Using Bar Codes to Improve Labor and Equipment Tracking in the Construction Industry

by

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University of Vermont

Submitted to the Department of Urban Studies and Planning in Partial Fulfillment of the Requirements for the Degree of Master of Science in Real Estate Development.

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Abstract

This thesis outlines the costs, advantages, and industry impacts of implementing a system to track resource allocations, procurement and deliveries of materials on construction job sites. By using bar code scanners and hand held data collection devices, the construction industry stands to reduce costs to owners by some $16 billion annually. The system will provide daily reporting of budget allocations across sets of phases, and automatically create various reports defined by the project team prior to beginning work. The result is improved quality, reduced project costs, and increased accountability of resources. The paper presents a dynamic system that has the capability to track a high level of labor and equipment cost detail, as well as an improved means of tracking submittals, approvals, fabrication, delivery, and installation of materials.

The need for the system stems from the demands placed on supervisory personnel in the construction industry. Supervisory personnel include foremen on job sites and in fabrication shops, vendors shipping materials to job sites, project managers, and management in supply houses. With improved data collection capabilities, these individuals will provide their supervisors with improved cost information with greater frequency. This data will result in lower costs per reports, such as project schedules and inventory reports, and bolster the companies' historical cost data for all operations performed. Additionally, the system will allow contractors to recover a greater portion of extra work expense than they do presently, as well as shorten payment durations from general contractors and owners.

The thesis examines the effect of implementation on a single subcontractor in a single trade. The potential ramifications of industry wide use of such a system are similar in scope to what the grocery industry experienced in the late 1970's and early 1980's as a result of implementing bar code technology to track and order inventory through the checkout process.

At a minimum, the system promises to help individual contractors realize savings and increas productivity on construction projects. At most, it could change the way the world buys $4 trillion in construction services globally every year.

Thesis Supervisor: John D. Macomber
Title: Lecturer, Department of Civil & Environmental Engineering

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Thesis Overview

1.0 Statement of Problem

The construction industry has always been quick to adapt better ways of doing things when the impact of doing so is easy to see. As owners clamor for delivery of buildings in ever-shortening project durations, contractors are forever looking for ways to improve their field operations. Although construction of buildings remains an awkward process of hanging various materials to some sort of frame, there have been countless minor innovations that have resulted in significant productivity gains for individual trades. For example, masons now spend far less time erecting and moving their work platforms, thanks to motorized scaffolding. More and more carpenters carry pneumatic nail guns instead of hammers, resulting in increased efficiency of a repetitive action.

One area where the construction industry has been slower to grasp the full benefit of technological advances has been in the area of computing and electronic data transfer. While the benefit of spending 1/3 the amount of time placing a nail is easy to see, it is more difficult to ascertain the less tangible benefits of data transfer and management using computers. All the same, as the construction industry moves slowly but steadily towards wider acceptance of computers and other electronic technologies, there exists tremendous potential for increased productivity, improved quality, and reduced costs to all parties involved. One aspect of construction that could benefit from the application of improved electronic technology is labor and equipment tracking on job sites. It is this aspect of construction that this thesis uses as a framework within which to illustrate the many wide-reaching benefits of the system outlined.

The current methods employed to track labor and equipment costs on job sites require data to be handled multiple times and are rife with opportunity for error. Additionally, the data is usually transferred from the job site to the home office by facsimile, by mail, or by runner on paper forms. The benefit of transferring cost data from the field directly into the job cost computer lies in the ability to manipulate data more efficiently into meaningful information for management.

This thesis outlines a system for data collection and manipulation on construction job sites. The system, as envisioned, will save employees responsible for a number of tasks a significant number of man-hours in accomplishing the critical task of tracking labor and equipment costs. The time saved will result in lower costs for the contractor, and improved quality and customer service for the general contractor and owner through the availability of more time on the project for the foremen and project management to "sweat the small stuff." The system also has the potential to reshape certain aspects of the industry, resulting in positive savings to subcontractors, general contractors, and owners.

For the purpose of this thesis, the discussion will focus specifically on a single contractor involved in a single CSI division of work. The focus contractor is a steel fabricator and erector, operating as a subcontractor. The reasons for this focus are discussed later.

1.1 Statement of Hypothesis

In implementing the cost tracking system outlined in this thesis, the author anticipates a savings to the subject subcontractor of 2% on gross revenue, or approximately $600,000 annually. The initial benefit realized by the subcontractor will be in reduced labor costs, improved accountability of resource expenditure, and improved quality to customers, which all lead to enhanced competitiveness on bid day. These aspects will eventually lead to increased profitability.

Looking beyond the computed time savings, the subcontractor will create the ability to shorten project durations. Since nearly every contemporary construction schedule is built around the delivery of the structural steel, this has serious implications for all players in the construction supply chain, from owners, architects, and engineers, to subcontractors and materials suppliers. Shortened project durations, even for a single trade, mean a new landscape for the rest of the players. In the case of an owner like IBM, starting production in a new wafer fabrication plant even a day early can easily be worth $500,000[1]. Multiplying the benefits of a system capable of improving a number of links in the supply chain across the entire construction industry yields a significant impact.

1.1.1 Outline of hard savings as % of revenue

As quantified in the next chapter, the amount of hourly savings anticipated by the system in full implementation is approximately $190,000 annually at current wage rates. This number is the sum of the various analyses shown in chapter two.

1. Ron Guido, Pizzagalli Construction Company. Telephone conversation with author, July 26, 2001. The current market for a 300mm wafer is approximately $1000-$1500. Production levels of 9,000 units/month is common, resulting in revenue of $489,130/day @ $1,250/wafer.

Assuming $30 million in revenues (see 1.4), our focus subcontractor would stand to realize hard savings of .63% on revenue, implementation not included.

1.1.2 Abstract of soft savings/gains

Aside from the hard dollar savings outlined above, the change to a digital data-collection system has a number of potential cost advantages that are not so clearly quantified. Certain of these "soft savings" are anticipated to be as significant as the sum of the "hard savings."

The most promising of the "soft savings" to an individual subcontractor is the Change Order and Delay Claim aspect of the system. The details of the system are discussed later. Based on interviews with the focus subcontractor's project managers, the average project foregoes approximately 2% of the contract amount in unpaid extra work. Assuming that the average contract is $1,000,000, using a conservative 1% of the contract amount gives a total of $10,000 in unrealized revenue. Over 30 jobs, this amounts to a total of $300,000 annually.

Currently, the majority of extra work items that cost less than $500 are not even quantified and presented to the general contractor. With a system that allows faster generation of an extra work claim, the management team will be better equipped to generate change requests, which will provide another level of smaller "throw away" claims when the project manager sits down to negotiate extra work compensation with the general contractor. If the project manager can improve the average percent of foregone extra work from 1% to .5%, the benefit to the company over 30 jobs is some $150,000 annually. This soft aspect alone, coupled with the above hard savings, results in savings of 1% on revenue annually. While not an immediate benefit to the owner, it results in more equitable distribution of funds among the contractors, in that companies that have legitimate extra costs are likely to be paid for the work. Conversely, those contractors that "padded" their bid in anticipation of potential work that they might not get paid for won't experience an undue windfall. In time, as individual contractors' margins increase as a result of being paid for a higher percent of the extra work they perform, bid prices will fall incrementally as contractors feel less need to "pad" bid prices to cover potential extra work. This will be particularly true on difficult jobs, or on jobs with incomplete drawings where a high level of extra work is anticipated.

A second "soft benefit" of the system is improved historical production data. This is discussed in Chapter Two. If improved cost data were responsible for one additional award per year, the benefit would be $1,000,000 in revenue, on average. Whether the job was competitively bid or negotiated is irrelevant. At 10% profit, that one additional job is worth $100,000.

The sum of the soft savings mentioned represents a total of $550,000, or 1.83% of revenue before implementation. The combined hard and soft savings represents some $718,000, or 2.39% of revenue before implementation. Implementation costs are discussed later, but are anticipated to be approximately $120,000, resulting in a conservative hard and soft savings estimate of 2.0% of revenue.

If all the subcontractors in the construction industry were to do their work for 2% less money while maintaining their profit levels in the $800 billion construction industry in the United States, the impact on the real estate industry (including government projects) would be something on the order of $16 billion annually. That doesn't consider the benefits of improved project delivery, as in the IBM example in 1.1 above.

1.2 Overview of Bar Code Technology

For many people, the most recognizable application of bar code technology is in the food industry. Just about every consumer can identify the familiar series of black bars on a white background on nearly every label and product in a grocery store. These labels have improved checkout, inventory tracking and reordering for grocery stores over systems used as recently as 20 years ago. They have also improved operations for participants across the supply chain, from producers, to wholesalers and distributors, to end consumers.

The adoption of the Universal Product Code (UPC) on April 3, 1973 meant that products had to be registered with the Uniform Code Council. Each producer was issued a unique code, embedded into the first half of a "bar code." A bar code is a series of vertical black bars that typically contain two groups of six bits of information. The second half of the bar code contained information to identify each individual product from that particular producer. Products were now recognizable to scanners in a standardized system. Lasers capable of scanning these bar codes revolutionized the checkout process in grocery stores in the late 1970's. The scanners eliminated the need for manual input of a product's price into the register. They also automatically updated the store's inventory, easing reordering tasks, and lowering inventory requirements. This type of efficiency is why an increasing number of industries are turning to bar codes and scanners to handle data collection tasks.

In the grocery industry, bar codes lead to the demise of the independent grocer. In their place evolved the regional distribution center. Stores are now stocked by regular deliveries of trucks filled with small amounts of diverse product from one location, instead of sporadic deliveries by trucks full of one product from many locations. The consolidation of the grocery industry has left consumers with a handful of super-efficient, national grocery chains. The parallel changes in store for the construction industry are discussed in section 2.0.

In the construction industry, there are a number of operations performed that involve the collection of data from the field for progress and cost tracking. The use of bar code technology, coupled with hand-held data collection devices, would greatly reduce the amount of time spent on collection and handling of this data, while increasing the accuracy and reliability of the information.

As in the grocery industry, there exists the possibility for sweeping changes in the construction industry as a result of the implementation of this technology. This thesis will detail the system's impact on a specific contractor in a specific division of work, and outline possible industry-wide impacts on different players resulting from its use, including owners, general contractors, subcontractors, and suppliers.

It should be noted that bar codes already exist to a small degree in construction, as a system for tracking small tools. Items such as circular saws and screw guns can be tracked on construction sites using bar codes and scanners. In fact, the proposal received in response to the RFP issued for this thesis included a "module" for tracking small tools. However, the scope of this thesis does not include small tool tagging and tracking. It is considered to comprise a very small portion of the possible gains to be realized through the system as described, and as such is not discussed.

1.3 The Culture of Monitoring

The implementation described in this thesis places the responsibility of collecting daily project data into the hands of the foreman on site, where it currently resides. The alternative is to place the responsibility in the hands of the individual tradesmen. For example, a welder who was installing bar joists on a building would have to track how many bar joists he secured in a day's work. That employee's compensation could be tied to production, so that the system could not be thwarted without affecting the employee's paycheck. In this manner, supervisors could know with a few keystrokes which employees on each job were producing the most, either for that particular day, the past week, or over the past year. This would have the effect of improving the overall quality of the contractor's work force, as those workers who were unwilling to have their pay tied to production (their own individually or that of a crew) will be the first to leave. In their place will materialize workers who are better than average, and are thus anxious to have their pay tied to production.

With this information, Precision would then be able to show their production records to general contractors as proof of their ability to get jobs done faster than their competition. As the industry accepts the technology, general contractors will use these production records as another consideration in awarding new work. The subcontractors will be able to show a particular crew's ability to perform, and guarantee that crew's presence on the site to secure the contract, if desired.

By and large, construction workers take great pride in their work, and a system that timed their every move would likely not be embraced without some resistance. Construction workers, like most people, would rather be left to do their job as a trusted professional, rather than policed in every action over the course of a day. In areas where labor is organized, the system may well be resisted as an infringement of workers' rights. The challenge will lie in demonstrating to the workers that the system will help make them better as a company, and is not intended as to police their actions.

Due to these complexities, the responsibility of data collection has been left in the hands of the foremen on site in this investigation. This also provides a less expensive implementation, as data collection devices are required for far less individuals. However, the system outlined in this thesis is likely a stepping stone to a world where every carpenter, millwright, ironworker, and equipment operator will have to track his or her own activities and production in order to be paid for it, with the above mentioned aspects resulting.

In contrast to the tradesmen on the job, the system will be well received by both foremen and project managers. While a period of adjustment is anticipated for foremen to get used to recording their crews' and equipment's activities as they are directed, the foremen will soon realize the advantage of not having to fill out paperwork at the end of the day. In fact, when the job shuts down, the foremen's reporting duties will be complete. Similarly, project managers will have better cost data on each of the jobs they are responsible for. The data will be more accurate, and will be updated every day instead of once a week, or once a month.

1.4 Overview of Concept--Methodology

The model used for the investigation of the system described in this thesis is a medium-sized steel detailing, fabricating, and erection company. Located in Raleigh, North Carolina, it services the majority of the southeast. It currently employees 165 people, has active projects in 5 states, and will complete approximately 30 projects in 2001. It is projecting revenues for 2001 of $30 million, compared to 2000 revenues of $15 million. The company represents approximately .03% of the steel contracting industry in the United States[2].

The use of Precision Steel for this thesis provides a case study approach to describing and evaluating the topic being examined. By focusing on one company, numerous specific details can be examined and applied without leaving various aspects of the system as "dependant on specific company characteristics."

Another advantage of using Precision Steel is the relatively unique scope of services it provides. Typically, when a general contractor buys services in Division 5 of the CSI code, it will write separate contracts for furnishing the steel and erecting it. Often a third contractor is required for miscellaneous metals, such as handrails, pipe bollards, gratings, and overhead doorframes. Precision offers contractors the chance to write one contract to furnish, fabricate, deliver, and erect the steel, including miscellaneous metals. They are also the source for the shop drawings that are used to fabricate and install the components they produce. This aspect is critical, as the shop drawings are the lynchpin in the final iteration of the system. Precision provides a current-day glimpse into the type of consolidation of services that is anticipated for the construction industry, due in part to the evolution of systems like the one being described in this thesis.

This level of internal control provides an excellent setting in which to

2. Based on steel representing roughly 15% of the $800 billion construction industry in the U.S.

implement a new system for tracking costs and materials. It is a controlled environment of people who are all on the same team. Implementing the system in phases is simplified, since costs, training, reporting, and evaluation are not required to cross company boundaries.

To determine a meaningful value of the conceptual system, a number of companies that specialize in providing similar data capturing solutions for industries such as manufacturing and warehousing were contacted. None had experience applying their solutions to construction in any way.

After determining a willingness to assist in the creation of this thesis, a request for proposal was sent to ScanLynx Technologies of Ft. Lauderdale, Florida (Figure #1a). The RFP is included to demonstrate the scope of the project and the level of involvement of ScanLynx. Their pricing is used to determine the costs associated with creating, training, and implementing the system (Figure #1b). Their assumptions about Precision are based on that request for proposal and a series of telephone and personal interviews between the author, the owner of Precision Steel, and a ScanLynx representative.

Precision Steel was the source of the current versus improved analysis outlined in Chapter 2. They are also the source of the time saving and hourly cost assumptions utilized. It should be noted that the costs associated with the system would likely remain largely similar to those quoted by ScanLynx regardless of the geographic location of the contractor. The same cannot be said for the savings shown for Precision. Hourly wage rates will vary widely depending on the location of the contractor, and whether or not the labor is organized. On a percentage basis, this could have a significant impact on the projected savings and NPV analysis.

Figure #1a

Request for Proposal

Requested by:

Precision Steel Erectors

Of:

ScanLynx Technologies

June 15, 2001

Scope of Work

The scope of work to be covered is the conception, design, and implementation of a bar code-based system for tracking labor, equipment, and material components of production for a medium-size steel detailing, fabrication, and erection organization with multiple office locations and job sites. The proposal should include required hardware, software, development and training.

Specifically, the proposal should include the following:

System sized to accommodate up to 50 office employees in 2 locations nationally.

Office employees should have capability to phase time as well as equipment across active phases.

System sized to accommodate 50 individual job sites, each with an on site foreman, and each with 1/3 project manager located in the main office.

Foremen should have capability to track production quantities against crew or individual employees.

Labor cost reporting across budget phases to project manager by foreman, reported to Timberline Gold by project manager.

Equipment cost tracking across budget phases to project manager by foreman, reported to Timberline Gold by project manager.

Material cost tracking across budget phases to project manager by foreman, reported to Timberline Gold by project manager.

Ability to generate monthly/weekly payment requisition from reported data.

Daily reporting capability on job site (did foreman beat or exceed budget for specific operations? today, yesterday?)

Provide ability to code in-house shop drawings to track approval, procurement, shipping, receiving, and installation of components.

Provide ability to code and track change orders and re-work on site, including labor, equipment, and material components.

Provide imbedded tool tracking system with individual (employee) accountability for specific tools/equipment.

Provide check system in cost or production reporting, whereby user is prompted to confirm or explain values that differ from historic values by a specified amount.

Phasing

The system should be phased in three parts: Office, Field, and Shop Drawings. The first phase will be implementation of the office labor and equipment tracking. This will include all office locations and personnel simultaneously.

Second will be labor and equipment tracking in the field, including the rework capability, tracking of changes and re-work, and tool tracking, and Timberline Gold reporting. Phase two will begin with 5 job sites, and proceed to include all 50 upon the satisfactory assimilation of the original 5.

Phase three will implement the shop drawing component, with approval, procurement, shipping and installation tracking capability. As with phase two, phase three will begin with 5 job sites, and proceed to include all 50 upon satisfactory assimilation of the original 5.

Unit Prices

Provide add/deduct pricing for hardware, including PDA's, label printers, etc.

Schedule

The proposal, including quotation, software, hardware, and development solutions, is to be received by ________.

Clarifications

Questions or clarifications should be directed to:

Jon Pizzagalli
224 Pine Haven Shore
Shelburne, VT 05482
(802) 985-5787
(617) 285-3785 cell

Figure #1b

Precision Steel

Listed below are high-level descriptions of modules that Precision Steel could benefit from in their day-to-day operations. Please note that functionality is based on a general specification provided by Precision Steel and an interview with Jerry Simms of Precision Steel. The purpose of this document is to provide high-level information and budgetary pricing. Functionality and price could change up or down when an actual scope of work is defined.

Fixed Asset Module

The Fixed Asset module will allow Precision Steel to: keep an inventory of fixed assets, track assets, and create preventive maintenance tasks. All fixed assets should have a bar code attached. Basic information can be populated in the database and accessed through the PDA or PC. This information includes: make, model, date of purchase, description, manufacturer, original cost, asset tag #, and a digital picture. For the tracking portion, the system will be able to track the location of the asset, when it was moved, and who moved it. Once again the bar code and the software on the PDA will be instrumental in gathering the data for the tracking portion of the Fixed Asset Module. Precision Steel will also be able to enter scheduled maintenance tasks for each asset, and then when these tasks come due, the person using the asset as well as the person responsible for performing the maintenance will be notified.

People Tracking Module

The People Tracking Module will allow foremen to enter employees' hours worked and associate it with a job task or other type of overhead function (vacation, travel, wait time, etc.). Drawings will all be bar coded for the overall job as well as each piece in the bill of material. The PDA will contain a list of all job tasks and the employee will scan the project bar code, the part(s) bar code, and pick the task. When they are finished, foremen will re-scan the drawing and indicate that they have completed the task. The people database will contain employee name, job title, and hourly rate.

Resource Allocation Module

This module will allow a foreman to schedule both people and fixed assets by project. This module will work in conjunction with the Asset Tracking Module and People Tracking Module, so those modules must be functioning in order for the Resource Allocation Module to work properly. The Resource Allocation module will also track and schedule change orders (description of change order, reason, additional material/labor/equipment/time, and approval). For both regularly scheduled tasks as well as change orders, the foreman (or other authorized employee) will be able to enter the estimated hours for labor/material/equipment by task. This will allow the Reporting Module to track status and % complete.

Claims Management Module

This module will allow Precision Steel to document with the use of the PDAs and the bar codes when they are unable to perform work at a job site due to another subcontractor. The foreman or employee will be able to capture the downtime, the reason, the affected people and fixed assets, and even take a digital picture of the problem to store in the database. This documentation will be valuable when cost issues arise later in the project.

Inventory Module

All parts should either be bar coded, or the bill of material or part drawing should be bar coded. The database will contain the basic information about the part (qty, description, part number, manufacturer, size, weight, and job number). The module will be able to track the location of the part (i.e. – jobsite, lay down area A). The status of the part can also be tracked (i.e. – in delivery, waiting for assembly, assembly in process, assembly complete). Longer term, not part of this scope, Precision Steel also desires to take the part status information and feed it back into the assembly drawing software package to provide a visualization of assembly progress.

Reporting Module

Various reports can be generated from all of the data in the database. ScanLynx will create 6 basic reports for Precision Steel, with the format and layout to be determined at a later date. Some examples of reports are: Listing of assets and their current location, schedule of all people and assets for the next 6 months, job status (% complete, cost spent versus budget, etc.), and requisition for payment form customer based on tasks completed within the past period.

Link to Other Software System

ScanLynx shall provide an interface to the Timberline Gold software package. ScanLynx will use the ODBC connection available with the Timberline package and will allow for various points of data transfer between the software packages.

Training

ScanLynx shall provide 3 levels of training: end user, power user, and system administrator. End user will be a hands-on interactive session in which all employees who will be using the PDA devices on the jobsite will be trained in their use. This class will last about 2 hours, and should be limited in size so that there are no more than 2 employees to a PDA device. Power user training will focus not only on the basic PDA use, but also on higher-level functions such as reporting. This class will last 1 day and should be limited in size so that no more than 2 students are sharing a PDA or computer. Finally a systems administration class will be held for 2 days which will not only train the students on the use of the system, but also the maintenance of the hardware and software.

Installation/Commissioning

ScanLynx shall install the software, configure the hardware, and test all aspects of the system.

Pricing

• Fixed Asset Module	$10k
• People Tracking Module	$10k
• Resource Allocation Module	$10k
• Change Management Module	$5k
• Inventory Module	$15k
• Reporting Module	$10k
• Link to Other Software System (this line item may vary greatly depending on the piece of software and the desired level of integration)	$8k each
• Training	$5k
• Installation/Commissioning	$5k
Total	$78k

1.5 Overview of Current Job Cost Methods

Traditionally, the duties of labor and equipment tracking fall to the project foreman, who reports daily use of labor and equipment to the appropriate phases within the project budget. In Precision's case, there is rarely more than one foreman assigned to a project. This information is submitted periodically (typically once a week) to a central job-cost department where the information is compiled and processed into reports, then returned to the project managers for budget tracking and decision-making.

This process is relatively time consuming. Foremen, with all the duties and responsibilities they are charged with in addition to tracking time, may not track their labor and equipment as accurately as possible. Motivating the crew, receiving deliveries, safety, delays, employee problems, hiring and firing, all take away from the foreman's attention to what his resources are doing. The absolute best that Precision can hope for from a foreman is to keep a handwritten book or sheet of employees' time and equipment time during the week, and compile the information at the end of the week onto company report sheets[3].

With all that happens on a job site during a typical day, it is difficult to imagine an ironworker foreman keeping a clipboard in his hands to record resource allocation. More likely, the level of detail and accuracy is far lower than hoped for, often reconstructed from memory, or fabricated outright.

The sheets are submitted at the end of the week to the payroll department and the equipment manager. Typically, this is accomplished by faxing the compiled time

3. Jerry Simms, Precision Steel. Interview with author. Raleigh, North Carolina, July 16, 2001.

cards of all employees and equipment on the site to the central office, with their time charged against various budget items, depending on what that employee or piece of equipment was doing during the week. If the foreman had his own "system" for keeping track of employees' time and equipment time, he will need to transfer it to the company's standard time card format.

1.6 Roles of Personnel in Job Costing

There are numerous roles played by several individuals in the job cost process. As mentioned, the foremen play key roles in tracking labor, equipment, and material costs in the field. In the office, the project manager is responsible for the flow of money to the various vendors and suppliers the subcontractor is utilizing on the job, and from the general contractor or owner for whom they are working. The project manager is also ultimately responsible for the actions of the foreman. If the foreman has too many or too few welders on a job site to complete the work efficiently, it is up to the project manager to correct the situation.

Precision's payroll department is comprised of a single payroll manager. The bulk of the payroll duties are contracted out to a payroll service. The information received by the payroll service is the responsibility of the payroll manager. A significant portion of the payroll manager's time is spent inputting employee time information received on paper from the field.

From an equipment perspective, the duties of tracking the location and billing for Precision's equipment fall on the equipment manager. Similar to payroll information, he receives a weekly list of each job's tools and equipment. The equipment manager also spends a considerable amount of time recording what each piece of equipment is doing on a weekly basis.

Each of these players in the process represents an opportunity for error. Individuals entering data manually is of particular concern. Foremen, with all the duties they are charged with on a daily basis, may or may not enter employees' time onto time cards until the end of the week. Time card (and equipment) data has the potential to be handled unnecessarily by multiple people. The foreman, project manager, equipment manager, and payroll manager all play active rolls in Precision's job costing effort. Each represents potential error.

Application

2.0 Potential for Bar Code Technology in the Construction Industry

In the construction industry, there are a number of operations performed that involve the collection of data from the field for progress and cost tracking. The use of bar code technology, coupled with hand-held data collection devices, will greatly reduce the amount of time spent on collection and handling of this data. It will also change the face of the industry.

The construction industry stands to experience fundamental changes in the way it operates, as was experienced by the grocery industry. In that industry, inventory levels were reduced by more efficient reordering methods. In turn, the distribution of products was consolidated into giant distribution centers that draw from many individual suppliers, and service several different stores. For construction, these changes include improved project schedules and reduction of costs to owners through improved ordering and delivery control of individual components, as well as consolidation of services among industries. For example, just as Precision Steel offers detailing, fabrication, and erection services, a single concrete contractor may soon commonly offer detailed shop drawings of the concrete and rebar, rebar fabrication and installation, concrete supply and installation, fabrication and erection of architectural and structural precast panels. In other words, complimentary services among divisions of work will be performed by a smaller number of contractors as control of various components is improved. These higher-order changes will result over time from the more immediate changes focused on a single subcontractor outlined in following sections.

This chapter outlines a system for collection of a number of key pieces of data to track labor and equipment costs, as well as submittals, deliveries, and project progress. The first phase of implementation makes use of email, while the second phase uses email coupled with a hand-held device. The final phase uses email, the hand-held device, and bar codes placed on drawings for collecting the necessary data.

2.1 Time Card Coding/Automation

A simple alternative to manually recording and transferring employees' time information from the field to the central office is the use of email. In the first phase of the implementation, a standard template would be installed on all company computers, shown in Exhibit #2a. The individual job sites would enter time onto this template, phased according to the individual operations being performed. This information could be entered as often as desired by the individual foremen. At week's end, the template is emailed directly to the job's project manager, who reviews the time card. Upon satisfactory review, the form is emailed to Precision's job cost computer and payroll service. The need for paper and faxes has been eliminated, with a permanent record of the documents stored on the company network.

A positive externality of this system is the fact that the fundamental flow of information remains unchanged, but becomes much more efficient. As the first step of a larger system implementation, this has the benefit of getting people to begin thinking about electronic data transfer, in the context of a familiar and repetitive action. The benefits to the individual foremen and payroll manager are minimal, but so is the impact of learning a new system.

Exhibit #2a Time Card

Name: **Glen Henry**

Week Ending: April 13, 2001

Job Number											Totals
Saturday											0
Sunday											0
Monday	10.0										10
Tuesday	12.5										12.5
Wednesday	9.5										9.5
Thursday	9.0										9
Friday											0
Totals	41	0	0	0	0	0	0	0	0	0	41
Overtime											1.00
Billable Misc											0

Week Ending: April 20, 2001

Job Number											Totals
Saturday											0
Sunday	2.0										2
Monday	16.0										16
Tuesday	12.0										12
Wednesday	13.5										13.5
Thursday	11.5										11.5
Friday	8.0										8
Totals	63	0	0	0	0	0	0	0	0	0	63
Overtime											23.00
Billable Misc											0

Codes

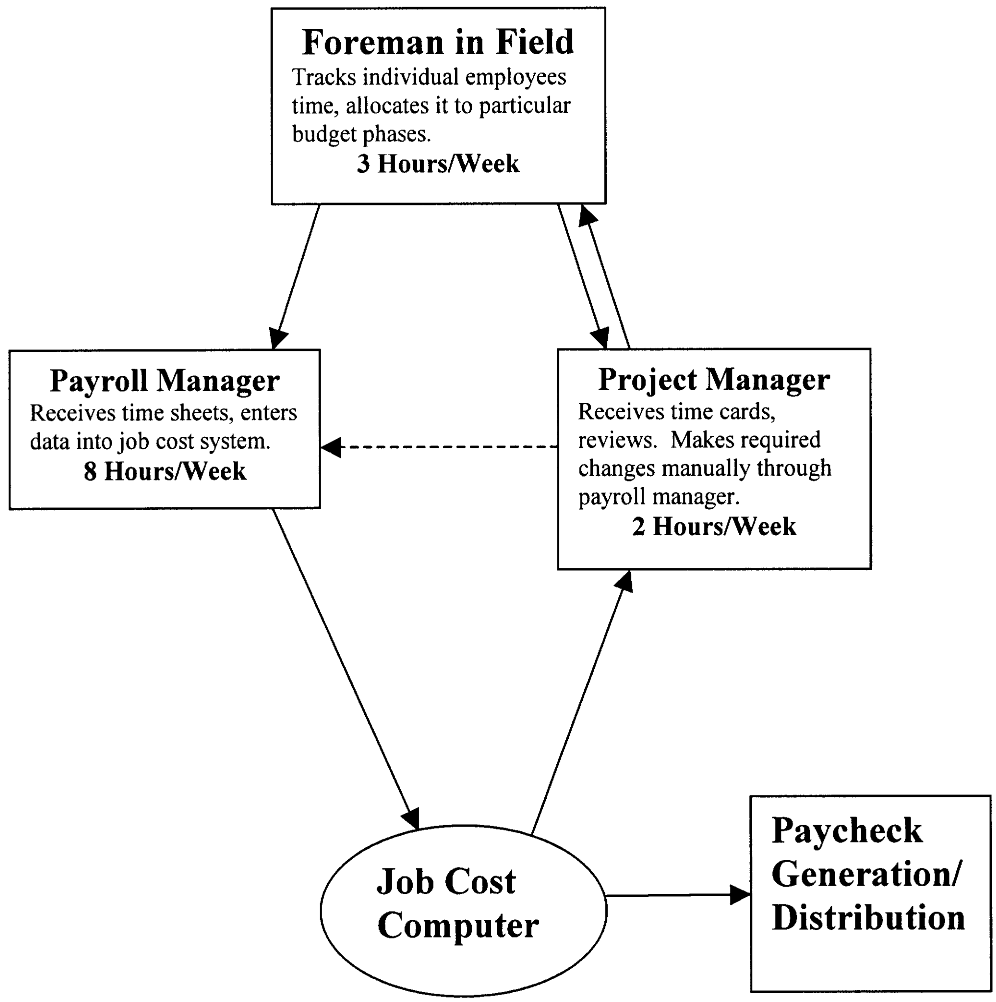
Printing: 5001
Vacation: 5002
Personal/Sick Leave: 5003
Holiday: 5004
Other: 5005

Comments:

Total Hours: **104**
Total Overtime: **24**

Current Flow of Employee Time Data

Figure #2b



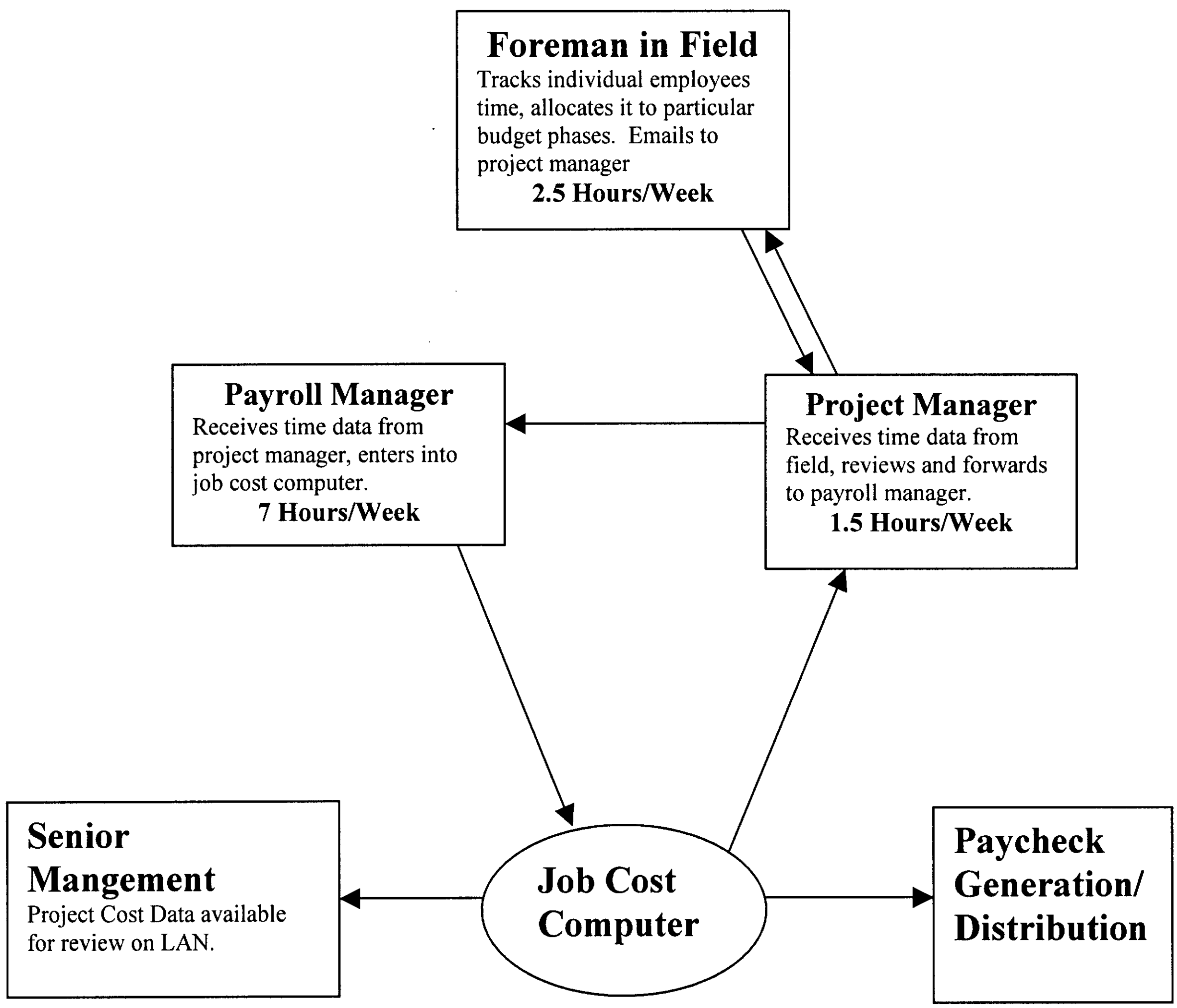
3 hours per week per job site (foreman), plus 2 hours per week per 5 jobs (PM), plus 8 hours per week (payroll).

Total for 30 jobs:	90 hrs @ $24.80= $2,232
	12 hrs @ $33.00= $ 396
	8 hrs @ $22.14= $ 177

Total Cost = $2,805 x 52 Weeks = $145,860
Labor Cost/Paycheck/Week (165 employees) = $17.00

Improved Flow of Employee Time Data

Figure #2c



2.5 hours per week per job site (foreman), plus 1.5 hours per week per 5 jobs (PM).

Total for 30 jobs:	75 hrs @ $24.80= $1,860
	9 hrs @ $30.00= $ 270
	7 hrs @ $22.14= $ 155

Total Cost = $2,285 x 52 Weeks = $118,820
Labor Cost/Paycheck/Week (165 employees) = $13.85
Labor Savings = $27,040

2.2 Equipment Report Coding/Automation

A simple alternative to manually recording and transferring equipment usage information from the field to the office is also through the use of email. A standard template would be installed on all company computers located where equipment might be used (primarily on job sites), shown in exhibit #3a. The individual job sites would enter time onto this template, phased according to the individual pieces of equipment being utilized. This information could be entered as often as desired by the individual foremen. At week's end, the template is emailed directly to the job's project manager, who reviews the time card. Upon satisfactory review, the form is emailed to Precision's job cost computer, where it is costed against the appropriate project. The need for paper and faxes has been eliminated, with a permanent record of the documents stored on the company network.

As above, a positive externality of this system is the fact that the fundamental flow of information remains unchanged, but becomes much more efficient. As the first step of a larger system implementation, this has the benefit of getting people to begin thinking about electronic data transfer, in the context of a familiar and repetitive action. The benefits to the individual foremen are minimal, but so is the impact of learning a new system.

Figures #3b and #3c show the difference in the current versus the improved system.

Exhibit #3a Equipment Report

Foreman: Glen Henry
Job Number: 11093

Week Ending: April 13, 2001

Phase #	0144	0129	0310	157							Totals
Equipment											0
22 Manitowak		32.0	8.0								40
Welder #5502	8.0										8
Welder #5506	8.0										8
Lift #9934			8.0								8
											0
											0
Totals	16	32	16	0	0	0	0	0	0	0	64
Billable Misc											0

Week Ending: April 20, 2001

Phase #	0144	0129	0310	157							Totals
Equipment											0
22 Manitowa		40.0									40
Welder #5502	24.0		16.0								40
Lift #9934	21.0		19.0								40
Lift #9921			8.0								8
											0
											0
Totals	45	40	43	0	0	0	0	0	0	0	128
Billable Misc											0

Codes

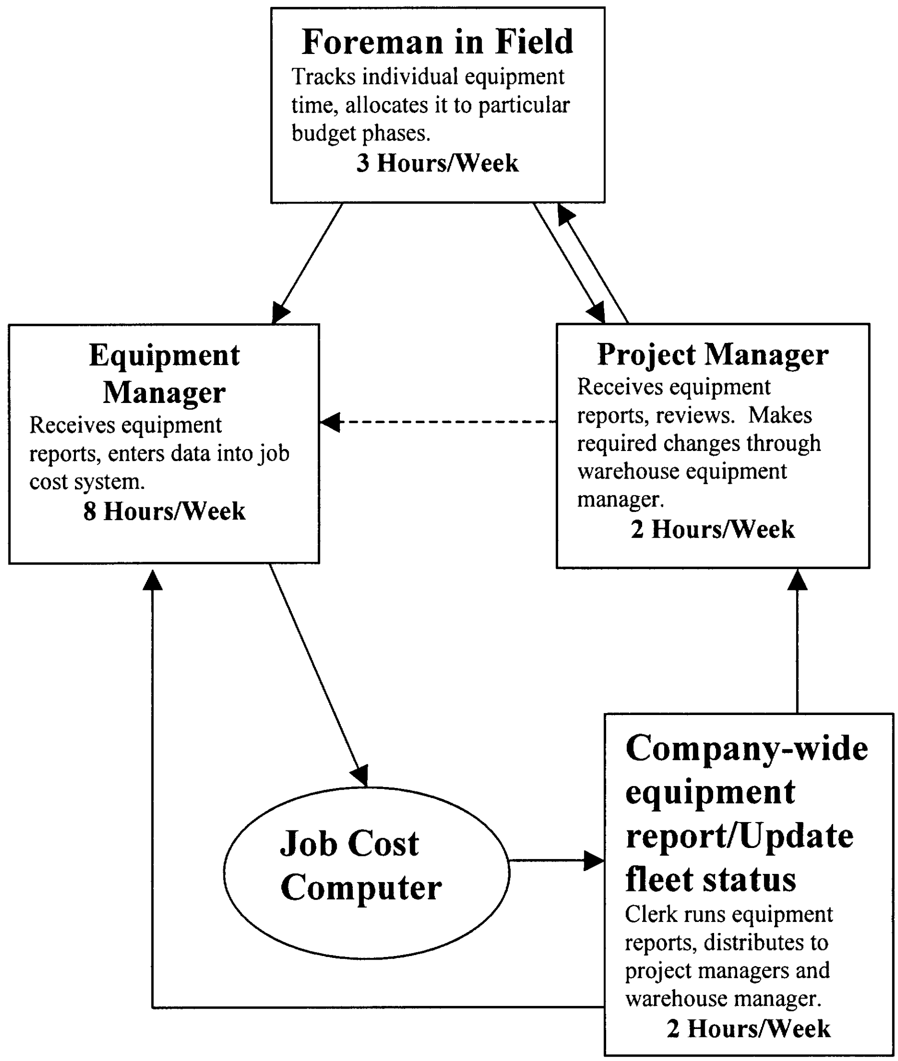
Material Handling	310
Erecting	129
Welding Deck	144
Welding Joists	157
Other:	5005

Comments:

Total Hours: **192**

Current Flow of Equipment Time Data

Figure #3b



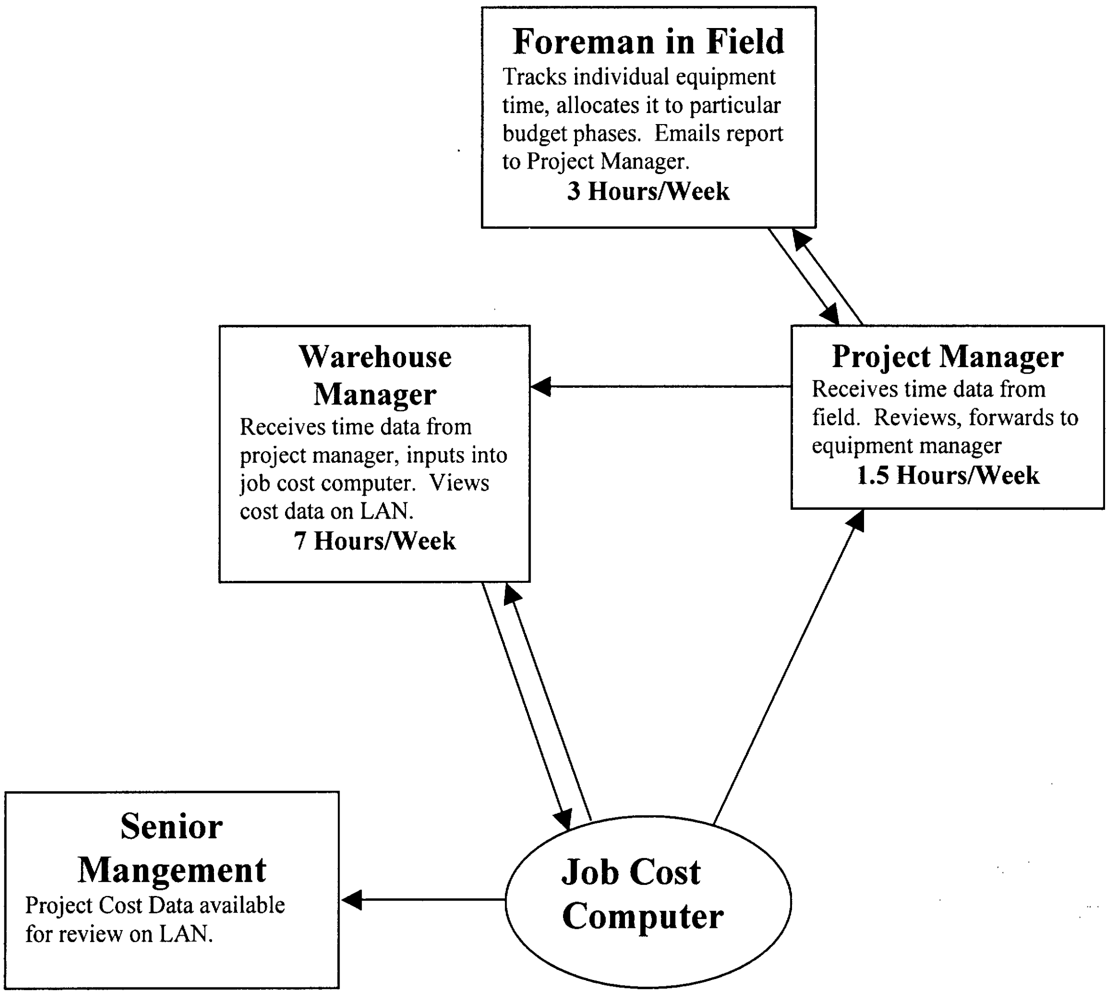
3 hours per week per job site (foreman), plus 2 hours per week per 5 job sites (PM), plus eight hours per week (equipment manager), plus two hours per week (clerk, all jobs).

Total for 30 jobs:	90 hrs	@ $24.80=	$ 2,232
	12 hrs	@ $33.00=	$ 396
	8 hrs	@ $25.14=	$ 201
	2 hrs	@ $22.14=	$ 44

Total Cost = $2,873 x 52 Weeks = $149,396
Labor Cost/Equipment Report = $95.77

Improved Flow of Equipment Time Data

Figure #3c



3 hours per week per job site (foreman), plus 1.5 hours per week per 5 job sites (PM), plus 7 hours per week (equipment manager).

Total for 30 jobs:	90 hrs	@ $24.80=	$ 2,232
	9 hrs	@ $33.00=	$ 297
	7 hrs	@ $25.14=	$ 176

Total Cost = $2,705 x 52 Weeks = $140,660
Labor Cost/Equipment Report = $90.17
Labor Savings = $8,736

2.3 Tracking Labor and Equipment Across Phases of Work

Since work plans on job sites are in a continual state of change, the ability of a foreman to accurately cost resources against the proper budget phase can be significantly compromised. With the use of a hand-held device similar in size to a Personal Digital Assistant (PDA), the foreman on a job site will have the ability to instantly document the deployment of various resources, and charge the appropriate budget phase for those resources. By having the ability to quickly and accurately record labor and equipment allocations as those allocations are made, the contractor realizes two important benefits.

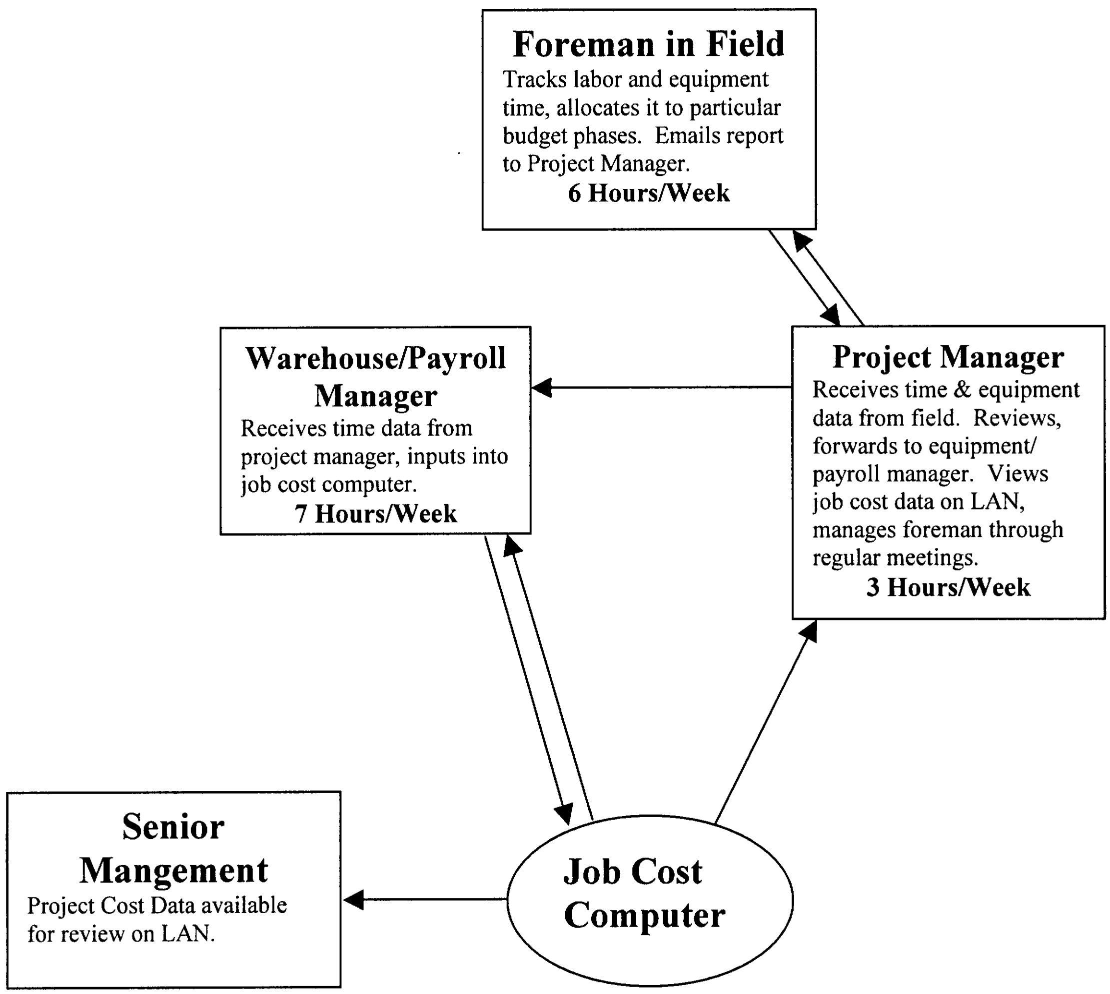
First, the weekly cost data reported to the project manager is more meaningful than that currently recorded. Budget phases will more accurately reflect what has actually taken place in the field. While merely giving foremen a new way to record data cannot be expected to eliminate faulty or erroneous reporting, the chance that foremen will "fudge" data will be minimized, as will the chance that data will be fabricated if the foreman lost track of his "cheat sheet" or other means of record keeping used currently.

Secondly, the company will quickly develop a superior collection of historical cost data for the various operations it performs in completing contracts. This translates into an advantage on bid day when pursuing competitively bid work. It also means more reliable data can be presented to prospective clients in a negotiated work situation. This is discussed further later in this chapter.

With the use of the hand-held device to track the allocation of resources in the field, the time card operation described above becomes even easier for the foreman.

Current Flow of Labor and Equipment Cost Data

Figure #4a



6 hours per week per job site (foreman), plus 3 hours per week per 5 job sites (PM), plus 7 hours per week (warehouse manager, all jobs), plus 7 hours per week (payroll manager, all jobs).

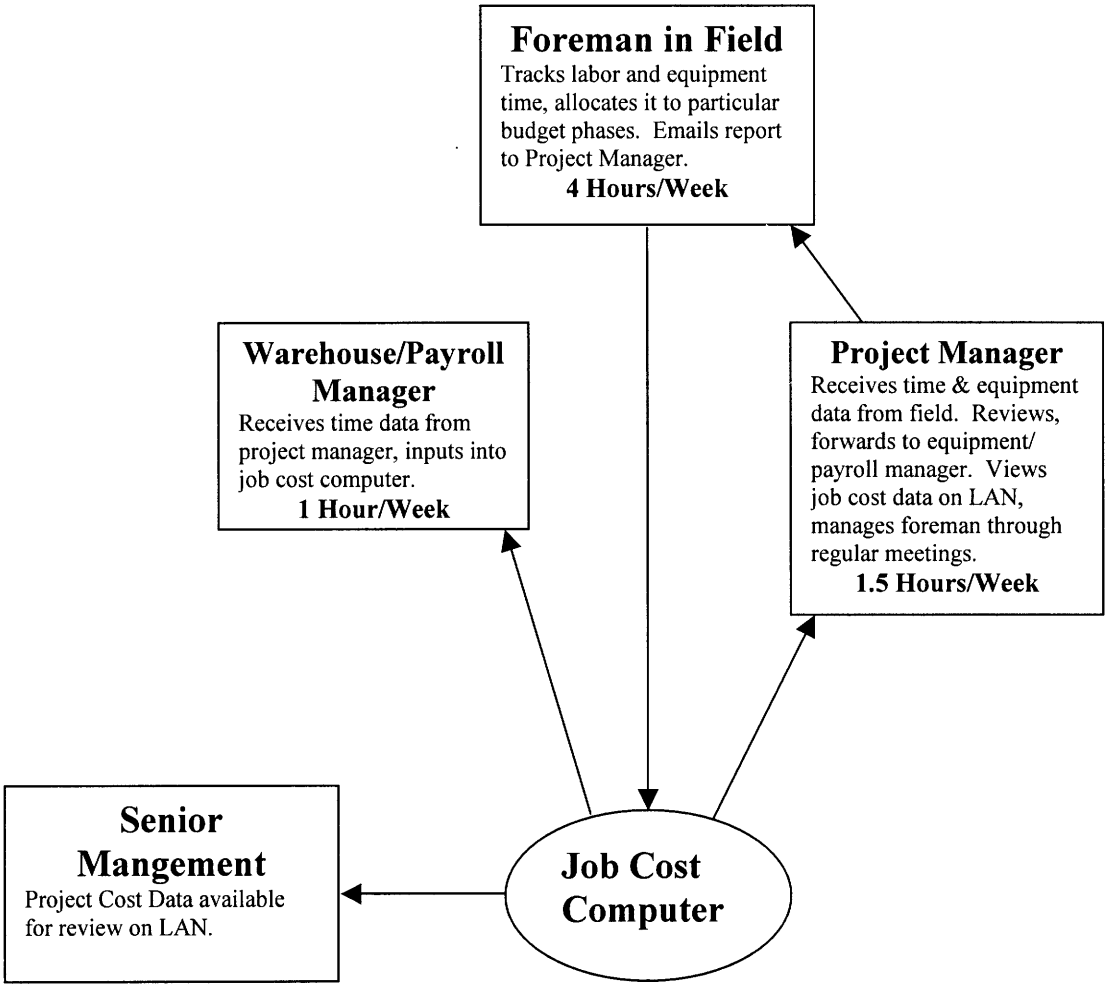
.

Total for 30 jobs:	180 hrs @ $24.80=	$ 4,464
	18 hrs @ $33.00=	$ 594
	7 hrs @ $25.14=	$ 176
	7 hrs @ $22.14=	$ 155

Total Cost = $5,389 x 52 Weeks = $280,228

Improved Flow of Labor and Equipment Cost Data

Figure #4b



5 hours per week per job site (foreman), plus 1.5 hours per week per 5 job sites (PM), plus 1 hour per week (equipment manager), plus 1 hour per week (payroll manager).

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Total for 30 jobs:	120 hrs @ $24.80= $ 2,976
	9 hrs @ $33.00= $ 297
	1 hrs @ $25.14= $ 25
	1 hrs @ $22.14= $ 22

Total Cost = $3,320 x 52 Weeks = $172,640

Labor Savings = $107,588

The time card shown in exhibit #2a is now updated automatically every time the hand-held unit is docked with its base station. The base station is the hardware that downloads the information collected on the hand-held unit and sends it via phone line to the computer located in home office. Likewise, the weekly equipment use form shown in exhibit #3a is automatically completed upon docking the foreman's hand-held unit.

Figures #4a and #4b show the difference in the current versus the improved system.

2.4 Programming Bar Codes for Various Uses

2.4.1 Shop Drawing Process

Shop drawings are the documents used by various trades to order, fabricate, and/or install materials and/or components that require specific information or detail that is beyond the scope of the Architect. Precision Steel performs work in a typical division of work that uses shop drawings: structural steel. The Structural Engineer will determine what size, shape, and quantity of major steel components will comprise the structure. From that relatively broad description on the project's structural drawings, the structural steel contractor creates shop drawings. The shop drawings contain very specific information about each piece of steel on the job. For example, they indicate the specific location, number, and size of holes to be drilled into stock for connection purposes. They also show the number, type, and size of bolt to be used in each connection. The level of detail is enough to show the reader how many threads should be showing after a bolt is tightened. If there is a question that could be asked about the work, the shop drawings have the answer.

Once the shop drawings have been created, they are sent to the General Contractor. The General Contractor acts as the clearinghouse for the shop drawings for all trades, and makes sure they are sent to the appropriate reviewing professional. In our example, the steel shop drawings are sent to the Structural Engineer, who reviews them and makes comments if something is deemed unacceptable. Once the shop drawings have been modified to the satisfaction of the Engineer, the material is released for fabrication. After fabrication is complete, the material is shipped to the job site and erected.

The nature of the shop drawing process means that several parties are working from the same set of drawings approved by the Structural Engineer. The project manager can track the approval process by scanning the drawings before they are sent to the Structural Engineer, and again upon their receipt. This provides an excellent platform for tracking some or all of the steps and processes from the contractor's perspective. Since the subcontractor has responsibility for making sure the material finds its way to the jobsite properly fabricated and gets erected, it makes perfect sense to use the shop drawings as an active tool in tracking the many steps in the process. If a component is fabricated in-house, Precision's shop foreman will scan the drawings when he ships a particular piece. If it is shipping from another subcontractor, the project manager can scan the drawing upon the subcontractor's say so. In this way, the project manager can scan a particular sheet in his office, and see whether or not that portion of the job has been fabricated, shipped, received, or erected.

2.4.2 Procurement

In construction terms, "procurement" refers to the process of getting material through fabrication and delivered to the job site. This includes submission, review, resubmission (if necessary) and approval of shop drawings described above. By utilizing bar codes on the drawings to track this series of operations, the project manager could scan the drawings, for example, as they were sent to the engineer, and scan them again upon receipt. He would then have a record of where in the process the drawings were, including how long they had been in the Engineer's hands.

2.4.3 Tracking Materials

With the shop drawings in the hands of all parties involved in the ordering, fabrication, and installation of construction components, tracking material becomes a matter of internal status reporting. By utilizing hand-held devices to collect data from bar codes on the shop drawings, the contractor will have information on each piece of a particular job updated daily. He could scan the shop drawings and input into the hand-held device the operation that was taking place, whether it be ordering, shipping material, receiving material, or installing. Each operation would be recorded, with durations of each operation updated on the project schedule, as discussed in the next section.

In the case of Precision, they are an ideal test case for this aspect of the system. Aside from the approval process, they control the remaining aspects of the entire process in house, from receipt to final erection. By putting the hand-held device in the hands of project managers, shop foremen, as well as field foremen, they will be able to track every step of the process.

This would be a vast improvement over Precision's current tracking system, which consists of limited use of Expedition™ software. Unsophisticated tracking of such vital aspects of a construction project is not a good policy. Having a system in place to know where documents and components are with limited effort will pay significant dividends to Precision.

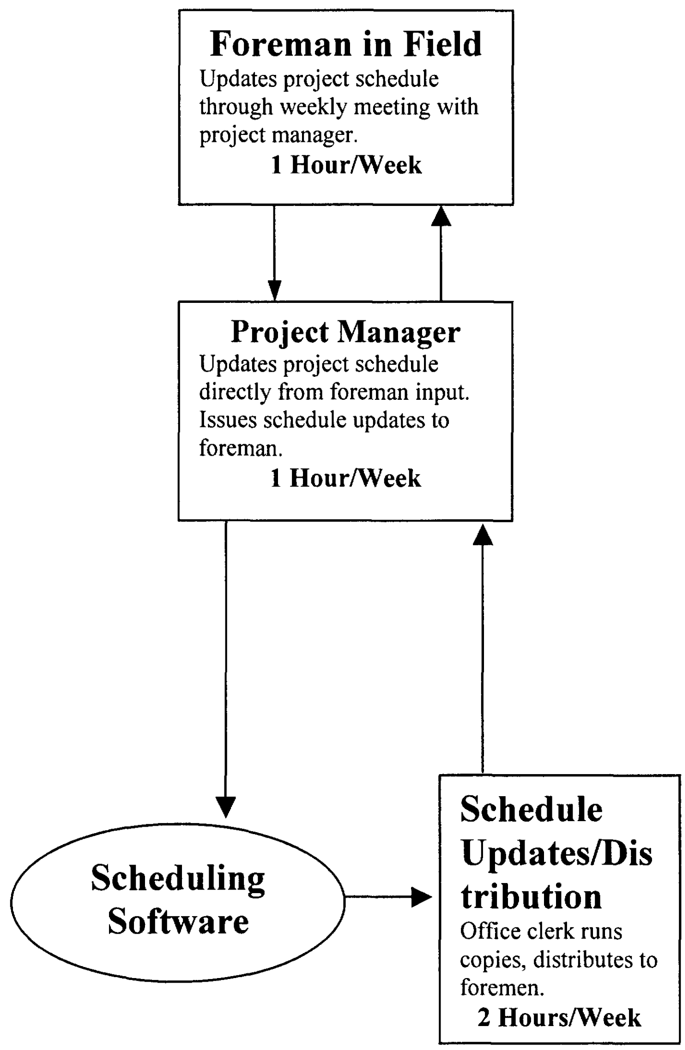
2.4.4 Direct Updating of Project Schedule

Another benefit of collecting data electronically is the ability to import data to the company's scheduling software. Once an operation is complete, the person responsible for that operation will scan the shop drawing to indicate it is finished. For example, when a particular column has been fabricated, the shop foreman would scan his copy of the shop drawings to show the column as fabricated and ready for shipping. When the device is docked and the information downloaded to the scheduling software, the computer would see that the column is fabricated, and update the particular procurement activity on the project schedule accordingly. This has the same effect as the time card operation, in that the foreman, together with the project manager, typically will update the project schedule on a weekly basis. By tracking the operations in the shop (or field) as they occur, the schedule is automatically updated.

With daily updates of the schedule, the project manager has the ability to see exactly what operations took place on a project without setting foot in the fabrication shop or on the job site. This is in no way intended to take the place of regular site visits by the project manager. However, it provides the project manager with a daily snap shot of the activities in the fabrication shop or on the job site. In this way, the project manager

Current Flow of Schedule Data

Figure #5a



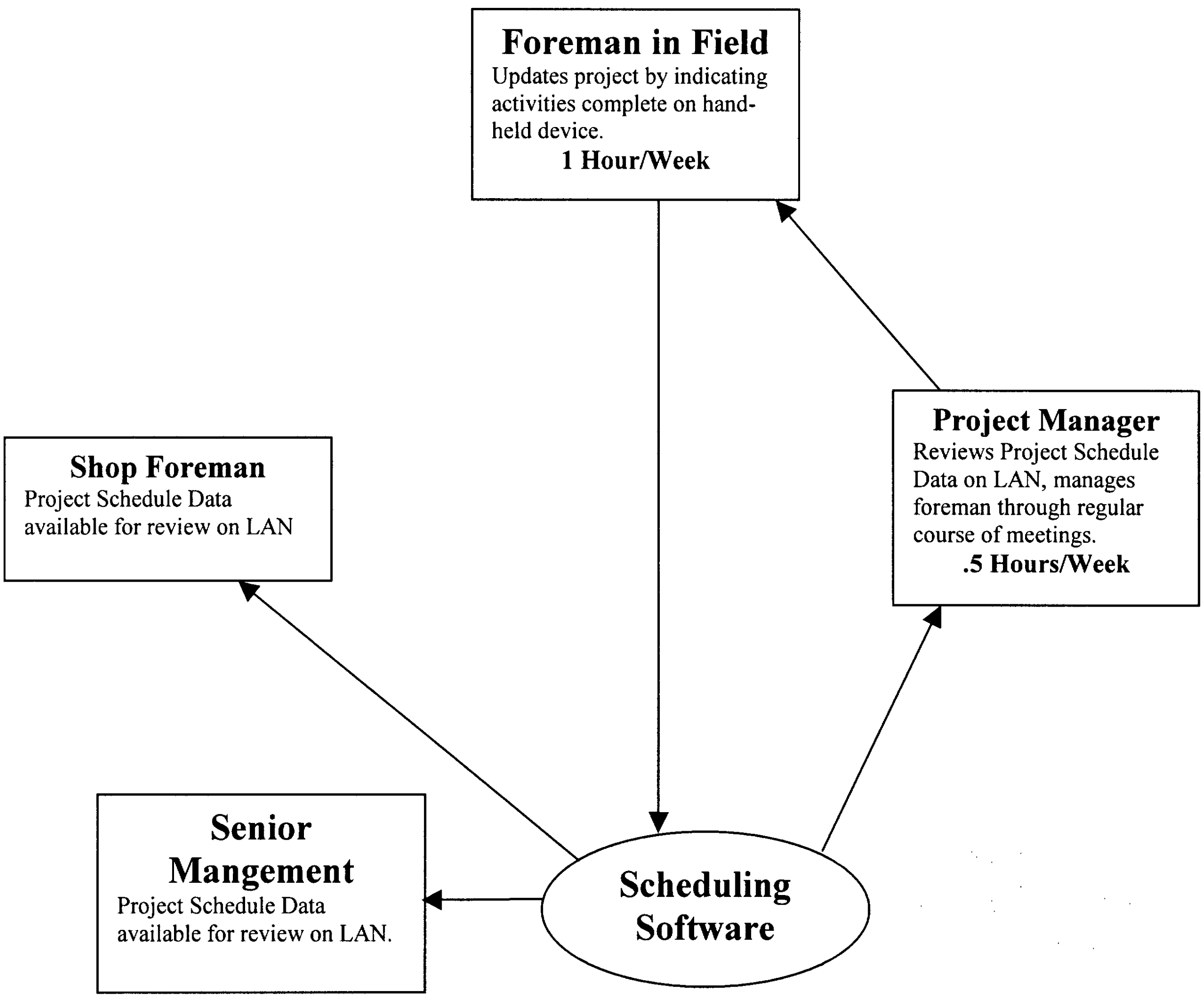
1 hour per week per job site (foreman), plus 2 hours per week per job site (PM), plus two hours per week (clerk, all jobs).

Total for 30 jobs:	30 hrs @ $24.80=	$ 744
	30 hrs @ $33.00=	$ 990
	2 hrs @ $22.14=	$ 44

Total Cost = $1,778 x 52 Weeks = $92,456
Cost/Schedule = $59.27

Improved Flow of Schedule Data

Figure #5b



1 hour per week per job site (foreman), plus .5 hours per week per job site (PM).

Total for 30 jobs:	30 hrs @ $24.80= $	744
	15 hrs @ $33.00= $	495

Total Cost = $1,239 x 52 Weeks = $64,428
Cost/Schedule = $41.30
Labor Savings = $28,028

can respond to inquiries by the owner or general contractor with information that is far better than merely what the project manager saw whenever the last time he or she was in the fabrication shop or on the job site. This will reduce the number of site visits required by the project manager. If the average project manager for Precision currently manages five projects, it is expected that halving the number of site visits, combined with the other time savings outlined in other parts of this thesis, will free up enough time for them to be able to handle a sixth project.

The benefits of improved schedule control cannot be overstated. It will allow Precision to complete more jobs on time than their competition, making them more attractive to general contractors. Improved control of a project's schedule will also enhance an insurance company's view of a subcontractor, which could bolster their case for expanded bonding capacity, since the subcontractor can demonstrate a higher level of understanding and control of the project schedule.

Figures #5a and #5b show the difference in the current versus the improved system.

2.4.5 Direct Construction of Applications for Payment

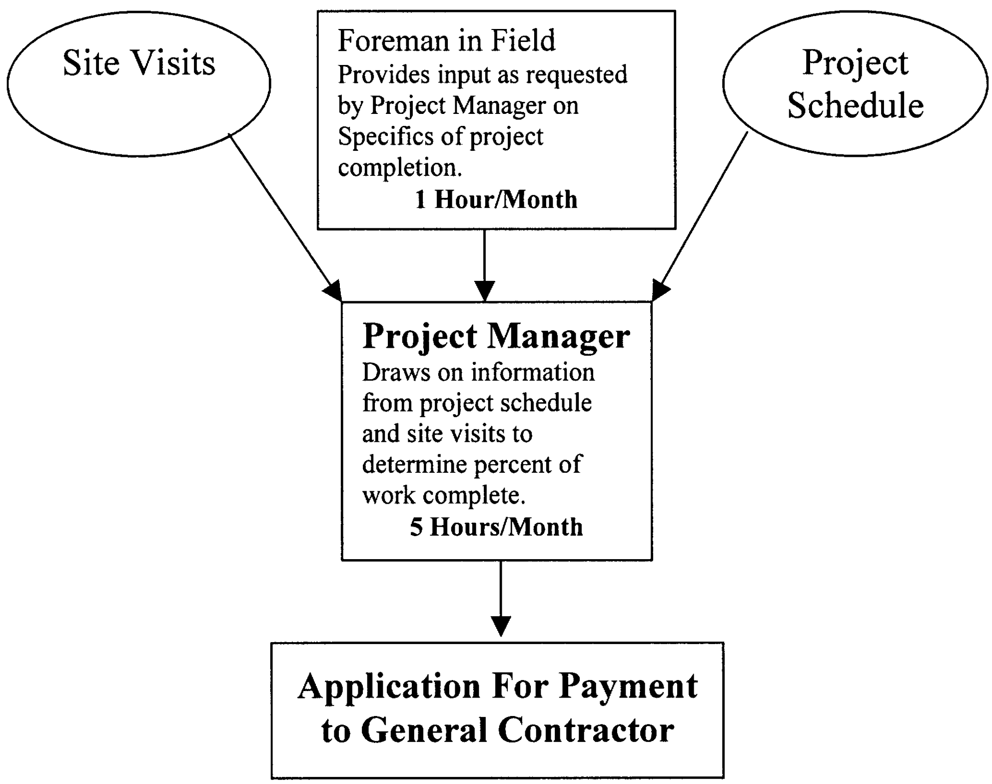
The construction industry is famous for billing for work not yet in place. The people paying the bills, whether it is the general contractor paying subcontractors, or owners paying general contractors, typically are aware of this. They therefore usually require their subcontractors (or general contractor) to submit detailed information regarding what has and has not been completed on the project. The application for payment submitted to the general contractor (or owner) is occasionally a point of contention. Depending on the relationship between the parties, the payee may feel compelled to overstate the amount of work complete, knowing that the payor is going to pay them something less than the amount requested. At a minimum, applications for payments are reviewed with a high level of scrutiny, often resulting in delayed payment to the payee, and unnecessary time and effort spent justifying and defending the application.

By tracking project progress with a device that directly inputs company payroll information, as well as job cost reports, creating monthly applications for payment is both more efficient and more accurate. By submitting applications for payment created with the same system that is paying the subcontractor's (Precision's, in this case) employees, as well as creating the company's job cost data, the subcontractor has a much better case for the percent of work complete they bill for. This will result in more timely payment from the general contractor, and foster better relations that will help in procuring future work.

Figures #6a and #6b show the difference in the current versus the improved system.

Current Creation of Application for Payment

Figure #6a



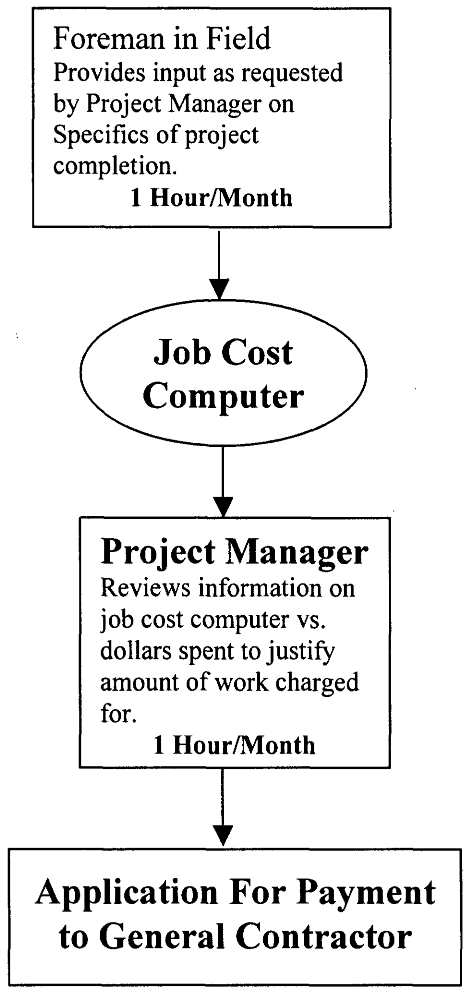
1 hour per month per job site (foreman), plus 5 hours per month per 5 job sites (PM).

Total for 30 jobs:	30 hrs	@ $24.80= $ 744
	30 hrs	@ $33.00= $ 990

Total Cost = $1,734 x 12 Months = $20,808
Labor Cost per Payment Application = $57.80

Improved Creation of Application for Payment

Figure #6b



1 hour per month per job site (foreman), plus 1 hour per month per 5 job sites (PM).

Total for 30 jobs:	30 hrs	@ $24.80=	$ 744
	6 hrs	@ $33.00=	$ 198

Total Cost = $ 942 x 12 Months = $11,304
Cost per Payment Application = $31.40
Labor Savings = $9,504

2.4.6 Feedback Into Company Database/Future Bid Advantages

Contractors rely heavily on their historical cost data to procure new work. Precision Steel is no exception. Detailed records are kept of every project's production for various activities. Cost per structural ton erected, per linear foot of weld, or per square foot of metal deck installed are examples. When new work is bid, the estimators look to the company's historical data for similar jobs to the one being bid to construct their price.

By giving foremen the ability to input unit cost data from the same operation as filling out their time card, the likelihood of them creating more accurate unit cost data is greatly enhanced. As discussed earlier, the propensity to "fudge" production rates in the field or to avoid charging phases that are over budget results in skewed production costs. Any measure taken to reduce this will result in better historical data, and therefore more competitive bids. As with improved control of the project schedule, it will also enhance an insurance company's view of a subcontractor. This could bolster their case for expanded bonding capacity, since they can demonstrate a higher level of understanding of production rates, and therefore anticipated job expenses.

As an illustration of the impact on the industry resulting from this improved production data, assume that Precision is able to submit a bid that predicted its labor component 1% better than currently possible. If Precision's labor component typically comprises 30% of a contract, then an average Precision project of $1,000,000 would yield a $3,000 savings over current pricing[4]. For a time, that is money that Precision can keep, until competitors implement the technology. Eventually, the savings will go to the

4. Jerry Simms, Precision Steel. Interview with author. Raleigh, North Carolina, 7-26-01.

owners, as the industry adopts the new method of operation. In aggregate, if the construction industry sees the same average labor component of 30%, then a 1% improvement in labor pricing in a $800 billion industry in the United States equates to $2.4 billion in savings to owners. That estimate is based on the industry staying the way it is. Imagine the possible savings to owners after the consolidation among individual divisions of work mentioned in 2.0 takes place.

2.4.7 Tracking Rework/Change Orders/Delays

Often on a project, a contractor finds itself performing extra work to be able to perform the work it has contracted for. If the work that was installed by a previous trade, concrete for example, is not per the drawings and specifications, it is often less expensive and time consuming for the next trade, steel in this example, to remedy the problem. The costs of doing so are then presented to the offending subcontracor. This is often a more efficient way of keeping the job moving forward than calling the concrete contractor to remedy whatever was done incorrectly. One of the general contractor's responsibilities on the project is to distribute and administer the costs of extra work of this type, and to request payment from the owner for legitimate additional work that was requested or could not be avoided.

Similarly, there are times when a subcontractor cannot perform its work at the time specified in the project schedule. If the concrete subcontractor in our example above had instead not completed the work necessary for the steel contractor (Precision) to begin its work, the foreman could create a new bar code for a delay claim. The new code would contain all the equipment that had been mobilized to the site in anticipation of beginning work per the project schedule, which is part of the contract. In this way, Precision can create an accurate bill for the idle equipment that should otherwise have been working.

As is the case with applications for payment, extra work invoices are reviewed carefully. The general contractor has a responsibility to make sure the charges are legitimate, as the invoice is usually presented to the contractor that performed the questionable work (the concrete subcontractor), not paid by the general contractor.

By having the capability to print bar code labels on site, a subcontractor can create a specific bar code for each extra work order to track the costs associated with that operation. The foreman would be able to create the new bar code, and attach a label to the actual work. This may be made of mylar or other relatively tough material to withstand the harsh environment of a construction site. When he allocates resources to that operation, he simply scans the code, and tells his device specifically what resources to charge for. The project manager prints a hard copy of the change order, and mails it to the general contractor. Not only does the foreman spend less time creating the invoice, the invoice itself is a high-quality document. Currently, many subcontractors present general contractors with hand-written invoices that are combed for simple errors that regularly show up. A professional-quality invoice for a change order or rework commands far more respect with a general contractor than a wrinkled hand-written invoice with coffee stains on it.

The labor savings realized by such a system of tracking extra work are shown in Figure #7a. The gains realized by efficiently tracking smaller cases of extra work, and billing for a higher percentage, are harder to quantify. The number of change orders requested and the amount of extra work required vary greatly with the type of job, the capabilities of the general contractor, and the thoroughness of the contract documents. For purposes of this thesis, a conservative estimate of the number of such changes was used[5].

The real benefit to using this system is the ease with which smaller portions of extra work can be tracked. The majority of extra work items that cost less than $500 are not even quantified and presented to the general contractor. With a system that allows faster generation of an extra work claim, the management team will be better equipped to generate change requests, which will provide another level of "throw away" claims when the project manager sits down to negotiate extra work compensation with the general contractor. If the project managers can improve the average percent of foregone extra work from 1% to .5% on each job, the benefit to the company over 30 jobs annually is some $150,000.

There is an added benefit, as the improved success ratio also means that Precision will receive payment for extra work earlier, and spend less project management time negotiating change orders and claims.

Savings not quantified in this example are project managers' time working with the general contractor to get the invoices paid, which can be a difficult task. With an improved invoice creation system, the number of questions form the general contractor will be reduced, translating to less time required of the project manager, not to mention more timely receipt of payment.

5. In determining a historic compilation of extra work on Precision projects, a thorough examination of Expedition ™ records showed no usable recording of extra work performed but not paid for. In the end, the "average" number of change orders per job and "average" amount of extra work not paid for as a percent of contract amount was derived from a meeting of all Precision project managers.

As was mentioned in the first chapter, a system that could help shave hours or days from the schedule of an owner with particularly sensitive time requirements could be worth millions of dollars. Assume that the system outlined allowed subcontractors to work with confidence that their extra work claims were going to be paid. If, instead of going through the time consuming process of responding to a Proposed Change Order by preparing a quotation for a scope of work, subcontractors were trusted to proceed on a say so with the accounting of the bar codes in place, it could mean several days saved over the entire project. This could translate into additional bonus money for early completion, or reduced liquidated damages.

Current vs. Improved Change Tracking

Figure #7a

Current

Number of changes or extra work orders per job:	20
Time spent creating each invoice:	.5 hrs
Number of jobs:	30
Total time	300 hrs
Cost @ $24.14/hr to create invoices:	**$7,242**

Improved

Number of changes or extra work orders per job:	20
Time spent creating each invoice:	.1 hrs
Number of jobs:	30
Total time	60 hrs
Cost @ $24.14/hr to create invoices:	**$1,448**
Labor Savings:	**$5,794**

Implementation

3.0 Implementation

Implementation of a job-cost system utilizing bar codes to track project components requires significant software solutions and a high level of training. Software solutions are available on a custom basis, costs for which are outlined later in this chapter. The hardware required is available off the shelf from a number of manufacturers. For the purposes of costing this system, a complete scope was quoted from a single contractor, including hardware, software, and training.

3.0.1 Phasing of Implementation

Implementation of such a far-reaching system as the one described would be best implemented in a phased approach. As designed, the system would impact the actual labor and equipment tracking last. This would allow management personnel (the smallest number of employees affected) to test and get to know the system. Bugs would be worked out in a controlled environment, with in-house and contracted IT and support people on hand.

3.0.2 Employee time cards

The most logical candidate for initial implementation is time card reporting. Conveying time data through email as described would eliminate the need for paper time cards altogether. Time cards would be emailed from foremen directly to the job cost computer. Project management would then have access to the information as it is posted on the company LAN.

In the big picture of a multi-phase rollout of the system, the time card aspect is the most easily implemented. It is low-cost, provides quick results, and requires a minimum of resources. Its low initial cost and readily apparent results will be visible to most, if not all, members of management, setting the stage for implementation of relatively more complex aspects. Showing early positive results to employees will play a major role in bolstering their level of interest in subsequent phases. It also involves foremen in the field from the first phase, reducing the need for redundant training.

3.0.3 Field labor time/Equipment time

Following successful implementation of paperless time card reporting, the second phase of the system will enable foremen in the field to report time for field personnel as well as report equipment use against budget phase numbers directly from the hand-held device. Differing from the office time reporting only in the interface the user sees, the system should require a low to moderate amount of training for foremen. The foremen will begin to familiarize themselves with and see the benefits of recording resource allocation as it is deployed. Training the foremen in the use of the hand-held device will ease them into the final phase, in which they will have the ability to review and update critical project information from the hand-held device. Training is discussed further in this chapter.

3.0.4 Shop Drawings/Full tie-in

The final phase for this system is the programming of shop drawings with bar codes that contain fields for various data. With the office and field personnel having cut their teeth on the first two phases, the final phase will appear a logical next step to all involved. The foremen will experience a significant expansion of the hand-held unit's capabilities. Project managers and foremen will now have access to whatever information is programmed onto the various bar codes. This information will be updated from the field whenever the hand-held device is docked. The technology to convey the information from the field to the job cost computer in real-time exists, but that aspect is not investigated in this thesis.

3.1 Hardware Requirements/Costs

As outlined in the ScanLynx proposal, the recommended hand-held device for the application described costs $1,500. In Precision's case, that amounts to an investment of $45,000 to provide one foreman on each of 30 job sites with the tools required.

The drafting department will require a means by which they can produce bar codes for the shop drawings. One option was to modify the CAD software system currently in use to generate bar codes. This method was dismissed as too complex a task for the scope of this thesis. Instead, the drafting department will be outfitted with two bar code printers, at a total cost of $1,000, including a supply of labels.

To facilitate tracking of change orders and delays in the field, each job site will be equipped with a standard bar code generator/printer. The foreman will then able to produce unique bar codes for each task that is deemed to be extra work or a delay. Each of these printers costs $500, for a total cost of $15,000.

All told, the hardware outlay for the entire system is $61,000. Phase one has no hardware outlays, phase two will have the hand-held devices at $45,000, and phase three will add the printers at an additional $15,000.

3.2 Software Requirements/Costs

Phase One, as described above, has a minimal software requirement. The templates shown in exhibits #1a and #1b have been developed in house at Precision. They are to be used as a stepping stone to make employees familiar with the idea of transferring data electronically.

Total software expenditure for the project is expected to be $45,000. Phase two will comprise approximately half of the software expense. The programming of the hand-held units and the reporting functions will make up the bulk of this expense. Customizing the information available to the foremen is an upfront cost to all types of users of similar systems in warehousing or manufacturing applications. Maintenance of the software is discussed later.

Phase Three software includes the addition of the bar code generator for importing bar codes onto the electronic drawings prior to printing, as well as the higher-order manipulations of the field data, such as schedule updating and creation of payment applications. Getting Precision's accounting and scheduling software to perform these functions is anticipated to cost an additional $7,500 per link to other software. The estimate is a conservative one, based on ScanLynx's knowledge of the systems Precision uses. Linking to Expedition™ and Timberline Gold™ will require two links, for a total of $15,000.

3.3 Personnel Implementation/Training

According to ScanLynx project representatives, the best way to divide the training required will be between "power/end users" and "system administrators."

The power/end users consist of the foremen and project managers. Their training will be broken into two parts: one half-day session for all foremen and project managers to learn how the hand-held units function and how to report resource use, and a second, half-day session for project managers only to describe higher-level functions such as reporting.

The system administrator training consists of a one-day session to teach users how to maintain the hardware and software. It is believed that this session can be conducted in a half-day format for the users, and a second half-day for the IT department to learn about the software maintenance. This will provide some "contingency" for Precision where the money for training is concerned.

3.4 System Maintenance

There is some maintenance anticipated for the system, mostly based on ScanLynx's experience with systems in place in manufacturing or warehousing applications. As discussed, the standard maintenance assumptions have been modified to some degree to anticipate the needs of the application.

3.4.1 Hardware Maintenance

In a typical manufacturing or warehousing application, the normal expected "consumption rate" of hardware is approximately 10% annually[6]. For the purposes of this analysis, the rate has been increased to 20% to account for the unusually rough environment in which the hardware will be used. Construction sites are notoriously hard on all types of equipment. Even bar code printers located in Precision's main office will be subject to particularly harsh conditions, as the adjacent fabrication shop creates excessive dust. Unusually high levels of dust and other airborne contaminates regularly wreak havoc with computer equipment located in the office.

The manufacturer has priced "ruggedized" hand-held devices, designed to withstand a four-foot vertical fall to concrete. The hardware is warranted against damage and failure within the design specifications, including limited exposure to weather and moisture. Even so, it seems prudent to assume a high "consumption rate" for hardware that will be used by ironworkers in an environment of heavy equipment and multi-story height exposures.

In Precision's case, a 20% consumption rate for hardware equated to an annual cost of $20,000. In the NPV analysis shown in Figure 3.1, the annual maintenance cost is reflected in the annual cash flows.

3.4.2 Software Maintenance

In a typical manufacturing or warehousing application, the projected

6. Robert Bradley, Scanlynx Incorporated. Interview with author. Raleigh, North Carolina, July 16, 2001.

maintenance cost is usually 15% annually[7]. This covers updating or reworking programming to accommodate new releases of software for which original code had to be written. In this particular application, this rate was deemed acceptable. In the NPV analysis shown in Figure 3.1, the annual maintenance cost is reflected in the annual cash flows.

7. Robert Bradley, Scanlynx Incorporated. Interview with author. Raleigh, North Carolina, July 16, 2001.

Value and Conclusion

4.0 Net Present Value of Project

The project's value to Precision Steel has been presented as its net present value, which is calculated in Figure #8a-c. Figures #8a-c use a conservative three-year phasing in of the three components. In reality, the first phase is expected to take far less time to implement successfully. This would improve the NPV results, as well as the payback analysis shown in Figure #9a. However, for simplicity, and to provide another measure of conservatism to the analysis, each phase was given a one-year window.

The project was given a five-year life, as that is the approximate point at which competition is expected to begin using similar or improved systems enough to affect Precision's pricing of new work.

As calculated, Figure #8a shows a net present value of $101,000 at a discount rate of 10%. Figure #8b shows a net present value of $117,000 at a discount rate of 7.5%. Figure #8c uses Precision's projected profit of 5% in showing a net present value of $136,000. Each year's expense or "inflow" has been adjusted to reflect hardware and software maintenance costs as discussed.

4.1 Payback Horizon

Figure #9a shows a simple payback analysis for the project. Phase one boasts an impressive payback of .43 years, due primarily to its low cost and immediate return. Phase two's payback is a somewhat longer 5.31 years. The initial outlay, combined with the conservative consumption assumption, sums to a longer payback. Phase three shows a payback of 1.42 years, revealing the true benefits of the system in full implementation. In aggregate, the project has a payback of 2.39 years from initial outlay to full implementation. The payback analysis would also be improved be a more aggressive implementation schedule that the three year approach outlined.

Figure #8a

Discounted Cash Flow Analysis @ 10%

Year	0	1	2	3	4	5
Phase 1: Time Cards	$ (10,000)	$ 23,088	$ 23,088	$ 23,088	$ 23,088	$ 23,088
Phase 2: Asset Tracking	$ -	$ (45,000)	$ 8,472	$ 8,472	$ 8,472	$ 8,472
Phase 3: Shop Drawings	$ -	$ -	$ (80,000)	$ 56,472	$ 56,472	$ 56,472
Totals	$ (10,000)	$ (21,912)	$ (48,440)	$ 88,032	$ 88,032	$ 88,032
NPV Phase 1	$ 70,474					
NPV Phase 2	$ (16,495)					
NPV Phase 3	$ 54,943					
NPV All Phases	**$100,886**					

Discount Rate: 10.00%

Cash Flows reflect annual maintenance costs of hardware ($8,000 phase two) and software ($12,000 phase three).

Figure #8b

Discounted Cash Flow Analysis @ 7.5%

Year	0	1	2	3	4	5
Phase 1: Time Cards	$ (10,000)	$ 23,088	$ 23,088	$ 23,088	$ 23,088	$ 23,088
Phase 2: Asset Tracking	$ -	$ (45,000)	$ 8,472	$ 8,472	$ 8,472	$ 8,472
Phase 3: Shop Drawings	$ -	$ -	$ (80,000)	$ 56,472	$ 56,472	$ 56,472
Totals	$ (10,000)	$ (21,912)	$ (48,440)	$ 88,032	$ 88,032	$ 88,032
NPV Phase 1	$ 70,474					
NPV Phase 2	$ (16,495)					
NPV Phase 3	$ 54,943					
NPV All Phases	**$117,023**					

Discount Rate: 7.50%

Cash Flows reflect annual maintenance costs of hardware ($8,000 phase two) and software ($12,000 phase three).

Figure #8c

Discounted Cash Flow Analysis @ 5%

Year	0	1	2	3	4	5
Phase 1: Time Cards	$ (10,000)	$ 23,088	$ 23,088	$ 23,088	$ 23,088	$ 23,088
Phase 2: Asset Tracking	$ -	$ (45,000)	$ 8,472	$ 8,472	$ 8,472	$ 8,472
Phase 3: Shop Drawings	$ -	$ -	$ (80,000)	$ 56,472	$ 56,472	$ 56,472
Totals	$ (10,000)	$ (21,912)	$ (48,440)	$ 88,032	$ 88,032	$ 88,032
NPV Phase 1	$ 70,474					
NPV Phase 2	$ (16,495)					
NPV Phase 3	$ 54,943					
NPV All Phases	**$135,847**					

Discount Rate: 5.00%

Cash Flows reflect annual maintenance costs of hardware ($8,000 phase two) and software ($12,000 phase three).

Figure #9a

Payback Analysis

Year	0	1	2	3	4	5
Phase One: Time Cards	$ (10,000)	$ 23,088	$ 23,088	$ 23,088	$ 23,088	$ 23,088
Phase Two: Asset Tracking	$ -	$ (45,000)	$ 8,472	$ 8,472	$ 8,472	$ 8,472
Phase Three: Shop Drawin	$ -	$ -	$ (80,000)	$ 56,472	$ 56,472	$ 56,472
Totals	$ (10,000)	$ (21,912)	$ (48,440)	$ 88,032	$ 88,032	$ 88,032
Payback Phase One	0.43	years				
Payback Phase Two	5.31	years				
Payback Phase Three	1.42	years				
Payback All Phases	2.91	years				

Payback for individual phases calculated from date of expenditure.
Payback for all phases calculated from time zero.

4.2 Conclusion

It is clear that a single contractor stands to benefit from the implementation of a system to track labor and equipment costs as well as documents and materials like the one outlined in this thesis. In the case of a steel contractor with annual revenue of $30 million, the present value is shown to be $100,000 in the case of the most conservative discount rate.

The new technology will change the way costs and deliveries are tracked on job sites. Initially, foremen will remain in charge of tracking resources as they are utilized. In time, however, individual workers will be given that responsibility, resulting in a migration of high-quality labor from those companies that are not using the system to those that are. The tradesmen and women that stand to benefit from having their pay tied to production will seek out the companies that are using it, bolstering those companies' labor forces with relatively better workers, further enhancing the temporary advantage those companies enjoy over their competition.

There is also likely to be a certain amount of consolidation among contractors of similar trades within CSI divisions of work. As companies are better able to perform work and tack costs and materials, they will move to bundle larger scopes of work to take advantage of these efficiencies. Projects will be performed more efficiently by a smaller number of contractors, resulting initially in improved margins for the consolidators, and eventually in savings to owners as consolidation becomes more commonplace.

While the advantage to a single subcontractor in any trade will be short lived as competitors realize the advantages and move to implement their own systems, the net gain that will eventually shift to the owners of projects will be longer lived. A scenario can be imagined where, in time, that gain will be passed to the users of the finished projects, as developers will no longer be able to afford to use contractors that don't utilize this technology. Construction costs for all types of projects will fall incrementally, resulting in savings to private developers and municipalities alike.

List of Interview Respondents

1. Ron Guido, Area Manager, Pizzagalli Construction Company. Telephone interview with author, July 26, 2001.

2. Jerry Simms, President, Simms Companies. Interview with author, July 16, 2001.

3. Terry Barcomb & Kevin Case, Project Managers, Simms Steel Erectors. Interview with author, July 16, 2001.

4. Robert Bradley, Area Manager, ScanLynx Incorporated. Interview with author, July 16, 2001.

5. Jacques Watters, Principle, ScanLynx Incorporated. Telephone interview with author, June 17, 2001.