A Micro Level Analysis Of The Relationship Between Changes In Equipment Technology And Wages In The U.S. Construction Industry

by

Paul M. Goodrum [1] and Manish Gangwar [2]

ABSTRACT:

A shortage of skilled labor exists in the construction industry. Fortunately, advancement in construction equipment and material technologies, along with modularized components and estimating and scheduling strategies have offset the shortage of skilled construction labor. The construction industry has witnessed a drop in real wages since 1970. Decline in real wages may be attributed to a combination of socioeconomic factors like migrant laborers, 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. There is a growing need to understand how changes in technology are affecting employment conditions in construction. If more could be known about how technology affects wages, the industry could formulate better strategies for future workforce needs. 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 U.S. Bureau of Labor Statistics' Current Population Survey (CPS) is used to examine the effects of computer usage on wages among hourly workers in construction.

KEYWORDS:

Construction; labor; equipment technology; wages; computer.

1. INTRODUCTION:

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

The shortage of skilled workers is considered to be one of the greatest challenges facing the U.S. construction industry. Not since the early 1970s and post World War II has the U.S. construction industry experienced such low 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 labor. However, there is a perception among industry leaders that the skilled worker shortage is getting worse. A survey of facility owners showed that 78% thought the skilled worker shortage had increased during the past 3 years (Rosenbaum 2001).

Although real wages in general in the U.S. began to outpace inflation in the late 1990's, there has been a long-term decline in construction real wages since the 1970's (Allmon, et al. 2000 and 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 socioeconomic factors including an increase in migrant laborers in construction, fringe benefits, and construction safety, and a decrease in union membership and worker skills (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 material technology. Construction equipment has become more powerful, automated, more precise, safer, and more functional, allowing workers to be more productive in construction activities. In many

1. Assistant Professor, Department of Civil Engineering, 151C Raymond Bldg., University of Kentucky, Lexington, KY 40506-0281 email: pgoodrum@engr.uky.edu

2. Graduate Research Assistant, Department of Civil Engineering, 151D Raymond Bldg., University of Kentucky, Lexington, KY 40506-0281

instances, technology has made construction equipment easier to use. One example is heavy machinery. Advancements 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 onboard earthmoving equipment now require equipment operators to be proficient in the use of computers.

2. 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 wage of workers in crews for 100 construction activities. Second, the effects of computer usage on construction wages are examined for 470 individual hourly construction workers.

2.1. 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.

2.2. 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.

Amplification of Human Energy: technology designed to make an activity easier to perform physically. In its simplest terms, it can be regarded as the shift in energy from human to machine bringing an increase in energy output.

Level of Control: advances in machinery and hand tools that transfer control from human to machine.

Functional Range: changes that expand a tool or machine's range of capabilities.

Ergonomics: technology that alleviates physical stresses imposed on a worker and helps the worker cope with the work environment

Information Processing: over time, construction equipment has been designed to provide greater and more accurate information regarding internal and external processes. This factor includes the incorporation of computers into the work processes.

3. DATA SOURCES

3.1. Estimation Manual

The data for the research came from the estimation handbook Means Building Construction Cost Data (Means) and the Computer and Internet Use Supplement, data files for 2001 from the U.S. Bureau of Labor Statistics' Current Population Survey. Wage data from the 1976 and 1998 Means estimation handbooks on 100 activities was collected to examine the effects of changes in equipment technology (as defined by the technology factors) on construction wages. Data from the CPS was used specifically to examine the effects of the use of computers on construction wages.

These estimation handbooks provide wage data, unit labor costs, unit equipment costs, physical output data, and work-hour requirements for construction activities. 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. Third, activities were selected to represent a wide range of activity types from different divisions of the Construction Specification Institute (CSI) master format.

3.2. CPS September 2001 Computer and Internet Use Supplement

To further examine the effects of computer usage on construction wages, data was collected from the September 2001 Computer and Internet Use Supplement from the U.S. Bureau of Labor Statistic's (BLS) Current Population Survey (CPS). The CPS is a monthly survey of approximately 50,000 households conducted by the U.S. Census Bureau for the U.S. Department of Labor. With the survey being conducted for more than 50 years, CPS data provides information on economic indicators, which influence U.S. 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 nonresidential use, or contain persons whose usual place of residence is elsewhere. Respondents are asked questions about the 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 computers, including the use of computers at work, which was used in the research's 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;
4. Hourly wage greater than or equal to the U.S. minimum wage of $5.15/hour.

The use of these selection criteria resulted in 470 cases.

4. ANALYSIS

4.1. Effects of Changes in Equipment Technology on Real Wages from 1976 to 1998

4.1.1. Measured Change in Equipment Technology

The authors identified and examined 43 types of hand tools and 31 types of machinery in the 100 construction activities. Obviously, many hand tools and machinery were used in several activities. Equipment technology changes were identified using equipment catalogs, handbooks and specifications. Figure 1 shows the number of activities that experienced a change in equipment technology in at least one tool or item of machinery for each of the technology factors.

As shown in Figure 1, more than 70% of the activities experienced an increase in energy output. Prior related research indicates that the metals, wood and plastic, 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 RPMs, 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 1, almost half 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. Also 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 slightly less than half of the activities (Figure 1). Through advancements in hydraulic controls and microprocessors, site-work machinery now has greater precision and a longer reach for booms and buckets. Excavators and backhoes are capable of digging deeper.

Figure 1 shows that exactly half 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 (Goodrum and Haas 2002). This finding explains why most construction activities did not experience such an improvement in equipment technology. For example, some heavy machinery now offer self-monitoring and self-diagnostic systems.

4.1.2. Measured Change in Real Wages

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

The overall average change from 1976 to 1998 in a worker's daily real wage was -$19.97, with a 95% confidence interval of ± $6.97. This confirms other findings that show a long-term decline in construction real wages (Allmon, et al. 2000, Oppedahl 2000). Figure 2 illustrates the average changes in daily real wages for each division of the CSI Master format.

On average, concrete activities experienced the largest decline in daily real wages, while masonry activities experienced little change. Further research is needed to determine the reasons behind the various sector changes.

4.1.3. Relation Between Equipment Technology and Partial Factor Productivity Change

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 Eta Square (e). 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 3 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 150% 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, which may result in lower wages. Further research in the area is needed to examine other reasons.

4.2. Effects of Computer Usage on Construction Wages

One result of the previous set of analyses was that information processing has a substantial and significant relation with activities that saw 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, data from the CPS September 2001 Computer Supplement was analyzed.

4.2.1 Measured Computer Usage Among Non-Supervisory Construction Workers

Of the 470 cases analyzed 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. Occupations in which there were no respondents indicating they used computers as work included: roofers, concrete and terrazzo finishers, electrician apprentices, hard and soft tile setter's, insulation workers and sheet metal duct installers. Unfortunately, the Computer Supplement data did not measure how the computers were used at work.

4.2.2. Relation Between Computer Usage and Wages in Construction

Data was analyzed 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 computer at work (Figure 4). The difference in education, work 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 (1) (U.S. Department of Labor. (1993)). The units of potential experience are given in years.

Potential Experience = Age – 6 – Years of School (1)

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

These analyses show that non-supervisory construction workers who use computers at work are significantly paid 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 analysis 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.

5. CONCLUSIONS:

The findings reported here indicate that:

1. The decline in real wages exists throughout all sectors and divisons in construction.
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. Non-supervisory construction workers who use computers at work earn higher hourly wages, although further research is needed to account for the effects of experience, education, and age.

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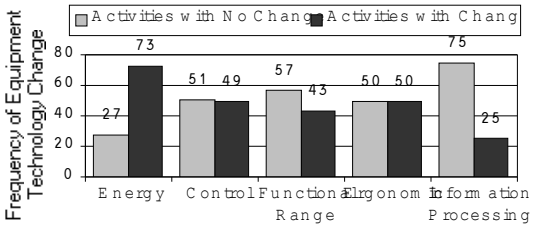

Figure 1: Change in Equipment Technology by Tecnolo Factors, 1976 - 1998

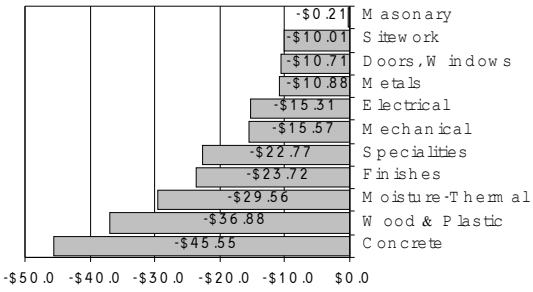

Figure 2: Change in Daily Real Wages (1990$) by Divisi (Data Source: Means 19XX)

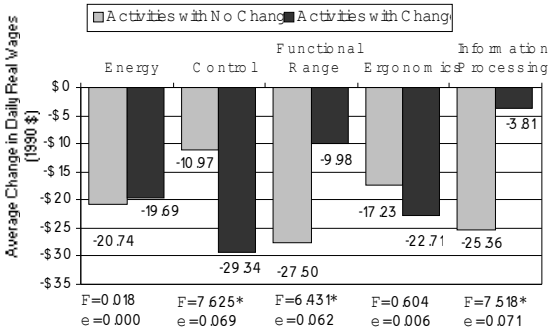

Figure 3: A Comparison of Daily Real Wages Change from 1976 to 1998 Activities that Experienced a Change in Equipment Technology and Activiti no Change, *p > 0.05

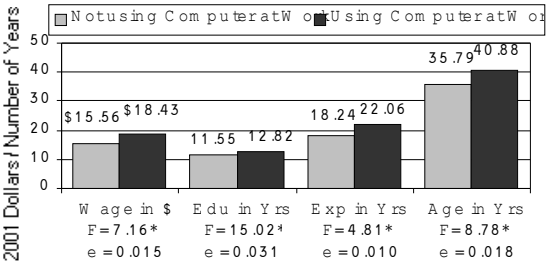

Figure 4: Difference in Average Wages, Average Educati Average Experience and Average Age Between Non-Super Construction Workers Who Use Computer at Work and Wo Who Do Not. *p > 0.05 (Data Source: CPS 2001 Supplemen Computer and Internet Usage)