CIFE CENTER FOR INTEGRATED FACILITY ENGINEERING

Potential Benefits of Internet-Based Project Control Systems – A Study On Time Card Processing

By

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SUMMARY
CIFE TECHNICAL REPORT #125

Title: Potential Benefits of Internet-based Project Control Systems - A Study on Time Card Processing

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1. Abstract:

AEC companies lack a consistent way to assess to what degree their processes are inefficient and thus do not know where investments in automation and integration tools could benefit them most. This report presents a detailed study of project management processes in the areas of cost control, contract management and financial management based on examples from the Stanford SEQ construction project. It discusses a framework for developing and analyzing business process models. This report focuses on time card processing. The report studies the effects internet-based systems could have on the organization, duration, and effort required for construction management processes. It presents the potential qualitative and quantitative benefits of an internet-based project control system over the current paper-based systems.

2. Subject:

This report studies what the potential benefits of internet-based project control systems could be by modeling and analyzing a business process model of the time card process. The key ideas investigated were how to model business processes to make them explicit and simpler to understand. A key observation is that most of the information used in project documents is not new, but is created in previous processes. The essential message is that by modeling the information flow and using internet-technologies to integrate the information, most of the activities to re-enter this information could be automated or eliminated, thus significantly reducing processing effort, which in turn translates into shorter process duration and cost savings.

3. Objectives/Benefits:

CIFE funded this research to extend the product and process modeling efforts to document management and cost control. CIFE members can now understand what type of benefits can be expected from integration using internet-based tools. Internet-based tools are increasingly being used to manage projects. The vision is that internet-based systems would automate many business functions and integrate heterogeneous systems using workflow technologies and business-to-business integration standards such that information will flow seamlessly across companies throughout the life cycle of a project, where each item of data is entered only once. The research attempted to explore how these technologies could be used to manage project costs and contract changes.

4. Methodology:

The research utilized data and case studies from the Stanford SEQ project as well as Excel and Visio computer models to build the business process models.

5. Results:

The major finding of this investigation is that, with an internet-based system:

- time cards could be processed with one actor instead of the three used today.
- the total effort to process time cards can be reduced by over 70%.
- 80% of the information used for all the time card processing activities can be taken from previous processes.
- the activities requiring clerical and technical skills drop from 80% to 26% shifting the focus to managerial activities.
- the majority (83%) of the effort will now be centered on preparing documents rather than authorizing them, processing them, locating them or updating the accounting database.

This offers tremendous opportunities for the AEC community to reduce the project duration and costs. The results are given in this report as a set of charts.

6. Research Status:

This research for the time card process is complete. The next logical step is to repeat the methodology and analysis to other processes including change orders, billings and payments. These results could be applied to create an internet-based cost control system to be used in the field office of construction projects and begin to enjoy the benefits of integration with the internet.

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Executive Summary

In today's fast-paced economy, Architecture/Engineering/Construction (AEC) companies are seeking new ways to streamline their business processes to reduce project duration and costs. The reasons are simple: Owners need to minimize the time to market of their products and thus need to reduce the delivery time for the facilities used to manufacture these products. Similarly, contractors, faced with intense competition, tight labor markets, and slim profit margins, need to optimize their allocation of human resources and minimize their working capital needs.

Given the inter-dependency of a project's physical and management activities, it is essential for AEC companies to manage and integrate information effectively and efficiently. Yet today, most project stakeholders in the US still manage and integrate information manually using paper documents or electronic files created by "best-of-breed" applications such as CAD, estimating, scheduling, document control and accounting systems as well as spreadsheets, word processing software and company paper forms. The business processes used to manage these documents are often ad-hoc, proprietary, and not explicit. People simply "know what to do" or, at best, are given a "list of steps" to follow. As a result, several process inefficiencies exist in the field and home offices such as paper-based activities, multiple document hand-offs, redundant activities, data re-entry, and distributed data storage, all of which can result in extensive delays, additional work, excessive costs, and potential data inconsistencies or error. Project managers are burdened with excessive clerical-level work in addition to their other duties on the project. Internet-based project management and coordination tools promise to help reduce these inefficiencies. However, AEC companies lack a consistent way to assess to what degree their processes are inefficient and thus do not know where investments in automation and integration tools could benefit them most.

This report presents a detailed study of the current, paper-based project management processes based on examples from a construction project. It shows how project management processes can be analyzed with respect to position, activity skill, effect of integration on activities, activity classification, transactions, and source of information. The dimensions we modeled were activities, organizations, actors, information, processing effort, and calendar time. One key aspect of our model is that it shows the source of every information element, thus establishing the relationships necessary for automated information flow. Based on the detailed documentation and analysis of today's processes, the report studies the effects internet-based systems could have on the organization, duration, and effort required for management processes.

It demonstrates that, with an internet-based system:

- time cards could be processed with one actor instead of the three used today.
- the total effort to process time cards can be reduced by over 70%.
- 80% of the information used for all the time card processing activities can be taken from previous processes.
- the activities requiring clerical and technical skills drop from 80% to 26% shifting the focus to managerial activities.
- the majority (83%) of the effort will now be centered on preparing time cards rather than authorizing them, processing them, locating them or updating the accounting database.

Although the impact on calendar time (process duration) is only one business day, the true value of integration will become evident as other management processes, such as payroll and change order management, make use of time

card information already in the system. The report concludes with a summary of our contributions and the potential benefits of integrating information with internet-based systems to manage construction projects.

We hope that this report provides the starting point and tools for a dialog between the many participants in project management processes and between software vendors and practitioners to enable professionals to use their expertise, time and attention in the best possible way.

1. POTENTIAL BENEFITS OF INTERNET-BASED PROJECT CONTROL SYSTEMS - A STUDY ON TIME CARD PROCESSING

1.1. Introduction

In today's fast-paced economy, Architecture/Engineering/Construction (AEC) companies are seeking new ways to streamline their business processes to reduce project duration and costs. The reasons are simple: Owners need to minimize the time to market of their products and thus need to reduce the delivery time for the facilities used to manufacture these products. Similarly, contractors, faced with intense competition, tight labor markets, and slim profit margins, need to optimize their allocation of human resources and minimize their working capital needs. In this type of environment, it is becoming more common to "fast-track" projects where construction begins before the design documents are fully complete. Consequently, many Requests for Information (RFIs) arise due to conflicts or omissions in the contract documents and give way to extra work not included in the original contract scope. This can result in additional costs and project delays. Contractors are then faced with the problem of tracking this extra work, submitting change order requests, waiting until they are issued a change order before they can bill for this work, and finally financing this additional working capital for months until they are compensated for the work they performed months before in order to meet the project schedule.

Given the inter-dependency of a project's physical and management activities, it is essential for AEC companies to manage and integrate information effectively and efficiently. Yet today, most project stakeholders in the US still manage and integrate information manually using paper documents or electronic files created by "best-of-breed" applications such as CAD, estimating, scheduling, document control and accounting systems as well as spreadsheets, word processing software and company paper forms. The business processes used to manage these documents are often ad-hoc, proprietary, and not explicit. People simply "know what to do" or, at best, are given a "list of steps" to follow. As a result, several process inefficiencies exist in the field and home offices such as paper-based activities, multiple document hand-offs, redundant activities, data re-entry, and distributed data storage, all of which can result in extensive delays, additional work, excessive costs, and potential data inconsistencies or error. Project managers are burdened with excessive clerical-level work in addition to their other duties on the project. Internet-based project management and coordination tools promise to help reduce these inefficiencies.

Yet today, AEC companies lack a consistent way to assess to what degree their processes are inefficient and thus do not know where investments in automation and integration tools could benefit them most. This report presents a detailed study of current, paper-based project management processes based on examples from a construction project. It also presents a framework we developed for modeling these processes at various levels of detail. This enables a better understanding of what processes are likely to benefit most from integration using internet-based systems and an estimate of the extent that these processes will be affected in terms of the organization, processing effort and process duration.

1.2. Internet-Based Systems

Over the last few years, over 200 startups with internet-based project management systems focused on the AEC industry have appeared and have promised to streamline business processes and thus add value to AEC companies. Their primary focus is in design collaboration (sharing CAD files and RFIs) and e-commerce (bidding & procurement) and to a lesser extent on project control (cost control, contract management & accounting). It is estimated that over $1Billion of venture capital has been invested in these startups in an effort to capture the "$3.2Trillion global AEC market"[1]. The sudden attention surrounding internet-based systems and standards efforts like aecXML has caused strong interest and confusion among project stakeholders regarding the level of impact internet-based systems will have on the industry and on projects in terms of reduced delivery cycles, cost savings, integration of information and quality of communication. Some research analysts estimate that web-based tools can save between 5-10% of a project's total installed cost, implying potential savings of up to $400 Billion annually by 2004[2]. Although these numbers are encouraging, it is not exactly clear how these estimates were derived nor do they point out what areas will be affected most and in what way.

Thus, the need remains to model the business processes managed by these systems to evaluate the potential quantitative and qualitative benefits an internet-based system would offer over traditional paper-based systems and to identify the processes that would benefit most. The vision here is that internet-based systems would automate many business functions and integrate heterogeneous systems using workflow technologies and business-to-business integration standards such that information will flow seamlessly across companies throughout the life cycle of a project, where each item of data is entered only once. The process model compiled for this study shows how far from this vision practice is today.

In conclusion, both AEC companies and startups need a way to model and analyze the current and improved business processes in detail to describe and compare what information is managed, who does what, what will change, who will benefit, what skills will be required, and how much time and money internet-based systems can be expected to save.

1.3. Overview of Research

In this research, we developed business process models based on observations of current practice. Our focus is on the cost control and contract management processes in the construction phase of a building project used to compensate contractors. The goal was to evaluate the potential quantitative and qualitative benefits an integrated internet-based system would offer over current paper-based systems. This report discusses how we developed these models as well as the analysis we performed based on the process models. The results of this research will be presented in a series of reports covering each process category (RFIs, Time Cards, Change Orders, Monthly Billings, and Payments) in detail and a summary report discussing the results from a global perspective. The current report focuses on time card process modeling and automation.

To motivate this discussion, this chapter first presents a case study of a project that clearly demonstrates some of the limitations of current paper-based systems and is the basis for the business process models we developed in this research. We then discuss some of the challenges facing the AEC industry in the area of integration and internet-based tools. Next, we present the purpose and scope of our research. A summary of the contributions this research makes to the AEC industry follows. Finally, we conclude this chapter with an overview of the rest of the report.

1.4. Practical Motivation

The construction project that motivated this research is the new Science and Engineering Quad (SEQ) at Stanford University. While unique in its design, this project is typical of many fast-track projects today that have tight schedules and budget constraints, but are late and over budget due to an incomplete design and the lack of integrated information systems between the participating companies.

The first phase of this project, which included the Teaching Center on which the case study in this report is based, eventually led to over 900 Requests for Information (RFIs), over 1200 Sub Change Order Requests (SCORs) and over 350 Owner Change Order Requests (OCORs) which affected the duration and cost of the project significantly. Given the paper-based systems available to manage the project documents, and the organizational structure of the project, it was not possible for the project participants to process the Change Order Requests and corresponding Billings in a timely manner. The first phase of the project was completed 7 months behind schedule at a cost close to 50% over the contract (Figure 1-1). The change order paperwork to compensate the General Contractor and all his Subcontractors was completed almost a year later.

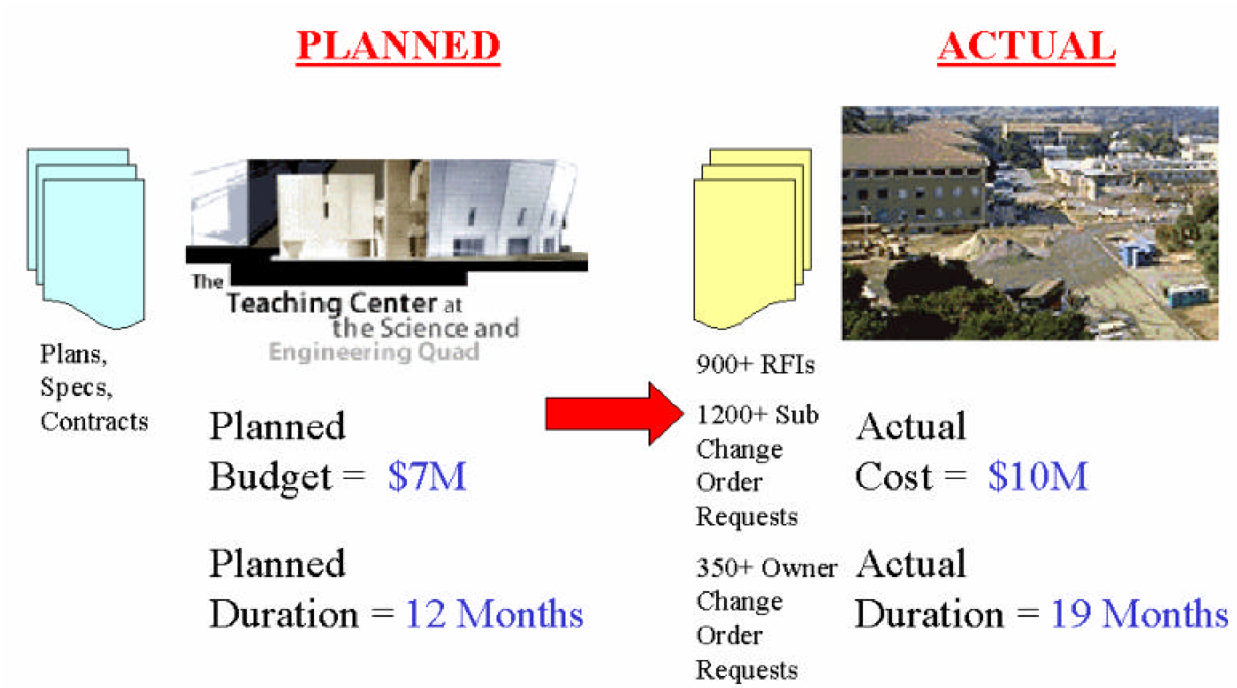


Figure 1-1. *Practical motivation inspired by difference between planned and actual results in SEQ project.*

The inefficiencies experienced on this project associated with managing paperwork inspired us to examine how things could have been different had there been an internet-based system to control the project. We prepared a case study from this project to illustrate how a typical issue required multiple manual re-entries of information for various project documents (see Chapter 2). We developed a business process model of the various management functions required to process the issue and used it to track the flow of information from the time the issue was raised to the time it was paid for (see Chapter 4). As this case illustrates, although the work to install the particular building components was performed in less than 100 man-hours, it took 8 companies and over 25 individuals over 20 work-hours and over 6 months to process the associated paperwork required to pay for this work. This process was typical of most issues in the SEQ project. Each process to resolve an issue took approximately the same time regardless of the actual cost of the issue. This project clearly illustrates that a project's duration and cost are determined not just by its physical activities, but by the sum total of the physical and management activities associated with it. Thus, it is critical to a project's success to consider not only physical activities, but also to understand and model the management activities and the relationships between the two.

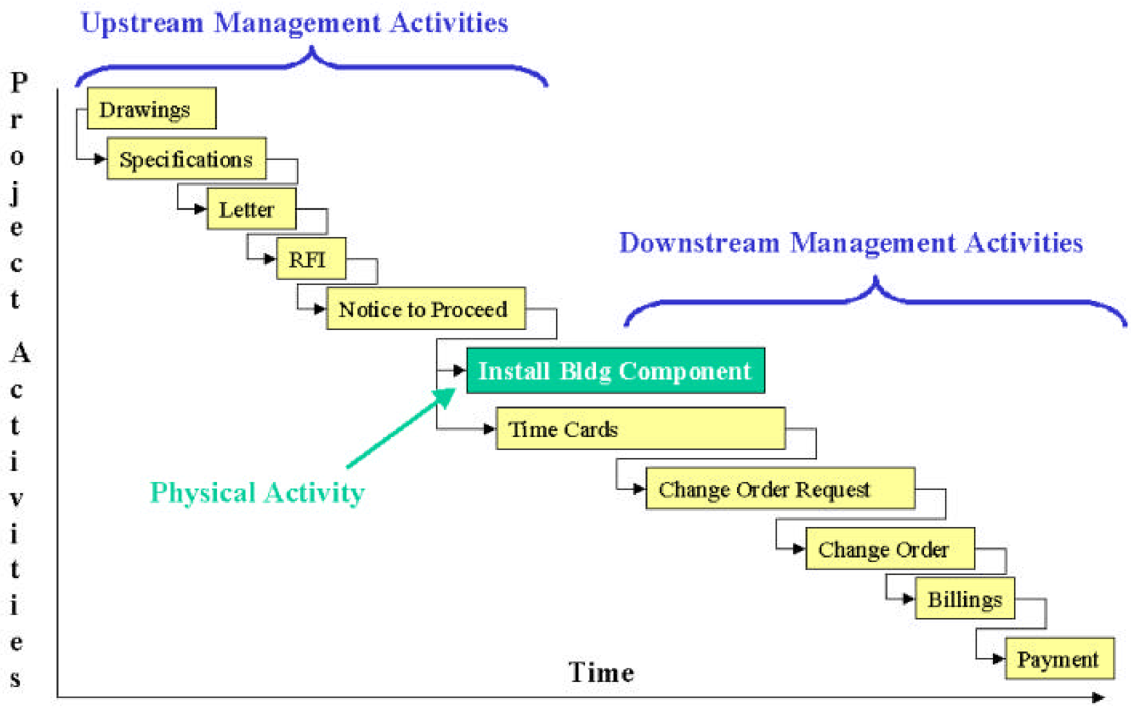


Figure 1-2. *The duration and cost of a project are a function of the physical activities plus the surrounding upstream and downstream management activities.*

1.5. Case Study Example

This case study focuses on the wood cubbies in the 2nd floor lobby of the Teaching Center (Figure 1-3). The paperwork to compensate the contractors for this issue included letters, an RFI, time cards, change order requests, change orders, applications for payment, payment requests, and eventually payment. The contractors received payment almost 11 months after the RFI was issued and over 6 months after the work was complete (Figure 1-4).

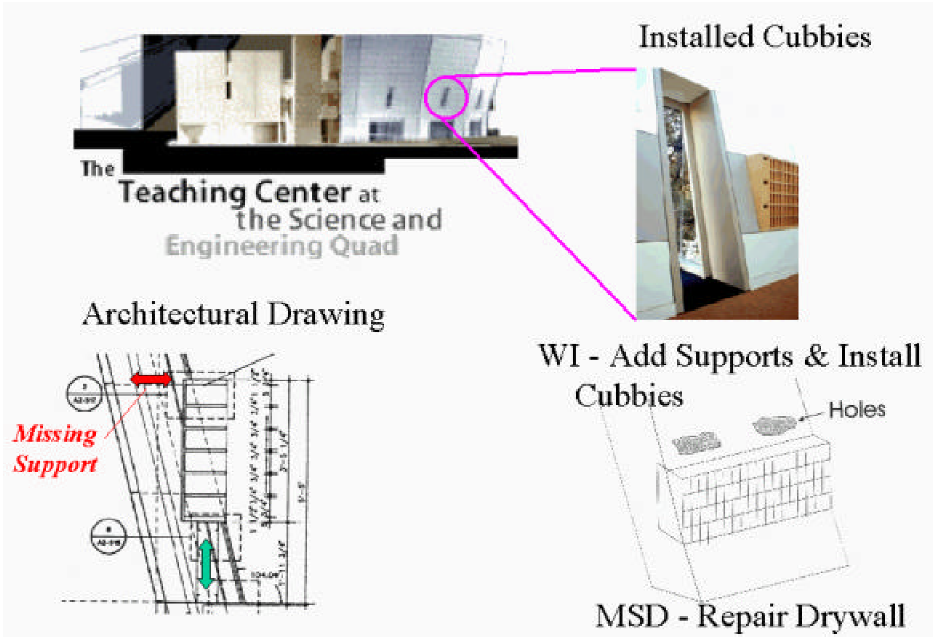


Figure 1-3. *Cubbies case study showing missing detail in drawings and resulting extra work.*

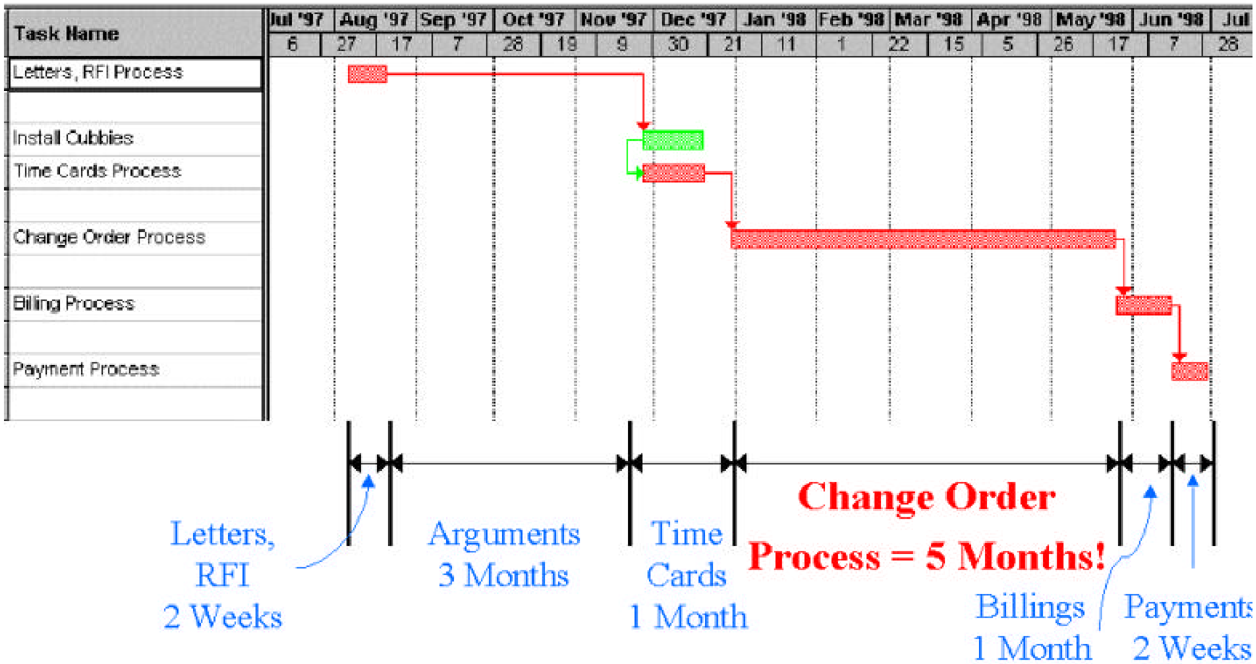


Figure 1-4. *Process duration view of the cubbies issue. It took 11 months from the time the RFI was sent to the time this issue was paid for. This was very typical of most issues on this project.*

1.6. Problem Statement

The case study illustrates that business processes are critical to the success of a project, yet with today's paper-based systems, they are lengthy and very inefficient. The main problems are threefold:

1.) Explicit business process models are virtually non-existent, thus the impact of management activities and decisions on physical activities is not understood and cannot be controlled or predicted.

2.) Business processes are complex and therefore require logical grouping and decomposition to make it easier to understand them.

3.) Business processes lack visibility into where inefficiencies exist. Therefore it is difficult to identify areas where processes would benefit from automation and integration.

We now discuss each of these points in more detail.

1.6.1. Business Processes are Implicit

Traditionally, most construction projects have been modeled only in terms of the physical components (CAD drawings) and **physical** activities (project schedule) required to construct the building, such as "Install Cubbies" and "Patch Wall". However, business processes are often the drivers of duration and overhead costs. Business processes, which consist of **management** activities dealing with documents such as RFIs, submittals, time cards, change orders and billings, are performed in support of physical activities. However, most of these business processes are implicit - project stakeholders simply "know what to do". Although these processes directly affect physical activities, their impact on the project schedule and cost is not well understood and cannot be controlled or predicted. Therefore, we see there is a need to model business processes explicitly to have a better understanding of their impact on project duration and cost. These models will then enable project stakeholders to prioritize their time and effort by providing them visibility into the impact their management activities will have on physical activities.

1.6.2. Business Processes are Complex

Given that business process models are necessary for project control and efficiency, the issue then becomes what to model and how to structure the model. Business processes can be described at various levels of detail from the project phase to a specific transaction at the document level to an activity at the information level. The challenge in modeling business processes is that the more detailed the process model becomes, the more complex and difficult it becomes to understand what matters. Therefore, it is useful to structure the process into various levels of detail in a logical way to keep things simple and associate related concepts. In decomposing the process using a top-down approach or grouping related activities in a bottom-up approach, it is essential to maintain consistency and clarity of purpose at each level of detail so that the resulting process models are aligned and can be compared across process categories on an equal basis.

1.6.3. Business Processes Need Visibility

The case study illustrates that business processes to compensate contractors are lengthy and inefficient. However, at the level of detail shown in Figure 1-4, it is virtually impossible to answer the following practical questions:

- Where are the process inefficiencies?
- How large are these inefficiencies?
- Why do process inefficiencies exist?
- To what extent could an internet-based system help reduce or eliminate process inefficiencies?
- Who is involved in these processes?
- What information do they manage?
- How does the information flow between documents?

To answer these questions, a detailed process model and analysis of these information management activities is needed. The analysis can then be used to determine where automation and integration could help make the process more efficient, and to estimate to what extent each process would benefit from automation and integration. This new level of visibility will help prioritize standardization and implementation efforts and also help AEC companies understand how to achieve the most return on their investment.

1.7. Purpose of Research

The purpose of this research project is to explore how and to what extent an internet-based system could streamline the management processes used during the construction phase of a project in the areas of cost control, contractual management and financial management. To achieve this purpose, we set the following objectives:

- Develop a framework to create AEC business process models that clearly describe the content, structure, relationships, logic, actions and sequence of business processes using multiple yet consistent and logical levels of detail. These models will help to describe, visualize, and compare business processes using different technologies across different categories.
- Model the following set of business processes in great detail using documents from a real project: RFI, Time Card, Change Order, Monthly Billings, and Payments processes. These models will help identify what information can be integrated and automated by specifying the source of each information element. At the lowest level of detail, it is also easier to estimate how much processing effort each activity takes.
- Estimate the quantitative and qualitative impact an integrated internet-based system would have over current paper-based systems by performing a detailed analysis of the management activities in these processes and measuring the number of activities, effort required, calendar time, and staffing, due to integration and automation.

Our analysis determines the logical flow of information and the areas where an integrated internet-based system would be predicted to add the most value. Hence the research results identify the potential areas where automation and integration can make the processes more efficient. Thus they can guide implementation and standardization efforts in a strategic way and help firms leverage the return on investment in integration and automation tools.

1.8. Scope of Research

We have divided the scope of this research effort into eight major categories:

1.) Manage Project Setup (Project Information, Company Information, People Information, and Contract Information).

2.) Manage Scope (Cost Codes and Schedule of Values)

3.) Manage Project Documents (e.g., RFI, Letters, etc.)

4.) Manage Field Resources (e.g., Time Cards, Material Data Sheets, etc.)

5.) Manage Contract Changes (e.g., Change Order Requests, Change Orders, etc.)

6.) Manage Billings (e.g., Monthly Schedule of Values, Application of Payment, etc.)

7.) Manage Payments (e.g., Employee Payment, Subcontractor Payment, etc.)

8.) Manage Reports (e.g., Cost Report, Manpower Distribution Report, Cash Flow Analysis, etc.)

We will present the results of this research in a series of detailed reports and a summary report discussing the results from a global perspective.

1.9. Research Contributions

Our research makes two contributions to knowledge in AEC:

- First, it extends the product and process modeling concepts developed in AEC research to model engineering and construction activities to include project documents and management activities.
- Second, it provides a framework consisting of several structured levels of detail to describe AEC business processes in a consistent and logical way. This is useful to describe and compare different business processes across companies, system types, project phases and categories.

1.10. Practical Benefits

Our research yields many practical benefits to the AEC building industry:

- First, it provides business process models of many common management activities in the areas of cost control, contract management and financial management. These models are useful to describe, visualize and understand what processes consist of and look like.
- Second, the process models identify where business processes could benefit from integration and automation by making the source of each information element explicit.
- Third, the process models help benchmark the time and effort processes take today using paper-based systems and help estimate the potential amount of processing effort that could be saved by enabling the integration and automation of AEC business processes using internet technologies.
- Finally, the analysis helps to understand what project phases and business functions are likely to benefit most and to what extent they will benefit. It also shows what information needs to be standardized. This will help guide the standardization and implementation efforts necessary to reap the rewards of integration.

We have noticed that the lights are often on late in the evening in many construction trailers. Clearly, everyone is working very hard to get the work done as quickly as possible. Even though processing a time card or most other documents does not take a professional very long, and in spite of the many long hours professionals are putting in, the calendar time to get financial and other documents processed and firms and people paid is often very long. The main reason for this long duration is that each document needs to pass through a number of hands in many firms. To reduce overall process time we must focus on reducing the time of each transaction and on redesigning overall processes across organizational boundaries to reduce redundant activities as much as possible. This redesign of the overall process can only be based on explicit business process models.

We hope that this report provides the starting point and tools for a dialog between the many participants in project management processes and between software vendors and practitioners to enable professionals to use their expertise, time and attention in the best possible way.

1.11. Future Directions for Research

Our long-term goals for this research are:

- To understand how to use the framework and models to achieve integrated financial management and cost control of a construction project based on standardized transactions and internet technologies, such as Java and XML.
- To demonstrate the generality and power of the framework described by applying it to other project phases such as estimating, bidding, and procurement.

1.12. Overview of Report

The current report focuses on time card process modeling and automation. The report is structured as follows:

- Chapter 1 introduces the **research motivation**, **problem statement** and the **purpose of the research**.
- Chapter 2 discusses the **case study** used to develop a business process model and the accompanying analysis.
- Chapter 3 describes the **information** in the time cards used in the case study. It also describes the **time card process**, the limitations of a paper-based system and the potential benefits of an internet-based process.
- Chapter 4 presents the methodology we used to **model business processes.** We also describe the analytical and graphical time card process model used in the analysis.
- Chapter 5 presents an overview of the **detailed analysis** comparing today's paper-based processes to those envisioned using an internet-based system and discusses the impact of the internet-based system qualitatively and quantitatively in terms of number of activities, processing effort, calendar time, people involved, and information attributes. Appendix C presents the details of this analysis.
- Chapter 6 concludes the report with a **discussion** of the insights and benefits drawn from this analysis. It points to future directions on how the model could be used to create the standardized transactions an internet-based system would use to integrate project information in practice.

CHAPTER 1 - REFERENCES

1. Cohan, Peter S. - "Deconstructing Buzzsaw.com." The Standard website. http://www.thestandard.com/article/display/0,1151,14952,00.html. May 15, 2000.

2. Daratech, Inc. - "Engineering/Construction/Operations Industry in Technology Transition. Technology-Enabled Savings to Approach $400 Billion Annually by 2004." Daratech News Release. May 8, 2000.

2. CASE STUDY DESCRIPTION

This chapter describes the case study we used to develop the analytical and graphical business process model discussed in Chapter 4. The purpose of this case study is to illustrate typical problems found with today's paper-based systems and to provide a basis for the different business processes we modeled and analyzed in this research. The case study discusses the background and development of the project issue in question from the RFI to the final payment. The process described in this section was very typical of most issues generated on the SEQ project. It shows the interplay between organizations, individuals, documents, time, money and information.

2.1. Cubbies Problem Description and Request for Information

The issue was initiated by Request for Information (RFI) # 644 which requests the design of a support system for the wooden cubbies in the second floor of the Teaching Center lobby. In the architectural drawings A2-509 and A2-517, the Architect shows a set of wood cubbies and a sketch of the metal stud framing necessary to support them vertically. However, the details for the horizontal support and attachment of the cubbies to the diagonally slanted vertical wall are not shown. The Specifications in Section 6400 call for "concealed fasteners". The Wood Supplier (WS) subcontractor asked in a letter dated Aug. 6, 1997 that the General Contractor (GC) request a design from the Architect. The GC issued RFI# 644 on Aug. 13, 1997 to the Architect asking him to provide a design for these fasteners.

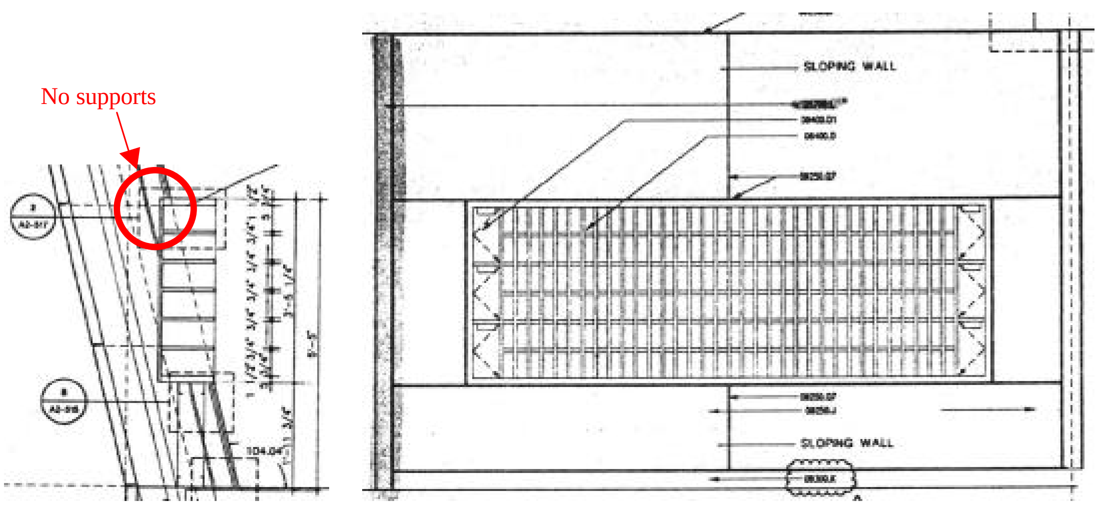


Figure 2-1. *Architectural drawings of cubbies. Side view (left) and front view (right).*

The Architect's RFI Response dated Aug. 19, 1997 included a sketch and a set of vendor specifications for a special type of fastener. The Wood Installer (WI) subcontractor notified the GC that this type of fastener would not work since the metal stud walls did not provide any support for these fasteners. The WI suggested to the GC that the metal stud walls would have to be modified to add the appropriate support for the fasteners. An additional problem was that the drywall around the cubbies had already been installed on the metal stud walls. This implied that in order to modify the metal stud framing, holes would have to be cut into the drywall above and below the cubbies.

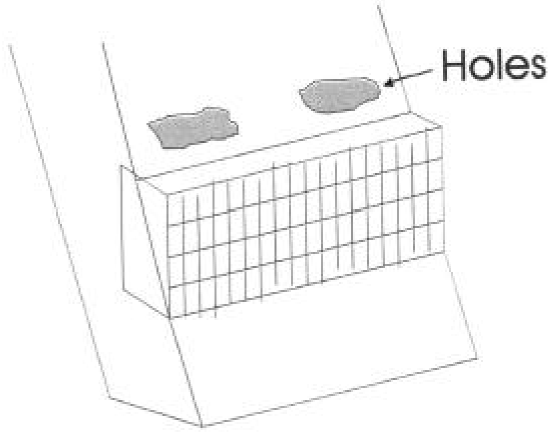


Figure 2-2. *Sketch of holes cut in drywall above the cubbies.*

2.2. Delay of Construction due to Lack of Responsibility for Design-Construction Conflict and Costs

On the cubbies issue, the Architect and Construction Manager (CM) at first said that this was a coordination issue that the GC should have anticipated and resolved, and that the Owner would not be responsible for the costs to open the walls, make the adjustments, and then patch them again. The resulting argument over who was responsible to pay for this extra work led to a delay of approximately 3 months from August to November 1997. Eventually, in the interest of finishing the project without further delay, the GC directed the WI to cut the holes in the drywall, make the required modifications to the metal stud framing, and add the horizontal supports for the cubbies. The GC figured the costs would be resolved at a later date with the Owner.

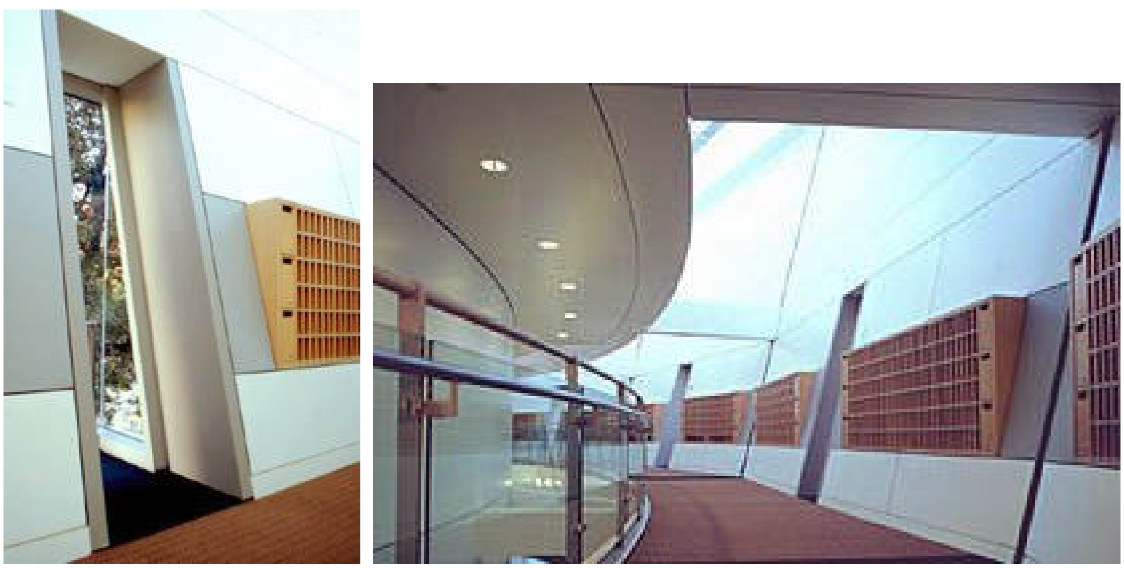


Figure 2-3. *Pictures of installed cubbies in Teaching Center lobby.*

2.3. Sub Change Order Requests

When subcontractors are asked to perform extra work, they typically submit a Cost Estimate. Once the work is complete the Sub submits a Change Order Request specifying the amount they agreed on with the GC. When the costs are difficult to estimate or there is no time to do the estimate, the Subs are asked to do the work on a Time & Materials (T&M) basis. This means the Subcontractor has to keep track of the labor hours and materials spent on the extra work, submit documents to verify the amounts billed (e.g. time cards) to be reimbursed through a Sub Change Order.

The Wood Installer (WI) subcontractor estimated it would take approximately 100 man-hrs at a cost of $60/man-hr to modify the walls to provide support for the fasteners. The WI performed the work between November 23, 1997 and December 15, 1997. On January 7, 1998, the WI issued a Change Order Request (COR) for $6,000.

The Metal Stud & Drywall (MSD) subcontractor repaired the drywall that was damaged to modify the walls in mid December 1997. On December 30, 1997 the MSD subcontractor issued a Change Order Request for $2,842 for this extra work.

2.4. Time Cards and Revised Sub Change Order Request

Because the WI did not provide any backup for the COR, and the work was T&M, the GC requested that the WI provide time cards as backup for the 100 hours charged. The WI retrieved the relevant time cards from his files and submitted these as backup with a revised Sub COR. Since the hours only added up to 89 hours, the WI revised its Change Order Request amount to $5,340. The WI re-issued the revised Sub COR on February 18, 1998. The WI project manager did not provide a cost breakdown of how he calculated the $5,340. Both the WI and the GC recorded the COR amount in a Sub COR Log to keep track of what issues had been processed.

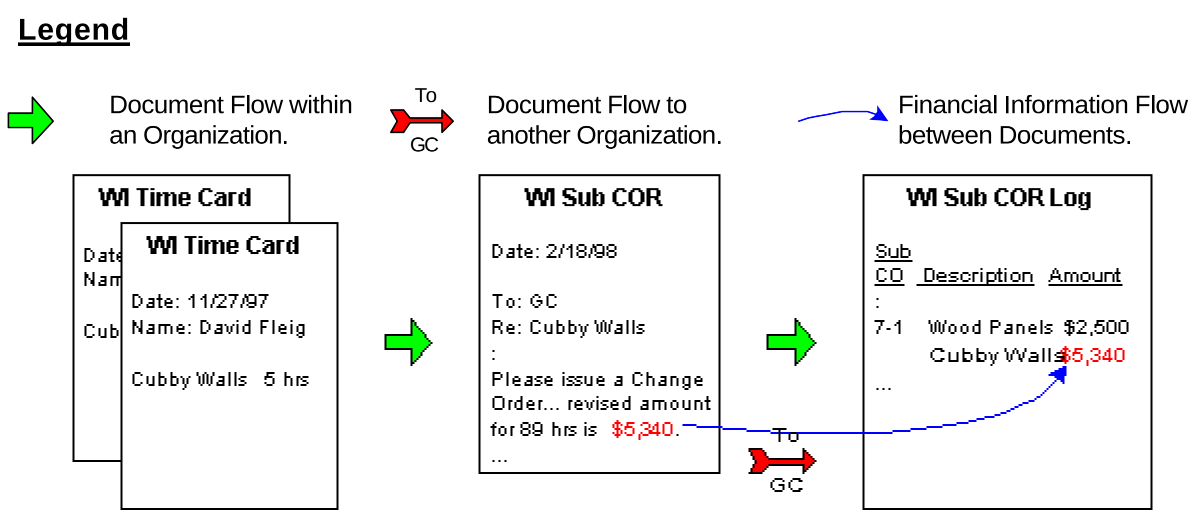


__Figure 2-4.__ The work hours on the 9 time cards totaled 89 hours. These hours times the $60/hr billing rate gives the $5,340 amount requested by the WI Sub COR. Both the WI sub and the GC re-enter this total in their respective Sub COR Log.

2.5. Owner Change Order Request

Due to the backlog of paperwork, the GC did not process this issue until April 22, 1998 when it created the Owner Change Order Request (OCOR) Cost Breakdown. The total amount requested was $10,610. This amount consisted of $5340 for WI, $2842 for MSD, and $2,428 for Overhead and Profit (O&P). The GC issued the OCOR to the Owner's Construction Manager (CM) on April 29, 1998.

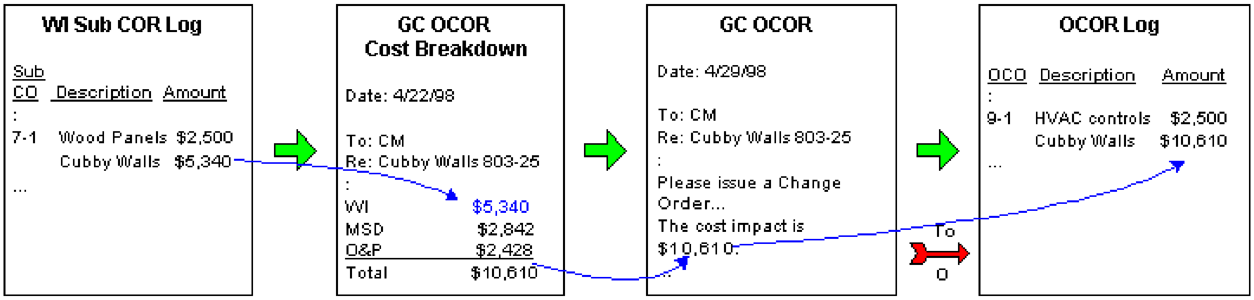


Figure 2-5. *The $5,340 WI amount is part of the $10,610 "OCOR Total Amount Requested". The GC re-enters this total in the OCOR. Once again, the GC and the Owner re-enter this amount in their respective and OCOR Log.*

2.6. Change Orders

The CM reviewed the OCOR and approved it agreeing to pay for this issue. In the Owner Change Order (OCO) #10 - Item 1, dated May 15, 1998 the Owner compensated the GC with $10,610 as requested. The GC then issued Sub Change Order #8.1 to the WI on May 20, 1998 and Sub Change Order #13.1 to the MSD on May 17, 1998 for this issue.

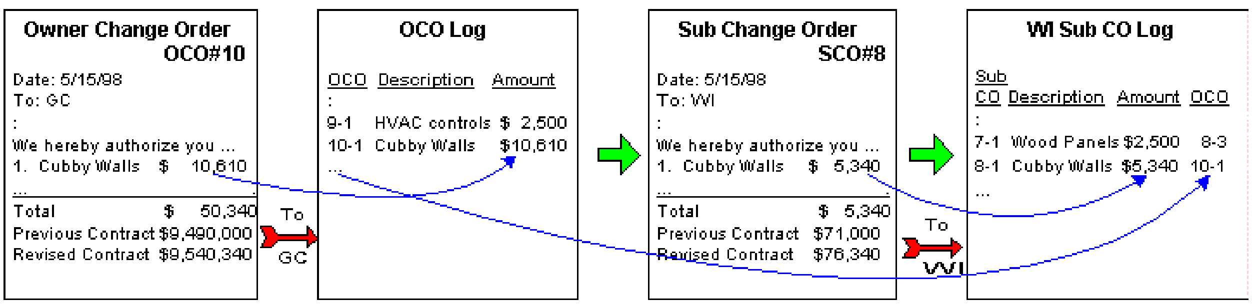


Figure 2-6. *The Owner Change Order and OCO Log repeat the $10,610 amount. However, the amount is now called the "OCO Amount Approved". Likewise, the $5,340 amount in the Sub Change Order and Sub COR Log is now the "Sub CO Amount Approved".*

2.7. Owner and Subcontractor Billings

The GC and the Subs need to receive a fully executed Change Order to increase their contract amount before they can bill for the work they have done. The GC billed for Owner Change Order #10 in Owner Billing #24 on June 1, 1998. The WI and MSD subcontractors also billed for the Change Orders in their May billings.

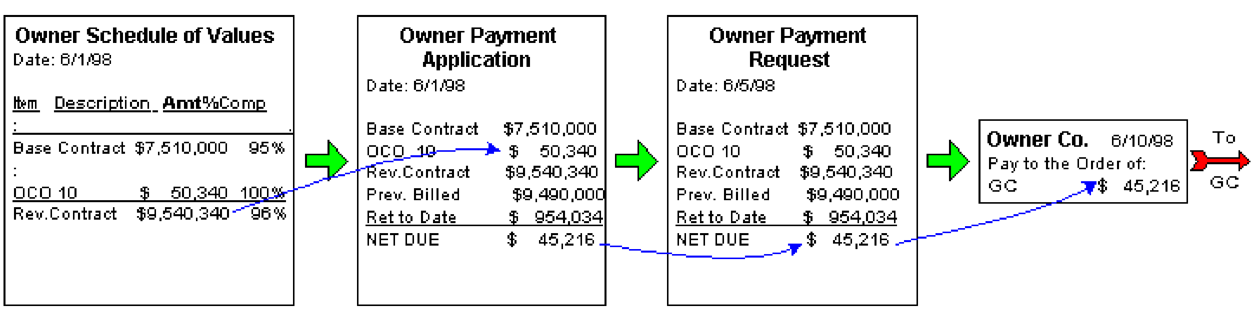


Figure 2-7. *The Owner Payment Application billed for the $10,610 "OCO Amount Approved" is included in the $50,340 "OCO Total Amount Billed". After subtraction of the retention, the GC received an "Owner Payment Total" of $45,216.*

2.8. Owner and Subcontractor Payments

The Owner Billing was paid on June 10, 1998. Since it is typical for the GC to pay their Subs within 10 days after receiving Owner Payment, the GC then paid the subcontractors on June 20, 1998, about 6 months after the work was performed.

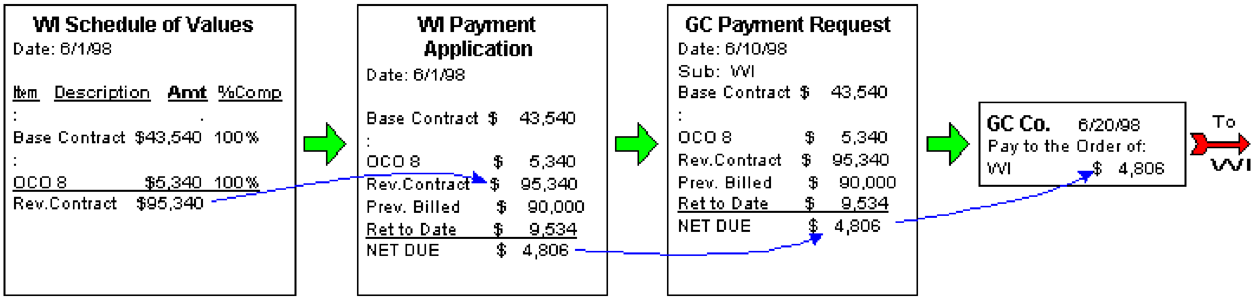


Figure 2-8. *The WI Sub Payment Application billed for the $5,340 "Sub CO Total Amount Billed" of WI SubCO No. 8. Minus retention, the WI sub received a "GC Payment Total" of $4,806 ? over 6 months after the work was complete.*

2.9. Observations Related to Case Study

From the case study, we can make several observations regarding today's paper-based process.

- Any physical activity (scope of work) can have several documents associated with it (e.g., RFI, Time Cards, Billings, etc.).
- Many organizations and individuals are involved in processing the documents.
- The information content of each document consists mostly of information obtained from other documents or results that are computed from a few other values.
- There is a lot of data duplication and re-entry across multiple systems, documents and companies.
- The same information value can be associated with multiple names depending on the context of the document.
- The overall process can take a long time, not because each individual document takes long to process, but because there is much inefficiency in the overall process.

These observations will be analyzed in more detail in Chapter 3 in the context of time card processing.

3. TIME CARD INFORMATION AND PROCESS

This chapter focuses on the details relevant to the study and the automation of time cards. Section 3.1 discusses the purpose of time cards and the information contained in the time cards. Section 3.2 presents an overview of the process to manage time cards with a paper-based system vs. an internet-based system.

3.1. Discussion of Time Cards

This section focuses on the time cards used by the Wood Installer (WI) subcontractor for the work to install the cubbies. We begin by presenting the purpose of time cards followed by a discussion of the actual information recorded.

3.1.1. Purpose of Time Cards

Contractors use time cards to record the work performed by their employees on activities related to a construction project.

The information recorded has four main purposes:

1.) To pay the employee for the work he/she performed during the week.

2.) To charge the labor costs to an account (cost code) with a budget.

3.) To determine the actual manpower distribution for each time period or activity.

4.) To bill for the labor cost component in a Change Order Request if the work was performed on a Time & Materials (T&M) basis.

The lack of understanding of these related purposes can lead to incomplete information in the time cards. If the systems used to perform these various functions are not integrated, multiple data re-entry is required and inconsistencies may result.

3.1.2. Scope and Cost Codes

The scope of this issue was to install the 10 wood cubbies in the exterior wall of the 2nd floor in the Teaching Center lobby. Each cubby consists of 2 halves denominated by L (left) and R (right). In total 20 building components had to be installed. WI had four different employees and two different activities that they could work on; each described by a different Cost Code. The work for installing the cubbies is given by a Cost Code we shall call **WI-INS-CBY**, which stands for Wood Installer (WI) Installs (INS) Cubbies (CBY). This Cost Code has a budget of 100 man-hours at $60/hr or a total of $6,000. There are no material or equipment costs to consider here.

Cost Code ID	Cost Code Description	Sub ID	Action	Building Components	Resource Use Estimate	Budget
WI-INS-CBY	Install Cubbies	WI	Install	Cubbies 1-10	100 man-hrs	$6,000
WI-INS-TRIM	Install Wood Trim	WI	Install	Wood Trim	150 man-hrs	$9,000

Table 3-1. *Two cost codes that Wood Installer used to fill in time cards in this example.*

3.1.3. Activity Duration and Schedule

The WI subcontractor worked only a few hours on any given day installing cubbies. The dates of the time cards on which the work was actually performed are shown in the schedule in Figure 3-1.

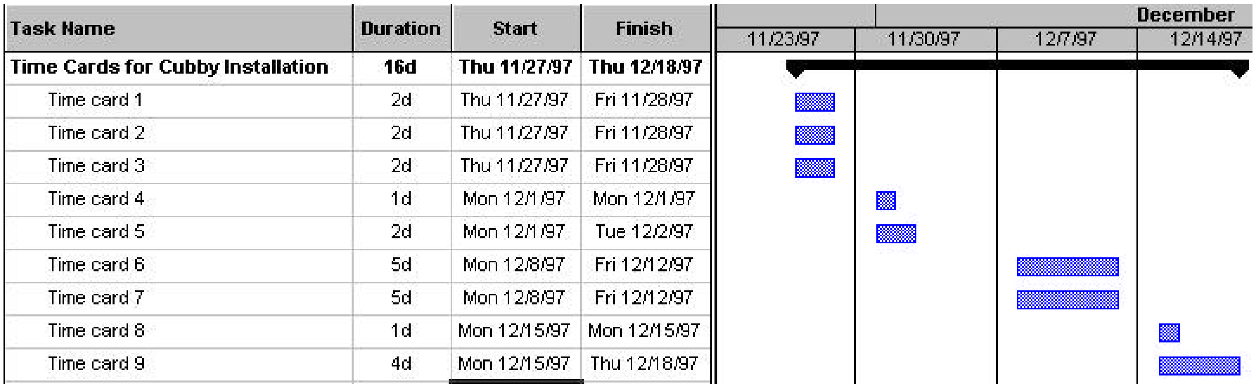


Figure 3-1. *Schedule showing actual dates of work to install cubbies obtained from time cards.*

3.1.4. Time Card Information

The typical information recorded on a time card includes the following:

- Date of work: To record the date the work was performed
- Cost Code: To identify the account the work should be charged to
- Description: To describe the activity performed
- Employee No: To identify the employee using the employer's identification system
- Employee Name: To describe the name of the employee
- Hours Worked: To quantify the number of hours worked
- Shift: To describe the type of hours worked - e.g., Regular Time (RT) vs. Overtime (OT)

The actual information recorded on all the time cards related to installing the cubbies, is as follows:

Time card NO	Employee First Name	Employee Last Name	Employee ID	Work Date	Mon=1	Activity Description	RT Work Hours
1	David	Fleig	12	11/27/97	4	Cubby Wall	3
1	David	Fleig	12	11/28/97	5	Cubby Wall	3
2	Mark	Klassen	203	11/27/97	4	Cubby Wall	3
2	Mark	Klassen	203	11/28/97	5	Cubby Wall	3
4	Shirley	Stephens	522	11/27/97	4	Cubby Wall	2
4	Shirley	Stephens	522	11/28/97	5	Cubby Wall	3
5	David	Fleig	12	12/1/97	1	Cubby Wall	7
5	David	Fleig	12	12/2/97	2	Cubby Wall	4
6	Kirk	Carlson	801	12/8/97	1	Cubby Wall	5
6	Kirk	Carlson	801	12/10/97	3	Cubby Wall	5
6	Kirk	Carlson	801	12/11/97	4	Cubby Wall	5
6	Kirk	Carlson	801	12/12/97	5	Cubby Wall	5
7	Mark	Klassen	203	12/8/97	1	Cubby Wall	5
7	Mark	Klassen	203	12/9/97	2	Cubby Wall	5
7	Mark	Klassen	203	12/10/97	3	Cubby Wall	5
7	Mark	Klassen	203	12/12/97	5	Cubby Wall	5
8	Mark	Klassen	203	12/15/97	1	Cubby Wall	5
9	David	Fleig	12	12/15/97	1	Cubby Wall	4
9	David	Fleig	12	12/17/97	3	Cubby Wall	6
9	David	Fleig	12	12/18/97	4	Cubby Wall	6
	TOTAL						**89**

Table 3-2. *Information recorded on time cards associated with installing cubbies in the lobby wall.*

There are nine time cards, as shown also on the schedule. Each time card records the work activities for one employee for an entire week. The dates of work on the cubbies span from 11/27/97 to 12/18/97 yet only a total of 89 hours were related to this activity. We can also group these hours by date to see how the work evolved over time as shown in Table 3-3.

Work Date	No. Work Hours	Time card No.'s
11/27/97	4 + 4 + 4 = 12	1, 2, 4
11/28/97	5 + 5 + 5 = 15	1, 2, 4
12/1/97	7	5
12/2/97	4	5
12/8/97	5 + 5 = 10	6, 7
12/9/97	5	7
12/10/97	5 + 5 = 10	6
12/11/97	5	6
12/12/97	5 + 5 = 10	6, 7
12/15/97	5 + 4 = 9	8, 9
12/17/97	6	9
12/18/97	6	9

Table 3-3. *Number of work-hours per day and associated time cards for activity to install cubbies.*

3.1.5. Observations Related to Time Cards

We will now discuss some general observations related to the time cards:

- Time cards can be used to measure the daily progress of an activity in terms of actual labor resource use. However, they do not measure the actual material quantities installed.
- Paper-based time cards will require multiple data re-entry for the accounting system and for a particular activity. In the case study, it was not obvious that 89 work-hours were used to install the cubbies until the time cards were analyzed.

3.2. Overview of Time Card Process

We now present a comparison of the process to manage time cards using a paper-based system vs. a hypothetical internet-based system. We then discuss the problems with the current system and summarize the expected benefits of an internet-based system.

3.2.1. Paper Based System

Today, time cards are typically paper forms filled in manually by the foreman in the field office at the end of each working day (Figure 3-2). The foreman enters basic information such as project name and number for each time card. He uses other documents such as a cost code list and an employee list to determine the cost codes and employee numbers. He manually computes the totals per day in terms of regular time (RT) or overtime (OT). He then reviews the time card and authorizes it with his signature and date. Finally, he or a clerk faxes it to the company's home office and archives the time card in a file cabinet.

In the home office, a clerk receives the time card and an accounting entry person posts the time card information into the accounting/payroll database. The time card is then archived in a file cabinet. At the end of the week, the checks are prepared for each employee. Every month, a cost report is also printed that summarizes the total costs for each cost code.

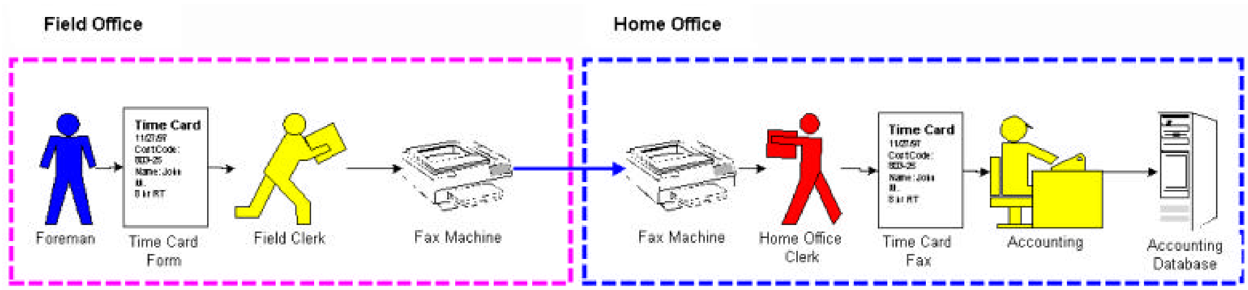


Figure 3-2. *Current paper-based process for processing a time card involves several people and re-entry of data.*

<u>*Problems with Paper Based System:*</u>

- The process to create and process a time card is not explicit. People "just know what to do".
- Information is re-entered in the field and in the home office.
- The process requires at least two people handling the same information.
- The relationship between the information in other documents like the cost code list and the time card is not explicit.
- Totals are calculated manually.
- The time to post the information to the accounting database is delayed by the amount of previous work the accounting entry person has.
- Access to this information is only available by either manually searching for the documents from the file cabinet or by waiting for the home office to create a summary report.
- To create other types of analysis like manpower reports or earned value analysis requires re-entry of the same information into a separate application like a spreadsheet.
- If the cost code list is long or unclear, the work may be charged to the wrong cost code.

3.2.2. Internet-based System

Using an internet-based system, a foreman could directly access the project model database using a browser or personal digital assistant (PDA) from the field office (Figure 3-3). The system would automatically enter all the basic information like the project name when he logs in. Only the applicable cost codes and employee ID's for that time period (determined from the current activities in the schedule) would be displayed in a drop-down menu, thus greatly simplifying the process. Potential errors would be virtually eliminated since he would enter either only new information or select information from a limited set of pre-selected choices. If bar-code technology were used, the foreman could even simply scan the appropriate bar-code on the employee's name tag to enter his ID. The system would automatically calculate all totals. Once completed, the foreman would submit the time card information directly into the project extranet database, which would then synchronize it with the home office accounting database. The reason for having the data in two different places is due to the need for cost control from the project perspective and the need for financial management from the home office perspective.

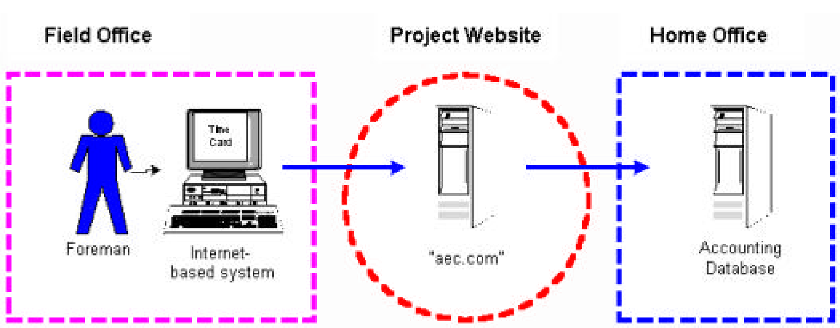


Figure 3-3. *Vision of internet-based time card process involving one person and no re-entry of data.*

Benefits of Internet-based system:

- The process to create and process a Time Card is explicit.
- Information is entered only once in the field.
- The process requires only one person.
- The relationship between the information in other documents like the cost code list and the time card is explicit.
- Totals are calculated automatically.
- The time to post the information is reduced to zero since this work is automated.
- Access to this information is immediate at any time. The information is searchable.
- Creating other types of analysis like manpower reports or earned value analysis is automatic since the information is already in the system.
- Any costs associated with processing, filing and copying time cards would be virtually eliminated since this information is now stored electronically.

Benefits of integrating Time Cards with 4D Production Model:

In the future, when 4D production models[1] are used as part of internet-based systems, we could associate the time card information directly with the 4D production model. By doing so, we could obtain even more benefits.

- Since the cost code is part of the 4D Production Model, it would be easy for the foreman to specify what exact component was installed.
- If a project manager wanted to know how the labor cost compares to the budget for any activity or object, instead of having to wait for the monthly cost report he could easily see that comparison by clicking on a building component or activity.
- The schedule would be automatically updated every day to reflect actual work progress based on quantity-based earned value calculations[2]. If any person wanted to know what work was done on any given day or time period, this would be readily available since the time card dates and cost codes would be automatically linked to the schedule. This assumes the use of integrated control cells where cost codes and schedule activities are essentially one and the same[3].
- If a project accountant wanted to prepare the labor cost for a change order, instead of having to search through many file cabinets and time cards, the system could simply import the corresponding time cards and calculate the total number of hours.

Now that we have introduced the time card information recorded and described the process to manage this information, we develop the business process model for the time cards in the case study in Chapter 4 in detail.

CHAPTER 3 - REFERENCES

1. Aalami, Florian B., Martin Fischer and John C. Kunz - "AEC 4D Production Model: Definition and Automated Generation". Stanford University Center for Integrated Facilities Engineering - Working Paper 052. September 1998. http://www.stanford.edu/group/CIFE/Publications/index.html
2. Fleming, Quentin W. and Joel Koppelman M. - "Earned Value Project Management". Project Management Institute Publications; ISBN: 1880410389. June 1996.
3. Rasdorf, William J. and Osama Y. Abudayyeh - "Cost and Schedule-Control Integration: Issues and Needs". Journal of Construction Engineering and Management, American Society of Civil Engineers, Volume 117, Number 3, pp. 486-502. September 1991.

4. BUSINESS PROCESS MODELING

"Everything should be made as simple as possible, but no simpler."

– Albert Einstein[1]

In Chapter 1, we discussed that business processes are implicit and complex. The result is that users lack visibility to determine where inefficiencies in the process exist and the relative magnitude of these inefficiencies. In Chapter 2, we discussed the case study that motivated this research. The point to note there is that much of the information contained in project documents comes from multiple documents, and this lack of integration contributes significantly to the process inefficiencies. In Chapter 3, we focused on the time card process and referred to some of the elements that make up that process such as the actors, documents, and actions those actors perform on the documents. This chapter describes the business process modeling framework we developed and the resulting time card process model. The framework consists of multiple levels of detail and activities with various attributes to make the models explicit, logical, consistent and simple. Chapter 5 will then discuss the analysis of this business process model and the results and observations we obtained of the expected value an integrated internet-based system would offer.

We first present the objectives of modeling business processes. Then, we discuss the point of departure from the research literature. Finally, we present the business process modeling framework we developed.

4.1. Objectives of Business Process Model

The purpose of our business process models was to understand in depth the processes necessary to compensate contractors for their work in the construction phase of a real project and how integration with internet technologies might be used to streamline these processes. The processes we studied are: RFI, Time Card, Change Order, Monthly Billings, and Payments. In developing these AEC business process models, we kept the following objectives in mind:

1. Describe the elements that make up the process explicitly. The idea is to clearly describe the content, structure, relationships, logic, actions and sequence of the activities that make up the process.

2. Structure the processes in multiple levels of detail from the highest process level down to the lowest information activity level in a consistent manner across companies, system types, project phases and categories for different types of documents and activities. This will enable comparison and analysis of processes across companies, system types, project phases and categories.

3. Visualize the flow of information. The purpose is to show the source of each information element. By doing this, it is now possible to determine where integration can occur and where automation might be possible.

4. Benchmark the effort and process duration. This is useful to know how much each activity and each process takes in real time and in calendar time using today's paper-based systems. By knowing the activities whose information has its origin elsewhere, we can now assume these activities' effort can be significantly reduced, completely automated or even possibly eliminated. The duration between activities in a process which otherwise might have been days in an actor's in-box may now be greatly reduced if those activities are automated or eliminated.

5. Estimate the impact of integration using an internet-based system. Once the effort and duration are assessed for the paper-based vs. the internet-based system, we can make some educated assessments of the magnitude and processes that will benefit most from integration using internet technologies.

To determine the components of each business process, we sought to answer the following questions:

- what documents are used in the process?
- what information does each document contain?
- is the information new or does it have its origin elsewhere?
- what other document is the source of the information?
- who processes each document?

- what actions does each actor perform on the documents?
- how much processing effort do these actions take?
- what skill is required to perform each activity (clerical, managerial, or technical)?
- what type of effect would an integrated internet-based system have on a management activity?
- how would the management activity be classified?
- how many days can be saved in calendar time from beginning to end of a process?
- how many times does a document change hands based on how many people are needed in each type of system?

4.2. Product and Process Modeling in AEC

To date CIFE has focused most of its research on the use of object-oriented product and process models to support engineering and construction activities. Standards efforts in AEC such as the International Alliance for Interoperability's Industry Foundation Classes (IFCs) and aecXML have also been heavily focused on modeling and standardizing the building components and physical activities of a construction project. The main work done to address documents and management activities was performed by Björk et al. in 1993[2]. Although they introduce a few classification systems for activity types and document types, the major limitation of their work is that it focuses on modeling documentation activities at the document level only. Since integration really occurs at the information level, this level of modeling cannot be used to analyze information flows nor the effects of integration with an internet-based system on the process.

The business process modeling framework we developed extends the research and standards efforts in product and process modeling to include management activities at the document level and the information element level as well. As part of this level of detail, we model the source of every information element. The idea is that it must be possible to trace all information back to its original source. If the information is not new, an internet-based system would integrate it automatically.

We now present some of the major programming concepts, standards efforts, and AEC product and process modeling concepts we used from the research literature to help develop the business process modeling framework.

4.2.1. Object Oriented Modeling Concepts

Recently, object oriented programming[3] (OOP) has become the preferred means of programming in many fields for various good reasons, such as its ability to model intuitive concepts and its modular nature that allows separation of the interface and encapsulation of the implementation. Many of the modeling concepts used in OOP can be used to model information processes. In our research, we used the concepts of classes, instances, inheritance, attributes, relationships, composition and overriding to model the construction management processes. We give here a brief description of these concepts:

Classes: Classes are "templates" or "molds" that specify all the basic elements of an object (in our case a business process) and how they are related. All our business process models are implemented as classes.

Instances: Instances are the actual objects that contain the data specified in the classes. We instantiated the business process model templates and populated them with the data we gathered in our case study documents.

Inheritance: Inheritance is the means by which instances receive or "inherit" all the basic properties or "attributes" in their parent class.

Attributes: Attributes are the specific properties that define each class. Each instance inherits the same attributes, yet has different values that make the instance unique.

Relationships: When the value of an attribute is another object, the attribute is called a relationship[4]. This was useful to specify the flow of information using the "source" attribute we modeled.

Composition: Classes and instances consist not only of information fields or attributes, but also of other objects nested within them. This property is called composition.

Overriding: Often classes have default values that they inherit to their children. The instances can "override" these values and provide their own to make them unique.

4.2.2. Standards Efforts

Several standards efforts in business-to-business (B2B) e-commerce have appeared over the last few years such as ebXML[5], cXML[6], RosettaNet[7], and BizTalk[8] in an effort to establish agreements for standardized online transactions. In AEC, others such as aecXML[9] and bcXML[10] are an effort to create industry-specific document schemas. We have chosen to discuss the elements of RosettaNet as this seems to be one of the most promising standards in practice that is relevant to our research.

The RosettaNet Implementation Framework Specification[11] recognizes the need to standardize the process as well as the data and structure to be exchanged. It describes process levels as clusters, segments, and partner interface processes (PIPs) (Figure 4-1). These are defined as follows:

- ***Clusters*** **-** "groups of core business processes".
- ***Segments*** **-** "cross-enterprise processes involving more than one type of supply-chain partner".
- ***PIPs*** **-** "system to system XML-based dialogs that define business processes between supply chain partners".

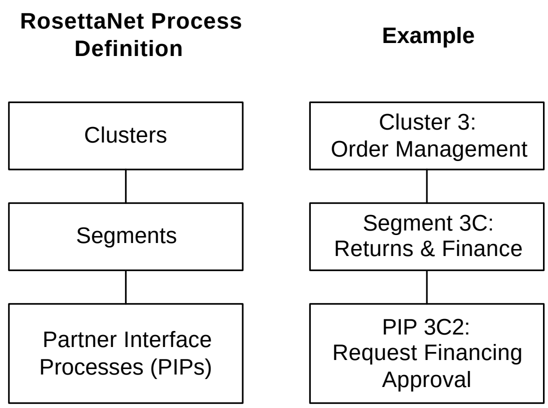


Figure 4-1. *RosettaNet defines its partner interface processes (PIPs) within a cluster inside a segment.*

RosettaNet also defines communication layers and corresponding protocols to handle the process communication (Figure 4-2). In the lower levels this includes the following layers:

- ***Process layer*** **-** "encapsulates conditional choreography of transactions for executing a partner interface process."
- ***Transaction layer*** **-** "provides transaction monitoring for sequences of message exchanges that perform a unit of work. Either all parties to the transaction commit to the unit of work or they all roll back to a previous state before the transaction was started".
- ***Action layer*** **-** "provides business actions that act either on or with accompanying information.

While the upper layers (internet protocols) are general and could be used in any industry, the lower layers are industry-specific. This is where standards such as aecXML would fit in. Given that these standards in AEC are still in their early stages, we feel our research is very relevant and could help influence the direction of their efforts.

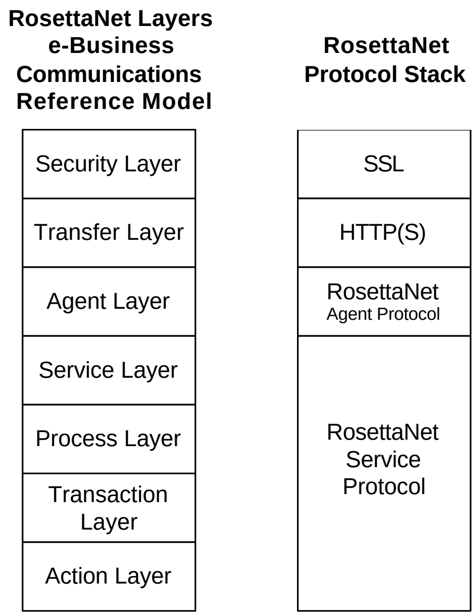


Figure 4-2. *RosettaNet uses the communication model shown above which defines the process, transaction, and action layers that define the behavior and integrity of business processes.*

4.2.3. Document Management Research

In 1993, Björk et al. published a paper entitled "Integrated Construction Project Document Management"[2]. This is the first effort we are aware of to model AEC documents and the activities used to handle them. However, as they clearly state, "the approach which will be introduced in this paper concentrates on the management of documents in digital form, *not on the management of the information within documents or databases*." This is an important distinction since the "atoms" they are concerned with are the documents themselves, while we are mostly interested in modeling the documents *as well as* the information inside the documents.

The paper introduces classification systems for activity types and document types:

- Five generic activities are used to manage documents: Receive, Fetch or Create, Edit, Update, and Distribute documents (Figure 4-3).
- Documents are grouped into three categories: Design documents, Project Management documents, and Contractual Documents.

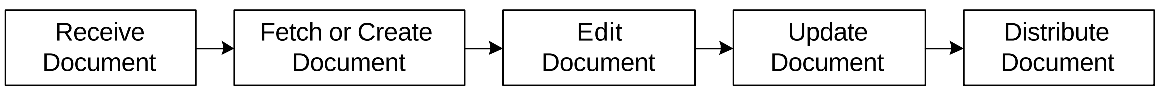


Figure 4-3 *Activity model defined by Björk et al. for document management.*

These generic activities correspond to the transaction stages in our business process modeling framework. We discuss this further in section 4.3.1.1.

4.2.4. Product & Process Modeling Concepts

Figure 4-4 shows the major concepts from the various AEC core process models presented by Froese[12] used to define a construction activity. We used and extended these concepts to define an information activity. These models do not provide any guidance regarding how to structure different levels of detail or the specific attributes within each business concept that are important. The only connections between an activity and higher levels of detail are a "contains" relationship to the "construction plan" in the GenCOM[12] model and a "performs" relationship to the "stage" in the ATLAS[12] model.

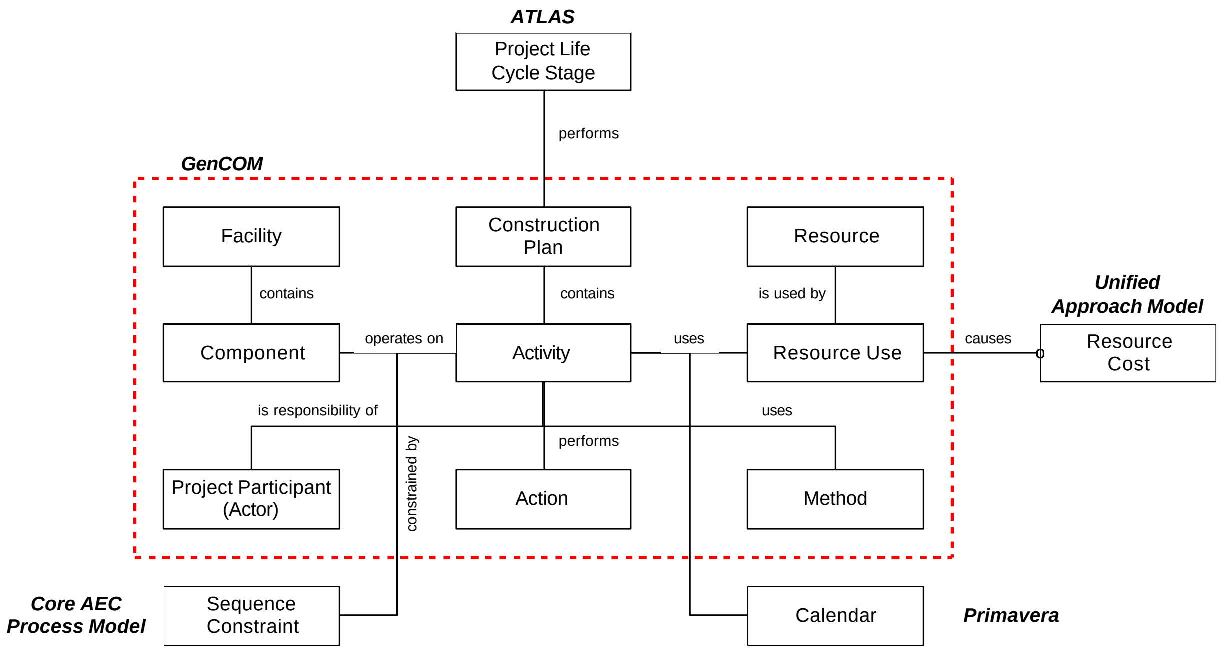


Figure 4-4. *The key concepts of AEC core process models that define a construction activity.*

Now that we have discussed the theoretical and research foundation for our work, we present a brief overview of the business process modeling framework we developed.

4.3. Business Process Modeling Framework

RosettaNet defines the term "business process model" as "***a graphical model of an organization's business process showing the activities, external processes and decisions along with the information exchanged between them***." This definition is good because it considers activities, decisions and the information as well.

Based on the process described in Section 3.2, and using the concepts just discussed in Section 4.2 we developed a business process modeling framework. One of our goals was to capture multiple levels of detail from the highest process level down to the lowest information activity level that is consistent across companies, system types, project phases and categories for different types of documents and activities. This is useful to create the standardized transactions we envision for integrating information with an internet-based system. Similar process modeling efforts such as RosettaNet[5] embody this idea through their use of layers and process hierarchies that include "Clusters", "Segments", and "Partner Interface Processes", as discussed previously.

The business process models are developed in two formats to show the hierarchical grouping of related processes in sequential order and to enable the process analysis:

- An analytical spreadsheet model to show the hierarchical grouping of related processes and to enable the process analysis, and
- A graphical model to visually show the flow of information between documents and to illustrate the effect of an internet-based system on each activity.

4.3.1. Analytical Model

The analytical model includes various levels of detail and multiple attributes associated with each activity in the process. These levels of detail are illustrated in Figure 4-5. The definition of an information activity and its attributes are illustrated in Figure 4-6. Figure 4-7 shows a portion of the analytical time card process model. The complete model for the time card process is shown in Appendix A.

4.3.1.1 Levels of Detail in Process Model

We modeled the business process model to various levels of detail by decomposing the model into process categories, process groups, transactions, transaction stages, activity groups and activities using a hierarchical structure.

- **Process categories -** As discussed in chapter 1, we modeled eight major management process categories which are the highest level "nodes" in our model. In this report, we make use of the following interrelated process categories:
  - S1. Manage Project Setup (i.e., project information, company information, employee information, contract information).
  - S2. Manage Scope (i.e., cost codes, schedule of values).
  - S4. Manage Field Resources (i.e., time cards).

  The notation we used for the process ID is an extension of notation in the IDEF0[13] modeling method. Therefore, instead of the typical IDEF0 "A0", here "S" stands for "Subcontractor" and "4" is associated with the function category "4 - Field Resources".

- **Process groups -** Each process category breaks down into process groups. We separated the major process category "S41. Manage Time Cards" into two process groups:
  - "S411 (Field Office) Manage Time Cards"
  - "S412 (Home Office) Manage Time Cards"
- **Transactions -** We decomposed each process group into <Action-Document> pairs we defined as transactions such as:
  - "S4111 - Prepare Time Card"
  - "S4112 - Authorize Time Card"
  - "S4113 - Send Time Card"

  We then decomposed these transactions into several transaction stages, activity groups, and activities.

- **Transaction Stages -** Björk et. al. (1993)[2] describe five "activities" at the document level. We prefer to think of them as transaction stages. These are Fetch or Create, Edit, Update, Distribute and Receive a document. In our model we find the following examples:
  - "S41111 - Create Time Card"
  - "S41112 - Edit Time Card"
- **Activity groups -** Sometimes we can group related activities by a concept such as "Project" or "Cost Code". Some examples in our model are:
  - "S411114 - Enter Project Information"
  - "S4111212 - Enter Cost Code Information"
- **Activities -** Activities are the basic units we consider in our analysis. An activity consists of an <Action-Information Element> pair and its associated attributes. Some examples are:
  - "S41112121 - Select Cost Code ID"
  - "S41112122 - Enter Cost Code Description"
- **Action -** the actual action required of the end user or automated system such as "Select" or "Enter".
- **Information Element -** the actual data field that is being modeled such as "Cost Code ID" or "Employee Name".

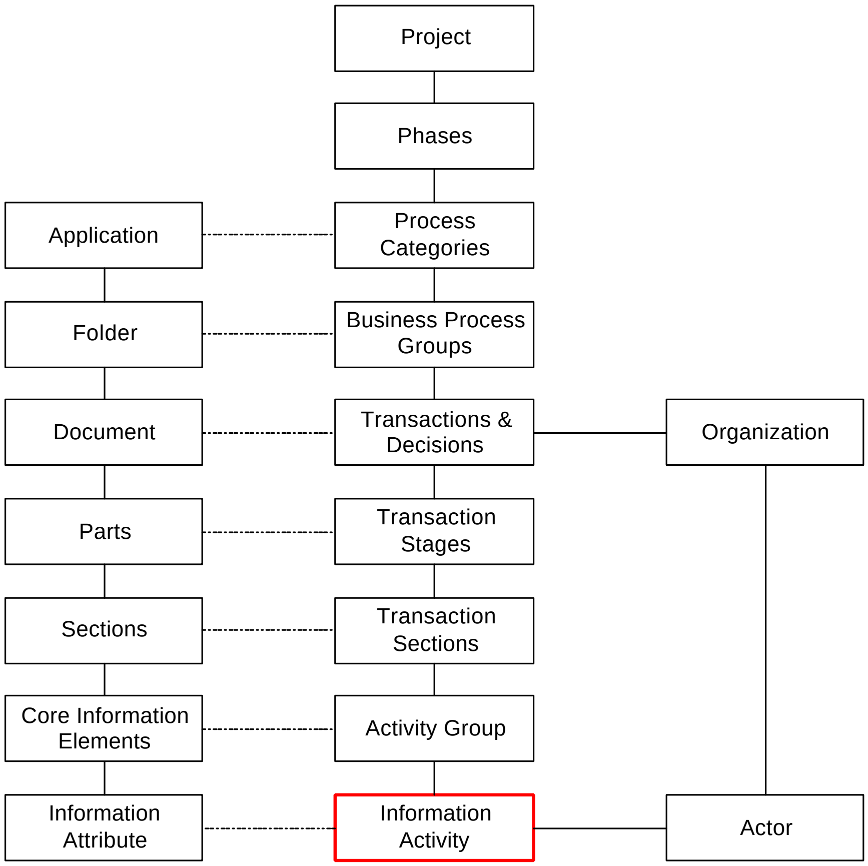


Figure 4-5. *Business process structure and levels of detail.*

4.3.1.2. Attributes Associated with Information Elements

Our model considers attributes associated with each information element. These are:

- **Name -** the name of the data field, e.g., "Cost Code ID".
- **Value -** the value of the data field, e.g., "CC-WI-INS-CBY".
- **Data type -** this could be text, date, $ amount, ID, number, hyperlink, etc.
- **Source -** refers to the source of the information.
  - If the information is new and requires *input* from the person filling out the form, then it is labeled as "DATA!" and is highlighted with a green background for visibility.
  - If the information can be generated automatically such as a timestamp, it is labeled "AUTO!" and is highlighted in yellow.
  - If the information can be generated automatically, as the result of another process within this same document, such as a calculation, it is labeled "CALC!" and is also highlighted in yellow.
  - If the information has its source in another document or previous external process, then the "Process ID" of the source is entered here.

The idea is that it must be possible to trace all information back to its original source. If the information is not new, an internet-based system would integrate it automatically.

4.3.1.3. Attributes Associated With Process Activities

Our model also considers attributes associated with each activity. We use these attributes to evaluate the potential savings and impact an internet-based system is expected to have. We discuss the relationship of these attributes in the Analysis discussion in Chapter 5. The attributes are:

- **Process ID -** the IDEF0 notation used to enumerate and identify every level of detail in the process.
- **Organization -** the company responsible for performing the activity. The major organization types are: Owner (O), Construction Manager (CM), Architect (A), Engineer (E), General Contractor (GC), Subcontractor (S), and Vendor (V).
- **Actor -** the individual within the company responsible for performing the activity. This could be for example: Project Manager (PM), Superintendent (S), Project Engineer (PE), Project Accountant (PA), Foreman (F), Office Clerk (OC), Field Clerk (FC), Accounting Entry (AE), etc.
- **Document -** the document, log or database in the process. For example, Time Card, Accounting Database, Cost Code List, etc.
- **Activity classification -** the category used to describe the nature of the activity. This is useful to understand how people spend their effort and to point out how an internet-based system can add value to the quality of their time. It could be one of the following:
  - "Prepare Document" - activities required to create or modify a document, e.g., open document, create document, edit document, save document, close document, etc.
  - "Process Document" - activities to distribute document to its next step in the process, e.g., assemble document, copy document, send document, receive document, deliver document, etc.
  - "Authorize Document" - activities to authorize a document, e.g., review document, approve document, sign document, etc.
  - "Locate Document" - activities to archive or retrieve a document, e.g., find document, retrieve document, archive document, etc.
  - "Update Database" - activities to update the accounting database, open database, etc.
  - "Update Log" - activities to update a document log, e.g., update SCOR Log, etc.
- **Activity skill -** the level of skill or authority required to perform the activity. These are:
  - "Clerical" - requires minimal clerical skills, e.g., copy document, send document, etc.
  - "Technical" - requires technical skill, computational power, knowledge, experience, e.g., calculate amount, analyze result, estimate cost, etc.
  - "Managerial" - requires judgment and authority, e.g., review document, approve document, sign document, etc.
- **System -** the "Paper-based system" or the "Internet-based system".
- **Processing Effort -** the estimate of the processing time or effort each activity requires on each type of system in seconds or minutes. If the activity is automated or eliminated the processing effort is 0.
- **Effect on Activity -** refers to how the internet-based system will affect the activity. The effect could be:
  - "Same" - the internet has no effect on the processing effort to perform the activity, e.g., "Approve time card."
  - "Reduced" - the internet is able to reduce the processing effort to perform the activity.
  - "Automated" - the activity remains, but due to the internet-based system, the human effort to perform it has been reduced to zero, e.g., "enter cost code description".
  - "Eliminated" - the activity is no longer necessary in the internet-based system, e.g., "print time card".

- "Reassigned" - the activity may be reduced or automated, but it has also been reassigned to another actor due to the internet-based system.

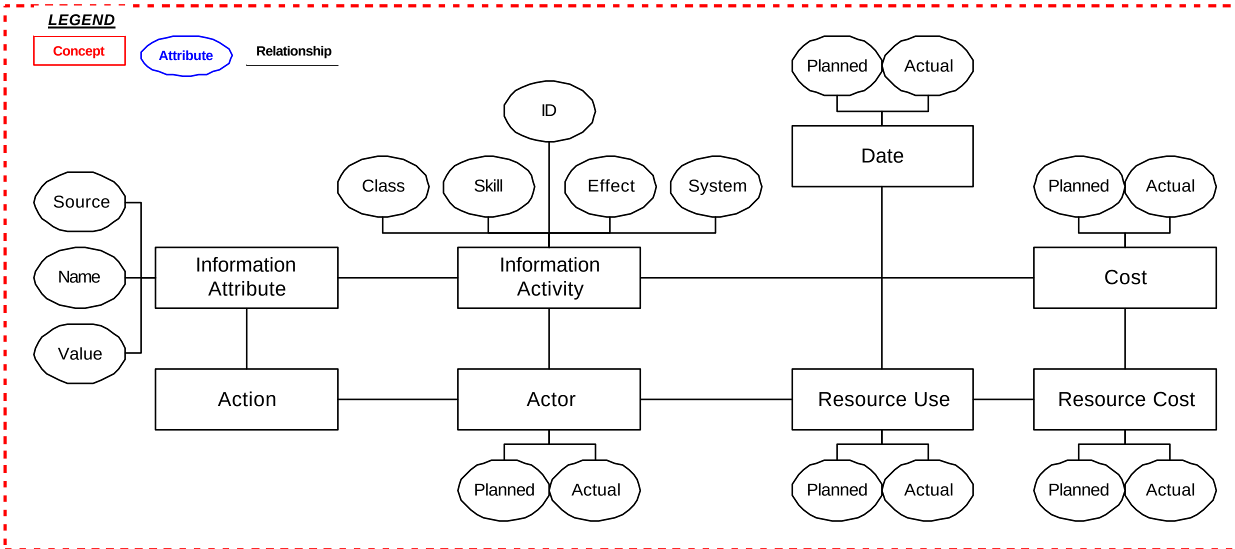


Figure 4-6. *Information activity with associated key concepts and attributes.*

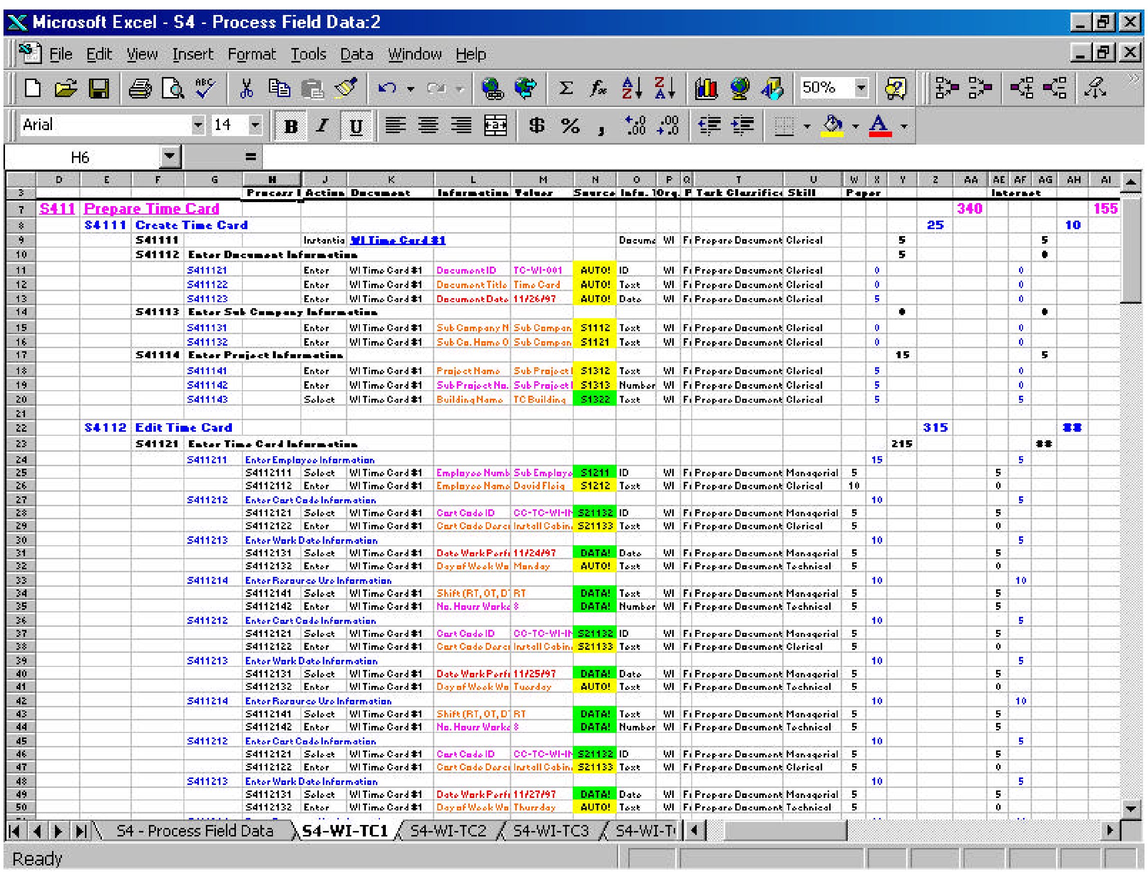


Figure 4-7. *A portion of the analytical time card process model showing the various levels of detail and associated attributes modeled for the analysis. The complete model is given in Appendix A.*

4.3.2. Graphical Model

The graphical model, derived from the analytical model, is useful to visualize how the process is structured, what the effect of the internet-based system is on each activity, and how information flows between documents.

4.3.2.1. Structure and Decomposition

The activities are structured in a hierarchical decomposition, shown by the vertical lines between the higher level process categories and the lower level transactions in Figure 4-8. The light black arrows indicate the sequence of transactions in the process.

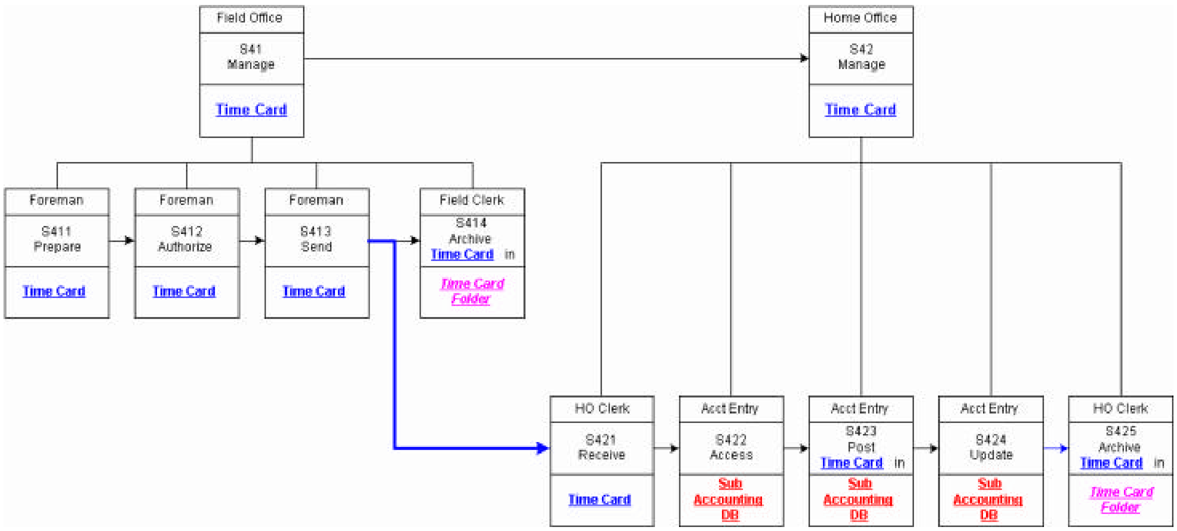


Figure 4-8. *High level graphical model of time card process S41 and S42* **-** *"Manage Time Cards".*

4.3.2.2. Source and Effect on Activity

We color an information element that is entered for the first time in green. If a activity is eliminated due to the internet-based system, the activity is crossed in red (Figure 4-9). If the information value can be obtained from another source, such as a previous document or database, we establish the relationship between these two information elements using a curved arrow (Figure 4-10). In this case, we assume the activity would be automated with the introduction of an internet-based system, and denote these activities in yellow.

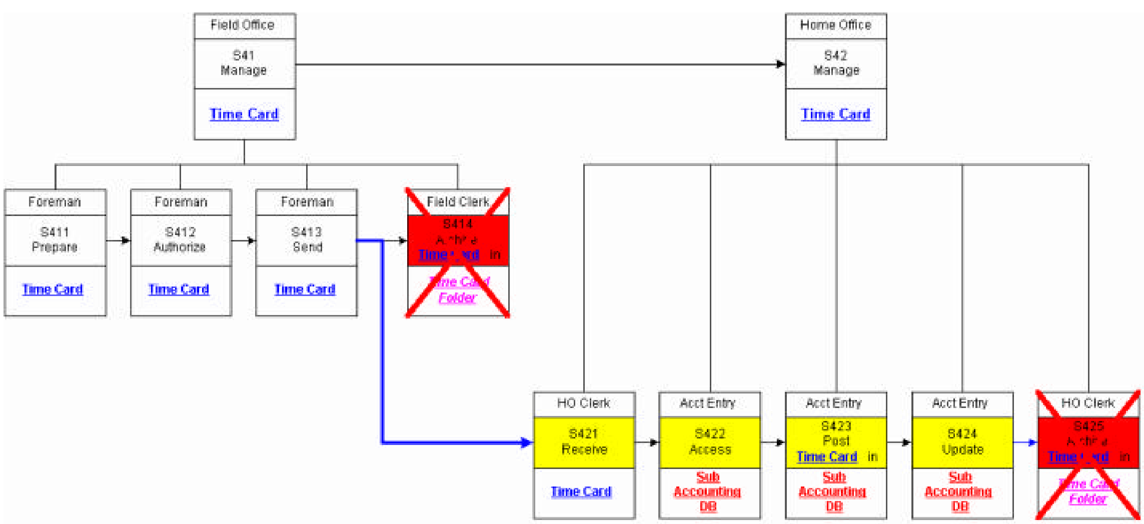


Figure 4-9. *High level graphical model of time card process shows the effect on activities due to an internet-based system. Yellow denotes automated activities. The red crossed color means the activity is eliminated.*

4.3.2.3. Document Transfer and Information Flow

A heavy red arrow indicates a document transfer between two different organizations. A heavy blue arrow indicates a document transfer between the same company, but from the field office to the home office or vice-versa. If the document changes hands between two different people in the same office as part of the same process, the arrow is also blue, but it is not heavy.

Curved arrows connecting each information element from the source to the destination show the information flow between activities (Figure 4-10).

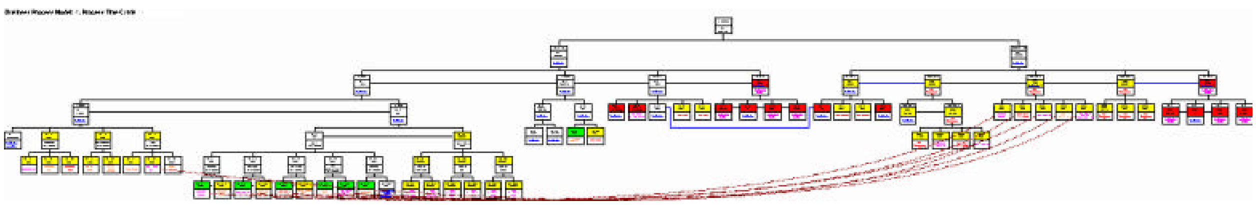


Figure 4-10. *Detailed graphical model of time card process showing the document transfer and corresponding information flow between the form created in the field and the accounting database in the home office.*

The detailed graphical model is given in Appendix B. The essential results will be discussed in Chapter 5. The main points to notice are the following:

- Fewer than 19% of the total time card process activities require entry of new data (shown in green).
- An integrated internet-based system can automate approximately 63% of the time card process either by generating values automatically, calculating values or integrating information with its source (shown by the curved arrows and/or yellow colored activities).
- An integrated internet-based system can eliminate approximately 14% of the time card process activities (shown in red). Most are related to archiving, retrieving, copying and printing documents.

Now that we have introduced the business process modeling framework we developed from the case study and examined how it relates to our research objectives, we present our analysis and results in Chapter 5.

CHAPTER 4 - REFERENCES

1. Einstein, Albert - "Collected Quotes from Albert Einstein". http://rescomp.stanford.edu/~cheshire/EinsteinQuotes.html.
2. Björk, B.-C., P. Huovila and S. Hult - "Integrated Construction Project Document Management (ICPDM)" EuropIA International Conference on the Application of Artificial Intelligence, Robotics, and Image Processing to Architecture, Building Engineering, Civil Engineering, Urban Design, and Urban Planning. (4th:1993:Delft, Netherlands). Advanced Technologies. M.R. Beheshti and K. Zreik (Editors). (c) 1993 Elsevier Science Publishers B.V. pp. 135-146. TA 345.E94 1993.
3. Stanford University "CS193J: Java Programming". http://www.stanford.edu/class/cs193j
4. Stanford University "CE214: Symbolic Modeling in Engineering". http://www.stanford.edu/class/ce214
5. Enabling Electronic Business with ebXML. http://www.ebxml.org/white_papers/whitepaper.htm
6. cXML http://www.cxml.org/
7. RosettaNet. http://www.rosettanet.org/
8. BizTalk. http://www.biztalk.org/
9. aecXML http://www.aecxml.org/

10. bcXML http://www.bcxml.org/

11. RosettaNet - RosettaNet Implementation Framework Specification. Version 1.1 Nov. 1999. http://www.rosettanet.org

12. Froese, Thomas. "Models of Construction Process Information". Journal of Computing in Civil Engineering. Vol. 10, No. 3, July 1996. P.183-193.

13. Knowledge Based Systems, Inc. "IDEF0 Overview". http://www.idef.com/idef0.html

5. TIME CARD ANALYSIS OVERVIEW

This chapter describes the analysis and results we obtained from the business process model for time cards presented in Appendix A. We begin the discussion of our results by presenting our analysis methodology.

5.1. Analysis Methodology

The business process model analysis and results are presented as follows:

- Section 5.1.1. presents the three key dimensions we used for the results of the analysis - number of activities, processing effort, and calendar time.
- Sections 5.1.2. discusses the parameters of interest we used in our model (e.g., organization, position, skill, activity classification, etc.).
- Section 5.1.3. explains the layout and format we used to present our results.
- Section 5.2 summarizes the highlights of the single-parameter analysis.
- Section 5.3 summarizes the insights of the multi-parameter analysis by analyzing how each parameter varies as a function of the other parameters. This is interesting to help us understand the relationships between the parameters and what the implications may be on staffing, productivity, skills required, etc.
- Appendix C describes the results of our single-parameter and multi-parameter analysis in detail.

5.1.1. Dimensions Measured in Analysis

The analysis measures these key dimensions:

- Number of activities - how many activities are performed in the process at the document or information element level to understand how an internet-based system would affect these activities.
- Processing effort - how much "real" time (minutes), as opposed to calendar time (days), each process takes, and how productivity is affected by the internet-based system. The time estimates for each activity were evaluated in increments of five seconds. The total effort estimates (expressed in minutes) can also be used to estimate the cost savings in terms of the wages of the people involved, though this was not part of our analysis.
- Calendar time - how much calendar time (days) each transaction in the process takes to understand the expected impact on the overall process duration due to the internet-based system.

5.1.2. Parameters Modeled in Analysis

The main parameters we modeled for each key dimension are:

- Transaction – the main high-level processes modeled.
- Organization – the organization responsible for each activity. This may be further subdivided into the Field Office (FO) and Home Office (HO).
- Position – the actor responsible for the activity (e.g., foreman, clerk, or accounting entry person).
- Activity skill – the skill required to perform the activity (i.e., clerical, technical, or managerial).
- Effect on activity – the effect due to the internet-based system (i.e., same, reduced, automated, or eliminated).
- Activity classification – the nature of the activity (i.e., prepare document, process document, authorize document, locate document, or update database).
- Source – the source of the information (i.e., DATA!, AUTO!, CALC!, or other Process ID).

5.1.3. Presentation of Results

The results are presented in the following format:

- A series of questions will frame each analysis.
- For each dimension, a histogram will graphically compare the paper-based system with the internet-based system.
- The values of the bars are given in the tables below the graph(s) for clarity.
- The tables also show the % distribution of each parameter as a function of the dimension.
- The last table shows the comparison between the two systems in terms of % change (decreased or increased).

5.2. Single Parameter Analysis Highlights

The graphs and tables presented in Appendix C clearly demonstrate the effects an internet-based system would have on the time card process by measuring one parameter at a time. The key insights or highlights of this analysis are summarized here in the same order presented in Appendix C:

<u>Effect on Processing Effort & Productivity</u>

- The overall processing effort for the time card process can be *decreased* by a factor of 74% from 13 work-minutes to just over 3 work-minutes, increasing the productivity by a factor of nearly 4 (Appendix C.1.1).

<u>Effect on Transactions</u>

- Of the nine transactions in the paper-based process, two are eliminated and four are completely automated (Appendix C.1.2).

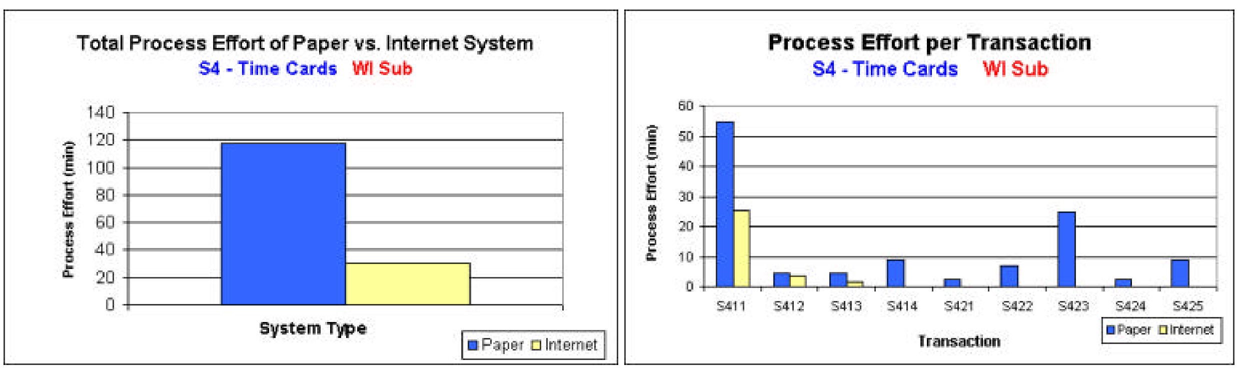


Figure 5-1. *A time card business process model analysis comparing the processing effort required with a paper-based system vs. a hypothetical integrated internet-based system in terms of total processing effort and effort per transaction.*

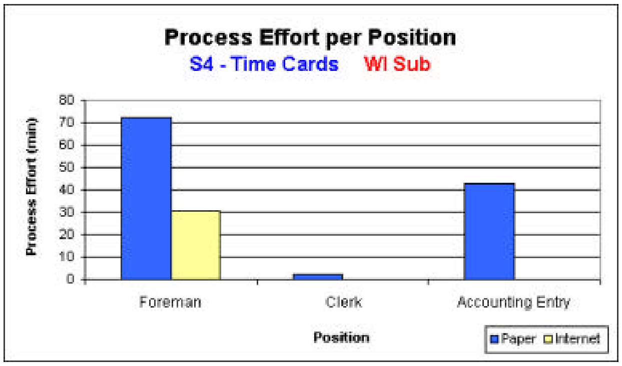
<u>Effect on Staffing</u>

- Only the foreman is needed to process time cards. The clerk and the accounting entry person are no longer needed since their activities are either automated or eliminated (Appendix C.1.3).
- Even though the foreman now carries out all the time card work, he would spend less than half the effort with an internet-based system than with the current paper-based system (Appendix C.1.3.).

<u>Effect on Skills Required</u>

- The paper-based process misuses the skills of management staff by only using minimum processing effort on managerial skills (20%) and instead requires maximum clerical (23%) and technical (57%) skills (Appendix C.1.4.).

- The internet-based process focuses management's processing effort on managerial skills (74%) and reduces the need for clerical (10%) and technical (16%) skills to a minimum (Appendix C.1.4.).



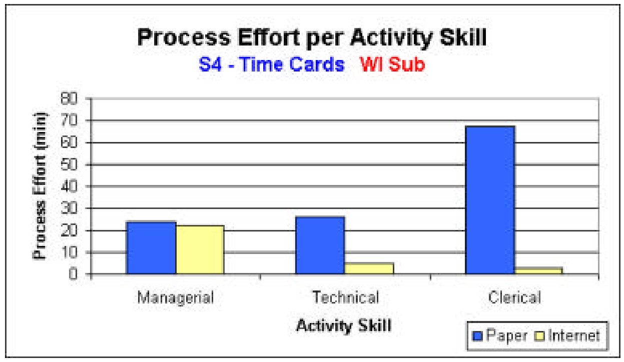


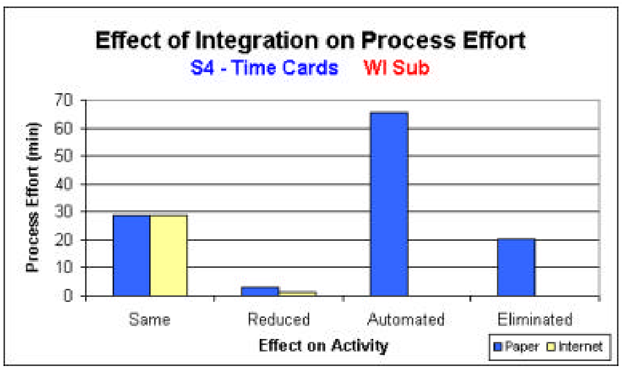
Figure 5-2. *A time card business process model analysis comparing the processing effort required with a paper-based system vs. a hypothetical integrated internet-based system in terms of processing effort per position and effort per activity skill.*

Effect on Activities Due to Internet-Based System

- The internet-based system has a significant effect on almost every activity. 63% of the paper-based activities are automated and 14% are completely eliminated (Appendix C.1.5), 22% remain the same and only 1% are reduced in processing effort.

Effect by Activity Classification

- In the paper-based system, 47% of the processing effort is centered on preparing documents (the time cards), and 4% on authorizing documents, while 8% is spent processing documents, 15% locating documents, and 26% updating the database.
- In the internet-based system, the majority of the processing effort (83%) is centered on preparing the time cards, instead of authorizing documents (5%), processing documents (12%), locating documents (0%), updating logs (0%) or updating the accounting database (0%) (Appendix C.1.6).



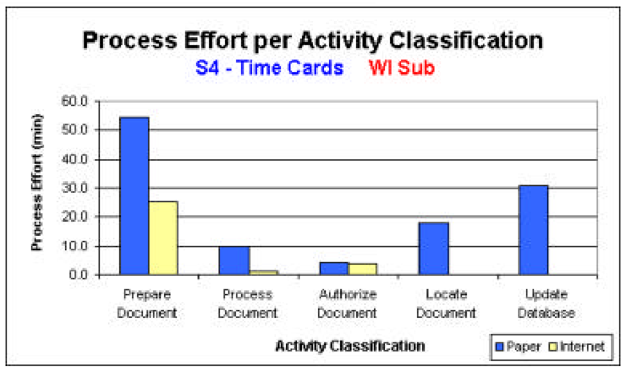


Figure 5-3. *A time card business process model analysis comparing the processing effort required with a paper-based system vs. a hypothetical integrated internet-based system in terms of effect on processing effort by system type and processing effort per activity classification.*

Analysis by Activity Level

- The number of activities at the information element level goes from 82% to 92% of the total activities. Hence, less effort is spent on non-value-adding activities at the document level, such as "print document" or "archive document". The processing effort for activities at the document level is reduced by 83% while the effort for activities at the information element level is reduced by 71% (Appendix C.1.7).

Analysis by Information Source

- Only 19% of the total activities at the information element level require new data entry. This means that over 80% of the information contained on time cards can be either obtained from a different document or generated automatically by an internet-based system (Appendix C.1.8).

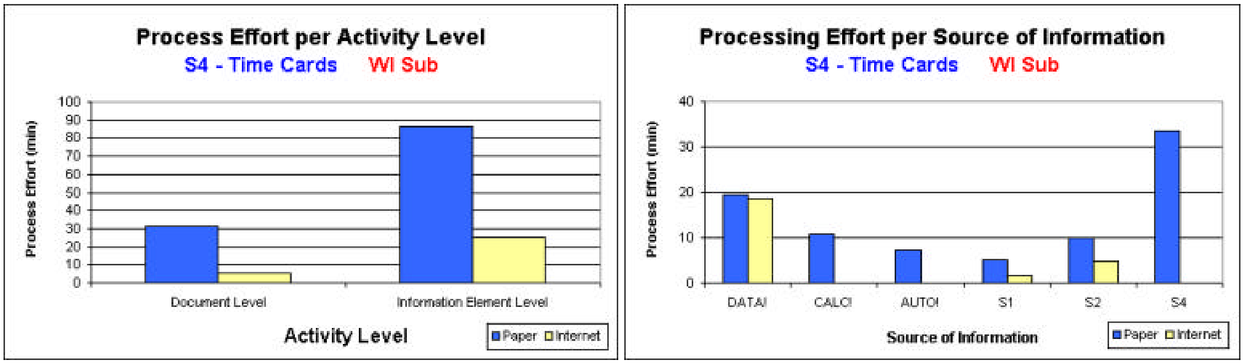


Figure 5-4. *A time card business process model analysis comparing the processing effort required with a paper-based system vs. a hypothetical integrated internet-based system in terms of processing effort by activity level and processing effort per source of information.*

Analysis by Data Type

- Although the purpose of time cards is to record the "number of hours" worked on an activity, only 31% of the activities in the process deal with numbers. Many other information elements of different data types (e.g., company name) are needed to give the document its context (Appendix C.1.9).

Effect on Calendar Process Duration

- The impact on calendar time by using an internet-based system to process time cards is minimal, about one business day going from one day in the field and one in the office to simply one in the field. Yet its true value will become evident as other management functions, such as payroll and the change order process, make use of time card information already in the system (Appendix C.1.1.3).

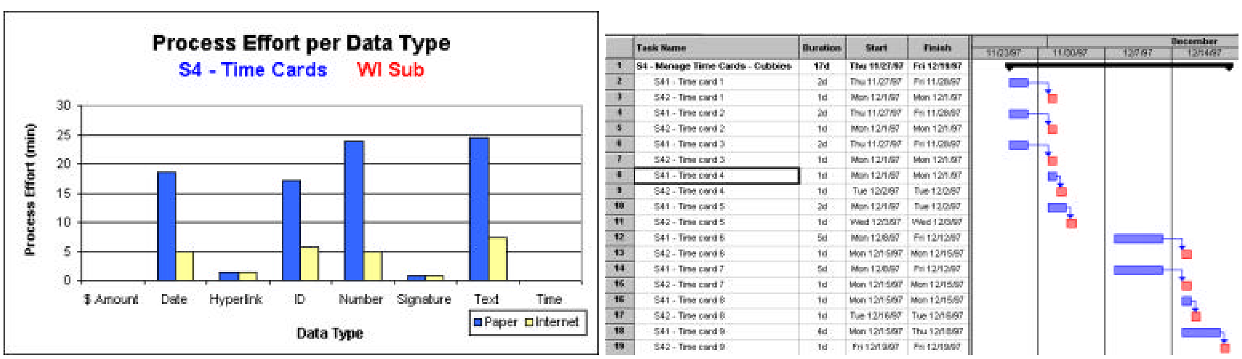


Figure 5-5. *A time card business process model analysis comparing the processing effort required with a paper-based system vs. a hypothetical integrated internet-based system in terms of processing effort per data type and calendar process duration.*

In summary, the internet-based system provides better use of time, effort, and resources, and makes information instantly accessible and reusable for other processes. Now, we give an overview of the results of our analysis where we compared two parameters at a time.

5.3. Multi-Parameter Analysis Highlights

The graphs and tables presented in Section 5.2 and Appendix C.1 clearly demonstrate the effects an internet-based system would have on the time card process by measuring one parameter at a time. This section and Appendix C.2 discuss how these parameters vary as a function of the other parameters. This gives further insight into where the internet-based system would have the greatest impact on the overall process.

The key insights or highlights of this multi-parameter analysis are:

- **Distribution by Position**
  - Only the foreman is necessary to perform the internet-based time card process (Appendix C.2.1.1.1).
  - The overall processing effort the foreman uses would be reduced from 73 minutes to 31 minutes, increasing his productivity by a factor of at least 2 (Appendix C.2.1.1.1).
  - With an internet-based system the foreman spends 74% of his effort on managerial activities compared to 31% with the paper-based system. This implies the foreman can use his skills and time more productively instead of on clerical activities (Appendix C.2.1.1.2).
  - Of the foreman's original processing effort, 40% remains the same, 4% is reduced, 42% is automated, and 13% is eliminated (Appendix C.2.1.2.2).
  - The work to process the time cards and update the information to the accounting database is reassigned to the foreman yet does not add processing effort to his activities since this work is automated (Appendix C.2.1.3.2).

- **Distribution by Activity Skill**
  - In the paper-based system, the clerk and the accounting entry performed mostly clerical activities to alleviate managerial people like the foreman from performing these types of activities. Now that these activities are automated, the foreman can perform 100% the activities himself and still spend less time (Appendix C.2.2.1.2).
  - The internet-based system has the greatest impact on clerical and technical activities. 71% of activities requiring clerical skills would be automated and 26% eliminated. 84% of activities requiring technical skills would be automated (Appendix C.2.2.2.1).

- **Distribution by Effect on Activity**
  - The distribution of the activities automated by an internet-based system in terms of actors is as follows: the foreman performed 55%, the clerk 3%, and the accounting entry person 42% (Appendix C.2.3.1.1).
  - 75% of the activities that remain the same are managerial. This is logical since the time to review a time card would not be affected significantly by the system used to create it (Appendix C.2.3.2.1).
  - The distribution of the activities automated by an internet-based system in terms of activity skill is as follows: 2% are managerial activities, 36% technical activities, and 62% clerical activities (Appendix C.2.3.2.1).
  - The distribution of the activities eliminated by an internet-based system in terms of activity skill is as follows: 100% are clerical activities (Appendix C.2.3.2.1).
  - The distribution of the activities automated by an internet-based system in terms of activity classification is as follows: 51% are to prepare the time cards, 7% to process them, 1% to authorize them, and 41% to update the accounting database (Appendix C.2.3.3.1).
  - The distribution of the activities eliminated by an internet-based system in terms of activity classification is as follows: 9% are to process time cards, and 91% to locate (archive) them (Appendix C.2.3.3.1).

- **Distribution by Activity Classification**
  - Of the total paper-based activities to prepare time cards, 28% are managerial activities, 51% are technical activities, and 21% are clerical activities (Appendix C.2.4.2.1).
  - Of the processing effort to prepare time cards: managerial activities would expend 74%, technical activities 20%, and clerical activities 6% with the internet-based process (Appendix C.2.4.2.2).
  - Of the activities to prepare time cards: 39% would remain the same, and 61% would be automated (Appendix C.2.4.3.1).
  - An internet-based system would eliminate 100% of the activities to locate time cards (Appendix C.2.4.3.1).
  - An internet-based system would automate 100% of the activities to update the accounting database (Appendix C.2.4.3.1).
  - An internet-based system would automate 54% of the processing effort to prepare time cards and 46% would remain the same (Appendix C.2.4.3.2).

In conclusion, our analysis shows internet-based systems can be very useful in streamlining the time card process and making the best use of people's talents by taking advantage of technology to automate clerical and technical activities and to eliminate paper-based activities that are no longer relevant.

We now present a summary of our contributions and expected benefits in Chapter 6.

6. CONTRIBUTIONS AND BENEFITS OF RESEARCH

In this report, we have discussed why modeling management activities is an essential step to achieve the vision of information integration in the AEC industry. This chapter summarizes the contributions our research has made towards information integration and offers some insights of the major qualitative and quantitative benefits an internet-based system can offer over paper-based systems of project control, based on our analysis of the time card process model.

6.1. Contributions of Research

The research contributes to two main areas of importance:

- First, it extends the product and process modeling concepts developed in AEC research to model engineering and construction activities to include project document and management activities.
- Second, it provides a framework consisting of several structured levels of detail to model AEC business processes in a consistent and logical way. This is useful to describe and compare different business processes across companies, system types, project phases and categories.

These contributions are necessary and useful to create business process models that provide a basis for useful and insightful analysis of where internet-based systems will provide value and an estimate of what this value will be.

6.1.1. Extending Previous AEC Research for Modeling Business Processes

Previous research and standards efforts in AEC product and process modeling have been heavily focused on modeling the building components and physical activities of a construction project. Relatively little has been done with respect to project documents and management activities. However, due to the intense fragmentation present today in managing paperwork across companies using paper-based systems, the potential of new internet technologies, and the need for standardized transactions across the AEC industry, research in this area is needed.

The good news is that many of the concepts developed to model construction activities and building components can be extended and modified to model management activities and documents. For example, the time card process model uses concepts such as project, facility, physical activity (action-building component), resource, resource use, date, time, cost, organization, actor, application, and document that are common to construction product and process models as well.

6.1.2. Levels of Detail in Business Process Modeling Framework

The business process modeling framework defines multiple levels of detail ranging from the business process category level, such as "S41 - Manage Time Cards", to the information activity level, such as "S41112122 - Enter Cost Code Description". The various levels of detail help us visualize how documents are created and processed, what information needs to be linked, and how information flows. Each activity compares the processing effort for the paper-based vs. an internet-based system allowing us to estimate the potential magnitude of the impact an internet-based system can have on productivity. The model also shows where internet-based systems are expected to have the most impact. This adds a unique perspective not found in most process models created by various organizations or companies, which are only at the document level.

The value of structuring business processes using the framework we developed is that it is now possible to model other business processes such as those in contract management and billing using the same levels of detail and compare the similarities and differences very easily. It is also possible to determine very clearly the logical flow of information. This is useful to help standards bodies and software companies define an implementation and standardization strategy for building applications that incrementally add value to the end-user by integrating with and building upon previous processes defined within other applications. This approach would add the most value and thus leverage the return on investment of everyone's time and effort.

6.2. Key Benefits of Internet-Based Systems

In this section, we highlight the major qualitative and quantitative benefits observed from the analysis of the time card process model:

6.2.1. Qualitative Benefits

- The process is streamlined.
  - Only the foreman would be needed to enter time card information directly into the accounting system.
  - Repetitive activities, such as "enter project name", will be automated.
  - Paper-centric activities, such as "print document" or "archive document", will be eliminated.
- The quality of information will increase.
  - The system could prompt the user to use only cost codes for activities that are currently scheduled.
  - There would be less chance of entering incorrect or incomplete information if the system checks the integrity of the information before committing it to the database.
  - The system would virtually eliminate the need for phone calls to clarify or request missing or potentially incorrect information entered on paper documents.
- The information will be available immediately.
  - Management would be able to forecast costs and measure performance against the budget, rather than have to wait weeks to get a cost report.
  - Management would be able to quickly identify areas of potential overrun that require immediate attention.
  - Others who need access to the information would have it available without having to go through intermediaries and associated delays.
- The information will be integrated with its source and across multiple processes.
  - The model shows the source of every information element, thus establishing the relationships necessary for automated information flow.
  - Better integration eliminates the need for intermediaries and data re-entry.
  - Key information can be centrally located for reuse in other processes like a change order request or manpower report or calculation of % complete for an activity.
  - Cost overruns could be immediately tracked back to their source.

6.2.2. Quantitative Benefits

- Productivity will increase as processes become more efficient.
  - Of the nine transactions in the paper-based process, two are eliminated and four are completely automated.
  - The overall process effort can be reduced by 74%, increasing the overall process productivity by four times.
- Automation or elimination of redundant activities and information.
  - Our model and analysis demonstrate that only 19% of the total activities at the information element level require new data entry.
  - This means over 80% of the information contained on time cards can be either obtained from a different document or generated automatically by an internet-based system.
- Quality of process effort will increase with an emphasis on value-added information and managerial activities.
  - The majority of the effort (83%) would be spent preparing the time cards rather than processing them or locating (archiving) them.
  - The internet-based system increases the relative amount of process effort spent on managerial activities from 20% to 74%, thus reducing mundane clerical and technical activities to a minimum.
  - The number of activities at the information element level increases from 82% to 92% of the total activities,

implying fewer non-value-adding activities at the document level such as "print document" or "archive document".

- Hard cost savings can be estimated.
  - Although we did not estimate hard cost savings, it is evident that the savings will come from the reduced process effort.
  - To be more precise, it would be necessary to include the printing costs, paper copy costs, and faxing costs saved and offset these with the costs to implement the internet-based system.
- Impact on calendar time is minimal for time card process.
  - Automating the time card process can probably save about one business day.
  - However, its true value will become evident as other management functions make use of time card information already in the system.

These benefits increase personnel productivity, reduce project duration, lower costs, and enhance the quality and integrity of information and communication on the project.

6.3. Conclusion

In conclusion, business processes today are inefficient and complex. The AEC industry needs a way to streamline these business processes to reduce project duration and costs. Internet-based systems have the potential to enable great time and money savings, but industry standards are required. Therefore, there is a need to model these business processes explicitly to understand and visualize the flow of information and to identify the source and quantify the magnitude of these process inefficiencies. In our research, we developed a business process modeling framework to create explicit business process models and assess the potential benefits of integration with internet-based systems over traditional paper-based systems. This report details our findings with respect to the time card process. Other reports describe our findings for change order, billings, and payment processes to gain a more global perspective. We believe this will become very important in the coming years as companies strive to streamline their information management processes and integrate seamlessly with their trading partners. We hope that this report provides the starting point and tools for a dialog between the many participants in project management processes and between software vendors and practitioners to enable professionals to use their expertise, time and attention in the best possible way.

APPENDIX A. ANALYTICAL TIME CARD PROCESS MODEL

See link on CIFE website.

APPENDIX B. GRAPHICAL TIME CARD PROCESS MODEL

See link on CIFE website.