants can address a question to an expert listed specifically in that community. For example, someone who needs to know something about asbestos can search for the word *"asbestos."* As a result of the search, a couple of people will appear with specific expertise from the management to whom one can address one's questions. This way one doesn't have to go though the process of brainstorming or research to solve the problem [Intellectual]. TeamRoom helps to solve people's problems easily and intuitively by creating new solutions rather than repeating problems or wasting time by searching for solutions. Nationwide not only shares the knowledge within the organization with its employees but also shares it with its subcontractors and suppliers through discussion boards and libraries. Security companies working with Nationwide are the biggest contributors of TeamRoom.

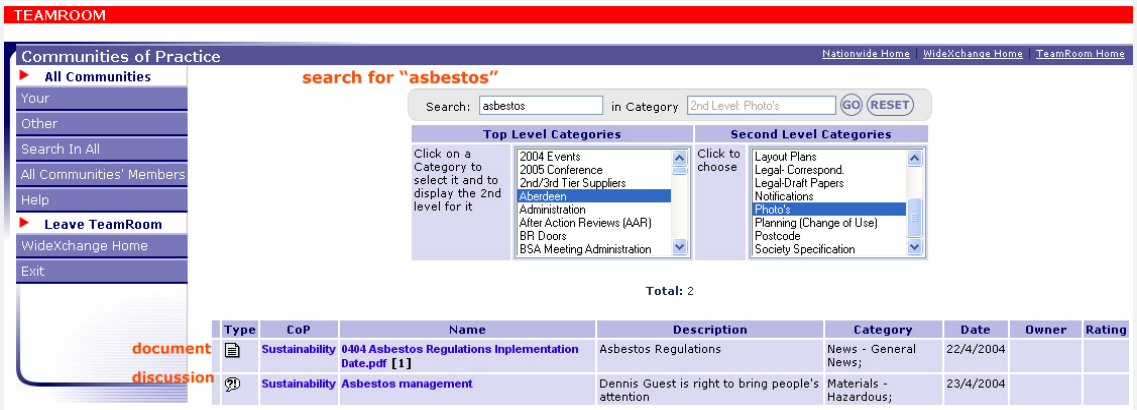


Figure 19. Results of *"asbestos"* search: people, documents, discussions, categories, and dates

The tool proved to be very useful in terms of time and cost savings in practical issues. Steve Head, service support manager at Nationwide, comments: *"We have been feeding the learning gleaned from each project back into our knowledge store – for example how difficult-shaped branches were handled, imaginative use of materials, effective building techniques, etc. We have even had competitive suppliers learning useful tips from each other and sharing expertise!"* [Analytical]. An example of knowledge sharing is a question asked by a contractor in the "sustainability" room about "pest waste." His question was answered by another contractor working in another project. Not only was this question answered in a short period of time, but some suggestions for where to find more information were provided by other people [Geographical]. Another example is immediate question and answer in the *"property and contract law"* community. If anybody has building-related legal issues, experts will answer these questions. For example, a question was asked by a supplier about field access. His question was answered immediately, free of charge. With the new version of TeamRoom, the relevant parties will be notified if a document is updated or a new version is added. Also, if a participant has a rough document that he wants others to comment on, he can post it in the library and open a discussion and link to the document.

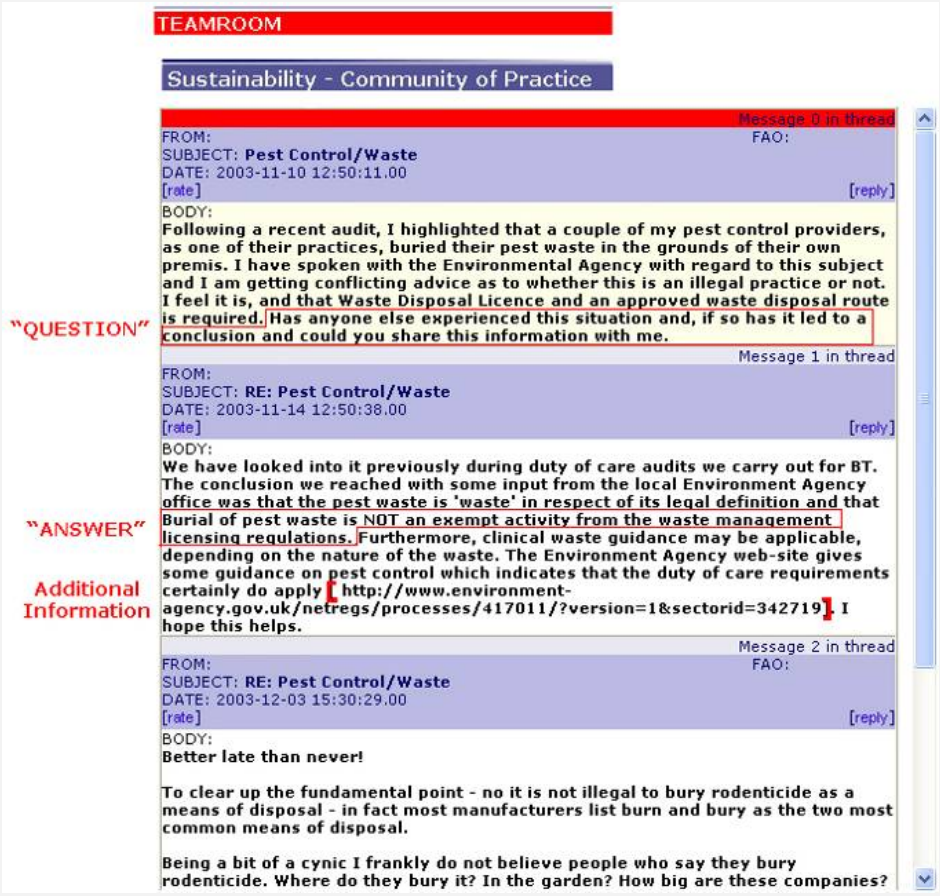


Figure 20. Answer and additional information to a question about pest waste

Nationwide is pleased to assist this fruitful collaboration and to be able to work with its contractors in a better way. The OCPM tool saves time as people spend less time searching for information and more time applying it. It improves the quality as lessons are learned from past experiences. In addition, there is less dependence on an individual, as some of their knowledge is available to all. Nationwide sees this chance of collaboration as an important learning opportunity rather than a sharing of their competitive advantage.

However, the question still remains: *How can you quantify the benefits of knowledge management?*

5.3.2. Process and Workflow Reengineering

Reengineering is a management approach that examines aspects of a practice and its interactions, and attempts to improve the efficiency of the underlying processes. It is rethinking and redesigning of a process or workflow to achieve improvements in critical, contemporary measures of performance such as cost, quality, service, and speed (Hammer and Champy, 2001). Workflow management is another process performance improvement in a cooperative networking environment (Aversano et al., 2002). There are very successful examples of OCPM technology implementations that have used the technology to create (if the organization was not working under a process model) or reengineer internal processes and workflows and establish procedures, templates, and determine the types of data to work with. In the context of this research, the research team came across two financial institutions that used the tool for this purpose. By doing so, the OCPM solution enabled organizations to review their existing processes and workflows, and provided a new way to reengineer them. Organizations gained the capacity to standardize and learn from what they have actually been doing for years. The approach was to configure the OCPM system to match the organization's processes rather than attempting to modify the processes to suit the technology.

Case Study 1:

Nationwide used their project and program management OCPM solution for refurbishment projects, of which they do about six thousand every year, and mandated that all contracted team members should use the OCPM solution for Nationwide projects. The OCPM implementation team *first* identified and explored Nationwide's refurbishment process, which has nine gates that the project actually goes through (Figure 21). These gates are: develop brief, allocate resources, feasibility, pre-contract period, lead-in period, site works, project review, performance review, and close out. *Then*, built these gates into the tool (Figure 22). For example, the project cannot proceed to the feasibility stage until a program plan for resource allocation is prepared and uploaded to the OCPM solution. Similarly, the site works stage cannot be complete until all snagging items are rectified. This *first* gave Nationwide a standard way of working, *second* assured a certain level of quality in all of their refurbishment projects while saving time by setting solid milestones, and *third* forced the information to be populated in these gates as the users cannot proceed from one phase to the next unless all the data is complete in the current phase. The main contractors are the biggest supplier of the documents. The system is also used for all data-storing requirements in Nationwide refurbishment projects.

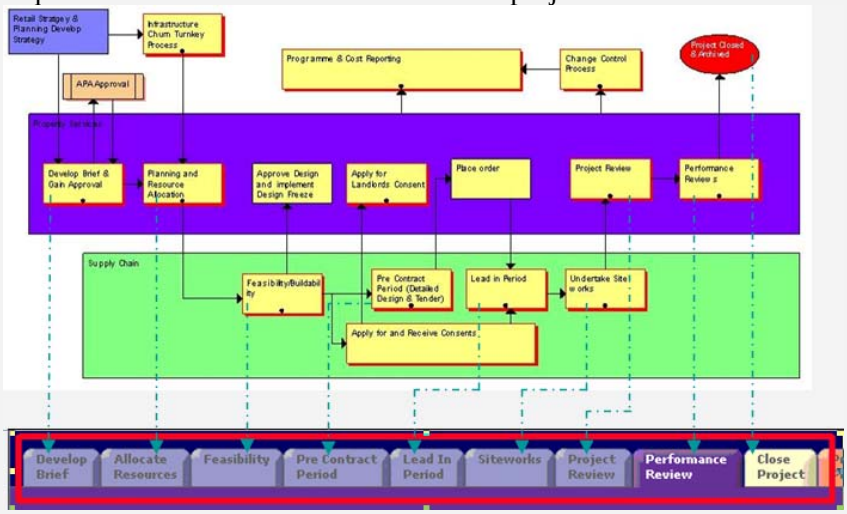


Figure 21. Refurbishment key gates/milestones (from Nationwide OCPM solution)

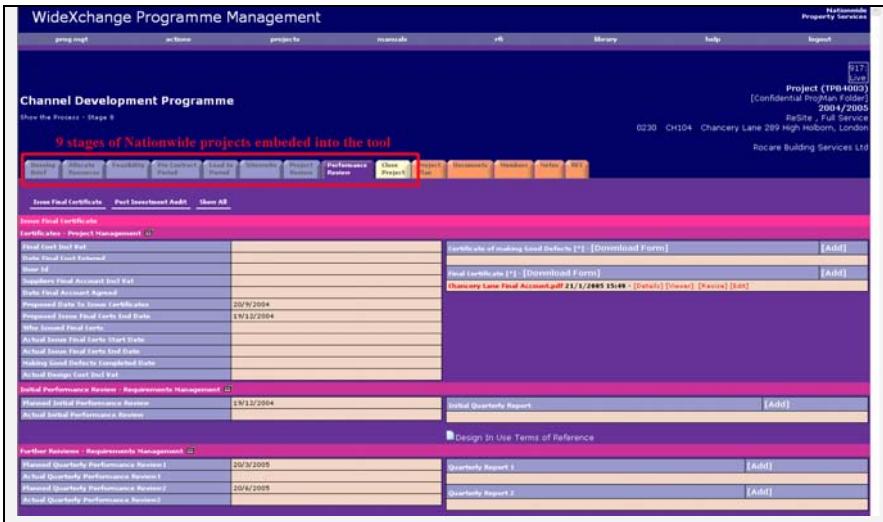


Figure 22. A screen shot of a project collaboration space in CDP; the project is in stage 9 (marked with white background)

Case Study 2:

Another financial institution from UK, the ITG Group, reengineered their design approval process completely, this time to keep up with the accelerated schedule of 1,750 branch refurbishments in a 14-week period. Finishing the project as fast as possible was crucial for ITG because the bank advertised the bank's new image in the media and announced the acquisition of another financial institution. Furthermore, the bank wanted to publicize the acquisition in the stock exchange as soon as possible, which was dependent on the completion of the refurbishment project. The timing, image, and reputation of the bank were three concerns. And any delays in the program would potentially harm the bank's reputation and customer perception.

The project team developed a new *"design approval process"* where traditionally complex aspects could be carried out with *"one click."* Simultaneously, any amendments to rejected designs were supported by an exceptions database. The team agreed to work with photographs and PDF documents instead of traditional architectural drawings, and the whole process was facilitated through the OCPM solution. An assigned person traveled and took pictures of 1,750 branches all around the country. The designers worked on the photographs, and when they finished the design, they uploaded the proposal to the system as PDF documents. Each of the photomontages (Figure 23) was supported with detailed design sheets, which included all changes to be made to the branch. The only thing photomontages offered was visual support, which satisfied UK planning authorities. A notification which included all iterations and revisions of the design proposal was simultaneously sent to the ITG project manager. If the ITG project manager approved the design proposal, the solution would send a notification back to the designer; otherwise the project manager would fill an exceptions log (Figure 24) which includes the reasons for the rejection and recommendations. A notification would be sent to the designer informing him that the proposal was rejected, including the reasons for the rejection. The next step would be the designer's corrections to the original proposal. The same uploading, notification, and project manager's approval or rejection would take place until the design was approved (Figure 25) by the ITG project manager. Similarly all users would be notified of new documents, approvals, rejections, and changes to any branch that they were involved in. Each document was stored in its native format with the solution, providing full version control as well as a definitive audit trail to guarantee effective project control. Many phases of the project required contributions from multiple team members to ensure that deadlines would be met. For example, the preparation of a photographic montage for each of the 1,750 sites required the designers to work exceedingly long hours. When extra resources were required, another team based in Prague was

commissioned. This very simple process enabled the ITG project manager to work from his home on the south coast of the UK and hastened the project schedule. The OCPM solution gave the bank a way to leverage their business processes.

Marek Suchocki, research and innovation manager at Atkins Management Consultants, says, *"This technology does certain things when you do the traditional process, but when you are looking at hundreds and thousands of projects in a small span of time, then one has to look at the technology and say 'how can we redo the old process?'"* Ben Myddelton, project coordinator at Atkins Management Consultants, says, *"The project would be possible but not with this schedule. It was a very speedy program."* William Lesley, the chief designer, agrees: *"It would be possible, but it would take a lot longer and it would be a lot more expensive."* Marek Suchocki searches and finds a project with a cost of £15,000. He says, *"What can you get for that money in a traditional project? You cannot actually get a consultant for that amount of money. That needs a lot of thinking."*

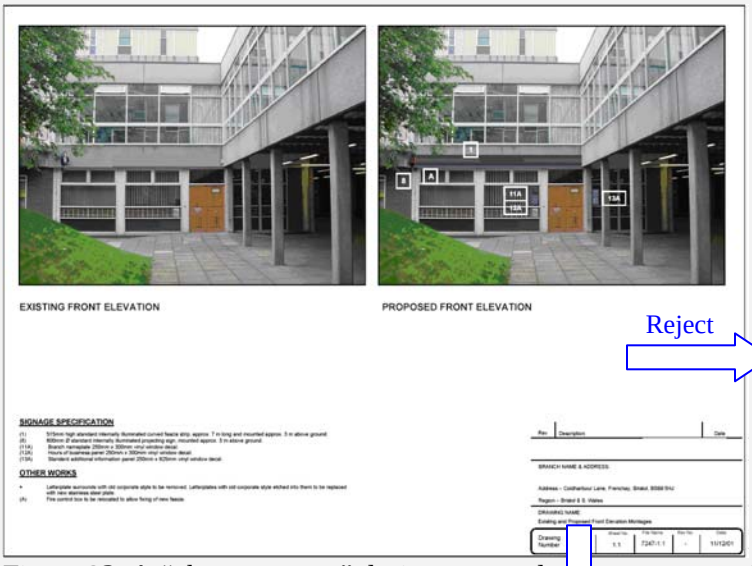


Figure 23. A "photomontage" design proposal

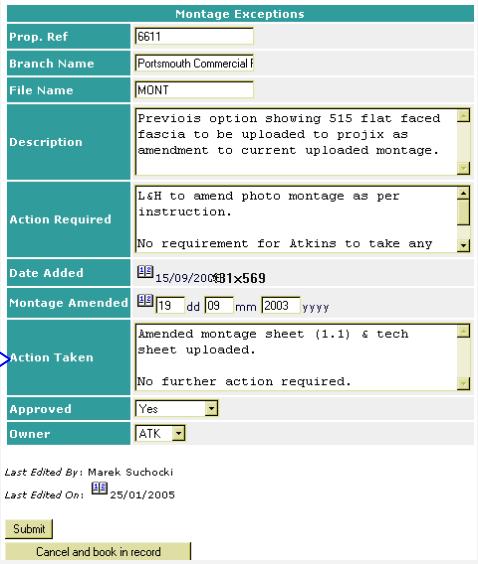


Figure 24. An exception's log

Reject

Accept

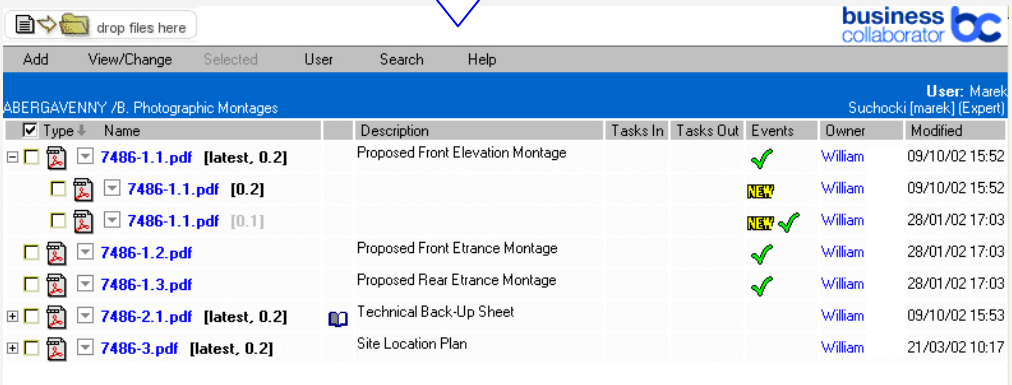
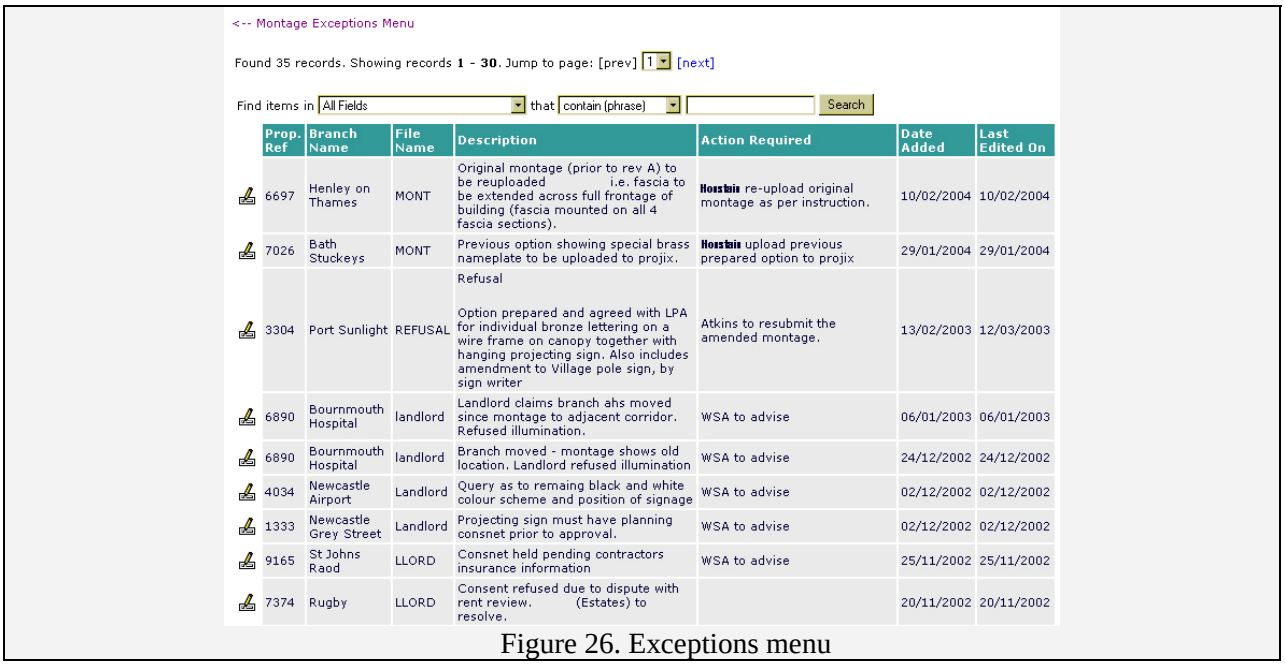


Figure 25. Design approval page



<-- Montage Exceptions Menu

Found 35 records. Showing records **1** - **30**. Jump to page: [prev] 1 [next]

Find items in All Fields that contain (phrase) Search

Prop. Ref	Branch Name	File Name	Description	Action Required	Date Added	Last Edited On
6697	Henley on Thames	MONT	Original montage (prior to rev A) to be reuploaded i.e. fascia to be extended across full frontage of building (fascia mounted on all 4 fascia sections).	Houstain re-upload original montage as per instruction.	10/02/2004	10/02/2004
7026	Bath Stuckeys	MONT	Previous option showing special brass nameplate to be uploaded to projix.	Houstain upload previous prepared option to projix	29/01/2004	29/01/2004
3304	Port Sunlight	REFUSAL	Refusal Option prepared and agreed with LPA for individual bronze lettering on a wire frame on canopy together with hanging projecting sign. Also includes amendment to Village pole sign, by sign writer	Atkins to resubmit the amended montage.	13/02/2003	12/03/2003
6890	Bournmouth Hospital	landlord	Landlord claims branch ahs moved since montage to adjacent corridor. Refused illumination.	WSA to advise	06/01/2003	06/01/2003
6890	Bournmouth Hospital	landlord	Branch moved - montage shows old location. Landlord refused illumination	WSA to advise	24/12/2002	24/12/2002
4034	Newcastle Airport	Landlord	Query as to remaing black and white colour scheme and position of signage	WSA to advise	02/12/2002	02/12/2002
1333	Newcastle Grey Street	Landlord	Projecting sign must have planning consnet prior to approval.	WSA to advise	02/12/2002	02/12/2002
9165	St Johns Raod	LLORD	Consnet held pending contractors insurance information	WSA to advise	25/11/2002	25/11/2002
7374	Rugby	LLORD	Consent refused due to dispute with rent review. (Estates) to resolve.		20/11/2002	20/11/2002

Figure 26. Exceptions menu

5.3.3. Supply Chain Integration

Supply chain management is the coordination, integration, and revenue maximization associated with the flow of products, services, information, and money across trading partners. It reaches beyond the boundaries of a single company to share the information between suppliers, manufacturers, distributors, and retailers (Hardaker and Graham, 2001). Optimizing supply chain activities is critical to all industries since it saves money and increases revenues. The research showed that the OCPM technology provides a valuable approach to supply chain management by reducing the waste and problems caused by myopic control. The benefits are seen in purchasing, inventory management, transportation, order processing, customer service, vendor relationships, and production scheduling (Rahman, 2003). By utilizing OCPM technology, companies can target new markets by offering low entry costs and relatively minimal complexity with more flexibility and a convenient way to transact business (Hardaker and Graham, 2001). By outsourcing and forming strategic alliances, companies provide an impetus to support the sharing of supplier, customer, and corporate information that was once proprietary with competitors and other cross-industry players.

An example recognized in this research would be Nationwide's branch refurbishment project where collaboration is needed between internal staff (needs to know what's happening when and what it will look like), financial staff (needs to know the costs), and technical staff (installs the IT systems). In this and many other cases, not only do departments within the organization work together, but external parties (a wide range of suppliers and subcontractors) also need to collaborate in order to realize construction projects. An example would be the need for communication between the Automated Banking Department and the Technology Department in planning an ATM installation, and communication with the main contractors for execution of the work. Previously the organization didn't have a single source to monitor what was being done when and by whom. It was impossible for external parties to get through the organization's firewall. With the implementation of the OCPM solution and hosted databases by the vendor, the organization started pushing and pulling information not just to the internal parties, but also to

the external parties. The tool brought multiple projects together and made them visible to the whole project team. The system is substantially supplementing the organization's delivery capability. The major benefit has been the improved communication both internally and across the supply chain. While this is a benefit, the more significant benefit is that it provides consistency in management and coordination in an efficient approach and, more importantly, enables knowledge exchange and management of risks. The tool brings reliability and easiness to information distribution and allows anyone in the supply chain with access to view all records and project and program progress. It ensures that information for all the projects is maintained and kept up to date at all times.

5.3.4. Competitive Advantage

Information technology (IT) helps companies to gain competitive advantage either by performing primary and support activities at a lower cost or performing these activities in a way that leads to differentiation and a premium price (Porter and Millar, 1985). The evaluation of IT is a perennial problem for businesses as they seek to improve their performance and sustain a competitive advantage (Love et al., 2004). While most industries are increasing their expenditure on technology, IT has not yet been recognized as a distinguishing factor that contributes to an organization's competitive advantage for some industries such as construction (Atkin, 1990).

However, it has been observed that many companies have implemented OCPM technology to save time and effort, to gain competitive advantage, to improve productivity, to better align objectives, and to improve product quality. Examples of competitive advantage gained through OCPM technology are competitive tender pricing, improved cost performance, high engineering standards, differentiated services, penetration of overseas markets, advantageous source of equipment, supplies and manpower development, and better service to the clients. Benefits are, mostly, realized by contractors, subcontractors, and construction management firms. These firms believe that they have gained competitive advantage by utilizing the OCPM tool earlier than their competitors. Many managers also agree that having an OCPM tool in place is becoming a contract requirement and a bigger topic of conversation with the owners; therefore it is becoming a larger part of the sales presentations. Clients are more interested in the use of OCPM technology, and how quickly a contractor can go live with the tool is very important, especially on large projects. From a new business standpoint, it is a huge plus to show what capabilities an organization can positively contribute to the owners beyond the standard way of thinking. Actually, some sophisticated owners already demand the use of an OCPM solution for the execution of their projects. The use of these systems is increasingly becoming part of the criteria of selection – if not of requests for proposals – and surprisingly a lot of contractors or construction managers are still not using anything similar to this technology.

5.3.5. Business Development

Besides the traditional implementation and use of OCPM systems, there are several innovative approaches followed by the AEC stakeholders. One of them is the use of an OCPM tool *first* to gain market share, *second* to build new relationships with end users, and *third* to bring visibility to sales. Inscape, a furniture manufacturer in Canada, wanted to use the OCPM technology to differentiate itself in the market by approaching clients to understand their needs and challenges in a construction project and providing them an OCPM solution as a solution to manage their projects. Inscape's main goal was to increase sales by gaining market access. They managed to

achieve their goal by building relationships with potential customers and by bringing the customers' projects to Inscape's attention. While all competitors in their field was trying to communicate the value of their work, Inscape wanted to provide a way to create a value by using OCPM technology.

Case Study:
Inscape Corporation (Inscape), headquartered in Holland Landing, Canada, is a leading designer and manufacturer of high-performance workplace solutions. Inscape offers a wide array of product solutions for modern office interiors, including movable walls, post-and-beam architectural products, office systems, storage products, seating, and ergonomic work tools. The increasing competition in the market squeezed Inscape, the smallest competitor, out of distribution. Therefore, Inscape decided that they needed to reinvent their marketing strategy and go ahead with a different marketing approach and out-innovate the competition.

Being the smallest player in the market took away the advantages a big player might enjoy such as a large sales force or competitive pricing. The company had never done two things: *first*, marketed to end users directly – they had always depended on channel partners for marketing as well; or *second*, tried to learn the needs of their clients. This caused a poor understanding of the market realities. As a result of a buyer behavior exercise conducted subsequently, they decided that their target should be the real estate brokers, building owners, and project managers, as these parties are the ones who know about a project well before anybody else does and they are the decision makers or influencers. Inscape started to think about the difficulties these people faced, and quickly identified *"project management and communication"* as a common challenging task, and one that isn't the core competency of most owners or brokers. Therefore, Inscape determined to become a very *customer-centric* company where customer needs and challenges are the priorities.

As part of their *new marketing strategy*, Inscape would offer the OCPM technology to real estate brokers and project management communities as a new way of managing owners' projects and potentially helping them save time and money. So Inscape started setting up projects and giving access to team members very inexpensively for project teams' internal communication long before the teams started to think about furniture. Later, as part of the launch of this go-to-market strategy, Inscape also offered up to four "test-for-fit" services facilitated through the OCPM solution. In this case, a potential customer of Inscape uploads their base-building drawings to the system. Then Inscape works on the fit-ins and sends the drawings back to the designer through the OCPM tool or the brokerage house as the case may be, for the end users to review. The end users can mark up and discuss the drawings electronically and send them back to Inscape through the OCPM solution. While the tool provides a practical way to facilitate this exercise, Inscape learns about the project ahead of time. In addition, the tool offers a complete and comprehensive audit trail of any information exchange, including online meetings, which are recorded and can be replayed later. Inscape's only requirement is to be given an equal chance of being a party to the project with the other furniture manufacturers. If Inscape is not awarded the furniture contract for some reason, they still allow the owner to use the tool for the project. In this case, Inscape creates guest licenses and allows their competitors to work only in that particular project without being able to invite others.

With the industry growing and Inscape's innovative use of the OCPM technology, Inscape is again well positioned. Its sales are growing steadily (tripled their presence in Toronto alone), as they now have a new approach to market and each collaboration partner has their own relationships they bring to the table. Besides the increased market access, this tool substantially helped Inscape in building long-lasting relationships with their customers. As construction projects require the collaboration of numerous parties, the OCPM tool is exposed to more projects and so is Inscape, building more relations with owners,

subcontracting trades, and contractors. As the OCPM tool brings several benefits to project teams from the project management standpoint, Inscape's negotiations for its product have become much easier. Inscape has noticed that the customers don't usually bargain for a price reduction on the furniture when they are enjoying efficient processes, shorter project cycles, and reduced costs. By offering this service to the project team, Inscape has gained access to the players down in the supply chain such as real estate brokers, designers, end users, and dealers. The tool and the service proposition enable Inscape to meet project stakeholders that they usually have no access to. Dan Kennedy, sales analyst at Inscape, says, *"Getting involved in the project sooner, this is one way that we can spark up in the conversation sooner. This is extremely important for our sales."* In addition, Inscape realized potential benefits in its own operations such as efficiency in its internal sales and design development. Internally, if they hadn't implemented the system they would have lost responsiveness to customer needs and requests, the speed and accountability of information transfer, as well as the audit trail. Jacquie Spencer, project coordinator, says, *"If we don't have the tool we would go back to extended response times because we will be dealing with overnights and time zones. It can slow down our process seriously."*

5.3.6. Forecasting

Another innovative use of OCPM technology is employing the solution for *forecasting.* For public entities such as the Los Angeles Unified School District (LAUSD), reporting and accuracy of information is critical as in most cases the success of the program depends on subsequent phases' success because funding for the new school construction program is primarily provided through tax revenues.

Case Study:

The Los Angeles Unified School District's (LAUSD) new construction program is a multi-phased, multibillion-dollar program to deliver new school facilities with the aim of relieving critical student overcrowding throughout LAUSD. This overcrowding has resulted from *one,* increased student enrollment; *two,* state-mandated class-size reduction; and *three,* lack of funding to expand capacity in the years prior to this effort. This new construction program requires LAUSD to identify target areas of need, acquire necessary sites, design and develop plans, and construct schools as quickly as possible. Over the next six years, LAUSD will complete 139 new construction projects to accommodate explosive growth in the student population. There are three finance mechanisms generating funding to meet the needs of a new construction program: *first,* bonds, which are issued by government agencies for the purpose of raising money; *second,* direct revenue generated from tax receipts and interest; and *third,* grants, which are gifts of money for a specified purpose from various sources. For public entities such as LAUSD, reporting and accuracy of the information is critical, especially in the preconstruction phase during which two factors, *design* and *acquisition of the land,* affect 95% of the total project costs. In the first six to eight months of construction projects, LAUSD certifies and makes its budget commitments. Therefore, accurate forecasting of the costs of a project is extremely important. LAUSD utilizes the OCPM solution in order to control the budget activity in an easier and more precise way.

Using the OCPM tool also as a forecasting tool required some degree of customization. LAUSD brought in experts to set up the entire set of budget constraints and a layer that shows all the potential costs. This allowed managers to check the budget of each project as well as the master budget for the overall program. LAUSD uses the OCPM tool to create a series of cost codes and ties the costs to LAUSD's accounting system. LAUSD built nine phases of construction into the tool. These phases are actually a crosswalk definitions table that ensures consistency between LAUSD's accounting system and the OCPM solution. Since LAUSD's accounting system is set up primarily for operating a school district (with teachers' salaries, etc.), they have attached the capital construction program on top of this system using only selected cost codes for proper coding. The phases refer to the work areas that occur throughout the

entire life of a project, including the site, environmental, plans (architectural, structural, etc.), construction (contracts, utilities, demolition, design and construction costs, etc.), management (real estate, design, project management, construction management), tests (soil, structure, other), inspection (construction, technology), furniture and equipment, and community outreach. LAUSD is planning an Oracle-based automatic upload from the accounting database to the OCPM system to include project contract commitments, expenditures, and encumbrances. LAUSD managers use the tool as a way to predict future costs. The tool has categories for budget (current, pending, estimated + adjustments, projected) and commitments (original, approved revisions, pending revisions, estimate to complete, anticipated). By comparing anticipated costs to projected budget, LAUSD managers have good track of what funds are available for each project and what has been spent to date in any given region. Charlie Anderson, LAUSD Program Manager, says, *"The single biggest benefit is that we can see where the trends are going and we have the power to do something before it is too late."*

ANTICIPATED COST REPORT (ACR)

		BUDGET				COMMITMENTS					OVER / (UNDER)
PHASE	Cost Code	Current Budget (C)	Pending Revisions (D)	Estimated + Adjustments (E + F)	PROJECTED C + D + E + F (G)	Original Commitment (H)	Approved Revisions (I)	Pending Revisions (K)	Estimate to Complete (L + M)	ANTICIPATED H + I + K + L + M (N)	Anticipated Costs vs. Projected Budget (N - G)
2 ENVIRONMENTAL											
2.E.1-71	DTSC (DEPT TOXIC SUBSTANCES CONTROL)										
2.E.1-72	PEA (PRELIM ENVIRONMENTAL ASSESSMENT)										
2.E.1-73	RAW (REMOVAL ACTION WORK PLANS)										
2.E.1-74	RAP (REMEDIAL ACTION PLAN)										
2.E.1-75	CEQA (CALIF. ENVIRONMENT QUALITY ACT)										
2.E.1-76	AIR TOXICS										

Figure 27. Example of one category and some of its subcategories from OCPM solution of LAUSD (Courtesy of Charlie Anderson)

5.3.7. Risk Management – Claims Mitigation and Management

Changes are major sources of construction claims and disputes. Many cases indicate that the main cause for claims is disagreement between the parties about equitable compensation. Timely and accurate project information is the cornerstone of a successful claims resolution in today's fast-paced, information-intensive projects. In broad terms documentation is essential to support the claims management process. During litigation planning, a claim analyst will rely on documentation to define the disputed issues, establish production facts, plan a case scenario, etc. Moreover, documentation is instrumental for discovering the relevance of a claim, establishing a damage value for the facts under dispute, setting up a credibility standard for proof of entitlement, ascertaining the impacts or damages, and supporting claims for additions or omissions for changes. The problems with claims management are most profound in the areas of claims justification and quantification and are acute with respect to retrieval of supporting information and adequacy of information (Vidogah and Ndekugri, 1998).

All project groups are susceptible at one point or another to becoming involved in a claim. Suppliers, subcontractors, trades, consultants, and owners need quick and easy access to the wealth of knowledge that exists within the collective documentation of the project operations in order to make claim decisions and realize their damages. The claims management stages involve: ensuring compliance with provisions of contract, justification of the claim principle, and quantification of the claim. On a major construction project, the main contractor has to assimilate paper-based documentation of, say, a dozen subcontractors as well as the design team, and manage subsequent changes. It is no surprise that vital evidence required to substantiate claims takes ages to identify, retrieve, and assemble. OCPM technology removes a major obstacle to preparation of well-substantiated claims less likely to be disputed. Absence of necessary information is particularly the case with information that establishes a casual link between the amounts claimed and the events giving rise to the claim. This absence forces contractors to use questionable approaches to the quantification of claims. In all cases of this research study, the

projects' team members stressed the importance of the OCPM solution *one,* to prevent potential claims, and *two,* to manage the review of construction disputes.

With the use of the OCPM solution, project teams minimize the risk of losing data. Considering the number of projects and the size of the construction programs, it has been very important for the investors that the information is centralized, recorded, and never lost. David Page of LAUSD, OCPM tool implementation leader, explains from his own experience: *"I was involved with a project in which we had everything in the tool. There was the first series of heavy storms. The contractor had started the excavation but they actually lost part of their job site because of flooding. The question came up about who is responsible for the erosion control. It was the time when most files were displaced and some were destroyed due to flooding. What we found out is during the pre-bid process, there was a significant RFI that came in from one of the contractors asking if erosion control is supposed to be in the earthwork contract. The response came back from the owner that it was. [Until then,] we didn't know that the same contractor who filed the claim had written a letter stating that they wanted to verify that the erosion control would in fact be included in their contract even though it wasn't stated in the bid documents. It was signed by the same gentleman who was filing the claim. The overall claim was about $300,000. The district paid $35,000 because we considered it as a natural disaster.* ***That one claim itself paid for the entire system****."*

Having an archive of all communication and information is important in case of any reviews and construction disputes. If the teams need to prove a point, the OCPM tool would give them access to final documentation as well as the previous communication in a structured and credible way. Michael McKay, TRM Healthcare's project manager, says, "*I think the increase of communication and having an archive of all of this communication in case of reviews are important benefits of the tool. We didn't have any claims or a major problem that we had to go back and resolve. But if we did, if a document wasn't there it wasn't anywhere."* According to John King of J.J. Gumberg, Carnegie Mellon University Collaborative Innovation Center project developer, with 30 years of experience in construction, it is hard not to have any unpleasant experiences during construction. He says, *"There are all kinds of things that can happen; litigations or weak memories. It is always good to have good record keeping. The Carnegie Mellon University project has been a very smooth project. But if there would be a structural problem 5 years from now, we would be able to go back and see if there were any questionable methods of doing something."* This means that, in case of any claims or disputes, the investor doesn't have to go back and spend a lot of time trying to research their archives or the email files of their employees. Dennis DiPalma of P.J. Dick Incorporated asks, *"What if the key personnel to solve the problem left the company?"* If all the information is in the system, it is documented and nothing can be deleted. From the owner's point of view having access to all project information is also crucial. For example, although the owner doesn't usually get involved with the RFI process directly, they would have access to all modules and could track any RFI in case of any disputes.

In most projects, all documents that are part of the contract and any information that is specified by the contractors are being tracked through OCPM solutions. Rodger Hughes of LAUSD, owner's authorized representative, says, *"You don't have to go and dig into a file cabinet. This is a great legal tool. Any backups the contractor has – sketches, letters, documents – are always in*

the system." Charles Wren, LAUSD's on-site representative, adds, *"We don't have any formal claims in the project yet, but we have several construction disagreements. I think the records will help us in case they turn into claims. All parties know we register everything to the system. The best way to stop a claim is to stop before it happens."*

5.3.8. Performance Measuring – Setting Incentives

Another innovative use of OCPM solutions is for reviewing the performance of the project and the main contractors once the project is completed. If the data from earlier work is integrated into the system, these solutions can enable measuring contractor performance against past performance. The tool can measure how they performed on a particular project. This enables the organization to set a benchmark of their work performance and evaluate main contractors' performances. According to these assessments, the investor can reward some contractors with more projects if their performance is good or improved, and reduce the workload of others if their performance level is low. There are several benchmarking capabilities built into these tools that allow the investor to manage the process and key drivers. Contractors and all other nominated parties are also able to manage their own key performance indicators (KPIs) to ensure that they can also manage their individual processes and make changes as necessary. KPIs are measures of different aspects of a project that can be used to monitor how a project or a program is performing against targets to review the delivery efficiency. For example, the investor (in this case the owner) could assess how accurate the final cost is compared to the budget cost as a percent of accuracy. This would enable the investor to assess and compare accuracy across all projects. Similarly the investor can measure the number of defects on completion as a score, to assess and compare the impact on the end user of any defects at the time of handover. Measures like this would enable some key performance statistics to be generated on a project or a program to assess how it has performed across a number of different categories. The investor in turn can track these changes through the tool. The performance module allows the investor to mine its project data to see whether it is hitting KPIs at project and also program level. They can also generate performance reports based on these KPIs.

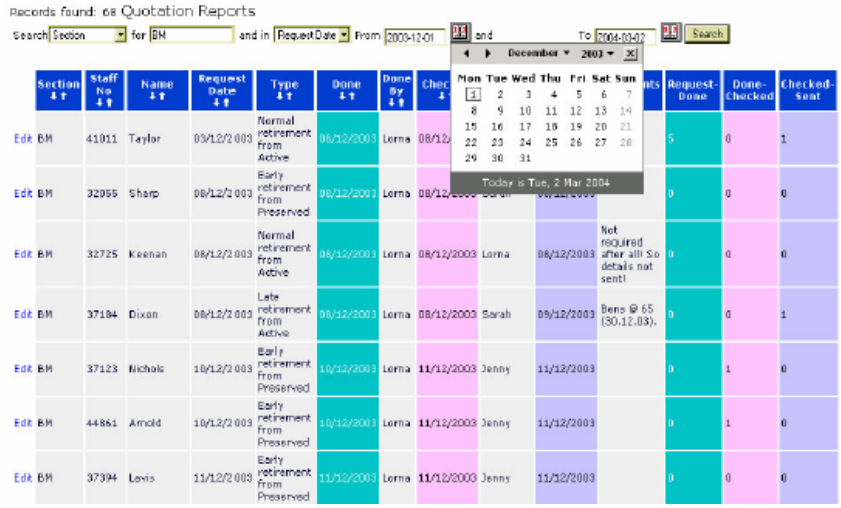


Figure 28. OCPM technology enables the team to run reports on progress and calculate KPIs

6. CONCLUSION

The evaluation method, explained in the previous sections, was successfully completed in nine case studies. The outputs of the OCPM technology evaluation method in each of these nine case studies can be seen in Table 2.

Case Name	Tangible Benefits ($)	Quasi-tangible Benefits (rating)	Intangible Benefits (identification)	Cost/Program Ratio
Indianapolis Public Schools *Owner*	**$59,000/year** (10 projects)	**3.94/5.00** **20 benefits** out of 27	*Not identified*	**0.07%** (considers 1st phase program)
Inscape Corporation *Supplier*	*Not considered*	**3.48/5.00** **12 benefits** out of 27	**4 identified:** Increased sales, Market access and exposure, Better customer relations, Negotiating power	Pass the cost to the owner
ITG Group *Owner*	*Not considered*	**4.04/5.00** **21 benefits** out of 27	**2 identified:** Process reengineering, Realization of ambitious schedule	**0.1%** (the cost includes development of the software)
Kitchell Contractors *GC/CM*	**$42,000/year** (10 projects)	**3.50/5.00** **15 benefits** out of 27	*Not identified*	Pass the cost to the owner
LA Unified School District *Owner*	*Not considered*	**3.80/5.00** **19 benefits** out of 27	**2 identified:** Forecasting, Risk management	**0.02%** (considers 2nd phase program & includes develop. fees)
Manhattan Construction Company *GC/CM*	**$59,000/year** (18 projects)	**3.64/5.00** **14 benefits** out of 27	*Not identified*	**0.04%** (assumes the firm has at least 4 $100mil. projects every year)
Nationwide Building Society *Owner*	*Not considered*	**3.90/5.00** **25 benefits** out of 27	**4 identified:** Supply chain integration, Knowledge management, Performance measurement, Process reengineering	**0.15%** (the cost includes development of the software: PM & KM)
P.J. Dick Incorporated *GC/CM*	**$47,100/year** (10 projects)	**3.50/5.00** **20 benefits** out of 27	**1 identified:** Competitive advantage	*"not released"*
TRM Healthcare *Owner*	**$536,500/year** (10 projects)	**3.65/5.00** **13 benefits** out of 27	*Not identified*	*"not released"*

Table 2. Tangible, quasi-tangible, and intangible benefits, and cost-to-project/program ratio, for nine OCPM technology investment implementations

In four out of nine case studies, the investors hadn't focused on tangible benefits during or after the investment decision regarding the OCPM technology; therefore these savings weren't and couldn't be considered in the study. In these cases, investors focused on organizational-level business benefits rather than project-level benefits. This has been experienced as a clear tendency among the investors. It was found that two major difficulties are making the OCPM evaluations

problematic to complete. The first difficulty is the process of identifying the benefits. It was secondly found difficult to estimate the value of the economic benefits. The evaluators often felt that the estimations given were too imprecise and therefore required a further examination.

If we examine the findings in depth, we realize that the tangible benefits vary between $42,000 and over $500,000. Even the lowest figure for the tangible benefits is more than the investment cost itself, which justifies the investment without any need to explore further. Quasi-tangible and intangible benefits become pluses of the investment after the break-even of tangible benefits. However, the research team finds tangible benefits arbitrary to a certain degree as they are based on some degree of assumptions such as percentage of printing and mailing. In addition, in some case investors don't get the direct benefits in savings but other team members realize them. For example, if the investor is the owner, most savings from printing, faxing, copying, etc. would be realized by the other team players.

However, the positive impact of OCPM tools on construction processes is quite obvious. Among these are electronic RFIs, bidding, and document transfer. The research findings show that the new RFI turnaround time is as low as ***5.4 days*** compared to 14 days of the industry average. Although it might be difficult to project reduced RFI turnaround time on the project schedule, most users believe there should be a positive correlation between the gained efficiency in the critical processes such as RFIs and the project's overall timeline. In addition to reduced turnaround of construction workflows, OCPM solutions bring enormous efficiency and savings to the document exchange process as well. As calculated by one of the investors, these savings can get as high as $536,500 depending on the organization's project portfolio, processes, and team members' number and locations. OCPM technology is also used commonly in the bidding process due to the efficiencies gained in preparing, distributing, and organizing the bid documents. Time and dollar savings are enormous. According to the calculations of one of GSA's Service Centers, the savings could be around $52,000 without any additional increase in cost of the investment. The research team came across similar use and benefits in several other implementations, one of which is an implementation by a government agency in the UK. The solution was successfully used in transferring over 3,000 data files, internal and bidder queries and answers, invitations to bidders, exchange of the documents, and circulars. As a result, the investor reduced the cost of the bidder query process and its onerous nature and realized cost savings in excess of $500K in document production and distribution alone. Besides the monetary savings, having a complete audit trail, controlled access to information, improved processes; clearer documents, up-to-date information, and faster RFI turnaround were among the most-quoted benefits of utilizing these tools in the bidding process.

In all, the average savings per project is $149,000. One may argue that this figure is subjective, because savings pass from one to another and it is very difficult to document how much is being printed, mailed, and copied between parties. Although efficiency savings are quantifiable in monetary terms, they are minor as compared to the rest both from investors' and collaborators' points of views.

If we look at the "non-quantifiable" benefits of OCPM technology, we realize that the quasi-tangible benefits were ranked 3.50 (out of 5.00) at the lowest end. The highest ranking for quasi-tangible benefits was 4.04 (out of 5.00). Intangible benefits were not identified in all of the cases.

Again, the main goal of the investor is extremely important when evaluating the benefits of OCPM tools. Special attention should be given to the drivers behind the investment decision: whether tangible, quasi-tangible, or intangible benefits, or a combination of these. In most cases, implementation beyond the regular use of OCPM technology was realized. Some examples of these are: increased sales and improved customer relations, forecasting, risk (claims) management, process reengineering, supply chain management, and competitive advantage. Although these benefits are not quantifiable or measurable, it has been experienced that they are extremely critical for organizations' business goals and profitability.

The cost information is considered to be commercially sensitive from both the investors' and the vendors' points of views. In two case studies, the cost of the system wasn't released upon the request of the investor and the solution vendor. However, in all, the highest cost-to-program ratio is ***0.15%***, which is quite small when information technology investments are considered. It should be noted that in this ratio, the cost includes a serious level of customization of the solution, which eventually increases the percentage. The smallest cost-to-program ratio realized was ***0.02%***. This number is quite low for any kind of efficiency realized in return. It is evident that once the investment is made, it is important to roll it out to as many projects as possible so that the investor can enjoy the benefits of economies of scale.

In terms of common trends in the implementation and use of OCPM technology in the AEC marketplace, there are several promising developments. First of all, the investors and users are fully convinced about the benefits of these tools in their operations. OCPM technology is becoming a standard way of managing construction projects, and going back to paper-based management systems seems almost impossible. However, the importance of the implementation has also been realized by the investors and users. Therefore, in most cases, the research team realized a verbalized need or action for new implementation strategies. The teams are considering optimizing the use of their OCPM solutions and starting with rolling out the most used modules, which generally include the document management module. In most cases, reimplementation is carried out by a staged strategy. Serious importance is given to training the users, mandating use of the tool, and supporting the implementation by top management. *Overcoming change and cultural barriers* are amongst the hottest topics of OCPM implementation.

In addition, the investors realize that integration of their OCPM solution with their other key software is critical for getting the best desired results. Some efforts in the industry are integration of the OCPM solution with accounting, contracting, and purchasing solutions. Many investors are considering ways to easily reuse and reconfigure their OCPM solutions for future projects. Being able to use the data, information, and knowledge collected throughout the construction projects by the OCPM technology is an area that investors pay serious attention to. For example, investors want to import information to their facilities management software and attach intelligent data to it. Knowledge management, revisiting data on past projects, and having a universally accessible library are common thoughts among the investors.

In summary, OCPM technology is an invaluable asset for AEC industry organizations and projects. Investors and users agree that if they didn't have their OCPM solution in place, they would lose:

- their control of the overall program,
- information availability to make valid decisions,
- advantage in resolving disputes,
- efficient communication and coordination,
- their ability to enforce the workflow and data population,
- individuals' time,
- accountability and accessibility,
- ownership of the data,
- decision-making advantage, and
- standardization throughout their projects.

The owners and general contractors are among the common investors and users of these tools. Architects, engineers, and construction/project managers are also frequent users of these tools. However, it is rare that the suppliers and subcontractors use the tools, mostly due to security, cost, and technology-proficiency-related reasons. OCPM technology seems more appropriate for repetitive and multiple projects, as owners are more willing to invest due to the ability it gives them to have easy control over the project or program, to look at cross projects and compare very quickly, and to stop and divert something before it happens. In addition, having an OCPM solution in place gives an advantage of learning from their previous mistakes and other peoples' experiences, helps to set standards, enables negotiating the cost with the vendors, and enables customizing the tools according to investors' needs.

In conclusion, the research shows that these tools will be *the new way of managing construction projects* in the future. Common sayings in the industry are that *"it is not only the technology!"* and *"the next big step is the implementation!"* Users acknowledge that it is important to *match the process rather than attempting to modify the process to suit the technology.* In addition, integration of several applications and expanded use of the tool with added modules by more collaborators will be realized more commonly in the industry. And eventually, the use of OCPM tools will become a requirement in construction projects.

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