THE EFFECTS OF COMPUTERS ON CONSTRUCTION FOREMEN

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CENTER FOR CONSTRUCTION INDUSTRY STUDIES

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Executive Summary

Foreman level task automation has been increasing at a rapid pace recently. Like office automation, there is some question whether the results represent a net benefit. Questions also arise, such as the potential of the average foreman to fully utilize and adapt to new automated systems and tools. The study reported here was conducted by the Center for Construction Industry Studies to begin to address these questions. The study attempted to determine the effects of computers on construction foremen in three areas: the effects of foreman-level task automation in terms of time saved, foremen's reactions to and experiences with task automation, and foremen-level task automation trends. Over 200 foremen employed by six companies utilizing foremen-level task automation were surveyed. Among the 179 foremen who responded, fifty-seven percent use a computer at work. Of the foreman surveyed who used a computer at work, seventy-seven percent reported that they were somewhat comfortable, comfortable, or very comfortable with computers. Based on the responses, the average amount of time saved per day due to computer use was about 14 minutes. This represents a small direct labor savings. In addition, however, a computer-using foreman spent 7% more time supervising than his counterpart who does not use computers. This may be assumed to represent a significant increase in potential production by the foreman and his crew. Other indirect savings such as improved materials tracking and control or quicker interpretation of drawings were not assessed, but they are the subjects of a follow-up study that will be conducted.

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CHAPTER 1: INTRODUCTION

Given that foremen influence approximately 33% of a construction project's budget, the effectiveness of foremen on a construction project has a great effect on project success (Borcherding 1999). This control stems from the fact that foremen direct the labor force in sets of crews ranging from 8 to 12 people. As first line supervisors, foremen are expected to perform several tasks during a construction project: interpreting plans and drawings; assigning crew members to construction tasks; providing discipline, training, and guidance to crew members; materials, equipment, and tool procurement; short interval scheduling; and completing paperwork. Paperwork includes items such as daily diaries, reports and time records.

Since the introduction of computers to the construction industry, foremen have been given more responsibility in terms of the amount of paperwork that they are required to complete (Wubbenhorst 1999). In the traditional project structure, project management has increased the amount of paperwork that foremen are required to complete in order to obtain the necessary information for automated project controls and payroll. Foremen see this paperwork as burdensome, though it is considered essential for good management. (Coble and Baker 1993) Foremen could spend more time planning, working, and supervising their crews by decreasing the time spent on paperwork and other non-construction related tasks, thus improving productivity. Automating these tasks with computer use is one way to achieve this goal.

Computer use at the foreman level, which is sometimes referred to as foreman-level task automation, greatly varies across the construction industry. Although most construction companies do not have foremen using computers, several leaders of the construction industry have begun to train their first line supervisors to use computers on the job site, both in and out of the field.

1.1 Objectives

The study undertaken for this thesis was part of a research project performed by the Center for Construction Industry Studies on the construction workforce. The primary objectives of this study were as follows:

1. Investigate the effects of foreman-level task automation in terms of time saved.
2. Investigate foremen’s reactions to and experiences with task automation.
3. Discover foreman-level task automation trends.

It was expected that an understanding of construction workers' attitudes and experiences would help better determine the potential of new labor utilization strategies and help to implement those strategies more effectively.

1.2 Scope

The scope of this project was limited to the US constructors who employ computers on the foreman level. Both union and nonunion sectors of the industry were included. The study was performed using contacts that were provided by the Center for Construction Industry Studies (CCIS) Workforce Research Team members, the Construction Industry Institute, and by a Multiskilling User Focus Group set up under the auspices of a related research project.

1.3 Methodology

The research effort began with a literature search of related topics. The study included the participants in a construction project, foreman tasks, skill levels, wages, company restructuring, computer-related productivity, worker attitudes toward task automation, and formulation of research surveys. Articles, theses, and dissertations relating to computer use and productivity were also examined.

Next, telephone and personal interviews with off-site construction management were performed. The purpose of the interviews was to receive qualitative responses that would provide rich, in-depth information on current practices for the implementation of computers on the foremen level. A dozen interviews were conducted over a seven-week period from late April to mid-June of 1999. A list of the interview questions may be found in Appendix A. Based on information gathered in these interviews, a survey of construction foreman was formulated.

To ensure the quality of the survey, it was edited by academic experts in construction, human resources, and statistical analysis and then beta tested with active foreman in the field. Necessary adjustments were made to the survey after each beta test. After the last beta test, the final survey version was distributed. The acquired survey data was analyzed and interpreted with the results reported in the form of this report. This report will provide conclusions of the research and recommendations for further research.

1.4 Report Structure

The structure of this report will follow a traditional format. Chapter 2 provides background information on several aspects of the construction industry and computer use in general. Chapter 3 describes the results of analyzing the foreman survey that was distributed. Chapter 4 presents the conclusions and recommendations drawn from the research.

CHAPTER 2: BACKGROUND

The following chapter provides background for the research. The literature review indicated that the introduction of computers into the workforce is relatively new to all industries, within the past ten years. While other industries have already jumped on the automation bandwagon, the construction industry is slow to follow suit. The majority of construction companies only recently introduced computers into the job-site office. The industry is slowly beginning to include foremen in task automation. Thus, it was necessary to perform a literature review on industries other than construction: manufacturing, banking, health care, and insurance. Experts have not agreed about the effects of the introduction of computers on workers' efficiency, skills, and productivity.

2.1 Information Flow on Construction Projects

The construction industry is a complex information arena, with information being produced, transferred, and analyzed throughout the design and construction process. The time sensitivity and accuracy of this information are critical to successful completion of a project. Among many others, examples of construction information are contracts, drawings, specifications, requests for information, change orders, transmittals, cost reports, crew time reports, daily reports, safety logs, injury reports, pay request, and material invoices.

Communications on a project are both written and oral. Figure 2.1 represents a typical on-site organizational chart for a relatively large construction project being carried out by a single contractor; however, it is one of many possibilities. The chart outlines the formal relationships among the various management positions. Information is expected to flow up through an organization, and authority is expected to flow down. Downward flows involve such items as plans, specifications, and a variety of written instructions. Upward flows carry feedback of various kinds about the accomplished task. For example, craft foremen receive instructions from and report back to craft superintendents.

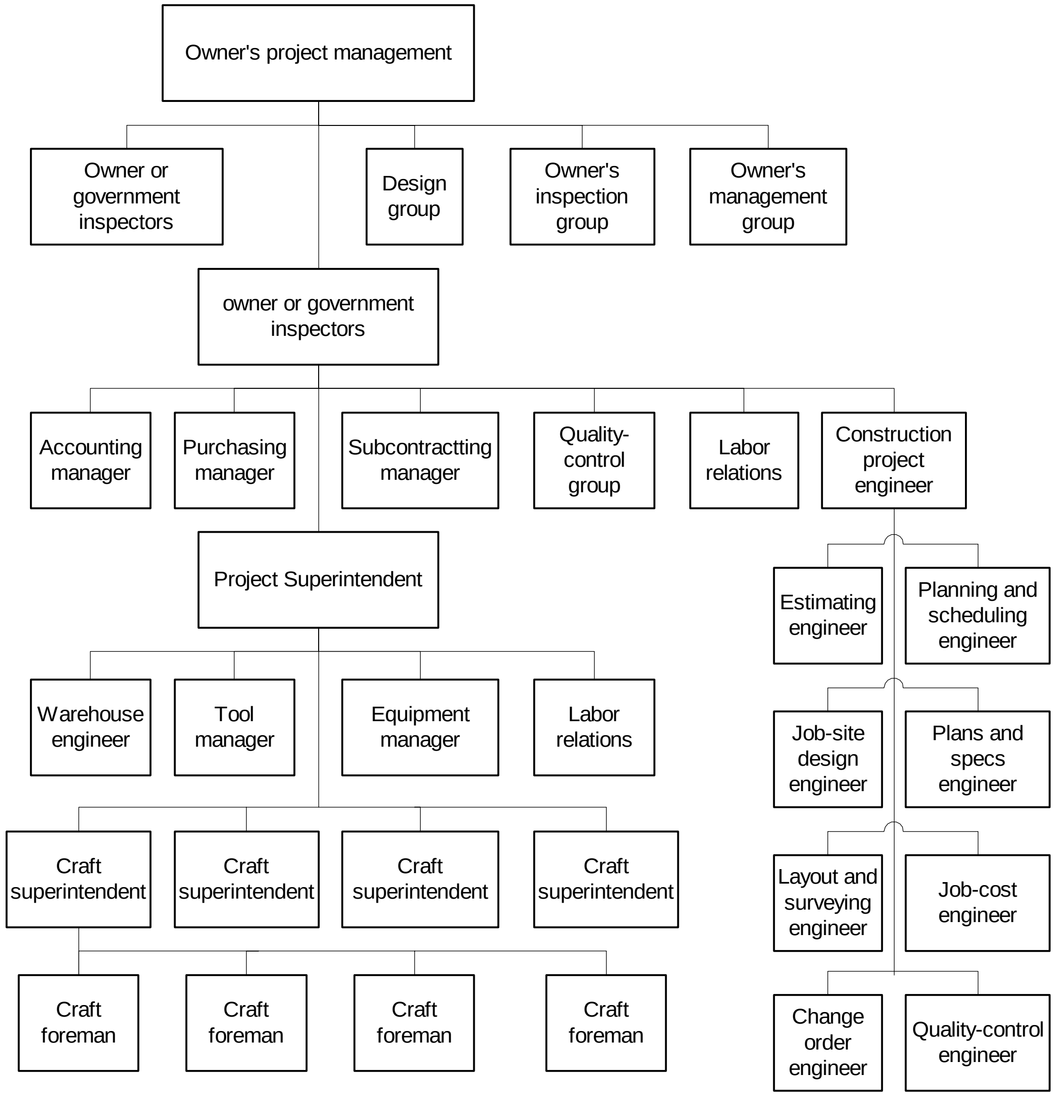

Figure 2.1 Organizational structure for a large construction project (Oglesby, Parker, and Howell 1989)

Computers have eased the complexity in handling this information exchange process and have also contributed in the creation of more information to track. The proliferation of computers for information generation and processing on a project site has traditionally been limited to the office staff (superintendent, project manager, project engineers, office engineers, and field engineers) and A/E designers. Designers and construction managers exchange information electronically but must relay this information manually to the field. Field level project information is mostly manually collected on a daily, weekly, biweekly, and monthly basis. The field information is then transmitted to data entry for construction management's use.

Construction managers analyze field level information in order to make decisions. From these decisions, high-level managers then typically generate automated instructions for transmission to the field level. Both the source and output of construction management endeavors must be translated from an automated format to a manual format for field use, which opens the possibility of transcription errors. A traditional information transfer process to the field level is illustrated in Figure 2.2.

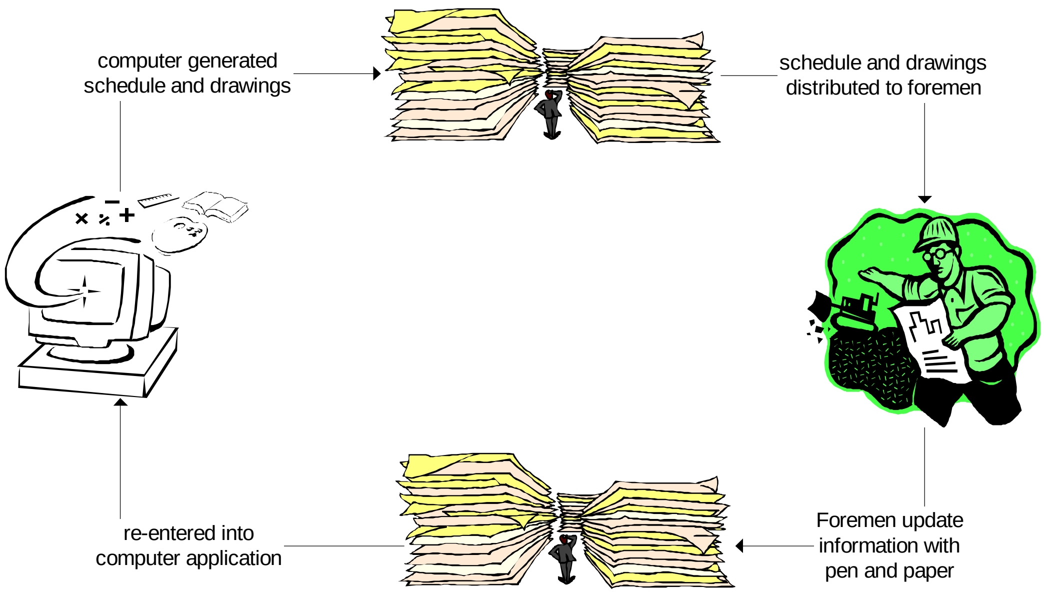

Figure 2.2 Manual information transfer at the field level (Wubbenhorst 1996)

In the above figure, electronically generated information is transferred into a manual format for field dissemination. Errors in this transmission may occur, supplying the field with inaccurate information. Returning this information to management and recoding it into an electronic format is also susceptible to the same error, compounding the accuracy and reliability problem. Computers on the foreman level can help remedy this problem while improving documentation without adding to the foreman's workload.

2.2 Information Technology and its Effects on Productivity

The productivity paradox is a term that economists coined to explain the anomaly of massive investments in technology that results in flat profits and stagnant productivity gains (Keyes 1995). Sophisticated computer and communication technologies have been placed on desktops for virtually all levels of management. This proliferation of computers has intensified the on-going debate about the ‘productivity paradox,’ showing the pressure on organizations to demonstrate tangible benefits from their use of computer technology. A consensus on the effects of information technology (IT) on productivity has not been reached.

Supporters believe that the payoffs associated with IT have occurred in terms of improved productivity and improved customer satisfaction but not improved profitability. Usually the gains in profitability are competed away by other firms who occupy the same information systems innovations (Weber 1999); however, the construction industry is an exception. Because of the industry’s slow acceptance of new technology, those who first implement this technology effectively will profit from their workforce’s increased productivity.

Other supporters claim that the productivity paradox is due to inadequately using technology. They believe that new IT cannot improve productivity because the source of the problem is organizational in nature (Seybold 1993). Organizational restructuring may not occur in concert with the implementation of new technology, causing the potential productivity gains to be lost while the organization is adapting to changes in its environment. The effectiveness of information technology on productivity is highly dependent on addressing organizational issues, including deciding which task is automated and how it is automated. In a case where organizational factors are not considered, computers can actually lower productivity when computer power is superfluous, when it fosters unnecessary applications, and when many business managers don’t fully understand the true costs of computerization (Schmitt 1998). If organizational restructuring is performed before implementation, the human factor may be an obstacle to productivity gains. This problem is caused by people’s reluctance to alter their work habits.

2.3 Worker Attitudes and Information System Success

The success of automation is generally a reflection of workers’ attitudes towards such a system. This is not reassuring since attitudes generally are not predictable. They only predict the extent of job computerization for those who had knowledge about the system and real freedom of choice about their computer system (Winter, Chudoba, and

Gutek 1998). Figure 2.4 manifests a set of hypothesized relationships among factors that are thought to have an impact on whether an information system is effective. This model shows that the users' beliefs about their ability to use their computers competently, or self-efficacy, affects the system's perceived usefulness and perceived ease of use. The system's perceived usefulness and ease of use affects how its users utilize the system in terms of frequency and type of use. In turn, how the system is used affects users' performance in their organization and ultimately the performance of the organization as a whole. How the system is used also affects the users' satisfaction with the system, which leads to the two-way relationship between information system satisfaction and individual impact, or job satisfaction. Job satisfaction has usually been associated with low employee turnover and absenteeism; however, it is also modestly indirectly related to job performance.

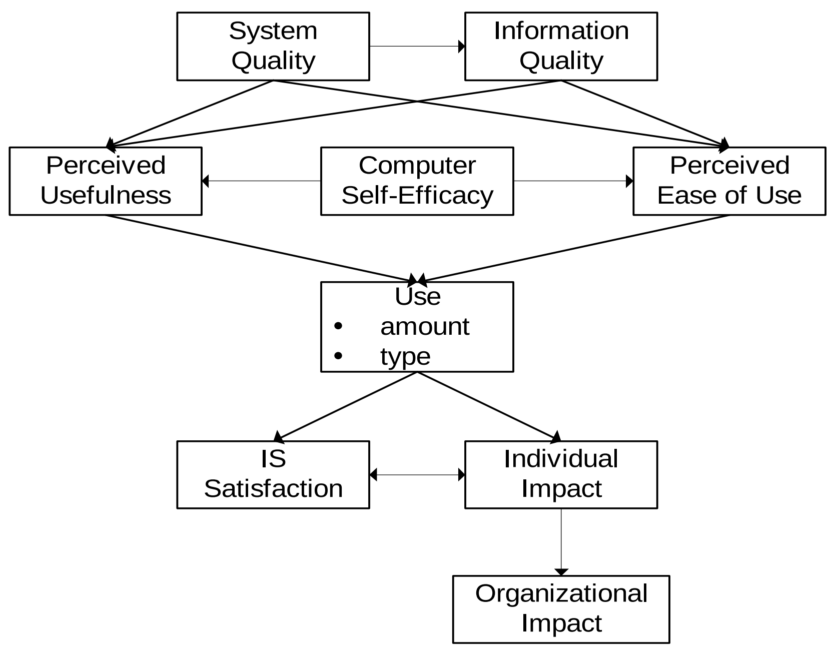

Figure 2.3 Model of factors affecting IS effectiveness (Weber 1999)

Perceived usefulness is the user's belief that using a specific application system will increase his job performance within an organizational context. Frequency of use is linked to perceived usefulness. For example, a user will increase use if he perceives that system use will increase job performance and ultimately rewards for good job performance. Perceived ease of use is the degree to which the prospective users expect the information system to be free of effort. Perceived ease of use is also linked with frequency of use. For example, if a user feels that a system is easy to use, he will use it more often.

2.4 Current Practices of Foreman-level Task Automation

Several companies require their foremen to use a computer in order to decrease the amount of time that foremen and office personnel spend completing paperwork. However, each company has a different approach to saving their foreman's time. The differences are evident when considering which tasks are automated at the foreman level and the degree of autonomy allowed a foreman once these tasks are automated. The differences in the degree of autonomy associated with the computer automation of tasks can be traced to the expectations of the skills of a foreman. It is important to determine if foremen are capable of operating a computer with full autonomy or if autonomy should be restricted because the foremen are not capable of learning computer skills.

This research determined how much of foremen's time has shifted toward the field and foremen's attitudes toward the introduction of computers. Described in the following subsections, actual examples of how foreman-level task automation can improve the time spent on foreman tasks identified in the survey are described: interpreting plans and drawings, locating updated/correct plans and drawings, materials procurement, tools procurement, equipment procurement, short interval scheduling/planning, crew supervision, and time reporting

2.4.1 Interpreting Plans and Drawings

Foremen spend a considerable amount of time interpreting drawings in the field. Unfortunately, field sketches, change orders, and requests for information are attached to a drawing as the project progresses, leaving the foreman to integrate all the information on those drawings. A foreman may need to interpret ambiguous information or draw an additional field sketch integrating all of the information into one drawing this takes considerable time. By using 3-D modeling, a company can decrease the number of ambiguities while integrating all of the information from various disciplines: structural, mechanical, electrical, and architectural. This new capability decreases the amount of time that a foreman spends interpreting drawings (Holy, Song, and Wubbenhorst 1999).

2.4.2 Locating Updated Drawings

As mentioned before, project designs are continuously being updated as the project progresses. In a typical project, the updated design is located in the site office and is not usually updated each day. Often foremen have to track down changes through paper trails in the office. By using CAD drawings to integrate information and to give foremen immediate access in the field, a company can considerably decrease the amount of time that a foreman spends trying to located updated drawings through a new capability.

2.4.3 Material, Tool, and Equipment Procurement

Today, a company can create databases tracking the location of materials, tools, and equipment. In today's construction environment progressive companies often use computers for inventory control, a direct substitution; however, companies can automate this task one step further into a new capability. A warehouse uses a bar scan for inventory control while a GPS system could track the location of these items and the location of the foreman requesting the items. This can enable a foreman to order materials, tools, and equipment from the field, without leaving his crew. Even without GPS, bar scanning decreases the amount of time needed to input the information describing the item and the foreman requesting the item, which also decreases the amount of time that a foreman spends away from his crew. Barcoding also reduces transcription errors and their associated repercussions.

2.4.4 Short Interval Scheduling

In this case, foremen are trained to use commercially available software because the company believes that a foreman is capable of operating a computer with complete autonomy. As with the case with automated time keeping, using computers for short interval scheduling saves the foreman and the office time. A direct substitution, the foreman saves time because he is no longer forced to duplicate previously scheduled activities, given that the schedules are created well originally. The office only needs to import the foreman's schedule into the project's CPM schedule, saving the office staff a sizable amount time. In some cases, foremen have taught themselves other programs that were installed in the computer and automated other tasks, such as material tracking, on their own (Bartley 1999).

2.4.5 Time Reporting

Some companies have automated the time keeping process by providing foremen with a program that requires as much computer skills as required for operating an ATM machine. In this case, it is assumed that a foreman is not capable of operating a computer with complete autonomy and is trained to use in-house software. This keyless entry program prompts the foreman to pick one of three choices at each interval. Instead of typing information into the computer, the foreman is provided with barcodes and a scanner to input a crewmember's name, hours worked, and activity that he or she worked on. Automated time keeping not only saves the foreman time but also creates a direct line of communication between a foreman and the accounting department.

CHAPTER 3: SURVEY ANALYSIS

All six of the companies who agreed to participate returned the survey to the researcher. One hundred seventy-nine surveys were received from the participating companies. A Microsoft Access database had been created to hold, manage, and manipulate the data from the pilot tests. This database was modified for the final survey. At this point, the survey's responses were entered into the database, using approximately 50 man-hours.

Once entered, the data was analyzed using both MS Excel and SPSS. Means, standard deviations, and various relationships were determined from the data. The results were presented to the Construction Workforce Thrust Area Advisory Board for feedback.

3.1 Respondent Demographics

According to research in information technology, a user’s age, tenure, education, and self-efficacy affect his attitude toward an information system. These effects were expected in the foremen’s responses to survey questions on foreman-level task automation. However, this was not the case. Despite relationships found between age, number of years in a supervisory position, self-efficacy, education, and perceived usefulness of an information system in previous research, a significant relationship could not be found in this study.

3.1.1 Age and Tenure

Because of their effects on worker attitude, age and the duration of service in a supervisor role previous to task automation may influence a user’s attitudes towards new technology. Therefore, it is important to determine the respondents' demographics because it is one key to understanding how and why respondents answer a particular way. Secondly, by comparing the demographics of the survey's sample to those of the U.S. population, it is possible to see if the sample is representative and true. The validity of the data is based in part on this fact. From the data, conclusions are drawn to determine why the sample matches or do not match the population. The rationalization of the sample and population's mismatch is the remaining factor, which validates the data.

The average age of the entire sample is 42.6 years old (standard deviation 8.3). The 42.6 years old average age is slightly higher than average age of construction workers found from the 1997 Center to Protect Workers' Rights study. The higher average age was expected because of the experience that is required to be promoted to a foreman.

The respondents' experience in construction varied from two months to forty-five years. On average, the respondents have spent 20.7 years (standard deviation 8.3) in the construction industry. The respondents experience as a construction foreman also greatly varied, from seven days to thirty years. The respondents averaged 9.4 years (standard deviation 7.1) as construction foremen. The wide range in ages was desired in order to avoid responses biased by age or fear of new technology.

3.1.2 Workforce Self-Efficacy and Education

The average of the amount of formal education was 12.3 years (standard deviation 1.6). Figure 3.1 shows the percentage of the foremen that obtained educational degrees of some sort. The majority of the respondents obtained a high school degree. Other degrees obtained were GED, associate, and vocational diploma. The survey asked for a numeric response for number of years of education received. While these statistics show that many foremen have at minimum a high school diploma or GED equivalent education, what they do not show is those workers who did not or could not fill out the survey because of lack of these skills. As mentioned earlier, the project managers distributed the survey and may have been discriminate in doing so, not by fault. Therefore, illiterate foremen may not have filled out the survey. Therefore, it is difficult to know the true education and literacy levels for foremen in the construction industry. The statistics found in this survey, as well as others, tend to be skewed for these reasons.

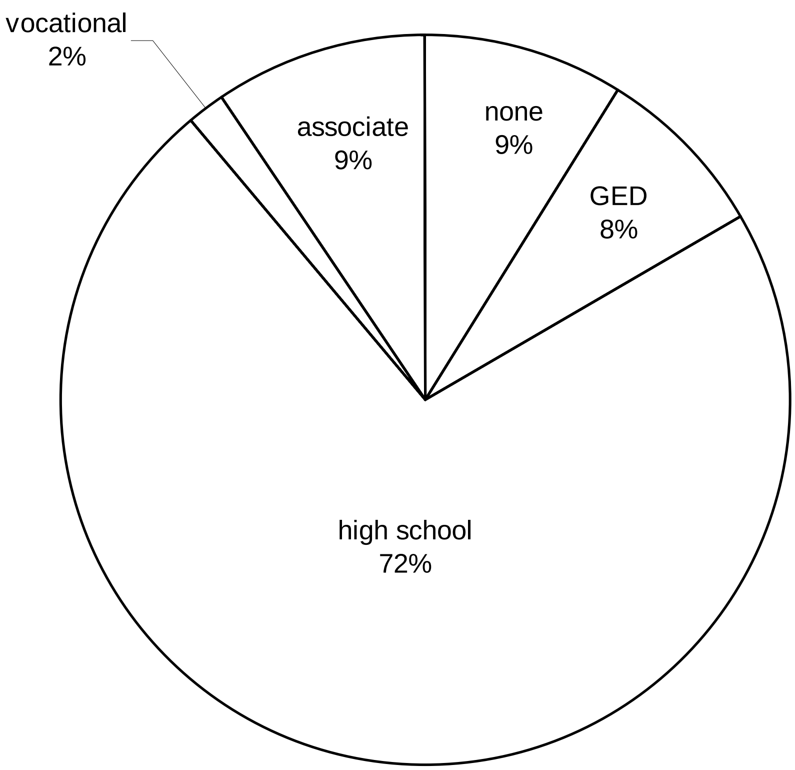

Figure 3.1: Percentage of Respondents with Various Degrees

Foremen who used computers at work were asked to rate their computer skills in one of six categories: very uncomfortable, uncomfortable, slightly uncomfortable, somewhat comfortable, comfortable and very uncomfortable. The average response was "somewhat comfortable" (Standard deviation 1.2). (See Figure 3.2 for foreman response distribution.) A statistically significant relationship between foreman self-efficacy and how each foreman acquired his computer skill was not found. The relationship between self-efficacy and the number of automated task that the foreman presently used was also statistically insignificant.

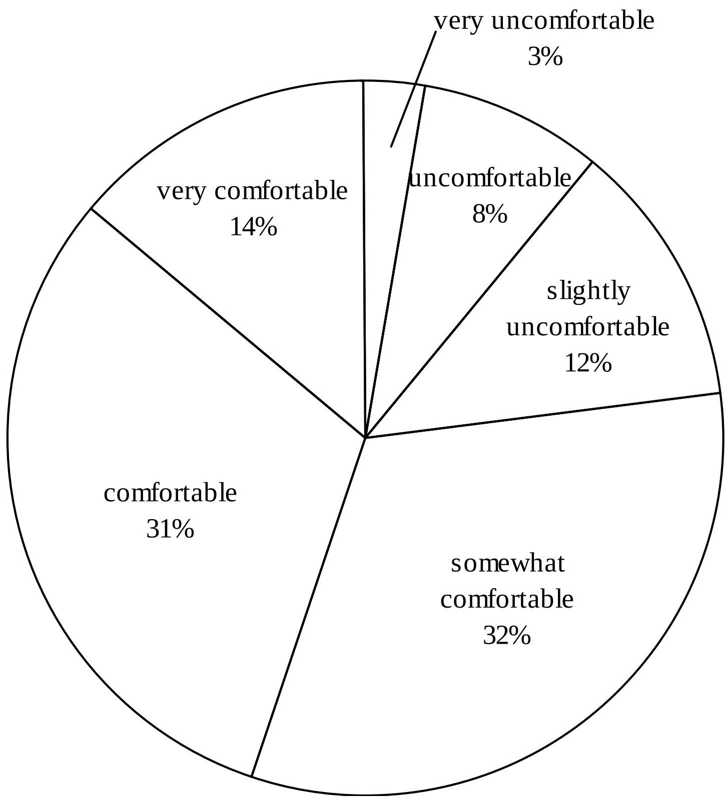

Figure 3.2: Distribution of foremen self-perceived computer skills who use computers

3.2 Foremen Computer Use

Foremen were asked if they used a computer at home. If they did use a computer at home, they were asked what kinds of programs they used. Foremen were also asked if they used a computer at work. If the foreman responded positively, he was asked several questions about his perceptions about the usefulness of foreman-level task automation. He was asked if he supervised more when he used a computer. He was then asked if his crew performed less rework since he has used a computer at work. Next, he was asked to quantify how much more time he saved when he used a computer at work. Lastly, the foreman was asked if his company saved money by having him use a computer.

3.2.1 Foreman Computer Use at Home

Surprisingly, ninety-one, or fifty-seven percent of the 179 foremen who responded, have a computer at home. Of those foremen, the number of programs that they used at home varied from zero to seven. The average number of programs used by a foreman at home was 1.8 (standard deviation 2.1). (See Figure 3.3 for percentages.) The two foremen who did not use any programs on their home computer explained that their children primarily used the computer.

Foremen were also asked to name the type of programs that they used at home. The categories that they were asked to choose from were word processing, spreadsheets, finances, internet surfing, e-mail, video games, and “other.” The respondents could choose as many categories as was necessary. The number of foremen using each category of application software is shown in Figure 3.4. When inspecting Figure 3.4, one must keep in mind that, of the eighty-five foremen who did use a computer at home, several used more than one program. Programs in the “other” category included stock trading and chat room software.

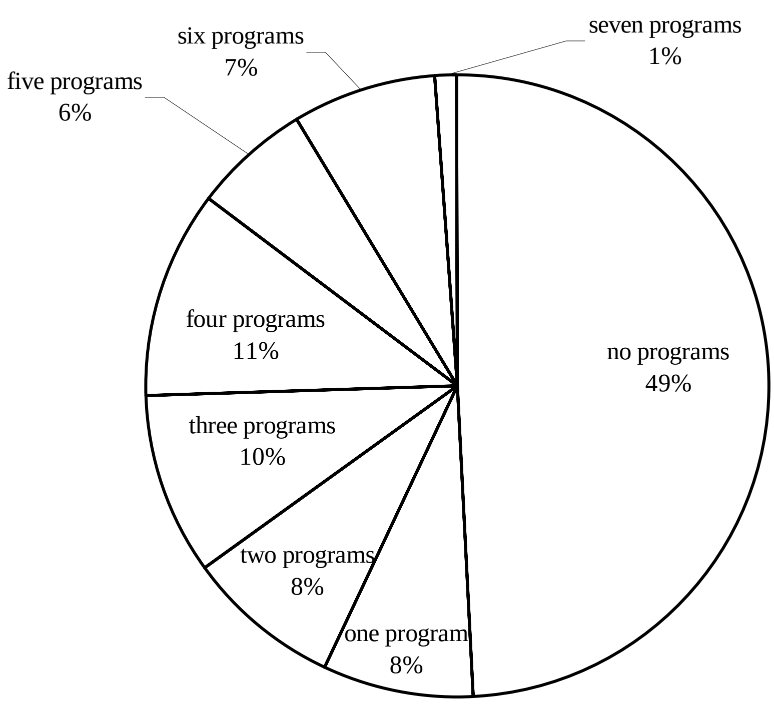

Figure 3.3: Distribution for the number of programs used at home by foremen who have a computer at home

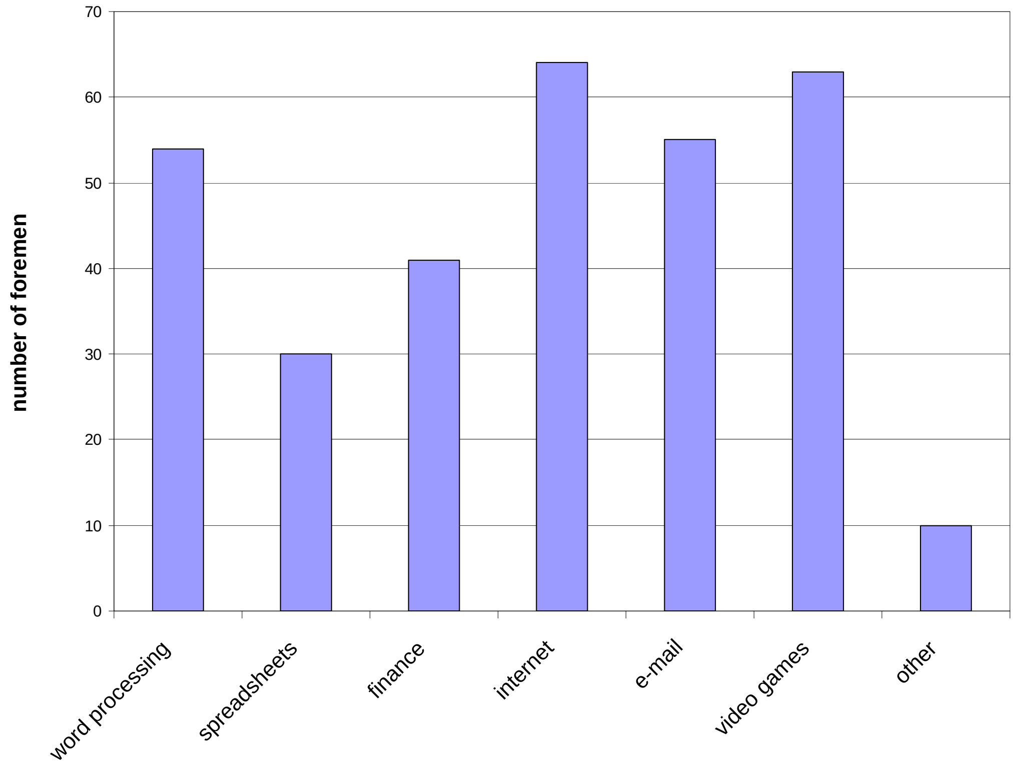

Figure 3.4: Number of foremen using each application

3.2.2 Computer Use at Work

Of the 179 foremen who responded, fifty-seven percent use a computer at work. Of those foremen, ninety-two percent used computers in the job site office while fourteen percent used them in the field. Forty-eight percent believed that they spent more time supervising since using a computer at work. Only twenty-nine percent of the foremen using computers at work responded that they performed less rework as a result of using a computer on the job. Based on foreman responses, the average amount of time saved per day due to computer use was 1.3 hours (standard deviation 1.6). Although foremen were generally not supportive about the effectiveness of foreman-level task automation, seventy-seven percent of the foremen who used computers at work believed that their company saved money by having them use computers.

The foremen were also asked to estimate the average length of a work day and the time devoted to performing various tasks on an average day: interpreting plans and drawings, locating updated/correct plans and drawings, materials procurement, tools procurement, equipment procurement, short interval scheduling/planning, crew supervision, and time reporting. Foremen could also add tasks that were not included in the list above. (See Tables 3.1 and 3.2.)[1]. All of the differences between the time spent with computer use and without computer use were statistically significant. (See Appendix D for ANOVA calculations.) The results show that foremen who use computers at work spend less time at work while spending more time supervising.

Table 3.1: The number of hours devoted to tasks without a computer on an average day

Length of Workday	Interpreting drawings	Locating plans	Material procurement	Tool procurement	Equipment procurement	Scheduling	Supervising	Time reporting	Other
9.03	**1.32**	**0.73**	**0.91**	**0.53**	**0.63**	**0.93**	**3.00**	**0.79**	**0.19**

Table 3.2: The number of hours devoted to tasks with a computer on an average day

Length of Workday	Interpreting drawings	Locating plans	Material procurement	Tool procurement	Equipment procurement	Scheduling	Supervising	Time reporting	Other
8.80	**1.01**	**0.55**	**0.78**	**0.43**	**0.52**	**0.74**	**3.81**	**0.68**	**0.28**

Because a foreman who uses a computer has, on average, a fourteen-minute shorter work day than a foreman who does not use a computer, the best way to compare times spent on individual tasks is to compare the percentages of time spent on each task. (See Figure 3.5.) By looking at Figure 3.5, one can also see that a foreman spends seven

[1] The activity durations were adjusted (interpreting drawings, etc.) to reflect the actual total time spent for each day. This was done by prorating the difference between the actual time spent and the summation of the activity durations. For example, if the workday lasted 9.03 hours and the activities totaled to 9.42, the difference of 0.39 was prorated to each activity. The result is shorter activity durations to correspond to the workday of 9.03. Tables in this report have been updated accordingly.

percent more time during the day supervising than his non-computer using counterpart. He also spends less time completing non-supervisory tasks than his non-computer using counterpart. If one assumes that a job has 15 foreman working eight hours each day at $12 an hour, and each foreman works fifty-two, five day weeks out of the year, that job can save $10,764 each year. This savings is solely due to the time savings of fourteen minutes and does not include productivity increases due to increased supervision.

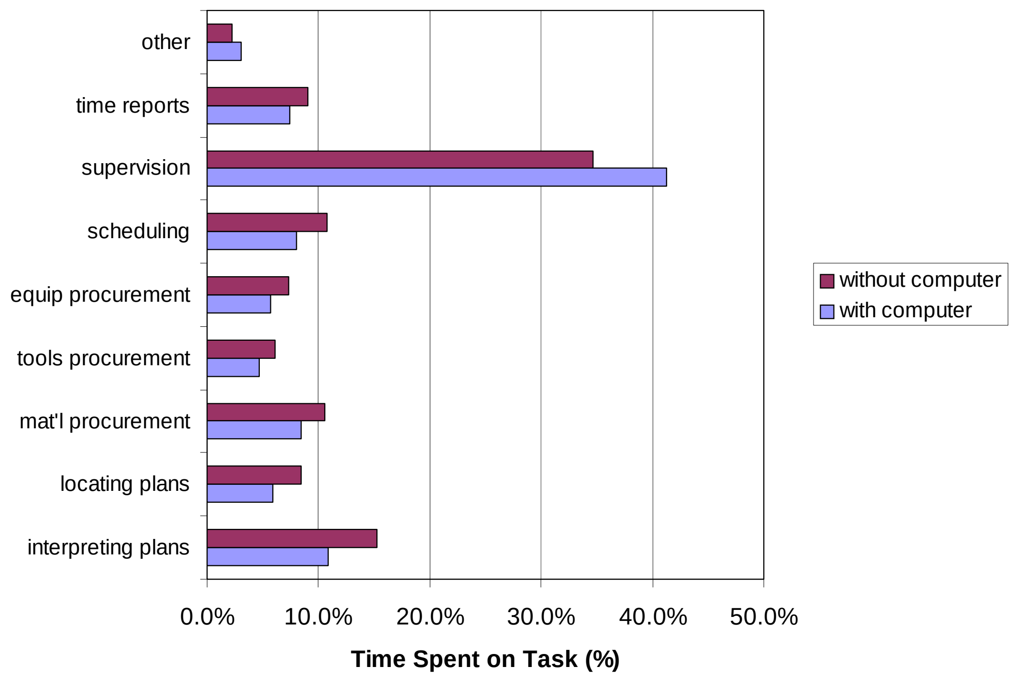

Figure 3.5: Percentage of Time Spent on Each Task

3.3 Trends in the Use of Foreman-level Task Automation

Foremen who presently use computers at work were asked which of their everyday tasks were automated by a computer five years ago, three years ago, and in the present. The time intervals were chosen because of the present lack of foreman-level task automation in the construction industry. Respondents could choose from several of the foreman-level automated tasks identified during the literature search and expert interviews: time reporting, access the latest drawing revisions, access other information, visualize future and present work through 3-D drawings, order tools, order materials, order equipment, order scaffolding, locate tools, locate materials, locate equipment, locate scaffolding, communicate with others on a project, and visually record job progress. Respondents could add additional tasks if necessary. From their responses, trends in automation implementation can be seen. The use of foreman-level task automation has increased in the seven companies currently using foreman-level task automation. (See Figure 3.6.) The automation level is the sum of the number of foremen working on all automated tasks.

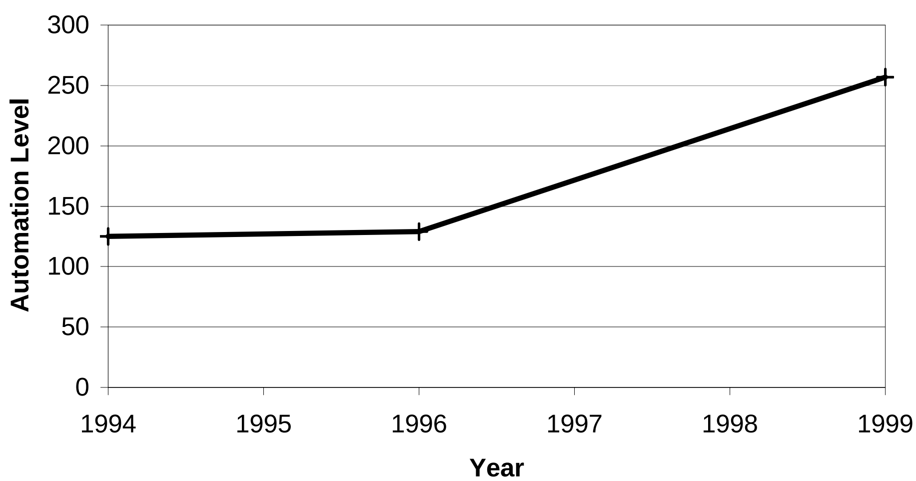

Figure 3.6: Use of Foreman-level Task Automation Trend

Once trend charts were created, three classes of foreman-level task automation could be deciphered based on the trends in the level of use. The first class, or Class 1, consists of five tasks: time reporting, accessing other information, communicating with others on a project, accessing the latest drawing revisions, and visualizing future and present work through 3-D drawings. Class 1 Automation is rapidly increasing in implementation. (See Figure 3.7.)

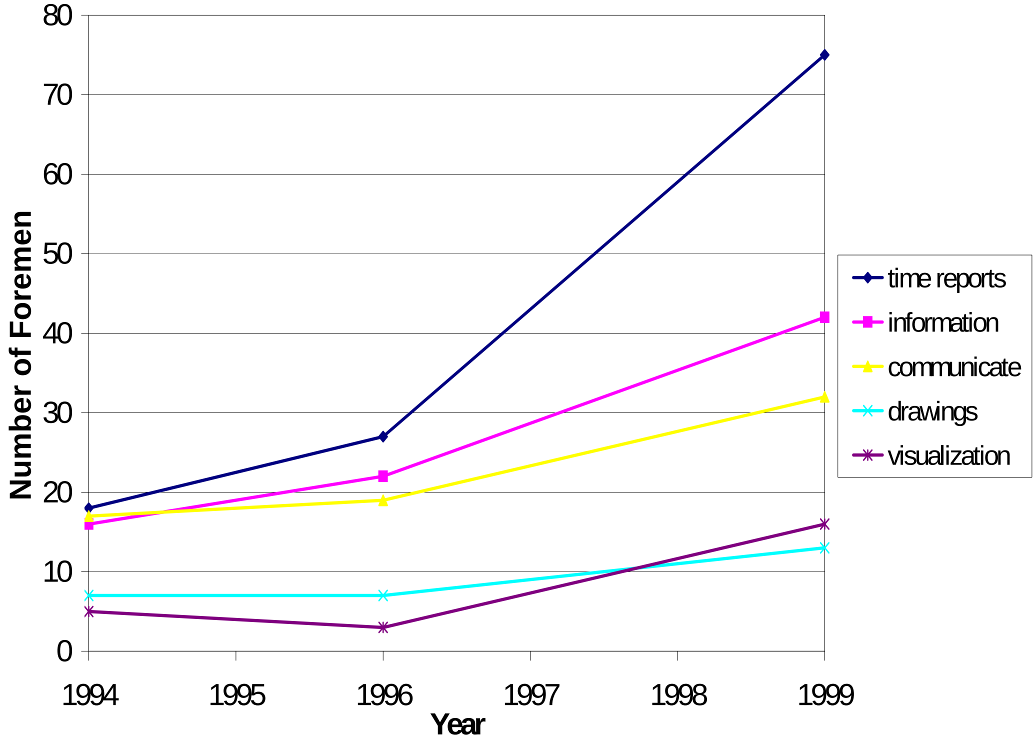

Figure 3.7: Trends in Foremen Use of Class 1 Automation

The next class, or Class 2 Automation, is slowly increasing in use and has a lower total usage than Class 1 Automation. This class consists of six tasks: ordering tools, locating tools, locating scaffolding, recording job progress, locating materials, and ordering materials. (See Figure 3.8.)

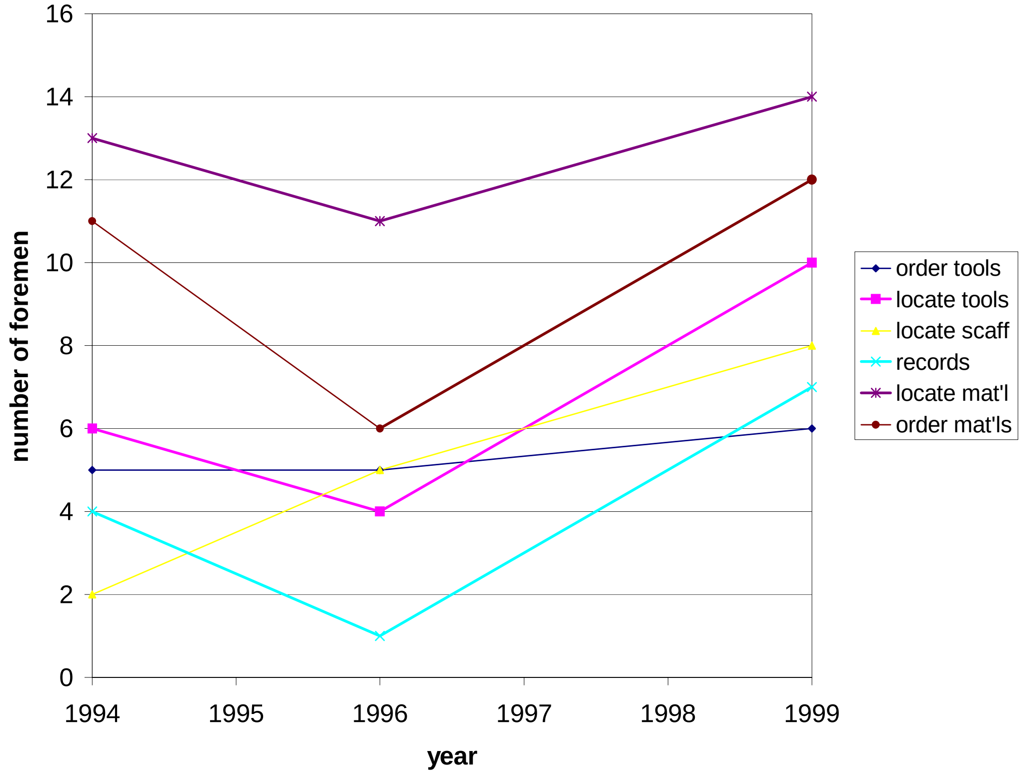

Figure 3.8: Trends in Foremen Use of Class 2 Automation

The last class of foreman-level task automation, named Class 3 Automation, consists of three tasks: ordering equipment, ordering scaffolds, and locating equipment. According to responses received, use of Class 3 Automation is either stable or decreasing. (See Figure 3.9.) The reasons for the reductions are unknown. One explanation may be that locating equipment and scaffolding effectively negates the need for ordering on some sites, however, the numbers themselves are statistically insignificant, so any explanation is highly speculative at this point.

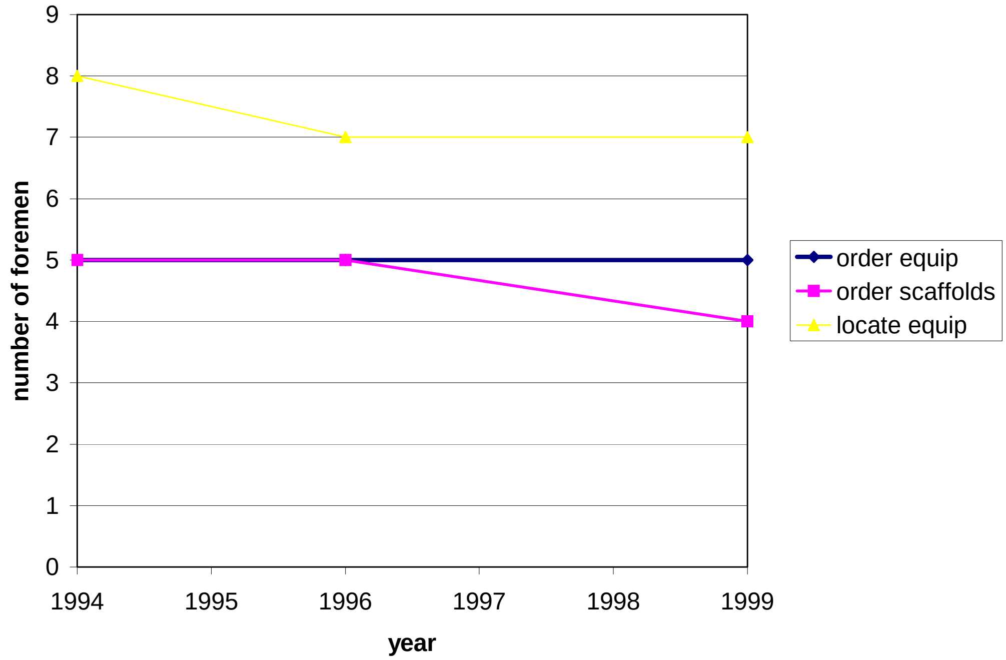

Figure 3.9: Trends in Foremen Use of Class 3 Automation

3.4 Foreman Requests for Future of Foreman-level Task Automation

Lastly respondents were asked which of the foreman-level automated tasks they wanted implemented in the future. Again, the list of tasks was compiled from the literature search and the expert interviews: time reporting, to access the latest drawing revisions, to access other information, to visualize future and present work through 3-D drawings, to order tools, to order materials, to order equipment, to order scaffolding, to locate tools, to locate materials, to locate equipment, to locate scaffolding, to communicate with others on a project, and to visually record job progress. The respondents could opt not to choose any tasks and could add any tasks that were not on the list. (See Figure 3.10 for foreman responses.)

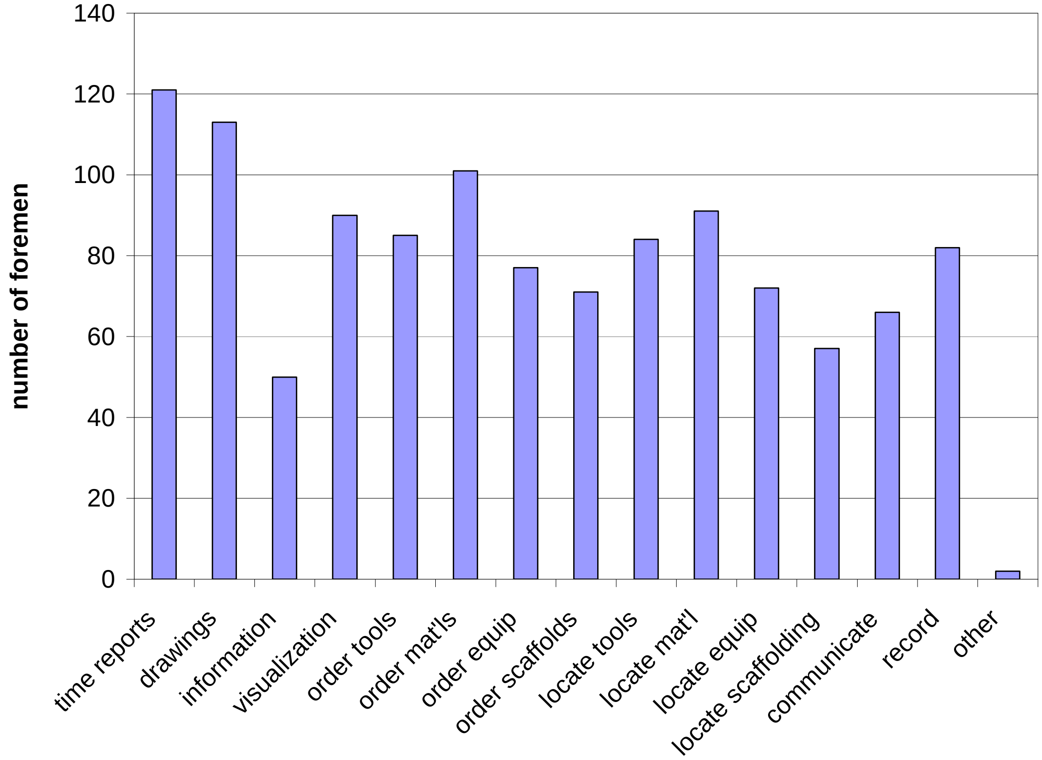

Figure 3.10: Foreman Attitudes Towards Future Task Automation

Figure 3.10 should be used to identify the most wanted of the foreman-level automated tasks. Companies may wish to concentrate on tasks having greater than ninety affirmations for future automation. Such tasks are time reporting, locating updated drawings and plans, and ordering materials. Time reporting and locating updated drawings and plans are classified as Class 1 Automation; however, it is surprising that any type of Class 3 Automation would actually be decreasing in use. Decisions on future implementation of foreman-level task automation should take these observations into account.

CHAPTER 4: CONCLUSIONS AND RECOMMENDATIONS

This research was motivated by the need to improve project performance. Foreman-level task automation offers potential to improve the efficiency of the time spent by foreman. This research had four main goals:

1. Investigate the effects of foreman-level task automation in terms of time saved.
2. Investigate foremen's reactions to and experiences with task automation.
3. Determine foremen-level task automation trends.

This research did not attempt to quantify the net value added to a project through computer use by foremen.

Among the 179 foremen who responded, fifty-seven percent use a computer at work. Of the foreman surveyed who used a computer at work, seventy-seven percent reported that they were somewhat comfortable, comfortable, or very comfortable with computers. Based on the responses, the average amount of time saved per day due to computer use was about 14 minutes. This represents a small direct labor savings. In addition, however, a computer-using foreman spent 7% more time supervising than his counterpart who does not use computers. This may be assumed to represent a significant increase in potential production by the foreman and his crew.

Although the results of this research are promising, further research on the subject should be conducted.

- A detailed benefit/cost analysis of the implementation of foreman-level task automation should be conducted.
- A more thorough understanding of current practices in foreman-level task automation should be ascertained through site visits.
- The effects the implementation strategy on foreman-level task automation on foremen perception and system use should be studied.

Construction firms should consider the results of this study when planning future implementation of foreman-level task automation.

APPENDIX A: REFERENCES

Bartholomew, Stuart H. Construction Contracting: Business and Legal Principles. Prentice-Hall, Inc.: Upper Saddle River, NJ: 1998.

Bartholomew, Doug. *Go Figure.* Industry Week: August 17, 1998.

Black, Sandra E. and Lisa M. Lynch. *The New Workplace: What Does It Mean for Productivity.* The National Center on the educational Quality of the Workforce: December 1997.

Browning, John. *No more 9 to 5.* Scientific American: vol. 276 p42. January 1997.

Carnevale, Anthony Patrick. (1991) *America and the New Economy.* Jossey-Bass Publishers: San Francisco, CA.

The Center to Protect Workers' Rights. *The Construction Chart Book.* The Center to Protect Workers' Rights Publications: Washington, D.C.. 1998.

Coates, Joseph F. *Skills Required for Twenty-first Century Employment.* Employment Relations Today: 22(3). Autumn 1995.

Deci, E.L. and R.M. Ryan. Intrinsic Motivation and Self-Determination in Human Behavior. Plenum: New York, NY. 1987.

Drucker, P.F. Post-Capitalist Society. Harper Collins: New York, NY. 1993.

Cutbacks Fuel Contingent Workforce. USA Today. March 3, 1993.

Fritz, Fred. Personal Interview. May 13, 1999.

Garner, Douglas F.; Borcherding, John D. and Nancy M. Samelson. *Factors Influencing the Motivation of Craftsmen and Foremen on Large Construction Projects.* Masters Thesis, Department of Civil Engineering, The University of Texas at Austin: August 1979.

Grusec**,** Ted. *Office Automation in Government Offices: "Productivity" and Other Myths.* Optimum. *16(2): 7-24. 1985.*

Haddad, Carol J. *Employee Attitudes Toward New Technology in a Unionized Manufacturing Plant.* Journal of Engineering and Technology Management: vol. 13 p. 145(62). 1996.

Hebert, Marilynne A. *Impact of IT on Health Care Professionals: Changes in Work and the Productivity Paradox.* Health Services Management Research. v. 11: 1998.

Holy, Shannon; Song, Ben; and Rob Wubbenhorst. *Implementation of an Integrated 3-D Information System for EPC Projects.* Fluor Daniel. 1999.

Hudson Institute. *2020: Work and Workers in the 21st Century.* Hudson Institute, Inc. Indianapolis, IN. November 1997.

Hunter, Larry W. and John J. Lafkas. *Information Technology, Work Practices, and Wages.* The Wharton School: Philadelphia, PA. January 1998.

Ilardi, Barabara C.; Leone, Dean; Kasser, Tim; and Richard M. Ryan. *Employee and Supervisor Ratings of Motivation: Main Effects and Discrepancies Associated with Job Satisfaction and Adjustment in a Factory Setting.* Journal of Applied Social Psychology. vol. 23, n. 21: 1993

Keyes, J. The Productivity Paradox. McGraw-Hill: New York, NY. 1995.

Levy, Frank. *A Future of Lousy Jobs? The Changing Structure of U.S. Wages (book reviews).* Industrial and Labor Relations Review: vol.44 n.4 p763(7). July 1991.

Levy, Frank. *In Future Path and Consequences of the U.S. Earnings/Education Gap.* Federal Reserve Bank of New York Economic Policy Review: vol.1 n.1 p35(7). January 1995.

Levy, Frank (1). *Inequity, Growth, and Restructuring (Panel Discussion).* New England Economic Review: p.178(2). May-June 1996.

Levy, Frank and Richard Murnane. (1996(1)) *Teaching the New Basic Skills.* The Free Press: NewYork, NY.

Levy, Frank and Richard Murnane. (2) *What Skills Are Computers a Complement?* American Economic Review: vol.86 n.2 .May 1996.

Levy, Frank; Murnane, Richard and John B. Willet. *The Growing Importance of Cognitive Skills in Wage Determination.* Review of Economics and Statistics: vol.77 n.2 p.251(16). May 1997.

Lightfoot, Warwick. *Does IT Make a Difference?* The European: pp.46(1). August 24, 1998.

Machin, Stephen. *Technology and Changes in Skill Structure: Evidence From Seven OECD Countries*. Quarterly Journal of Economics: November 1998

Marquie, J.C.; Thon, B.; Baracat, B. *Age Influence on Attitudes of Office Workers Faced with New Computerized Technologies: a Questionnaire Analysis*. Applied Ergonomics: vol. 25 n. 3 p.130 (142). Jun 1994.

Mathews, John A. *Organizational Innovation and the Sociotechnical Systems Tradition.* Human Relations. v.50 n.5 May: 1997.

Mykytyn, Peter P. Jr. and Green, Gary I. *Effects of Computer Experience and Task Complexity on Attitudes of Managers*: Information & Management: vol. 23: 1992.

Oglesby, Clarkson H.; Parker, Henry W.; and Gregory A. Howell. Productivity Improvement in Construction. McGraw-Hill: New York, NY. 1989.

Prasad, Baba and Patrick T. Harker. *Examining the Contribution of Information Technology Toward Productivity and Profitability in U.S. Retail Banking*. The Wharton School: Philadelphia, PA. March 1997.

Industry Week. *Productivity at the Speed of Sound.* Industry Week: p16. September 21, 1998.

Reish, Mark. *U.S. Manufacturers Say Workers Lack Basic Skills.* Chemical and Engineering News: v.57 n.48 p.11(2). December 1, 1997.

Rifkin, Jeremy. *Laid off! Computer Technologies and the re-engineered workplace.* The Ecologist: vol.24 n.5 : September-October 1994.

Schmitt, Joseph. *Computers Are Tools, Not Your Profession.* Contractor: v.45 n.2 pp.16(1). February 1998.

Seybold, Patricia. *The Learning Organization.* Byte: April 1993.

Van Nort, Peter. Personal Interview. April 1999.

Weber, R. Evaluating System Effectiveness and Efficiency. Prentice Hall: Upper Saddle, NJ: 1999.

Winter, Susan J.; Chudoba, Katherine M.;. and Barbara A. Gutek. *Attitudes Toward Computer: When Do They Predict Computer Use?*: Information and Management. vol. 34 n. 5 p.75 (84): November 30, 1998.

Wubbenhorst, Robert. *Pen Computer Applications and Potential for Collecting and Transferring Field Level Construction Information*. Masters Thesis, Department of Building Construction, The University of Florida: May 1996.

Wubbenhorst, Robert. Personal Interview. April 21,1999.Appendix A. Interview Questions

APPENDIX B: EXPERT INTERVIEW QUESTIONS

This research is focused on the possible effects of computer use on a construction foreman. Since construction companies make their profits in the field, foremen can make or break a project. A foreman whose time is spent efficiently could save can save his company substantial amounts in time and money. We want to eventually focus on the productivity savings that can be produced through computer use in terms of time and money saved. Some examples of computer use by foremen are bar coded materials, wearable computers with up-to-date drawings, and bar coded crew time reports.

These are preliminary questions. Since I do not have a well-versed background in this subject, I may not be addressing all of the pertinent concerns. I am interested any concerns that you feel should be addressed and should not be addressed. Also, I'm concerned about parceling out the effects of project size from computer use on foreman since foreman tasks and responsibilities change with project size. You'll see this concern as you look through the questions. If you have any suggestions of how to differentiate between these two predictors, I would appreciate all the help that I can get.

1. Describe the degree of automation that existed:
    a. 1 year ago
    b. 5 years ago
    c. 10 years ago
2. How has foreman responsibility changed with the introduction of computer use? Why do you think that this is true?
3. How many people does a foreman usually supervise?
    a. How does that change with automation?
    b. How does that change with project size?
4. What tasks do foremen perform during the daily? How much time do foremen spend on each task?
    a. How do these tasks vary with the project phase?
    b. How do these tasks vary with project size?
    c. How do these tasks vary with automation?
    d. How do these tasks vary with the number of subcontractors on a job?
5. Does the amount of subcontractors on a project affect the extent of computer use for foremen?
6. Are foreman tasks complicated by computer automation?
7. Does the time that foremen spend on each individual task decrease with computer use?
8. Means and methods:
    a. Has computer use increased a foreman's communication with others on a project? How?
    b. Has computer use increased foremen abilities? How? (e.g. ability to pull up the latest drawing revisions, decreased red tape in attaining other information, access to tool and material locations, etc.)
    c. How has the degree of computer automation changed the extent of foreman planning and autonomy?

d. To what extent has foreman planning changed at each level? How much autonomy is he/she given in planning?
    - Tools
    - Equipment
    - Crews
    - Individual crew members
    - Tasks

9. Supervision To what extent does this differ with project size and the degree of computer use?
    a. Do foremen assign tasks to crews?
    b. Do foremen perform physical labor with their crews, or are they focussed on supervision?
    c. Degree of responsibility for accounting
        - Time sheets
        - Task cost assignment
        - In-place materials and equipment
    d. Do foreman have the authority to order tools and/or equipment?
10. How are craft workers chosen for promotion to foreman?
    a. Years with company
    b. Experience in trade
    c. Computer skills
    d. Education
11. What is the order of importance of individual skills when selecting a craftworker for promotion to foreman?
12. Do you believe that a foreman with computer skills could eventually replace a superintendent?
13. Approximately how much does it cost to implement and maintain a computer system for foremen?

APPENDIX C: FOREMAN SURVEY

1. What company do you work for? ________________________

2. What craft are you affiliated with? ________________________

3. How many years have you worked in the construction industry?_____

4. How long have you worked as a foreman?______________________

5. Do you use a computer at home?

   ☐ Yes — Go to Question 6.

   ☐ No — Go to Question 7.

6. What do you use the computer at home for? (Check all that apply.)

   ☐ Word Processing (e.g. Word Perfect, Microsoft Word)

   ☐ Spreadsheets (e.g. Lotus, Microsoft Excel)

   ☐ Finances (e.g. Quicken, Peach Tree)

   ☐ Internet Surfing (e.g. Netscape, Microsoft Explorer)

   ☐ E-mail (e.g. EudoraPro, Microsoft Outlook)

   ☐ Video Games

   ☐ Other Please specify:__________________

7. Do you currently use a computer at work?

   ☐ Yes — Go to Question 8.

   ☐ No — Go to Question 28.

8. Where did you acquire your computer skills?

   ☐ Self-taught off the job

   ☐ By on-the-job use

   ☐ Through company sponsored training

   ☐ Formal education/schooling

9. Are you comfortable with the computer skills that are required to perform your job?

☐ very comfortable

☐ comfortable

☐ somewhat comfortable

☐ slightly uncomfortable

☐ uncomfortable

☐ very uncomfortable

10. Where do you use your computer? (Check all that apply.)

    ☐ Office ☐ Field → Please describe field conditions:

    ____

11. Does using a computer allow you to spend more time supervising and working with your crew?

    ☐ Yes ☐ No

12. Does using a computer result in less rework performed by your crew?

    ☐ Yes ☐ No

13. About how much time do you save on an average day by using a computer?

    ____

14. Do you save your company money when it requires you to use a computer?

    ☐ Yes ☐ No

15. Were you a foreman 10 years ago?

    ☐ Yes Go to Question 16.

    ☐ No Go to Question 17.

16. Did you use a computer as a foreman 10 years ago? ☐ Yes ☐ No

17. Were you a foreman five years ago?

- ☐ Yes — Go to Question 18.
- ☐ No — Go to Question 20.

18. What project were you working on five years ago?________________

19. On that project, for which of the following tasks did you use a computer? (Check all that apply.)

- ☐ Did not use a computer at that time. (Go to question 16.)
- ☐ For time reports
- ☐ To access the latest drawing revisions
- ☐ To access other information
  What kind of information?______________________________
- ☐ To visualize future and present work through 3-D drawings?
- ☐ To order tools
- ☐ To order materials
- ☐ To order equipment
- ☐ To order scaffolding
- ☐ To locate tools
- ☐ To locate materials
- ☐ To locate equipment
- ☐ To locate scaffolding
- ☐ To communicate with others on a project
  If you answered yes, then
  With whom?_________________________________
  By what means?______________________________
- ☐ To visually record job progress
- ☐ Other. Please specify:___________________

20. Were you a foreman three years ago?

☐ Yes — Go to Question 21.

☐ No — Go to Question 23.

21. What project did you work on three years ago? ___________________

22. On that project, for which of the following tasks did you use a computer? (Check the appropriate box.)

☐ Did not use a computer at that time. (Go to question 16.)

☐ For time reports

☐ To access the latest drawing revisions

☐ To access other information

What kind of information?______________________________

☐ To visualize future and present work through 3-D drawings?

☐ To order tools

☐ To order materials

☐ To order equipment

☐ To order scaffolding

☐ To locate tools

☐ To locate materials

☐ To locate equipment

☐ To locate scaffolding

☐ To communicate with others on a project

If you answered yes, then

With whom?_________________________________

By what means?______________________________

☐ To record job progress visually (e.g. with digital cameras)

☐ Other. Please specify:___________________

23. At present, for which of the following tasks do you use a computer? (Check the appropriate box.)

- ☐ For time reports
- ☐ To access the latest drawing revisions
- ☐ To access other information

  What kind of information?______________________________

- ☐ To visualize future and present work through 3-D drawings?
- ☐ To order tools
- ☐ To order materials
- ☐ To order equipment
- ☐ To order scaffolding
- ☐ To locate tools
- ☐ To locate materials
- ☐ To locate equipment
- ☐ To locate scaffolding
- ☐ To communicate with others on a project

  If you answered yes, then

  With whom?_________________________________

  By what means?______________________________

- ☐ To visually record job progress
- ☐ Other

  Please specify:_____________________

24. Since using a computer on the job, do you spend more time supervising your crew?

☐ Yes Go to Question 25.

☐ No Go to Question 26.

25. How much more time do you feel that you spend supervising? ______

26. Since using a computer on the job, how many hours do you work on an average day? ______________

27. At present, how much time is devoted to performing the following tasks on an average workday? (Specify times in hours for all tasks regardless of computer automation.)

Interpreting plans and drawings	_____________
Locating updated/correct plans and drawings	_____________
Materials procurement	_____________
Tools procurement	_____________
Equipment procurement	_____________
Short interval scheduling/planning	_____________
Crew supervision	_____________
Crew time reports	_____________
Other	_____________

Please specify:___________________

28. If you do not presently use a computer (or if you recall a project where you didn't use computers), how many hours did/do you work on an average day (on that project)?

____

29. If you do not presently use a computer (or if you recall a project where you didn't use computers), how much time is devoted to performing the following tasks (on that project)? (Make your best estimates in hours for an average day.)

Interpreting plans and drawings	_____________
Locating updated/correct plans and drawings	_____________
Materials procurement	_____________
Tools procurement	_____________
Equipment procurement	_____________
Short interval scheduling/planning	_____________
Crew supervision	_____________
Crew time reports	_____________
Other	_____________

Please specify:___________________

30. Which tasks do you think should be computer automated within the next ten years? (Check all that apply.)

- ☐ For time reports
- ☐ To access the latest drawing revisions
- ☐ To access other information.

  What kind of information?______________________________
- ☐ To visualize future and present work through 3-D drawings?
- ☐ To order tools
- ☐ To order materials
- ☐ To order equipment
- ☐ To order scaffolding
- ☐ To locate tools
- ☐ To locate materials
- ☐ To locate equipment
- ☐ To locate scaffolding
- ☐ To communicate with others on a project

  If you answered yes, then

  With whom?_________________________________

  By what means?______________________________
- ☐ To visually record job progress
- ☐ Other. Please specify:___________________

31. What is your age? ___________________

32. How many years of education have you completed? _____________

33. Which of degrees have you completed? (Check all that apply)

- ☐ GED
- ☐ high school
- ☐ associate degree
- ☐ bachelor degree
- ☐ post-graduate degree