Construction Management and Economics

Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/rcme20

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Published online: 13 May 2010.

To cite this article: Paul M. Goodrum & Manish Gangwar (2004) The relationship between changes in equipment technology and wages in the US construction industry, Construction Management and Economics, 22:3, 291-301, DOI: 10.1080/0144619032000116543

To link to this article: http://dx.doi.org/10.1080/0144619032000116543

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The relationship between changes in equipment technology and wages in the US construction industry

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Received 14 November 2002; accepted 7 May 2003

The US construction industry has witnessed a drop in real wages since 1970. The decline in real wages may be attributed to a combination of socio-economic factors like migrant labourers, fringe benefits, safety procedures, union membership and worker skills. Another factor that may be impacting construction real wages is technological changes over the past couple of decades, including technological changes in construction equipment. This paper examines the relationship between changes in equipment technology and changes in construction wages with the help of five factors of equipment technology change: control, energy, ergonomics, functionality and information processing. Furthermore, data from the US Bureau of Labor Statistics’ Current Population Survey is used to examine the effects of computer usage on wages among US hourly workers in construction. The research findings show significant relations exist between changes in equipment control, functionality and information processing with wages among non-supervisory workers. Another finding indicated that although non-supervisory construction workers who use computers at work earn higher hourly wages, there was no added wage benefit after controlling for the effects of experience, education and age.

Keywords: Construction, labour, equipment technology, wages, computer

Introduction

The US construction industry contributes significantly to the US economy. When one includes construction related business involving design, equipment and materials manufacturing, and supply, the construction industry accounts for 13% of the US gross domestic product (GDP), making it the largest manufacturing industry in the USA (BEA, 2000).

The shortage of skilled workers is considered to be one of the greatest challenges facing the US construction industry. The US construction industry has experienced a sustained long-term increase in output as measured by the US Census Bureau’s Value of Construction Put in Place (see Figure 1). However, with the increase in output, the US construction industry has also experienced a worsening shortage of skilled construction labour as can be seen by the long-term decline in its unemployment rate (see Figure 2).

Not since the early 1970s and post World War II has the US construction industry experienced such low

Figure 1 US construction industry output, 1976–2002 (source: US Census Bureau, Value of Construction Put in Place)
unemployment rates (BLS, 2002). Advances in construction equipment and material technologies, modularized components and estimating and scheduling strategies have offset the shortage of skilled construction labour. However, there is a perception among industry leaders that the skilled worker shortage is getting worse. A survey in the USA showed that 78% of facility owners thought the skilled worker shortage had increased during the past three years (Rosenbaum, 2001).

Although real wages in general in the USA began to outpace inflation in the late 1990s, there has been a long-term decline in construction real wages since the 1970s (Allmon et al., 2000; Oppedahl 2000). Other industries, such as manufacturing, have also experienced declines in real wages; however, the declines have typically been greater in construction. This greater decline may be due to a combination of socio-economic factors including an increase in migrant labourers in construction, fringe benefits and construction safety, and a decrease in worker skills and collective wage agreements as a result of declines in union membership (Oppedahl, 2000; Goodrum, 2002).

Another factor that may be impacting construction real wages is technology. Over the past couple of decades, there has been a wide array of technological changes in construction equipment and materials. Construction equipment has become more powerful, automated, more precise, safer and more functional allowing workers to be more productive in construction activities. In many instances, technology has made construction equipment easier to use. One example is heavy machinery. Advances in hydraulic controls and microprocessors have automated and simplified the operation of earthmoving machinery. There have also been advancements in construction equipment that have introduced new technologies that require skill sets normally outside those traditionally required for construction. For example, the use of global positioning systems (GPS) onboard earthmoving equipment now requires equipment operators to be proficient in the use of computers.

While this paper examines the relationship between changes in technology and wage, one cannot ignore the relationship that both of these factors have with worker skill level. Previous research on the manufacturing industry finds that the relationship of technology with wage and worker skill will depend, at least partly, on the type of technology. A number of studies find a positive correlation between an increased use of information technology and an increase in the skill level of the worker, especially among supervisory workers such as engineers, technicians and administrative assistants (Berndt et al., 1992; Berman et al., 1994; Autor et al., 1996). With this change in both information technology and wage, an increase in worker wage has occurred as well (Krueger, 1993; Dunne and Schmitz, 1995; Autor et al., 1996; Siegel, 1998).

While the positive correlation among technology, wage and worker skill may appear obvious to many, the historical relation between these factors is less obvious among non-supervisory workers. It has been suggested that the change among these factors occur in two distinct phases (Goldin and Katz, 1998; Murphy et al., 1998). First, as technologies transform a work environment from a manual craft oriented environment to a mechanized production environment, the workforce may initially experience a decrease in the demand for skilled relative to unskilled labour and, as such experience, declining wages as well. Second, as technology continues to increase from a mechanized production environment to an automated assembly environment, an increased use of skilled labour and increase in wages occur.

Goldin and Katz (1998) provide a description of one industry that has experienced both phases, the automotive industry. During the early 1900s when automobiles were first manufactured, they were produced in one spot by a few all-round craftsmen (Braverman 1974). In 1913, Ford standardized the design and began using more interchangeable parts. This lead to the creation of assembly lines, which required a significantly less skilled and lower paid workforce. Many decades later, robotized assembly lines appeared, which reversed the skill trend by requiring more skilled crewman who earned higher wages.

There are many obvious differences in the US manufacturing and construction industries. For example at the industry level, the construction industry is composed of abundantly more firms than manufacturing, and firm size is typically much smaller in construction than in manufacturing. The manufacturing industry also invests significantly more in developing new technologies than the construction industry. According to the US National Science Foundation, governmental agencies and private businesses spent $691 million in 1999 on research and

![Figure 2](US construction industry unemployment rate, 1976–2002 (source: US Bureau of Labor Statistics, Current Employment Survey))
development in the construction industry compared to $117 billion in the manufacturing industry. In addition, the final product of construction is usually of unique design and differs from workstation to workstation making it difficult for arrangement of equipment or aids to help industrialize the process. Other differences exist and have been described by others (Oglesby et al., 1989; Finkel, 1997; Hillebrandt, 2000; Riley and Clare-Brown, 2001). Despite these differences, it is reasonable to believe that the relation between technology, skills and wages follow similar patterns in construction and manufacturing.

Methodology

This paper examines the effect of equipment technology on construction wages in two parts. First, the effects of changes in equipment technology on real wages from 1976 to 1998 are examined. This involves examining the changes in five technology factors (amplification of human energy, level of control, functional range, ergonomics and information processing) and the change in the average daily real wage of workers in crews for 200 construction activities. Second, the effects of information technology on construction wages are examined. This involves examining the effects of computer usage on wages for 470 non-supervisory construction workers.

Equipment technology defined

This research examines the effect of changes in equipment technology on construction wages, specifically the equipment technologies of hand tools, machinery and computers. Hand tools include pneumatic nail guns, electric drills, circular saws and similar types of tools. Machinery includes cranes, grout pumps, bulldozers and similar types of implements.

Technology factors

To examine how different mechanisms of equipment technology change have influenced construction wages, five factors were identified (defined below and examples discussed later) to characterize changes in technology.

(1) amplification of human energy: amplification of human energy is defined as technology designed to make an activity physically easier to perform. In its simplest terms, it can be regarded as the shift in energy requirements from human to machine and causing an increase in energy output.

(2) level of control: level of control relates to advances in machinery and hand tools that transfer control from the human to the machine.

(3) functional range: changes in equipment’s functional range are those changes that expand a tool’s or machine’s range of capabilities.

(4) ergonomics: ergonomics has been generally defined as technology that alleviates physical stresses imposed on a worker and helps the worker cope with the work environment.

(5) information processing: over time, construction equipment has been designed to provide greater and more accurate information regarding internal and external processes.

Equipment to labour ratio

Measuring technology change has challenged economists and engineers for years. Previous research has examined relative changes in capital vs. labour costs as a measure of technology use (Salter, 1966; Koch and Moavenzedah, 1979). In the context of economic theory, capital refers to all goods used to produce other goods and services, including factories, machinery, and equipment (Ammar and Ammer, 1984). These goods are often referred as either fixed capital, such as buildings or machinery, or circulating capital, such as raw material stocks. This paper focuses on fixed capital, including equipment costs for tools and machinery, and measures changes in fixed capital to labour costs as one measure of equipment technology change using the following formula:

\[
\Delta \text{Capital - to - Labor Ratio}(K/L) = \left( \frac{K_{98'}}{L_{98'}} \right) - \left( \frac{K_{76'}}{L_{76'}} \right)
\]

where \(K_{98'}\) is 1998 unit capital costs; \(K_{76'}\) is 1976 unit capital costs; \(L_{98'}\) is 1998 unit labour costs; and \(L_{76'}\) is 1976 unit labour costs.

The capital-to-labour-ratio is used with the assumption that technological advances require less labour (Salter, 1966; Koch and Moavenzedah, 1979). For example, consider a factory that uses two units of machinery and 10 workers and produces 10 units of output. A new version of the machinery uses three units of machinery but only five workers and produces the same amount of output. This typical technological improvement represents a relative increase in capital to labour requirements.

Data sources

Estimation manuals

The data for the research came from the estimation handbooks including: Means Building Construction Cost
Data (Means Company, Inc., 1976, 1998), Richardson’s Process Plant Construction Estimating Standards (Richardson Engineering Services, 1976, 1998), and Dodge Unit Cost Books (McGraw-Hill Inc., 1976, 1998) as well as the Computer and Internet Use Supplement data files for 2001 from the US Bureau of Labor Statistics’ Current Population Survey. Wage, unit labour cost and unit capital cost data from the 1976 and 1998 Means, Richardson, and Dodge estimation handbooks on 200 activities was collected to examine the effects of changes in equipment technology (as defined by the technology factors) on construction wages. While the handbooks are a valuable source of information about construction cost and productivity across time, there are some limitations to the data. The contractors who provide the figures for the manuals are not required to build a project using their estimations; this leads some contractors to submit inflated estimates of construction costs (Pieper, 1989).

Three criteria were used to select activities for inclusion in the study. The first criterion was that the same activity be found in both the 1998 and 1976 estimation manuals. Due to changes in methodology, materials or lack of use in construction, a number of activities included in the 1976 manual were not included in the 1998 manual. Likewise, a number of new activities were included in the 1998 manual due to new methodology or materials. Second, activities from a diverse range of technological changes were selected. Only changes in equipment technologies that are widely diffused in the US construction industry were examined. Third, activities were selected to represent a wide range of activity types from different divisions of the US Construction Specification Institute (CSI) master format.

CPS September 2001 Computer and Internet Use Supplement

Data from the US Bureau of Labor Statistics’ Current Population Survey (CPS) was used specifically to examine the effects of the use of computers on construction wages. Data was collected from the September 2001 Computer and Internet Use Supplement from the US Bureau of Labor Statistic’s (BLS) Current Population Survey (CPS). The CPS is a monthly survey of approximately 50 000 households conducted by the US Census Bureau for the US Department of Labor. With the survey being conducted for more than 50 years, CPS data provides information on economic indicators, which influence US governmental policy. Data from the CPS is available to the public via their website. (http://www.bls.census.gov/cps/cpsmain.htm).

Each month, the CPS randomly selects 59 000 housing units (e.g. single family homes, townhouses, condominiums, apartment units and mobile homes) for the sample, and approximately 50 000 are occupied and eligible for the survey. The other units are found ineligible because they have been destroyed, vacant, converted to non-residential use or contain persons whose usual place of residence is elsewhere. Respondents are asked questions about their employment information and demographic characteristics of each member of the household over 14 years of age. In September 2001, the Computer and Internet Usage Survey was added as a supplement to that month’s CPS. In addition to the demographic data collected each month, the Computer and Internet Supplement contained questions about the respondent’s use of desk or laptop computers, including the use of computers at work, which was used in the research analysis.

A number of criteria were used to select cases (each case representing an individual respondent) from the September 2001 CPS Computer Supplement data. First, only individuals listing their primary industry of employment as construction were selected. Next, each case had to meet the following series of additional selection criteria:

1. full-time hourly workers;
2. male construction workers;
3. non-supervisory construction workers; and
4. hourly wage greater than or equal to the US minimum wage of $5.15/hour.

The use of these selection criteria resulted in 470 cases.

Analysis

Effects of changes in equipment technology on real wages from 1976 to 1998

Measured change in equipment technology

The authors identified and examined 43 types of hand tools and 31 types of machinery in the 200 construction activities. Obviously, many hand tools and machinery were used in multiple activities. Equipment technology changes were identified using equipment catalogues, handbooks and specifications. Figure 3 shows the number of activities that experienced a change in equipment technology factor, 1976–1998.

![Figure 3 Positive changes in equipment technology by technology factor, 1976–1998](http://www.blscensus.gov/cps/cpsmain.htm)
technology in at least one tool or item of machinery for each of the technology factors. As shown in Figure 3, more than 75% of the activities experienced an increase in energy output. Prior related research indicates that the metals, woods and plastics, and site-work divisions experienced the greatest amount of change in tool and machinery energy output (Goodrum and Haas, 2002).

One example of change in energy output in the metals division involves welding machines, which offer increased wattage output. The powder actuated systems in the metals divisions used in metal decking offer greater depth penetration for installed studs. In addition, by 1998 cranes offered more lifting capacity than available in 1976. In the wood and plastic division, circular saws operated at higher revolutions per minute, and the pneumatic nail gun required less human energy than a hand held hammer. Most site-work machinery increased in horsepower output including front-end loaders, dump trucks, backhoes, bulldozers, graders, asphalt pavers and scrapers.

As seen in Figure 3, 49.5% of construction activities experienced a change in the amount of human control needed from 1976 to 1998. Welding machines in the metals division, for instance, are now equipped with remote controlled amperage adjusters, and powder actuated systems have semi-automatic loading capability. The pneumatic nail gun has replaced the hand-held hammer in the woods and plastic division and in formwork installation in the concrete division. In addition, in the concrete division, pump trucks are now equipped with remote controlled booms, and concrete vibrators automatically adjust the vibration frequency to match the concrete’s slump.

Changes in functional range occurred in 47% of the activities (Figure 3). Through advancements in hydraulic controls and microprocessors, site-work machinery now have greater precision and a longer reach for booms and buckets. Excavators and backhoes are capable of digging deeper.

Figure 3 shows that 54.5% of the construction activities experienced some change in ergonomics. For example, by 1998 many hand tools – such as circular saws, hand drills, pneumatic nail guns and caulking guns – were lighter and operated with less noise and vibration than their predecessors.

Almost all of the advances in information processing occurred in heavy machinery. This finding explains why only 28% of the study’s construction activities experienced such an improvement in equipment technology. For example, by 1998 bull dozers and excavators were equipped with self-monitoring and self-diagnostic systems.

**Measured change in real wages**

Daily crew wages as reported in Means, Richardson and Dodge were divided by the number of crewmembers in each activity to estimate individual worker’s daily wage as shown in Eq. 2. In order to measure real wages (wages adjusted for inflation), the US Census Bureau’s Construction Cost Index was used to normalize wages to 1990 levels. A description of the Census Construction Cost Index can be found at the US Department of Commerce’s website (http://www.census.gov/prod/3/98pubs/c30-9805.pdf).

\[ \Delta \text{Daily Real Wage (1990$)} = \frac{\text{DCW}_{98'}}{\text{CS}_{98'}} - \frac{\text{DCW}_{76'}}{\text{CS}_{76'}} \]  

where DCW_{98'} is 1998 Real Daily Crew Wage in 1990$ and DCW_{76'} is 1976 Real Daily Crew Wage in 1990$.

The overall average change from 1976 to 1998 in a worker’s daily real wage was −$25.12, with a 95% confidence interval of ±$7.85. This confirms other findings that show a long-term decline in construction real wages (Allmon et al., 2000, Oppedahl 2000). Figure 4 illustrates the average changes in daily real wages for each division of the CSI Master format.

On average, electrical and concrete divisions experienced the largest decline in daily real wages. Site-work was the only division that did not experience a decline in real wages; its daily real wage increased on average by $12.55. Further research is needed to determine the reasons behind the various sector changes.

**Relation between equipment technology and changes in construction real wages**

Analysis of variance (ANOVA) is used to test whether two or more groups have statistically significant different means. The ANOVA test estimates the statistical significance of the difference between the means (F-value), and it measures the amount of variation in the dependent variable that is explained by the independent variable (Etas Square denoted as \( \eta^2 \)). The ANOVA analyses compared the daily real wage changes from 1976 to 1998 for (1) activities that experienced a change according to the technology factor and (2) activities that had not. Figure 5 shows the ANOVA results.

With the exception of energy and ergonomics, the activities that observed a change in equipment technology experienced a statistically significant different decline in daily real wages. Activities with an equipment change in functional range and information processing experienced over 60% less of a decline in daily real wages compared to activities without such changes. One possible explanation for these differences is the added skills required for workers to adopt these types of equipment technology changes, which may result in higher wages. Activities experiencing a change in level of control actually experienced over 180% more of a decline in real wages compared to activities without change. A possible explanation for this added
decline is that many changes in level of control serve to simplify the processes, requiring less skill resulting in decreased wages.

To further examine the relationship between equipment technology and changes in real wages, regression analysis was used. The first regression modelled the relationship between changes in the capital-to-labour-ratio (see Eq. 1) and changes in daily real wage (see Eq. 2). The results are presented in Figure 6. The regression line in Figure 6 indicates that changes in daily real wages increased as changes in the capital-to-labour-ratio also increased, and real wages were best fit with a quadratic formula for the capital-to-labour-ratio.

There are some activities that experienced no change in their capital-to-labour-ratio but still experienced an increase in daily real wage. As mentioned previously,
there are many factors that influence construction real wages (unionization, the increase in migrant workers and other socio-economic factors that have already been discussed). Regardless, the increased use of technology as measured by the change in the capital-to-labour-ratio explains a significant portion (25%) of the total variability in the changes in daily real wage.

Next, regression models were constructed to include a series of dummy (binary) variables for the five technology factors (e.g. energy, control, function, ergonomic and information). Each variable was coded 1 if a tool or machinery in the activity experienced a technological change from 1976 to 1998 or 0 if otherwise. The variables were added to the regression analysis one variable at a time (Table 1, see Eqs C through G). The most significant variables were retained for the final model (Equation I).

The equipment technology factors control and information produced consistent statistically significant effects above the 95% confidence level on real wages, and function was consistently statistically significant above the 85% confidence level. These factors, along with the changes in the capital-to-labour-ratio, explained 30% of the total variation in daily real wages (Table 1, Eq. I). Once again, positive changes in control had a negative effect on real wages. Activities with a change in control experienced a further decline in daily real wages of $−21.73$ (controlling for changes in the capital-to-labour-ratio, function and information – see Table 1, Eq. I). Meanwhile, positive changes in function increased daily real wages by $11.03$ and changes in information increased it by $19.69$. Changes in energy and ergonomic displayed no statistical significance when added to the regression model. The t-value for energy was 0.83 (Table 1, Eq. F), and the t-value for ergonomic was 0.32 (Table 1, Eq. G).

**Table 1** Regression of capital-to-labour-ratio and binary variables on change in daily real wages in construction, 1976–1998

<table>
<thead>
<tr>
<th>Eqn.</th>
<th>Constant (K)</th>
<th>K/L</th>
<th>K/L²</th>
<th>Control</th>
<th>Function</th>
<th>Information</th>
<th>Energy</th>
<th>Ergonomic</th>
<th>F</th>
<th>R²</th>
<th>Adj. R²</th>
</tr>
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<td>A</td>
<td>−29.36</td>
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<td>62.67</td>
<td>14.75</td>
<td>2.21</td>
<td>6.74 (0.83)</td>
<td>16.60</td>
<td>17.89</td>
<td>62.38</td>
<td>0.24</td>
<td>0.24</td>
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<td>(−8.34)</td>
<td>(7.90)</td>
<td>(2.12)</td>
<td>(2.27)</td>
<td>(1.99)</td>
<td>(0.32)</td>
<td>(2.41)</td>
<td>(2.36)</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>B</td>
<td>−31.60</td>
<td>122.74</td>
<td>65.28</td>
<td>−16.17</td>
<td>17.73</td>
<td>6.02 (0.92)</td>
<td>19.89</td>
<td>17.97</td>
<td>33.69</td>
<td>0.26</td>
<td>0.25</td>
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<td>(6.76)</td>
<td>(2.12)</td>
<td>(2.27)</td>
<td>(1.99)</td>
<td>(0.32)</td>
<td>(2.41)</td>
<td>(2.36)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
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<td>115.38</td>
<td>65.28</td>
<td>−16.17</td>
<td>17.73</td>
<td>6.02 (0.92)</td>
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<td>17.97</td>
<td>24.78</td>
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<td>(1.99)</td>
<td>(0.32)</td>
<td>(2.41)</td>
<td>(2.36)</td>
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<tr>
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<td>56.86</td>
<td>14.75</td>
<td>17.73</td>
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<td>19.89</td>
<td>17.97</td>
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<td>(2.41)</td>
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<tr>
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<td>121.81</td>
<td>60.23</td>
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<td>17.73</td>
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<td>17.73</td>
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<td>−17.88</td>
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<td>(0.32)</td>
<td>(2.41)</td>
<td>(2.36)</td>
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</table>

Notes: Dependent variable: change in daily real wage; t-values shown in parenthesis; n = 200 Activities; K/L = change in capital-to-labour-ratio.
Both the ANOVA and regression analyses seem to support what others have found regarding the relationship between technology and wages. Functional range and information processing – two equipment technology factors that require increased worker skill – are associated with positive effects on real wages. Conversely, changes in control, an equipment technology factor that simplifies the construction process and decrease required worker skill, had the opposite association with real wages.

Traditional economic models on technology adoption address how low wages can have a substituting affect on technology, which motivates companies to employ more labour rather than invest in expensive machinery. Certainly, this theory applies to many sectors of the construction industry. During the late 1980s and early 1990s, there was a boom of research and development on construction robotics capable of executing different facets of the construction process. Although successful prototypes were developed, very few robotic devices to date have been implemented on construction projects. Although there are numerous factors affecting the implementation of these and other innovations in construction including fragmentation of the industry, human resistance to change, regulatory barriers, liability and uniqueness of project designs, one very significant barrier is cheap labour costs due to declining real wages. One additional factor that further complicates the relation between technology adoption and wage is the fact that the real costs of many tools and equipment have declined over the past 25 years. A simple example is the cost of corded electrical drills. In 1976, the typical 1/3 HP corded reversible drill cost approximately $100 (in 1998 dollars). In 1998, a similar drill cost only $38 (Sears and Roebuck 1976 and 1998). This example demonstrates the difficulty of applying the substituting effect of labour for technology to all cases of technology adoption in construction. The example also demonstrates the keen weakness of using the capital to labour as a measure of technology change, at least for construction. Additional research is needed to identify and develop reliable measures of construction technology change.

**Effects of computer usage on construction wages**

One result of the previous set of analyses was that information processing has a substantial and statistically significant relation with activities that experienced less of a decline in daily real wages compared to activities that did not experience such a change. Because this phase of the study was limited to examining changes in equipment technology that were widely diffused in construction, most of the changes in information processing were found only in heavy machinery. To further examine how changes in information processing affect construction wages, particularly in the form of desktop or laptop computer usage, data from the CPS September 2001 Computer Supplement was analysed.

**Measured computer usage among non-supervisory construction workers**

Of the 470 cases analysed in the CPS September 2001 Computer Supplement, 49 (10.4%) indicated they used a computer at work. The top three occupations that used computers were: (1) electricians, (2) electrical power installer and repairers and (3) plumbers. Unfortunately, the CPS September 2001 Computer Supplement data did not measure how the computers were used at work.

**Relation between computer usage and wages in construction**

Data was analysed using ANOVA from the CPS September 2001 Computer Supplement to examine the effects of computer usages on construction wages by comparing hourly wages between construction workers who use a computer at work and those who do not use a computer at work (Figure 7). The difference in education, work experience, age, and hourly wages are significant (p < 0.05) (source: US Bureau of Labor Statistics, Current Population Survey 2001 Supplement for Computer and Internet Usage).

![Figure 7](image-url)

**Figure 7** Difference in average wages, average education, average experience and average age between non-supervisory construction workers who do or do not use computers at work (p < 0.05) (source: US Bureau of Labor Statistics, Current Population Survey 2001 Supplement for Computer and Internet Usage)
experience, and age was also examined between those who do and do not use a computer at work.

Information from the CPS is used to create more than 350 variables. The CPS, however, does not ask respondents about their work experience, an important consideration in a study on wage differentials. One method for estimating work experience, used by the BLS, is to use CPS data to calculate potential experience using the following equation (3) (US Department of Labor, 1993). The units of potential experience are given in years.

\[
\text{Potential Experience} = \text{Age} - 6 - \frac{\text{Years of School}}{12} \tag{3}
\]

Variable for education was recoded by the researchers to represent number of years of education completed at school. Women’s work experience were found to be substantially influenced by being married and having children. To avoid this influence, this study focuses on men.

These analyses show that non-supervisory construction workers who use computers at work are paid significantly more than workers who do not use computers at work (the average hourly wage among workers who use computers was $18.43 compared to $15.56 for those who did not). At the same time, workers who use computers at work are statistically significantly more experienced (workers who used computers had on average 22 years of experience compared to 18 years of experience for those who did not), more educated (workers who used computers had on average 12.8 years of education compared to 11.6 for those who did not) and older (workers who used computers were on average 40.8 years old compared to 35.7 years old for those who did not).

Although this ANOVA indicates a relation between higher wages and the use of computers for non-supervisory construction workers, it is not clear whether the increase in average hourly wage is due to usage of computer or merely a reflection of already established relations with experience, education and age. Regression was used to further investigate the relation of computer usage and wage while controlling for these effects. While Experience and Education were included in the regression as continuous variables, Computer Usage was included as a binary variable, coded 1 if a respondent used a computer at work or 0 otherwise. Results of the regression are shown in Table 2.

The model was found to be best fit with a quadratic term for Experience, which confirms previous research that the relation between Wage and Experience follows a quadratic relation (Goodrum, 2002). Computer Usage had a substantially significant effect on hourly wage; construction workers who use a computer at work earned on average an additional $1.12 per hour controlling for the effects of Experience and Education. However, Computer Usage was statistically insignificant, because its t-value was only 1.10, which is well below even the 80% confidence level. This may be an indication that either: (1) no relation exists between computer usage in construction and wage; and/or (2) there is too little data to confirm if the relationship really exists, since the t-value is dependent upon sample size.

It is interesting to note that information processing has a significant relationship with wages but computer usage does not. Changes in information processing are most prevalent in the site-work division where computer chips and sensors have become integrated into tools and machinery and the construction processes. Computer usage as measured by the US BLS was found more prevalent in electrical and mechanical divisions. In these areas, computers in the form of personal computers are mainly used in system installation testing and administrative functions. The authors theorize that computers and other forms of information technology have a greater impact on wages when these technologies become more integrated into the work processes. Although the CPS data indicates that there is currently no significant relation between computer usage and wages among construction workers, this may change as computers become more diffused into the work processes of construction. Advances in ubiquitous computing and other technological advances that increase the mobility of computing will help accomplish this objective.

These findings directly indicate that relationships do exist between changes in workers’ wages and changes in equipment technology. Indirectly, relationships between equipment technology and worker skill level have also been identified. The relationships between technology, wages and skills are similar in construction compared to the relationships previously identified in other industry studies. Technological changes that require increased skill are associated with increased wages. Vice versa,


<table>
<thead>
<tr>
<th>Eqn.</th>
<th>Constant</th>
<th>Experience</th>
<th>(Experience)^2</th>
<th>Education</th>
<th>Computer Usage</th>
<th>F</th>
<th>R^2</th>
<th>Adj. R^2</th>
</tr>
</thead>
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<tr>
<td>J</td>
<td>1.40</td>
<td>0.48</td>
<td>-0.01</td>
<td>0.65</td>
<td>1.12</td>
<td>21.05</td>
<td>0.15</td>
<td>0.15</td>
</tr>
<tr>
<td></td>
<td>(0.71)</td>
<td>(5.77)</td>
<td>(3.77)</td>
<td>(4.52)</td>
<td>(1.10)</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Notes: Dependent variable: hourly worker wage ($/hr);
t-values shown in parenthesis;
\( n = 470 \) respondents.
technological changes that simplify the process are associated with decreased wages.

What has not been addressed are two aspects related to worker skill: (1) changes in training requirements in relation to changes in worker skill; and (2) the changing characteristics of skilled labour. For example, a surveyor who is capable of laying out a horizontal curve using traditional survey methods with a transit and theodolite possesses great knowledge and skills to do so. However, a surveyor who is capable of laying out a horizontal curve with more technologically advanced equipment, such as GPS, would also possess great knowledge and skills, although both would be different from the prior individual. Therefore, one might ask which surveyor should be considered more skilled. The differences in these knowledge and skill requirements need to be better understood and applied to the training of future workers.

Conclusions

The findings reported here indicate that:

(1) The decline in real wages exists throughout multiple sectors and divisions in construction. The only division that did not indicate a decline in real wages between 1976 and 1998 in the USA was site-work.

(2) Activities that experienced a change in functional range and information processing experienced less of a decline in real wages compared to activities that did not.

(3) Not all changes in equipment technology are related to lessened declines in real wages. Activities that experienced a change in level of control actually experienced greater declines in real wages.

(4) ANOVA indicated that non-supervisory construction workers who use computers at work earn higher hourly wages. However, when the effects of experience and education were controlled in regression analysis, no statistically significant relation was found between computer usage and hourly wages for non-supervisory construction workers.

References


