# Analysis of Building Sector Construction Productivity Trends in North America between1995 and 2009

by

Hani Ahmed

A thesis
presented to the University of Waterloo
in fulfillment of the
thesis requirement for the degree of
Master of Applied Science
in
Civil Engineering

Waterloo, Ontario, Canada, 2011

## AUTHOR'S DECLARATION

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

## Abstract

In a 2001 study, Paul M. Goodrum examined the impact of equipment technology on productivity in the U.S construction industry between 1976 and 1998. This research and its results have been included in a larger discussion about productivity trends in the U.S, since then. The objective of this research is to extend the Goodrum study to the period between 1995 and 2009, so that further insight into long term trends and effects can be obtained. The study begins with a brief review of the research that has been completed in the last ten years with respect to the analysis of construction productivity trends in the U.S., Canada, and other developed countries.

Then the study examines the characteristics common to all construction projects and factors affecting construction productivity, because an accurate understanding of the correlation between these factors will lead to improved productivity. A statistical significance test (t-test) is used as a method of measuring the validity of the observed changes in productivity between 1995 and 2009.

The main finding of this research is that there is a slight improvement in partial factor productivity in the United States between 1995 and 2009 as measured using the Means estimating manuals while the labor productivity remains almost the same between 1995 and 2009. Through statistical significant test (t-test), it is found that the construction partial factor productivity have changed significantly between 1995 and 2009.Finally, samples of

construction typical projects were taking as an example to show how the mentioned productivity improvements will affect the construction industry in the United States.

The result of this study can be used as a guideline for planners, decision makers, owners, engineers, and contractors to develop insight with respect to the challenge of improving productivity in the North American construction industry. The implementation of the findings of this study will also be helpful for any specific project, because the duration of the project can be decreased and the productivity of the construction increased. The research provides some recommendations which may assist others who are interested in working in this area.

## Acknowledgements

First, I thank ALLAH, the most Gracious and the most Merciful, for giving me the will and strength to complete this work.

Second, I wish to express my deep gratitude to my supervisor, Dr. Carl T. Haas, for his sincere guidance, extensive assistance, critical insight, and patience, without which I would not have been able to complete this work. I am deeply impressed with his wealth of knowledge, excellence of teaching, and dedication to academic research. It has been a great honor to work with and learn from him.

My warmest gratitude is to my father and mother for being wonderful parents. There are not enough words to thank my parents for the love of learning they have instilled in me. Without their heartwarming encouragement, I would not have had the strength to undertake such a task, and without their loving care, prayers and constant support I could never have completed it.

I am mostly greatful to my wife, Sara, for her love, support, and dedication. I am also in debt to my son, Omar, because of the time I have spent away from him while studying and researching.

I also wish to express my gratitude to the University of Waterloo for the outstanding facilities provided. Last, I thank the University staff, my professors, and my friends.

## Dedication

To my wonderful and sweet mother, Dr. Awatif Khogeer, the sunshine of my life.

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# Chapter 1
# Introduction

## 1.1 Introduction and Need for Research

The construction industry is a significant contributor to the economy of any country. For example, in the U.S., the construction industry accounts for 13 % of the GDP, making it the largest manufacturing industry (Harvey M. Bernstein, Andrew C. Lemer, 1996). In order for the construction industry to contribute to economic growth with other industries, construction productivity must grow as well as with the other industries. Therefore, the productivity of a major sector like construction in the economy of Canada and U.S. is of great importance. However, it is difficult to increase or even measure productivity as there are limited comparable input and output (Finkel, 1997).

Park, Thomas, & Tucker, 2005) identified that improving the construction productivity is the key for economic success for any company who wishes to survive in the construction industry which is related to the high competitiveness of construction business environment. It is too complicated to understand productivity in the construction industry, and the nature of the industry adds to such difficulty. According to the United Kingdom's Department of Trade and Industry, productivity was defined as a relative measure of labor productivity (Bernstein, 2003). Due to a lack of suitable data for productivity indices of the U.S. construction activity and because there is not enough reliable and meaningful information upon which the industry can rely, it is difficult to form an accurate vision of productivity related to the construction industry. In spite of this challenge, it is essential to present accurate of trends in construction productivity to improve industry effieciency.

This research focuses on trends in the productivity of the construction industry during the last two decades. The two measures of productivity used in this study are labor productivity, which is defined as work hours divided by physical output, and partial factor productivity, which is defined as the cost of labor and equipment divided by the physical output. Because the construction industry plays a significant role in both the Canadian and United States economies, construction productivity trends must be analyzed accurately. To obtain at least approximate information about trends for each type of productivity, the research calculates the percentage difference between 1995 and 2009. Specific statistical tests are then used in order to analyze whether or not the changes are significant.

## 1.2 Research Objectives and Scope

### 1.2.1 Research Objectives

The main objective of this research is to determine the changes in labor and partial factor productivity in construction industry in North America between 1995 and 2009. The detailed goals of the research are as follows:

- Introduce clear definitions of productivity trends in the construction industry.
- Collect real-life data from construction estimation manuals (R.S. Means).

- Analyze the changes in labor and partial factor productivity trends at the activity level in the Canadian and U.S. construction industries based on data from the estimation manuals for the same time period.
- Examine the results using specific statistical testing approaches in order to determine their significance.

### 1.2.2 Research Scope

This work is a continuation of another study conducted by Goodrum, (2001). Using the time frame between 1979 and 1998, a clear definition of construction productivity were measured and trends developed overtime. These trends have not been calculated in a similar fashion since 1998, and knowledge about current trends is essential for improving the research about the construction industry. To fill this knowledge gap, this work has measured and validated the percentage change in labor and partial factor productivity in Canada and the United States between 1995 and 2009. This study is limited to the use of only one data source: the R.S. Means construction estimation manuals. The effect of the cost of materials on the results has been excluded from the analysis in order to limit the variables used in the study, and only one statistical approach has been used in order to validate the results.

## 1.3 Research Methodology

To achieve the objectives of this research, the following methodology was followed:

- Conduct a literature review of the definitions of construction productivity.
- Review previous research that relates to trends in construction productivity for both labor and partial productivity.

- Collect data from a well-known construction estimation manual, such as R.S. Means (the 1995 & 2009 editions).
- Determine the percentage changes in both labor and partial productivity between 1995 and 2009.
- Identify the significance of these changes.
- Provide the researchers in this field with clear conclusions and recommendations about trends in construction productivity in order to improve the performance of the construction industry.

## 1.4 Thesis Organization

This thesis consists of four additional chapters. Chapter 2 presents definitions of productivity used in the construction industry. Proceeded by a literature review related to trends in construction productivity in different countries. Chapter two also explains how R.S. Means manage their estimating manuals and presents a detailed discussion of the factors that affect productivity in the construction industry, including a review of the impact of modularization on construction. Chapter three introduces the research methodology and the process used to collect a large sample of construction activity data from construction estimation manuals. The estimation manuals are explained, and the categories of data collected are described. A systematic procedure for checking the significance of the results is also explained.

Chapter four presents the data taken from the estimation manuals and explains how the analyses were performed. The analysis focuses on trends in construction labor and partial factor productivity based on the research data between 1995 and 2009. The significance of these changes for the construction industry is then shown through statistical tests. The chapter concludes with a discussion of the research results and a comparison with results from other sources. Chapter 5 provides a summary of the study and recommendations for extending the current research in the future.

# Chapter 2
# Background and Literature Review

## 2.1 General

This Chapter includes a detailed literature review in order to provide a better understanding of the research approach and findings. Technical definitions of productivity in the construction industry are presented to elaborate the nature of construction productivity, and then construction productivity trends are clearly explained. How R.S. Means manages their estimating manuals and the factors that affect productivity in construction, taking into consideration the different points of view, are also described. Finally, the impact of modularization is included as the final element in the complete assessment of productivity improvements in the construction industry.

## 2.2 Definition of Productivity in the Construction Industry

It is important to understand and improve the construction productivity as the construction industry represents more than 13 % of the U.S economy (U.S. Bureau of statistics, 2000). Over 10 million people work in the construction field and many studies showed a recognizable increase in construction productivity (P. M. Goodrum, Haas, & Glover, 2002); but more improvements are required. The construction industry is believed to be a main generator of jobs and it is an important component of the gross domestic product.

In 2007, the number of people who worked in construction was 11 million workers which form about 8 percent of the total U.S. workforce. Besides, the buildings and infrastructure that they constructed were valued by $1.16 trillion (P. M. Goodrum et al., 2002). The construction industry accounted for $611 billion more than many other industries, including information, arts and entertainment, utilities, agriculture, and mining. Construction's portion of the GDP would increase to more than 10 percent if the equipment, furnishings, and energy required to complete buildings were included (Haas, 2009).

The concept of construction productivity can be difficult to define, measure, and communicate. This is because there is a lack of comparable inputs and outputs, and projects' variation in the construction industry. Besides, the difficulty in analyzing productivity statistically arises from the fact that it has different units of measurement for each construction activity (P. M. Goodrum & Haas, 2004). It was also stated by (H. Thomas & Yiakoumis, 1987)that there has been no standard definition of productivity in construction industry because each company defined productivity depending on their own internal system which is not the same in each company. And none of them succeeded in forming standard definitions or survey tools that can be used to collect standard productivity data (Park et al., 2005). Also, each construction project is unique and non-repetitive.

However construction productivity can be defined in many ways. First, it is how well, how quickly, and at what cost construction projects can be constructed. Second, it was defined by The American Association of Cost Engineers as a relative measure of labor efficiency, which is defined as the output per hour worked, either good or bad depending based on the reality that productivity changes over time. Third, a common measurement of construction productivity is factor productivity (H. Thomas et al., 1990), which is defined as:

$$\text{Factor Productivity} = \frac{\text{Physical Output (Units)}}{\text{Labor (\$)} + \text{Equipment (\$)} + \text{Material (\$)}}$$

Fourth, another definition of productivity is partial factor productivity which can be defined as:

$$\text{Partial Factor Productivity} = \frac{\text{Physical Output (Units)}}{\text{Labor (\$)} + \text{Equipment (\$)}}$$

Finally, Partial factor productivity is the relationship between output and one input, usually, but not necessarily, labour or capital while multifactor productivity (MFP) or total factor production (TFP) relates output with all of the inputs that can be measured and labour productivity can be measured in terms of output per hour worked or output per worker (Harrison, 2007).

Labor Productivity equals physical outputs per work hours. Fifth, Construction labor productivity is generally defined as the ratio between input and output in a given period which could be an hour, a day, or a year and defined as the forms of either “input/output” or “output/input”. Sixth, labor productivity is defined as the ratio of output to labor hours (P. M. Goodrum & Haas, 2004). Another definition for Engineering Productivity is the ratio of direct engineering work hours to the engineering outputs. Also, it is mentioned that productivity presents how efficiently the major resources are used to produce the outputs. (Liao, Thomas, O'Brien, Mulva, & Dai, 2009).

Using relative instead of absolute values is a way to solve the difficulty of measuring productivity. Therefore, the percentage change of partial factor productivity for each activity between 1995and 2009 is used (P. M. Goodrum & Haas, 2004). Therefore the percentage change in labor productivity from 1995 to 2009 is used to measure productivity for each activity in this study. This is accomplished using the following formula:

$$\%\ \text{Change in labor productivity, 1995–2009} = \frac{\text{labor productivity 2009} - \text{labor productivity 1995}}{\text{labor productivity 1995}} * 100$$

Total factor productivity is considered to be a common measurement of productivity. It is used by the United States’ Department of Commerce and other governmental agency to monitor other industries (H. Thomas et al., 1990).Total factor productivity is used to monitor the state of the economy. It is considered an economic measure since both the outputs and inputs are in dollar amounts. However, it is considered unsuitable for construction by many people, because the inputs of any given project are difficult to be predicted (Thomas et al., 1990).Productivity describes the output potential of a production process conditional upon its inputs (Bernstein, 2003).

Many people; including (Rojas & Aramvareekul, 2003a), measure productivity as output per hour of work. In contrast, (Allmon, Haas, Borcherding, & Goodrum, 2000) measured productivity in terms of unit labor costs, output, and direct work rates at the individual work task level. It was found that construction productivity has increased in the past few decades, as measured by cost per unit of work and physical output per hour of work (Rojas & Aramvareekul, 2003a).

Productivity can be simply illustrated by an association between an output and an input. Two forms of productivity were used in previous industry studies:

1- $\text{Productivity} = \frac{\text{output}}{\text{input}}$ , and 2- $\text{Productivity} = \frac{\text{input}}{\text{output.}}$

Labor productivity = input over output = actual work hours for installed quantity.

As shown in the above equation, labor productivity is measured in actual work hours per installed quantity; that is, the number of actual work hours required to perform the appropriate units of work and as noted, when defined in this manner, lower productivity values indicate better productivity performance (Park et al., 2005). Various engineering productivity measurements have been used in the previous research. For example, Thomas (1999) measured engineering productivity using hours per drawing, and (Liao et al., 2009) used hours per designed element.

Finally, confusion sometimes arises because economists and business people have different ideas about what productivity means. To business people productivity often means an increase in sales or output per worker, leading to increased profit margins, measured in current dollars. Economists have a related, but different definition of productivity. They define productivity as the relationship between outputs of goods and services and inputs of resources, in both human and non-human form, used in the production process, with the relationship usually expressed in ratio form. Both outputs and inputs are measured in physical volumes and are thus unaffected by price changes (Harrison, 2007).

### 2.3 Literature Review of Productivity Trends in the Construction Industry

Measuring productivity for the construction industry is challenging. Despite its importance to the national economy, there is no official productivity index for this industry. Such indexes are available for manufacturing, agriculture, and other industries that produce outputs that are easily recognizable and measured: for example, numbers of vehicles, tons of steel, or bushels of wheat (Pieper, 1990). Construction industry's output are difficult to compare and measure even within the industry: for example, imagine comparing single-family houses to roads, schools to bridges, or office buildings to shopping centers.

Factors affecting construction and labor productivity include resources (materials, information, tools, equipment, workforce skills, and support services), the quality of on-site supervision, project management, work flow sequencing, weather, and safety (P. Goodrum, 2009). It is not appropriate to measure the construction industry's performance depending on some productivity measurements, since it is a complex industry. If measured on the basis of labor productivity the most recent figures collected by Statistics Canada for the construction sector from 1997 to 2002 shows an average increase of 1.9% per annum (with a decrease in 2001 of -2.3%) while the rest of the country's economy increased at an average of 2.3% per annum (Haas, 2009).

This difference in productivity measures caused different results. For example, in the U.S., aggregate level productivity measures show long-term declines, while activity level productivity measures show long-term improvements (Allmon et al., 2000). At the activity level, extensive research indicates that both labor and partial factor productivity have improved. When construction productivity has been measured at the aggregate level, research has shown a decline in productivity by 0.72% annually compounded from 1968 to 2000 (Teicholz, 2000.). While opposite results were found when productivity was measured at the activity level. (Paul McGinley Goodrum, 2001) collected data on 200 activities using the Means, Richardson and Dodge estimation manuals from the years 1976 and 1998 and found an increase in construction productivity of 1.2% compounded annually.

The discrepancy between macro and micro measures also affected the outcome results. For example, it was suggested that during 1979-1998 labor productivity in the construction industry has significantly declined and this is according to the macroeconomics data, which is the opposite of what is indicated by the microeconomic studies. The same was mentioned during the 1980s and 1990s.

Industry analysts differ on whether construction industry productivity is improving or declining. Some analyses for the industry as a whole indicate that productivity has been declining for 30 years or more. Other studies document improved productivity for construction projects and construction tasks (e.g., the laying of pipe or concrete). However, due to a lack of longitudinal productivity data in construction, there has been little effort to quantify the factors that impact productivity trends (Haas, 2009).

On one hand, it was widely assumed that unlike other industries in recent years, construction industry has shown no development in productivity. Moreover, data showed that productivity is rather declining (Bernstein, 2003). It was noticed that there has been a decline in the productivity of construction industry in the Canadian economy in the early 1980s which is contrasted to an increase in productivity for all other sectors. However, Canada is believed to do much better than the U.S. in construction labor productivity (Rao et al. 2004).

The current trends in construction productivity fell under large debate. Prior research suggested that construction labor productivity fell at an annual rate of 2.4% between 1968 and 1978 (Allen, 1985). This position was supported among owners when the Business Roundtable's Construction Industry Cost Effectiveness Project (1983) assumed a similar decline in both labor and total factor productivity, but noted the lack of data to quantify it. However as will be summarized, there are some inherent problems of using aggregate productivity measures in construction.

It was mentioned that declining productivity will result in some negative economic impacts. This will result over time in the decrease of wages, the increase of construction costs, lower quality, and less profit (Rojas & Aramvareekul, 2003a). Canada's labor productivity growth in the economy as a whole has generally lagged that in the United States since 1995, especially in the last three years. During 2000-2003, output per hour in the Canadian business sector increased at only 1.3 per cent per year, compared to 2.2 per cent in the second half of the 1990s. In three of the four major sectors — primary, construction and manufacturing — labor productivity growth declined in the 1995-2000 and 2000-2003periods.

(Paul McGinley Goodrum, 2001) examined over 200 industry activities within 10 specific construction trades and found all of them to have productivity improvements between 0.8 and

2.4% annually compounded. One research (Allmon et al., 2000) supported the perception that construction productivity has not been declining over the last twenty years. (Rojas & Aramvareekul, 2003a)concludes by arguing that the construction industry has achieved moderately improving productivity over the past two decades and that the challenge now is to broaden and accelerate those gains.. He measured project-level productivity using two different methodologies. He concluded that productivity for individual projects increased about 33 percent, or 0.78 percent per year, between 1966 and 2003.He also stated that we are receiving more building for less money than we did 37 years ago, and moreover, the product is qualitatively superior. He concluded that these improvements are the result of increased productivity made possible by mechanization, automation, prefabrication, less costly and easier-to-use materials, and lower level of real wages.

According to official Statistics Canada productivity estimates, the rate of growth of real output per hour in the construction industry in Canada over the 1981-2006 period was 0.53 per cent per year, one-third of the of the business sector average of 1.46 per cent (Harrison, 2007). It is not inevitable that construction productivity growth be weak. Labour productivity growth in the construction industry in many countries was above 1.5 per cent per year over the 1979-2003 periods. The UK construction industry, for example, experienced output per hour growth of 1.9 per cent per year (Harrison, 2007).

For example, the United States saw an average annual decline of 0.8 per cent in output per labor hour per year. Estimates of construction productivity growth rates by province show very large differences ranging from -1.13 per cent to 0.69 per cent per year between 1987 and 2005 (Harrison, 2007).

Note, there is a weakness in using just two points in time to measure the change in productivity, since the results can be affected by the choice of the two years. Particularly, it is noted that 1976 was a year of stagflation and excess capacity in the United States. It is expected that fluctuations in the change in productivity would occur in a year-by-year analysis. However, by examining the changes in productivity over a 22-year time period, the research was designed to focus on the long-term trends in construction productivity (P. Goodrum, 2009).

Many studies have been conducted that compare productivity between nations or regions within nations. Fewer studies compare the competitiveness of construction industries between nations, and even fewer studies compare innovation strategies (Haas, 2009). As shown in table 2-1, the author has a comparison between productivity trends between Canada and the U.S.

**Table 2-1 Comparison of different trends between Canada and U.S**

Source: (Haas, 2009)

| Source of Estimate | Data Dimension | Canada | United States |
|---|---|---|---|
| Harrison (2007) | Construction labor productivity improvement rates(1961 to 2006) for Canada and (1961 to 2005) for United states | 1.09% | -1.44% |
| Harrison (2007) | Construction labor productivity improvement rates per period for Canada | 1.8%(1961 to1981)<br>0.53%(1981 to 2006) | |
| Harrison (2007) | Construction labor productivity growth rates ( 1979 to 2003) | 0.40% | -0.84% |
| Teicholz (2000) | Construction labor productivity growth rate (1964 to 2000) | | -0.72% |
| Goodrum et al. (2002) | Construction labor productivity growth rate (1976 to 1998) | | 0.80-1.80% |

Regarding to the comparison of National Construction Productivity Analyses, (Harrison, 2007) calculates U.S. construction productivity at the national level based on the National Economic Accounts and Industry Economic Accounts of the Bureau of Economic Analysis. He estimates that between 1961 and 2005, construction productivity in the United States declined at 1.44 percent annually. He notes that construction labor productivity growth was positive for Canada in the same period, but he also points out that within Canada, the construction labor productivity growth rates vary substantially from province to province, by as much as 2 percent per year, and compared to Canada's average construction labor productivity, rates vary by as much as plus 18 percent and minus 33 percent depending on the province.

Harrison (2007) also points out that underestimates of output quality may shave almost half a percent per year from the true construction productivity growth rate in Canada in the past two decades. Teicholz (2001) estimates a compound decline in the United States of 0.48 percent annually between 1964 and 1996 based on BLS and U.S. Department of Commerce data. His estimates vary slightly based on period.

U.S. industries have experienced almost continuous productivity growth for the past several decades. Overall, between 1961 and 2006 construction industry productivity grew at a compound annual rate of 1.09 per cent, compared to 2.06 per cent in the business sector as a whole. In the earliest period, between 1961 and 1981, construction industry output per hour advanced at a rapid 1.81 per cent per year, and total business sector productivity also grew quickly at 2.81 per cent per year. Between 1981 and 2006 productivity in the construction industry grew at only 0.53 per cent per year, while total business sector productivity advanced at a much more robust 1.46 per cent per year (Harrison, 2007).

### 2.4 Factors That Impact Construction Productivity

Early studies identified factors that affect productivity in the construction industry. These researches have attempted to identify and account for the range of factors that affect construction productivity performance. For example, Horner (1982) mentioned that there are eleven factors which can affect construction productivity:

1- Quality;
2- Number and balance of labor resources;
3- Motivation of labors;
4- Degree of mechanization;
5- Continuity of work;

6- Complexity of work;

7- Required quality of finished work;

8- Method of construction;

9- Type of contract;

10- Quality and number of managers; and

11- Weather.

Another study made by (Rojas & Aramvareekul, 2003b) identified and categorized the major productivity drivers in the construction industry:

1- Management Systems and Strategies: This category includes management skills, scheduling, material and equipment management, and quality control.

2- Manpower: The manpower category encompasses drivers such as worker experience, specific activity training, education, motivation, and seniority.

3- Industry Environment: it includes adverse weather conditions, uniqueness, working conditions, activity interactions, and subcontractor integration.

4- External Conditions: it includes scope changes, the economy, research and development, and information technologies.

Based on what (Rojas, 2009) mentioned in the study, although the labor productivity factors tend to be project based, there are two other labor and partial productivity factors which tend to impact the whole industry: labor organization and real wage trends. In addition, (Allen,

1985) showed that there are six possible causes of declining productivity that can be examined as follows:

1- Capital-labor ratio;
2- Economies of scale;
3- Labor quality;
4- Unionization;
5- Changes in the location of construction activity;
6- And changing in the mix of construction output.

Another extensive research done by (Harvey M. Bernstein, Andrew C. Lemer, 1996) has divided the factors that affect the construction productivity into two major categories: external and internal factors which positively related to the construction productivity performance. They defined external factors to include: design, weather, changes made by client, level of economic development and political stability. Also they considered management practice, technology and labor skills and training to be internal factors (Abdel-Wahab, Dainty, Ison, Bowen, & Hazlehurst, 2008).

Examples of labor productivity drivers in the construction industry include weather conditions, coordination of subcontractors, scheduled overtime, and material management, as well as worker motivation, training, experience, and supervision, among many others (Rojas, 2009). There is number of research evidence, which has suggested that skills are an important factor affecting productivity performance in the construction industry. For example, Rojas and (Rojas & Aramvareekul, 2003b)found that management skills and manpower issues are the two areas with the greatest potential for affecting productivity performance in the construction industry (Abdel-Wahab et al., 2008).

Moreover, Arditi and Mochtar (2000) argued that poor quality on projects results in rework which causes drop in productivity levels. They explained that poor quality emanated from the scarcity of a properly trained workforce, which was caused by inadequate levels of training, in addition to the poor quality of training provision that resulted in such skills shortages (Abdel-Wahab et al., 2008).

A study made by (Allen, 1985) mainly proofed that the decline in construction industry productivity by 8.8% between 1968 and 1978 resulted from the reduction of skilled labor intensity. This productivity decline cannot be neglected, since construction accounts for 5% of employment and output.

However, most previous studies focused on defining factors that influence productivity and on measuring limited parts of activities at a micro level to investigate the relationship between factors and productivity. Improving productivity performance is a primary driver of the UK economic performance and long-term sustainable competitiveness (Abdel-Wahab et al., 2008).

Accordingly, the UK government has developed a strategy for improving productivity, which focuses on five key drivers:

1- improving competition,
2- promoting enterprise,
3- supporting science and innovation,
4- raising labor skills,
5- And encouraging investment

When talking about the obstacles to improving construction productivity, a study reported by (Haas, 2009) showed that some obstacles can affect the improvement of the construction productivity including:

- A diverse and fragmented set of stakeholders: owners, users, designers, builders, suppliers, manufacturers, operators, regulators, manual laborers, and specialty trade contractors.
- Segmented processes: planning, financing, design, engineering, procurement, construction, operations, and maintenance.
- The image of the industry work that is cyclical, low-tech, physically exhausting, and unsafe which makes it difficult to attract and retain skilled workers and recent graduates;
- The one-of-a-kind, built-on-site nature of most construction projects;
- Variation in the standards, processes, materials, skills, and technologies required by different types of construction projects;

- Variation in the building codes, permitting processes, and construction-related regulations propagated by states and localities;
- The lack of an industry-wide strategy to improve construction efficiency;
- The lack of effective performance measures for construction-related tasks, projects, and the industry as a whole; and
- The lack of an industry-wide research agenda and levels of funding for research that is inadequate.

The 1983 report of the Business Roundtable entitled More Construction for the Money (BRT, 1983) identified an array of obstacles hindering productivity:

- Adversarial relationships between owners and contractors, management and labor, union and open-shop workers, business and government;
- The lack of accurate information about the industry, its projects, and its labor supply;
- Poor safety performance;
- Undertrained foremen and poor job-site management;
- A lack of training and education for the workforce;
- Disinterest in adopting new technologies and a slow pace of innovation;
- The lack of management systems;
- Collective bargaining agreements and labor practices; and
- Government regulations, including building code administration.

Based on work by Thomas, et al. (1994), some factor can have huge impact on certain activities while having a slight impact at other construction activities in the same project at the same time. For example, weather has a significant impact on the labor productivity in earthmoving operations such as excavation and hauling where muddy conditions can hamper efficiency, but has a minimal impact on interior finishing activities such as sheetrock installation which is generally sheltered from the elements.

Different studies showed different factors that might affect the Construction Labor productivity. For example; (Zhai, Goodrum, Haas, & Caldas, 2009) proved that there is a significant relation between the use of automation and integration on the sampled projects and the Construction Labor productivity.

A skilled labor becomes an essential need in construction management, since studies showed that a skilled labor has an advantage in adopting new technologies. For example, a carpenter of higher education adopts technologies earlier than other carpenter of less education (Greenwood, 1997).

## 2.5 Impact of modularization

Modularization can be defined as the amount of material and elements that can be manufactured constructed, customized, and assembled off-site in factories-which are remote facilities- and then delivered to their intended site of use on-site prior to installation. Another definition of Prefabrication, preassembly, modularization, and off-site fabrication involve the assembly or fabrication of building systems and components at off–site locations and plants. Once completed, the systems or components are shipped to a construction job site for installation at the appropriate time.

According to the modular building institute, there are some advantages of using prefabricated elements in the construction industry:

1- Cost efficient compared to conventional construction elements.
2- These elements are typically constructed in an enclosed facility; therefore weather is not a factor in the construction time line which increases work efficiency and avoids damaged building material.
3- Speed of Construction of these elements, reducing the overall completion schedule.
4- Low waste. With the same plans being constantly built, the manufacturer has records of exactly what quantity of materials is needed for a given job.
5- More environmentally friendly construction process by reducing the construction material waste.
6- Compressed project schedules: by changing the sequencing of work flow.
7- Increased workers safety by reducing exposures to inclement weather, temperature extremes, and ongoing or hazardous operations to provide better working conditions
8- Less Site Disturbance: by reducing the time and impact on the surrounding site environment, as well as reducing the number of vehicles and equipment needed at the site.

The increasing use of manufacturing technologies is considered one of the many items affecting construction efficiency. In carrying out construction projects, people have to choose between on–site and off-site fabrication (Eastman & Sacks, 2008). It was considered according to the U.S. Economic Census that construction business are those which carry out their activities at the construction site, whereas off-site fabrication is regarded as manufacturing (Census 2004a, b). This distinction between the off-site and the on-site construction activities may cause the cancelation of many important innovations that were meant to enhance productivity in construction (Eastman & Sacks, 2008).

There have been no studies that have methodically compared productivity of both on-site construction activities and off-site construction activities with similar scope. Studies that have investigated off-site production of building components have shown that the method has become significantly more labor productive, in contrast to related on-site activities. They don't only have a higher current level of labor productivity, but also their rate of productivity growth is greater than comparable on-site sectors (Eastman & Sacks, 2008). And based on the result for the previous research, off-site productivity grew by 2.32% annually, while on-site productivity grew by 1.43%.

Finally, it was found that those construction sectors that had both off-site and on-site production activities fell in between the productivity levels of those that were completely on site and those whose activities were totally off site (Eastman & Sacks, 2008).The problem is that the mentioned improvements in the prefabricated construction elements are counted towards the manufacture industry and not for the construction industry. A study made by (Peter Harrison April, 2007) showed that the greater use of pre work, defined as modularization, prefabrication and preassembly, in the construction industry, while resulting in productivity gains in terms of overall labor requirements for construction projects, is not considered when investigating the overall construction industry. That is why the use of prefabricated has no effect on output per hour in the construction industry itself.

# Chapter 3
# Methodology

## 3.1 General

This chapter explains the methods used to collect the data required for an analysis of the trends in construction productivity from 1995 to 2009, specifically with respect to labor and partial factor productivity. Based on the discussion in Chapter 2, it is obvious that most recent research has focused more on productivity in other industries than in construction. Research that has investigated trends in construction productivity has examined mainly the national economic statistics. However, as described in the preceding chapter, there are problems using these numbers because of the impact of the output measures and of modularization. The main objective of this research is to study a specific, representative, and statistically valid number of individual construction activities and use them to represent the construction industry as a whole.

The percentage changes in labor and partial factor productivity for each of 200 individual activities grouped into 12 divisions were measured. The average of the percentage change for each division represents the trend for that particular division. Taking the overall average of these activities provides an approximate representation of the trend in construction productivity for the period under investigation.

The remainder of the chapter describes the research method in detail and provides a clear description of the data source (R.S. Means) and the criteria based on which the data were chosen. An explanation of how the cost of any individual item is adjusted due to the inflation rate and how this could affect the results is also included.

### 3.2 Construction Estimation Manual

There are number of sources of published cost data that are available and can provide important information required in the estimating process; though, some are prohibitively expensive to obtain for this research. R.S. Means' references are considered an important source of cost data. R.S. Means publishes Building Construction Cost Data Books. These books are of great importance, since they work as pricing guides and they provide data related to crew formations, hourly rates, and production rates of crews in different tasks related to buildings.

The data source for this research is R.S. Means Building Construction Cost Data. Data were collected from estimation manuals: (R.S. Means Company, 1995) and (R.S. Means Company, 2009). These manuals are designed to provide construction cost data for project estimating purposes. One of the main advantages of using the data from R.S. Means is that they enable the development of an overall picture of the industry, since these estimation manuals contain productivity data for numerous trades.

The R.S. Means cost books can be used for estimation purposes. They are very useful for forming an accurate and dependable estimate of construction projects since they contain valuable information about costs and productivity which enables the reader to estimate values for any projects.

The main reason for using these manuals as a data source was the availability of cost, output, and crew composition data for the years 1995 and 2009. The manuals provide unit labor costs, unit equipment costs and physical output data. Means bases its labor costs on the average wage rates from 30 U.S. cities while they base the equipment costs on rental rates plus operating costs, which include fuel, lubricants, tires and electricity, if applicable (Paul McGinley Goodrum, 2001).

The books are organized according to the 16 divisions of the Master Format made by Construction Specification Institute. Under these 16 main divisions, the book contains information about more than 21,000 items (construction methods). These items use 345 predefined crew configurations that are provided in the book. An example is shown in Table 3-1.

**Table 3-1 Sample Table Taken From the R.S. Means Manual**

**03 30 Cast-In-Place Concrete**

**03 30 53 – Miscellaneous Cast-In-Place Concrete**

| 03 30 53.40 Concrete In Place | | | Crew | Daily Output | Labor-Hours | Unit | 2009 Bare Costs Material | Labor | Equipment | Total | Total Incl O&P |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 0010 | CONCRETE IN PLACE | | | | | | | | | | |
| 0020 | Including forms (4 uses), reinforcing steel, concrete, placement, | | | | | | | | | | |
| 0050 | and finishing unless otherwise indicated | R033053-50 | | | | | | | | | |
| 0300 | Beams, 5 kip per L.F., 10' span | | C-14A | 15.62 | 12.804 | C.Y. | 400 | 515 | 49 | 964 | 1,300 |
| 0350 | 25' span | | " | 18.55 | 10.782 | | 430 | 430 | 41 | 901 | 1,200 |
| 3850 | Over 5 C.Y. | | | 75 | 1.493 | | 198 | 57 | .34 | 255.34 | 305 |
| 3900 | Footings, strip, 18" x 9", unreinforced | | C-14L | 40 | 2.400 | | 120 | 89.50 | .65 | 210.15 | 271 |
| 3920 | 18" x 9", reinforced | | C-14C | 35 | 3.200 | | 157 | 122 | .74 | 279.74 | 365 |
| 3925 | 20" x 10", unreinforced | | C-14L | 45 | 2.133 | | 117 | 79.50 | .58 | 197.08 | 252 |
| 3930 | 20" x 10", reinforced | | C-14C | 40 | 2.800 | | 147 | 107 | .64 | 254.64 | 330 |
| 3935 | 24" x 12", unreinforced | | C-14L | 55 | 1.745 | | 116 | 65 | .47 | 181.47 | 229 |
| 3940 | 24" x 12", reinforced | | C-14C | 48 | 2.333 | | 147 | 89.50 | .54 | 237.04 | 300 |

In the Table 3-1, each item includes information related to the crew code, which describes the crew composition in terms of labor, material, and equipment categories. Table 3-1, shows how the manual data is arranged in the R.S. Means manual. The numbers 1 and 2 are the division and line numbers. The number 3 represents the description list of each individual activity. The crew column number 5 designates the typical crew used to install the item. Number 6 indicates the productivity (daily output per man-hours). Number 7 identifies the column that lists units for each individual construction task. Numbers 8 and 9 show the bare and total costs for the whole activity.

The R.S. Means manuals also include the crew production rate. It is mentioned that crew production is represented by two types of information in separate columns: the daily production in units/day; and alternatively, labor hours/unit of production. We can derive both representations from each other. The difference between them is that the daily production in units per day can only be achieved by a pre-specified crew configuration. On the contrary, the labor hours per unit output is more general and can be used with various crew configurations that can be decided at the time of the estimate. For example, if a concreting job requires 0.5 labor hours per cubic feet, then, the estimator may estimate for example the labor required to pour 100 cu ft (requiring a total of 100*0.5 = 50 labor hours) in different ways:

- Using a crew of four laborers, 8 hours/day will take duration of 1.5 days.
- Using a crew of five Laborers, 10 hours/day will take duration of 1 day.

Daily Output: number of units a crew will install in a normal 8-hours day (i.e. Units/Crew day), and Labor Hours: number of labor hours required to install one unit of work.

The estimation manuals collect their data from a variety of sources across the construction industry. The resources which provide the data are: contractors, owners, and trade organizations. These manuals are reported to be updated annually (Paul McGinley Goodrum, 2001).

Although the estimation manuals provide one of the best sources of time-series data on productivity that is publicly available, there are weaknesses in the data that should be recognized. As many contractors will claim, the estimation manuals should only be used as a data source for cost estimation if no other data source is available. The perception amongst many contractors is that the manuals produce inflated numbers. This may be partly due to the difficulty of adjusting cost figures from the manuals to reflect actual geographic conditions such as labor and material availability, weather, and environmental considerations (Paul McGinley Goodrum, 2001).

Although the manuals do provide cost indices for different geographic locations, economic conditions can change faster than the manuals can be updated. In addition, contractors who submit the hypothetical data in the estimation manuals know they will not be required to construct the project based on their estimates (Pieper, 1990).

The research uses randomly selected construction activities and investigates how they changed along the time frame. For the study, 200 activities were taken from one specific construction estimation manual. This research is mainly based on these selected activities in order to better estimate the trends in construction productivity trend during the period studied. Other researchers have also recognized the value of using the estimation manuals as a data source. For Example, (H. Thomas & Yiakoumis, 1987) studied the effects of weather on construction productivity by investigating the correlation between temperature and relative humidity to variations in construction productivity over a period of four months.

The manuals do a good job at updating unit cost data, but are rather slow at updating physical output. Although this estimation manual has some weaknesses as explained in the literature, its value as a data source for studying long-term construction trends is significant.(Paul McGinley Goodrum, 2001)

### 3.2.1 Historical Cost Indices

Historical cost indices provide the reader with data for adjusting construction costs over time. These indices enable the estimation of the approximate cost of a specific project today through a comparison with the costs of a similar project in the past.

### 3.2.2 City Cost indices

The city cost indices section can be used to determine a national average of costs in 209 major cities throughout Canada and U.S., so that it can be used effectively. The scope of the R.S. Means books is limited to three key areas:

- A material price based on a national average is established.
- Labor costs are computed based on a 30-city national average of union wage costs.
- Data has been collected only for projects of a specific size range: mainly projects costing more than $500,000, large multi-family housing projects, or custom single-family housing projects.

R.S Means claims that in order to ensure reliable and up-to-date cost information, developments in the construction industry are monitored regularly, and new items are frequently added due to changes in materials and methods. The costs represent U.S. national averages and are given in U.S. dollars. The R.S. Means staff coordinated and communicated with manufacturers, dealers, distributors, and contractors throughout the U.S. and Canada in order to determine national average material costs.

The labor cost data is based on the average of wage rates from 30 major U.S cities. Equipment costs include not only rentals, but also operating costs for equipment under normal use. Normal operating expenditures are included, whereas the extraordinary operating expenditures are excluded. Mobilization and demobilization are not included but can be found in the unit price section.

However, many factors can affect costs, such as the following:

- Quality;
- Overtime;
- Productivity;
- Size of project;
- Location;
- Season;
- Contractor management; or
- Weather conditions.

### 3.3 Selection of Activities

The following data were obtained from R.S. Means. Two years have been examined: 1995 and 2009. For each year, three factors were considered: daily output, man-hours and bare cost. The cost and output data were also collected manually from the 1995 and 2009 estimation manuals of means.

The two hundred activities were taken randomly and used in the analyses from R.S. Means. The criteria used for selecting activities in the study as follows:

- Activities were chosen that were similar to those used in Goodrum's research, but an identical set was not possible due to evolution of methods.
- Activities were chosen to represent a wide spread variation in type of construction activities.

Using the above criteria, the construction activities were selected randomly from all the activities listed. As shown in Figure 3-1, the data were categorized according to the twelve construction fields, and an approximately equal number of activities were chosen for each category.

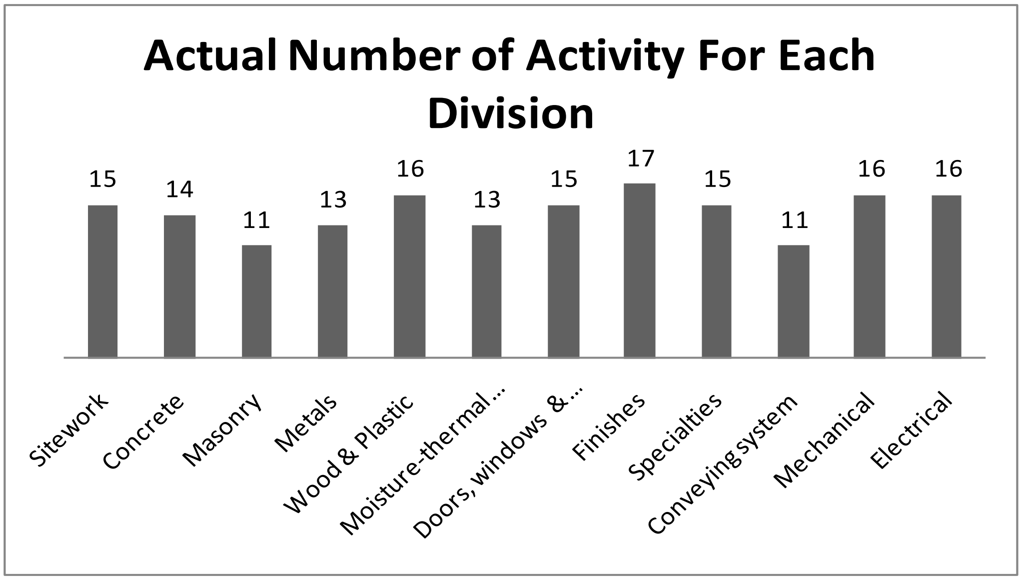


**Figure 3-1 Activity Distribution by Construction Division**

### 3.4 Data Categories and Sampling (from a Statistical Perspective)

Although the data chosen could be almost evenly divided into the twelve categories of construction field, some activities were missing for reasons which will be discussed later in section 3.6. Table 3-2 shows the number of activities for each category.

**Table 3-2 number of activities for each division**

| | Division | Number of activities |
|---|---|---|
| 1 | Sitework | 15 |
| 2 | Concrete | 14 |
| 3 | Masonry | 11 |
| 4 | Metals | 13 |
| 5 | Wood & Plastic | 16 |
| 6 | Moisture-thermal control | 13 |
| 7 | Doors, windows & glass | 15 |
| 8 | Finishes | 17 |
| 9 | Specialties | 15 |
| 10 | Conveying system | 11 |
| 11 | Mechanical | 16 |
| 12 | Electrical | 16 |
| | Sum | 172 |

### 3.5 Cost Adjustment Due to Inflation

Since this research compares two partial productivity values for two different years, the costs must be adjusted. All partial productivity numbers for 1995 were modified due to the inflation rate by converting them to 2009 dollars, based on the rate of inflation, which required the application of a specific price conversion.

A variety of measures can be employed to adjust prices for the rate of inflation. According to the U.S. federal government, two common indices are used; the consumer price index (CPI) and the Means Historical Cost Index. The consumer price index CPI is calculated by using all kind of goods and then creates the index; while, the Means Historical Data is only using construction projects to come up with the conversion factors. Therefore; the Means Historical Cost Index is more appropriate for this study since its “basket of goods” is more for the construction industry and was therefore used in this study to convert the construction prices in 1995 to 2009 dollars, thereby enabling an accurate comparison of the two years.

### 3.6 Missing (Dropped) Activities between 1995 and 2009

As discussed earlier, the targeted number of construction activities used in this research is two hundred activities. Because these two hundred activities were taken from two different years: 1995 and 2009, 28 out of the two hundred activities were dropped from the complete list of the study. This drop means that 28 activities in 1995 R.S Means book weren't found in the 2009 manual based on the criteria discussed earlier in Chapter three. Therefore, the 28 activities were assumed to be missing due to some technological and commercial changes. Table 3-3 shows the possible reasons for dropped activities.

**Table 3-3 Dropped Activities with Possible Reasons**

| Possible reasons for dropped activities (why hard to track activities) | # of activities | Example |
|---|---|---|
| Different Descriptions | 5 | 17, 71, 74, 95, 114 |
| Material no longer used. | 1 | 24 |
| Different equipment | 1 | 105 |
| Dimensions no longer available because not Manufactured | 4 | 15, 36, 55, 65 |
| Whole systems have changed | 5 | 153, 163, 166, 167, 168 |
| New technology for construction method | 1 | 8 |
| Hazardous methods no longer used | 1 | 29 |
| Other | 10 | 28, 31, 34, 43, 53, 60, 64, 116, 118, 119 |
| **Total** | **28** | |

As shown in the Table 3-3, there are possible reasons why these 28 activities were dropped intentionally from the study. These reasons can be categorized as follows:

- Materials are no longer used.
- Dimensions are no longer used because they are no longer manufactured or are no longer included in building codes.
- A whole system has changed.
- New technology is being used for a particular construction method.
- Hazardous methods are no longer used.

Table 3-4 shows the discription of the dropped activities and the reasons why they were not exisiting in the newer version of the construction cost data manual.

**Table 3-4 Dropped Activities Descriptions**

| Activity # | | Activity Descriptions |
|---|---|---|
| 8 | Activity Description | Excavating trench by hand with pick and shovel, 2' to 6' deep, heavy soil |
| | Possible Reason | Trenches 2' to 6' deep are excavated by either 3/8, 1/2,5/8, or 3/4 excavators and hands are no longer used. |
| 15 | Activity Description | Forms in place, columns, round steel, 4 uses/mo, 12" diam |
| | Possible Reason | They are using 14" listed of 12" diam |
| 17 | Activity Description | Splicing reinforcement bars, column splice clamps, sleeve & wedge, or end bearing, #7 to #8 bars |
| | Possible Reason | Different description in MEANS 2009 see page 57 &58. |
| 24 | Activity Description | lightweight concrete, concrete plank, lightweight, nailable, T&G, 2" thick |
| | Possible Reason | It doesn't exist in newer MEANS and might not be applicable anymore |
| 28 | Activity Description | Brick masonry, coping for 12" wall, stock units, aluminum |
| | Possible Reason | Other |
| 29 | Activity Description | Sand blast, building face, wet system, minimum |
| | Possible Reason | It might be hazardous method that is not being used anymore |

| | | |
|---|---|---|
| 31 | Activity Description | Masonry: Common, 4"x2-2/3"x8", 4" wall, face brick |
| | Possible Reason | Other |
| 34 | Activity Description | Sandstone Veneer, 2'x4', 2" Thick |
| | Possible Reason | Other |
| 36 | Activity Description | Fireplace for prefabricated fireplace, 30"x24" opening, plain brickwork |
| | Possible Reason | Different Dimensions in 2009 see page 342 in MEANS 2009 |
| 43 | Activity Description | Structural steel projects, paints and protective coatings, sprayed, zinc rich primers, self cure, spray, inorganic |
| | Possible Reason | I couldn't find the reason why It doesn't exist in 2009 |
| 53 | Activity Description | Structural panels, Stunned skin plywood roof panel, 3/8" group 1 top, skin, 3/8" exterior AD bottom skin, 1150f stringers, 4'x8' panels, 4.1/4" deep |
| | Possible Reason | Other |
| 55 | Activity Description | Building Insulation - Sprayed; Fibrous/cementitous, 3/4" thick |
| | Possible Reason | 1" thick is used instead of 3/4" thick |
| 60 | Activity Description | Roofing tile, clay tile ASTM C1167, gr1, severe weathering |
| | Possible Reason | I couldn't find the reason why It doesn't exist in 2009 please see page 202 |

| | | |
|---|---|---|
| 64 | Activity Description | Composite panels, Exposed aggregate panels, polymer concrete matrix, 1/4" thick, small size agg. |
| | Possible Reason | Other |
| 65 | Activity Description | Cladding/siding, Wood product siding, siding, hardboard, 7/18" thick, prime painted, lap, plain or grooved finish |
| | Possible Reason | Other |
| 71 | Activity Description | Roll-up grille, aluminum, manual , mill finish |
| | Possible Reason | Different descriptions |
| 74 | Activity Description | Multileaf vertical lift doors, Vertical lift, doors, motor operator, incl. Frame 25'x20' high |
| | Possible Reason | Different Descriptions in 2009 see page 247 in MEANS 2009 |
| 95 | Activity Description | Escalators, per single unit, minimum |
| | Possible Reason | Different description in MEANS 2009 see page 428 (more detailed). |
| 105 | Activity Description | Backfill,Structural,dozer,75 h.p,50 feet haul, sand &gravel |
| | Possible Reason | in 1995 dozers are 75h.p while in 2009 they are 80h.p |
| 114 | Activity Description | Adobe masonry , brick, unstabilized with mortar,4*3*8 |
| | Possible Reason | Different description in 2009 see page 91 |

| | | |
|---|---|---|
| 116 | Activity Description | Drilling & layout for anchors per inch, 3/8 inch diam. |
| | Possible Reason | doesn't exist in 2009 see page 102 |
| 118 | Activity Description | Steel Structural, wide flange, A36 steel 2 tier, W8*24 |
| | Possible Reason | Doesn't exist |
| 119 | Activity Description | Space frame steel modular 40*70 span minimum |
| | Possible Reason | Doesn't exist in 2009 |
| 153 | Activity Description | Access flooring computer room |
| | Possible Reason | new system design |
| 163 | Activity Description | Elevators, passenger pre engineered 5 stories hydraulic. |
| | Possible Reason | new system design |
| 166 | Activity Description | material handling systems, motorized car minimum 50*100 |
| | Possible Reason | System design change completely |
| 167 | Activity Description | Material handling systems, chain conveyer, 125lb/L.F, Capacity |
| | Possible Reason | System design change completely |
| 168 | Activity Description | Material handling Systems, conveyers, vertical, automatic selective to 10 floors base price. |
| | Possible Reason | System design change completely |

# Chapter 4
# Data Analysis and Discussion

## 4.1 Introduction

As mentioned, the main objective of this research is to study a number of individual construction activities and to use them to represent the construction industry as a whole. This chapter describes the measurement of the percentage changes in labor and partial productivity for each individual activity. The almost 200 activities are divided evenly according to the divisions set out in the estimation manuals. The average of the percentage change for each division represents the trend for that particular division. Finally, the overall average of all the activities then approximately represents the trends in construction productivity for the specific period.

The data described earlier were used to calculate two productivity measures: labor and partial factor productivity. More specifically, the data taken from the R.S. Means were used to calculate the percentage change for both types of construction productivity in 1995 and 2009. The research uses a certain way to analyze the activities and then get the trend in both labor and partial productivity between the years 1995 and 2009.

Since this study has only two years to compare over a long time period, the change in both construction productivities and the trend will be assumed cumulative. Using this assumption, a long term trend over the specified time period will be relatively accurate.

## 4.2 Labor Productivity Trends from 1995 to 2009

The data taken from the R.S. Means manuals were used to calculate the percentage changes in the two types of construction productivities from 1995 to 2009: labor and partial factor productivity. A specific method was used for the analysis of the 200 activities and to determine an approximate indication of the trends in both labor and partial productivity between 1995 and 2009 in Canada and the United States.

**Table 4-1 Sample of Labor Productivity % Change Calculations**

| Division | Activity # | R.S. Means 1995 | R.S. Means 2009 | Labor Productivity = Man-Hours | | |
|---|---|---|---|---|---|---|
| | | MAN-HOURS | MAN-HOURS | 1995 | 2009 | % Chnage (2009 &1995) |
| Sitework | 9 | 9.143 | 4.267 | 9.143 | 4.267 | 114.272 |
| Concrete | 19 | 0.582 | 0.457 | 0.582 | 0.457 | 27.352 |
| Concrete | 109 | 17.910 | 19.743 | 17.910 | 19.743 | -9.284 |
| Masonry | 25 | 0.018 | 0.023 | 0.018 | 0.023 | -21.739 |
| Masonry | 30 | 0.348 | 0.188 | 0.348 | 0.188 | 85.106 |

As explained in Chapter 2, for the purpose of this research, labor productivity is defined as physical output units per work-hour. The percentage change in labor productivity, taken from the 1995 and 2009 estimation manuals was measured for each individual activity as listed in Appendix A. Table 4-1 show the measured average percentage change in labor productivity for each division. These measurements and the application of a hypothetical weighting factor for each division, depending on its importance in the field, produced a clearer picture of how labor productivity has changed from 1995 to 2009.

The weights are to some extend arbitrary but were taken from the cost estimate for a typical warehouse type building. The weights would be very different for the University of Waterloo E6 building, and there is no data source of which we are aware which would allow a set of representative weights to be derived for the construction industry as a whole. However, the Means manuals then solves this issue by including typical sets of weights for different types of buildings, and examples of those weights are illustrated and used in section 4.4.

The following formula is used to calculate the % change in construction productivity. This change is used for each construction activity in order for the study to avoid the conflict of different units for each activity.

$$\%\ \text{Change in labor productivity, } 1995\text{–}2009 = \frac{\text{labor productivity } 2009 - \text{labor productivity } 1995}{\text{labor productivity } 1995} * 100$$

**Table 4-2 Average % Change in Labor Productivity for Each Division**

| Division | Unweighted % Change in Labor Productivity | | | Weight Factor | Weighted % Change in Labor Productivity |
|---|---|---|---|---|---|
| | Min | Average % Change | Max | | Average % Change |
| Sitework | 0.00 | 7.62 | 114.27 | 0.04 | 0.30 |
| Concrete | -11.11 | 0.50 | 27.35 | 0.12 | 0.06 |
| Masonry | -21.74 | 8.05 | 85.11 | 0.08 | 0.64 |
| Metals | -90.00 | -9.29 | 14.29 | 0.20 | -1.86 |
| Wood & Plastic | -70.00 | -3.37 | 16.00 | 0.08 | -0.27 |
| Moisture-thermal control | -9.09 | -0.70 | 0.00 | 0.06 | -0.04 |
| Doors, windows & glass | 0.00 | 0.60 | 9.02 | 0.06 | 0.04 |
| Finishes | -61.54 | -7.21 | 30.84 | 0.06 | -0.43 |
| Specialties | 0.00 | 0.00 | 0.00 | 0.10 | 0.00 |
| Conveying system | 0.00 | 0.99 | 10.94 | 0.06 | 0.06 |
| Mechanical | 0.00 | 0.12 | 1.85 | 0.08 | 0.01 |
| Electrical | 0.00 | 0.00 | 0.00 | 0.06 | 0.00 |
| Overall findings (Avg.) | -90.00 | -0.22 | 114.27 | 1.00 | -1.490 |

The average cumulative percentage change in labor productivity for the 200 activities between 1995 and 2009 was a decrease of 0.22 %. This represents an annual compound rate of negative improvement of 0.016%. This number indicates that in the U.S building Sector that that the construction labor productivity remains almost steady with no change between 1995 and 2009.

As shown in the bar chart in Figure 4-1, an average increase in labor productivity was experienced in some activities like site work and Masonry. While concrete division and conveying systems showed a slight improvement over the period of the study. The greatest improvement was in site work, which experienced an 83.48% increase in labor productivity. This is likely mostly due to the “stakeless” earthmoving technology. In addition, metals, finishes, and wood showed the greatest decline, which varied between 3-9% negative changes in labor productivity. The remaining divisions such as electrical, mechanical and specialties remained relatively flat with no change over the study time frame.

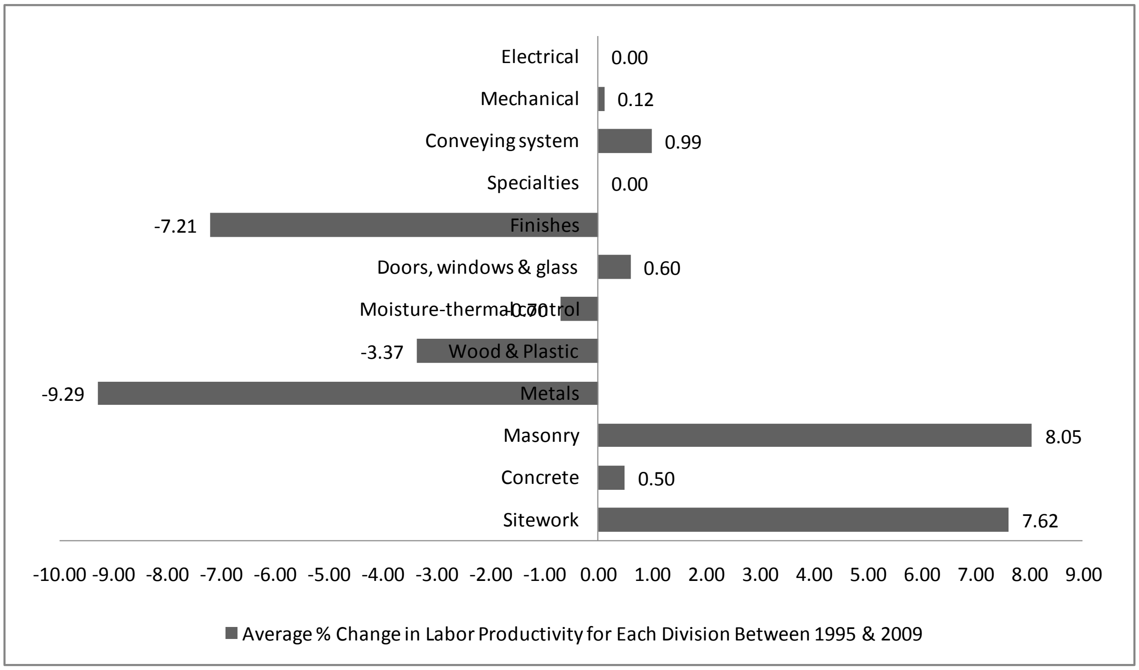


**Figure 4-1 Average % Change in Labor Productivity for Each Division**

## 4.3 Partial Factor Productivity Trends from 1995 to 2009

After the change in labor productivity was determined, the percentage change in partial factor productivity was measured. An effective understanding of the results requires a definition of partial factor productivity. Partial factor productivity is defined as the physical output per labor and equipment costs based on the estimation manuals.

**Table 4-3 Sample of Partial Factor Productivity % Change Calculations**

| Activity # | Bare Cost ($) Year 1995 | | Bare Cost ($) Year 2009 | | Partial Productivity (Daily Output/(Labor+Equip.) | | |
|---|---|---|---|---|---|---|---|
| | Labor | EQUIP. | Labor | EQUIP. | 1995 | 2009 | % Change (1995 to 2009) |
| 1 | 2.6 | 1.5 | 4.3 | 2.2 | 7.2 | 6.5 | 10.572 |
| 2 | 11.1 | 0.0 | 18.1 | 15.8 | 19.2 | 33.9 | -43.346 |
| 3 | 0.2 | 0.7 | 0.4 | 0.9 | 1.6 | 1.3 | 25.528 |
| 4 | 0.2 | 0.4 | 0.4 | 0.9 | 1.1 | 1.2 | -11.508 |
| 5 | 1.7 | 1.9 | 2.8 | 4.4 | 6.2 | 7.2 | -13.254 |

Table 4-3 shows the average percentage change in the partial factor productivity for each division. These measurements reveal a clear picture of how partial productivity has changed from 1995 to 2009. For these measurements, the cost data were adjusted for inflation using the historical data from the R.S. Means estimation manuals.

**Table 4-4 Average % Change in Partial Factor Productivity for Each Division**

| Division | Unweighted % Change in Partial Productivity | | | Weight Factor | Weighted % Change in Partial Productivity |
|---|---|---|---|---|---|
| | Min | Average % Change | Max | | Average % Change |
| Sitework | -13.25 | 21.51 | 148.13 | 0.04 | 0.86 |
| Concrete | 3.12 | 12.55 | 47.45 | 0.12 | 1.51 |
| Masonry | -8.87 | 27.15 | 209.47 | 0.08 | 2.17 |
| Metals | -34.06 | 9.01 | 57.06 | 0.20 | 1.80 |
| Wood & Plastic | -68.09 | 6.69 | 29.30 | 0.08 | 0.54 |
| Moisture-thermal control | -1.80 | 9.14 | 44.90 | 0.06 | 0.55 |
| Doors, windows & glass | 5.11 | 9.33 | 19.43 | 0.06 | 0.56 |
| Finishes | -52.88 | 1.33 | 45.96 | 0.06 | 0.08 |
| Specialties | 2.98 | 8.99 | 30.01 | 0.10 | 0.90 |
| Conveying system | -11.45 | -0.49 | 13.25 | 0.06 | -0.03 |
| | 1.91 | 4.37 | 10.85 | 0.08 | 0.35 |
| Electrical | 4.41 | 5.47 | 10.00 | 0.06 | 0.33 |
| Overall findings | -68.09 | 9.59 | 209.47 | 1.00 | 9.61 |

Based on the results shown in Table 1-6, the average cumulative percentage change in partial factor productivity between 1995 and 2009 for the remaining of 200 activities was an increase of 9.59%. This represents an annual compound rate of improvement of 0.7%. This number again showed that the construction partial factor productivity slightly improved between 1995 and 2009.

As shown in the bar chart in Figure 4-2, the majority of the improvement was related to both masonry and site work which varies between 21 to 27% over the 14 years of the study. The remaining of the division showed positive improvement varies between 0 to 9% roughly over the same time between 1995 and 2009. Except for finishes and conveying systems, which showed almost no change in the partial factor productivity, all divisions experienced noticeable improvement in Partial factor productivity.

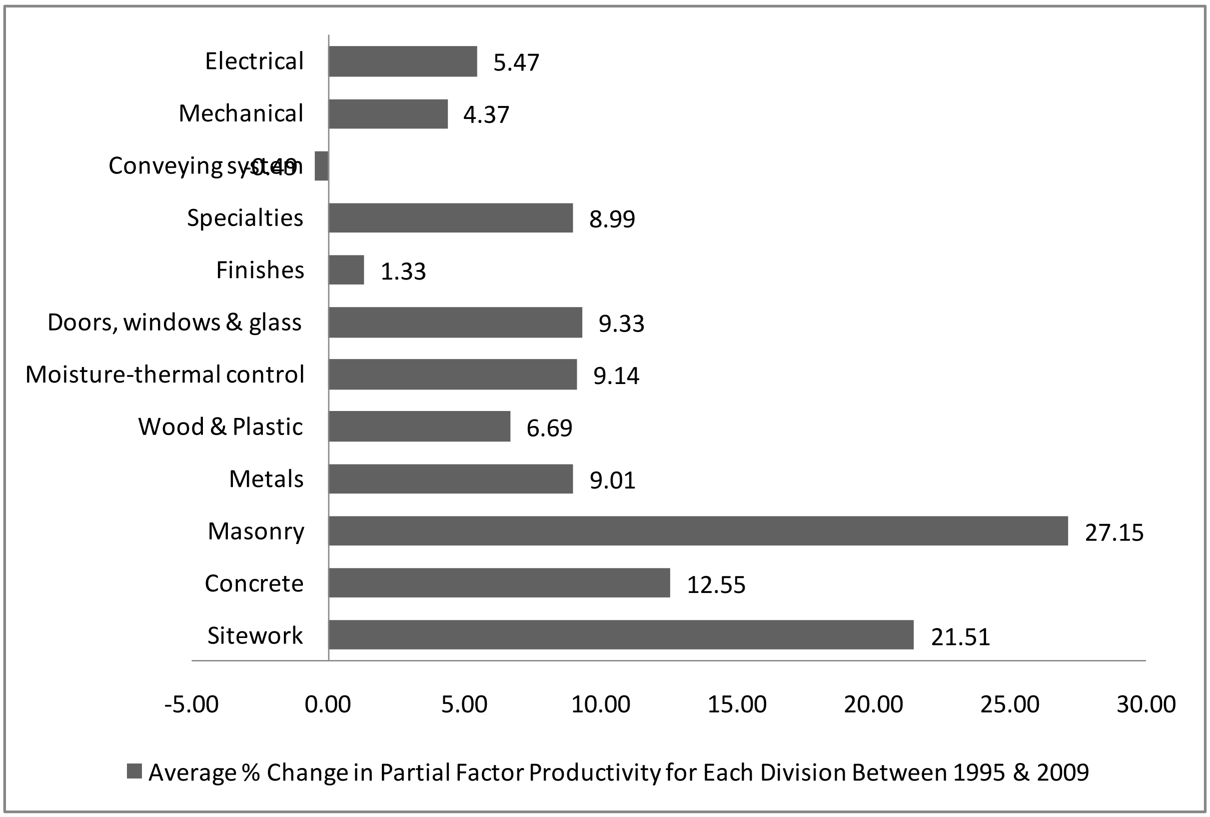


**Figure 4-2Average % Change in Partial Factor Productivity for Each Division**

## 4.4 Significance Testing for Changes in Labor and Partial Factor Productivities

In order for this study to validate the changes occurred to both labor and partial factor productivities, a t-test is essential to clarify the significance of the results. As shown in **Error! eference source not found.**, the actual number of activities is 172 activities. The t-test will be significant in this case, since the number of samples exceeded 30 samples. It is obvious from the table that the average percent change in labor productivity is too small. In addition to that, the variation of the data is considerably big. Therefore, the results yielded from the t-test showed a non significant change for labor productivity.

**Table 4-5 t-test results for both sample Labor & Partial Productivities**

| t-test results | Labor productivity | Partial Factor productivity |
|---|---|---|
| Mean | -0.22 | 9.24 |
| Variance | 269.55 | 535.66 |
| Observations | 172 | 172 |
| df | 171 | 171 |
| t Stat | -0.347549412 | 5.236782361 |
| P(T<=t) one-tail | 0.364303007 | 2.37649E-07 |
| t Critical one-tail | 1.653813324 | 1.653813324 |
| P(T<=t) two-tail | 0.728606013 | 4.75298E-07 |
| t Critical two-tail | 1.973933915 | 1.973933915 |

Changes in partial factor productivity yielded different results. As shown in Table 4-5Table 4-5 t-test results for both sample Labor & Partial Productivities, partial factor productivity has experienced a slight improvement of almost 10 % between 1995 and 2009. Out of the 172 activities, the t-test showed that this average % change in the partial factor productivity is significant.

In Summary; by considering the t-test results, labor productivity showed no significant improvement since the P value is more than the significance level ($\alpha$=0.05). Therefore, the test fails to reject the null hypothesis in which the average percent change with regards to its variation equal to zero. In contrast, the partial factor productivity results showed significant improvement since their P value is much less than the confidence value ($\alpha$=0.05). Therefore, the null hypothesis can be rejected with 95% confidence.

### 4.5 Examples on How These Trends Related to the Construction Industry

In this section, three samples were taken from the square foot chapter in the R.S. Means 2009 book. These examples are presented to elaborate the effect of weighting each division with regards to the building types. The three examples are as follows:

- Low Rise (1-3) Story Building;
- Fire Station.
- Warehouse & Storage Building.

As shown in Table 4-6, Table 4-7, and Table 4-8, it is clear that different sets of weights, corresponding to different building types, do not substantially change the overall results, in terms of cumulative changes. Because the percentage of using the site work and masonry in the warehouse example is high, it showed slightly better improvement in the productivity. In contrast, in the fire station example and according to R.S. Means, there are no site work activities. That is why it experienced less improvement than the warehouse.

## Table 4-6 Example: 1 (Low Rise Apartments)

| Appartments Low Rise (1-3 story) | Average % S.ft of Total | Unweighted % Change in Productivity | | Weighted % Change in Partial Productivity | |
|---|---|---|---|---|---|
| | | Labor Productivity | Partial Factor Productivity | Labor Productivity | Partial Factor Productivity |
| Site Work | 10.6 | 7.6 | 21.5 | 0.8 | 2.3 |
| Masonary | 3.7 | 8.1 | 27.1 | 0.3 | 1.0 |
| Finishes | 10.8 | -7.2 | 1.3 | -0.8 | 0.1 |
| Equipment | 4.0 | 1.0 | -0.5 | 0.0 | 0.0 |
| Plumbing | 9.0 | 0.1 | 4.4 | 0.0 | 0.4 |
| Heating, ventilating, air conditioning | 5.6 | 0.1 | 4.4 | 0.0 | 0.2 |
| Electrical | 6.7 | 0.0 | 5.5 | 0.0 | 0.4 |
| Remaining | 49.8 | -0.2 | 9.6 | -0.1 | 4.8 |
| Overall % Change | | | | 0.3 | 9.2 |

## Table 4-7 Example: 2 (Fire Station)

| Fire Station | Average % S.ft of Total | Unweighted % Change in Productivity | | Weighted % Change in Partial Productivity | |
|---|---|---|---|---|---|
| | | Labor Productivity | Partial Factor Productivity | Labor Productivity | Partial Factor Productivity |
| Masonary | 11.7 | 8.1 | 27.1 | 0.9 | 3.2 |
| Roofing | 4.9 | -7.2 | 1.3 | -0.4 | 0.1 |
| Painting | 1.6 | -7.2 | 1.3 | -0.1 | 0.0 |
| Equipment | 2.0 | 1.0 | -0.5 | 0.0 | 0.0 |
| Plumbing | 7.4 | 0.1 | 4.4 | 0.0 | 0.3 |
| Heating, ventilating, air conditioning | 7.4 | 0.1 | 4.4 | 0.0 | 0.3 |
| Electrical | 8.7 | 0.0 | 5.5 | 0.0 | 0.5 |
| Remaining | 56.5 | -0.2 | 9.6 | -0.1 | 5.4 |
| Overall % Change | | | | 0.4 | 9.8 |

## Table 4-8 Example 3 Warehouse & Storage Building

| Warehouse & Storage Building | Average % S.ft of Total | Unweighted % Change in Productivity | | Weighted % Change in Partial Productivity | |
|---|---|---|---|---|---|
| | | Labor Productivity | Partial Factor Productivity | Labor Productivity | Partial Factor Productivity |
| Site Work | 13.0 | 7.6 | 21.5 | 1.0 | 2.8 |
| Masonary | 7.4 | 8.1 | 27.1 | 0.6 | 2.0 |
| Equipment | 1.8 | 1.0 | -0.5 | 0.0 | 0.0 |
| Plumbing | 4.8 | 0.1 | 4.4 | 0.0 | 0.2 |
| Heating, ventilating, air conditioning | 5.0 | 0.1 | 4.4 | 0.0 | 0.2 |
| Electrical | 7.2 | 0.0 | 5.5 | 0.0 | 0.4 |
| Remaining | 60.8 | -0.2 | 9.6 | -0.1 | 5.8 |
| Overall | | | | 1.5 | 11.4 |

### 4.6 Discussion of Results

A number of possible factors may be driving the differences between labor and partial factor productivity changes observed in this thesis. They include:

- Possible relative reduction in equipment and tool costs due to improved technology, competition, trade, and industry trends toward renting rather than buying and amortizing equipment.
- Possible impact of improved productivity in the prefabrication and modularization sector leaving the more difficult assembly tasks for the field.
- Possibility of sample size being too small, or the building sector not being representative of construction in general.
- Unknown impact of the loss of the 28 activities those were not comparable between 1995 & 2009 manuals.

# Chapter 5
# Conclusion and Recommendations

## 5.1 Conclusions

The construction industry is by nature difficult to evaluate due to the enormous variation in projects and because of the dynamic and complex environment. The ability to measure the changes in construction productivity over a specific time period requires a detailed comparison of a wide range of construction activities. The main objective of this research was to provide an overview of the trends in construction productivity in Canada and the U.S. from 1995 to 2009 in the buildings sector. This research has determined that partial factor productivity in Canada and the U.S. construction industry have improved approximately 10% between 1995 and 2009 and that this change in construction productivity is significant.

In summary:

1) Labor productivity in construction in North America in Building sector relatively has not changed from 1995-2009.
2) Partial factor productivity in construction in North America has almost 10% positive improvement over the time period of the study.

The study also reveals that twenty eight activities that existed in 1995 were no longer listed in 2009, for reasons that can be categorized as follows:

- Some materials are no longer used.

- Some dimensions are no longer used, because they are no longer manufactured or are no longer included in building codes.
- Whole systems have changed.
- New technology is being used for a particular construction method, and
- Hazardous methods are no longer used.

## 5.2 Construction Productivity Trends and significance testing, 1995-2009

Studying the sample of 200 construction activities has provided a better understanding of the trends in productivity. Labor productivity decreased with an average of 0.22% in the 14 years between 1995 and 2009. In addition, partial productivity showed an average increase of 10%between 1995 and 2009 and this was corrected by controlling for inflation using the construction-specific historical cost indices of the Mean Historical Cost Index between 1995 and 2009.

Applying the statistical significance test (t-test) showed that the changes in partial factor construction productivity were significant between 1995 and 2009 while the labor productivity almost remains the same.

## 5.3 Remarks about R.S Means

R.S. Means manuals are very useful for forming an accurate and dependable construction estimate since they contain valuable information about costs and productivity. Historical cost indices can provide some data to adjust construction costs over time. By using these indices one can estimate roughly the cost of a certain project today, through the comparison with the costs of the same project in the past.

For R.S. Means developers to ensure reliable and up-to-date cost information, developments in the construction industry are monitored regularly, and new items are frequently added due to changes in materials and methods. City cost indexes are used to discuss the ''national average'' costs for 209 major cities throughout Canada and U.S. In order to be used effectively. The costs represent the U.S national averages and are given in U.S. dollars.

The RS Means staff contacts manufacturers, dealers, distributors and contractors all over the U.S and Canada to determine national average material costs. Labor costs are based on the average of wage rates from 30 major U.S cities. Equipment costs include not only rentals but also operating costs for equipment under normal use.

## 5.4 Recommendations for Future Work

This research could be used as an avenue for other researchers to conduct additional studies of trends in construction productivity. The results of this study have been proven to be valuable for illustrating trends in labor and partial construction productivity in Canada and the U.S. for the period between 1995 and 2009. However, a number of additional areas could be investigated in the future research:

- The study could be applied to different countries and cities with different data as long as there are valid conversion factors such as city cost indices.
- Different statistical approaches could be used in order to compare the results and obtain an accurate trend.

- Using different, independent data sources would help validate the research findings.
- The study could be experimented for more years in order to obtain an accurate and clear trend over individual segments of the time range.
- Computer software could be used to choose different data sets randomly in order to obtain the most accurate overall trend for the construction activities as a whole.
- Of the 200 activities, 21 activities showed the most improvement. Further research work could therefore focus on these activities in order to determine why they are exceptional.
- Factors which affect the construction productivity over the research period can be also studied in order to clarify these trends.

# Appendix A

## R.S. Means 1995 Cost Estimation Data

| R.S. Means 1995 Data | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Activity # | Page | CREW | DAILY OUTPUT (Units/Crew Day) | MAN-HOURS (Labour hours/unit) | UNIT | BARE COSTS ($) | | | | TOTAL INCL O&P ($) |
| | | | | | | MAT. | LABOR | EQUIP. | TOTAL | |
| 1 | 25 | B-8 | 15300 | 0.004 | C.F. | 0 | 0.09 | 0.14 | 0.23 | 0.29 |
| 2 | 39 | A-1 | 0.12 | 66.667 | ACRE | 0 | 1300 | 500 | 1800 | 2625 |
| 3 | 39 | B-11C | 135 | 0.119 | C.Y. | 0 | 2.64 | 1.52 | 4.16 | 5.8 |
| 4 | 42 | 1 Clab | 14 | 0.571 | C.Y. | 0 | 11.1 | 0 | 11.1 | 17.7 |
| 5 | 42 | B-10B | 1200 | 0.01 | C.Y. | 0 | 0.23 | 0.7 | 0.93 | 1.13 |
| 6 | 43 | B-10G | 1300 | 0.009 | C.Y. | 0 | 0.21 | 0.42 | 0.63 | 0.79 |
| 7 | 44 | B-47 | 300 | 0.08 | C.Y. | 1.4 | 1.73 | 1.87 | 5 | 6.35 |
| 9 | 49 | B-42 | 7 | 9.143 | L.F. | 42.5 | 198 | 151 | 391.5 | 535 |
| 10 | 51 | C-17C | 36 | 2.306 | L.F. | 37 | 59.5 | 11.15 | 107 | 147 |
| 11 | 54 | B-19 | 760 | 0.084 | V.L.F. | 4.7 | 2.1 | 1.83 | 8.63 | 10.7 |
| 12 | 59 | B-26 | 3000 | 0.029 | S.Y. | 13.9 | 0.64 | 0.61 | 15.15 | 17 |
| 13 | 87 | C-2 | 470 | 0.102 | S.F. | 2.36 | 2.46 | 0.08 | 4.9 | 6.6 |
| 14 | 85 | C-2 | 340 | 0.141 | SFCA | 1.38 | 3.4 | 0.11 | 4.89 | 7.05 |
| 16 | 88 | C-1 | 371 | 0.086 | SFCA | 0.91 | 2.01 | 0.08 | 3 | 4.3 |
| 18 | 98 | C-3 | 2600 | 0.025 | Lb. | 1.14 | 0.62 | 0.06 | 1.82 | 2.37 |
| 19 | 103 | C-20 | 110 | 0.582 | C.Y. | 0 | 12.2 | 5.85 | 18.05 | 25.5 |
| 20 | 102 | 2 Clab | 70 | 0.229 | C.S.F. | 5.3 | 4.43 | 0 | 9.73 | 12.9 |
| 21 | 106 | C-12 | 525 | 0.091 | L.F. | 9.1 | 2.22 | 0.8 | 12.12 | 14.4 |
| 22 | 107 | C-11 | 288 | 0.25 | S.F. | 8.2 | 6.65 | 5.3 | 20.15 | 27 |
| 23 | 108 | C-14 | 200 | 0.72 | L.F. | 19.5 | 17.25 | 5.65 | 42.4 | 55.5 |
| 25 | 109 | D-4 | 1750 | 0.018 | L.F. | 0.62 | 0.4 | 0.08 | 1.1 | 1.41 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 110 | 1 Bric | 180 | 0.044 | EA. | 1.1 | 1.12 | 0 | 2.22 | 2.97 |
| 27 | 120 | D-8 | 1.5 | 26.667 | M | 315 | 615 | 0 | 930 | 1300 |
| 30 | 122 | D-10 | 115 | 0.348 | L.F. | 12.6 | 8.2 | 4.07 | 24.87 | 31 |
| 32 | 124 | D-10 | 130 | 0.308 | S.F. | 11.85 | 7.25 | 3.6 | 22.7 | 28.5 |
| 33 | 123 | D-12 | 85 | 0.376 | L.F. | 11.65 | 8.6 | 0 | 20.25 | 26.5 |
| 35 | 126 | D-1 | 125 | 0.128 | V.L.F. | 2.26 | 2.87 | 0 | 5.13 | 7 |
| 37 | 130 | E-10 | 1030 | 0.016 | Ea. | 0.36 | 0.44 | 0.46 | 1.26 | 1.71 |
| 38 | 127 | E-4 | 350 | 0.091 | L.F. | 2.55 | 2.53 | 0.22 | 5.3 | 7.7 |
| 39 | 131 | E-14 | 240 | 0.033 | L.F. | 0.09 | 0.97 | 0.32 | 1.38 | 2.26 |
| 40 | 132 | F-1 | 5.8 | 1.379 | C.L.F. | 54.5 | 34 | 1.66 | 90.16 | 116 |
| 41 | 132 | E-4 | 240 | 0.133 | L.F. | 7.45 | 3.69 | 0.32 | 11.46 | 15.4 |
| 42 | 137 | E-6 | 11 | 11.636 | Ton | 960 | 315 | 114 | 1389 | 1750 |
| 44 | 141 | E-4 | 1460 | 0.022 | S.F. | 2.49 | 0.61 | 0.05 | 3.15 | 3.92 |
| 45 | 141 | E-4 | 4500 | 0.007 | S.F. | 0.78 | 0.2 | 0.02 | 1 | 1.23 |
| 46 | 143 | E-4 | 45 | 0.711 | Riser | 156 | 19.65 | 1.73 | 177 | 210 |
| 47 | 144 | E-4 | 255 | 0.125 | L.F. | 11.5 | 3.47 | 0.3 | 15.27 | 19 |
| 48 | 145 | E-4 | 510 | 0.063 | S.F. | 11.15 | 1.73 | 0.15 | 13.03 | 15 |
| 49 | 150 | F-2 | 0.7 | 22.857 | M.B.F. | 555 | 560 | 27.5 | 1142 | 1525 |
| 50 | 157 | F-3 | 2560 | 0.016 | SF Flr | 1.25 | 0.39 | 0.17 | 1.81 | 2.19 |
| 51 | 149 | F-1 | 1.3 | 6.154 | C.Pr. | 44 | 151 | 7.4 | 202.4 | 299 |
| 52 | 154 | F-2 | 1600 | 0.01 | S.F. | 0.31 | 0.25 | 0.01 | 0.57 | 0.74 |
| 54 | 159 | 1 Carp | 17 | 0.471 | Set | 25 | 11.6 | 0 | 36.6 | 46 |
| 56 | 168 | G-1 | 3000 | 0.019 | S.F. | 0.11 | 0.38 | 0.05 | 0.54 | 0.85 |
| 57 | 374 | 1 Elec | 10 | 0.8 | C.L.F. | 9.3 | 23 | 0 | 32.3 | 45 |
| 58 | 171 | 1 Carp | 1000 | 0.008 | S.F. | 0.32 | 0.2 | 0 | 0.52 | 0.66 |
| 59 | 175 | G-2 | 3000 | 0.008 | S.F. | 0.32 | 0.17 | 0.09 | 0.58 | 0.7 |
| 61 | 175 | 1Rofc | 5.5 | 1.455 | Sq. | 21.5 | 32 | 0 | 53.5 | 80 |
| 62 | 177 | 1Rots | 1.35 | 5.926 | Sq. | 120 | 131 | 0 | 251 | 360 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 63 | 177 | G-3 | 1200 | 0.027 | S.F. | 0.54 | 0.63 | 0.02 | 1.19 | 1.62 |
| 66 | 178 | G-3 | 1000 | 0.032 | S.F. | 1.7 | 0.76 | 0.03 | 2.49 | 3.1 |
| 67 | 189 | 1 Shee | 120 | 0.067 | L.F. | 0.8 | 1.87 | 0 | 2.67 | 3.81 |
| 68 | 191 | G-3 | 11 | 2.909 | Ea. | 305 | 69 | 2.62 | 376 | 445 |
| 69 | 194 | F-2 | 17 | 0.941 | Ea. | 150 | 23 | 1.13 | 174 | 203 |
| 70 | 203 | F-2 | 15 | 1.067 | Ea. | 182 | 26 | 1.28 | 209 | 243 |
| 72 | 205 | 2 Carp | 4 | 4 | Opng | 850 | 98.5 | 0 | 948.5 | 1100 |
| 73 | 205 | L-5 | 360 | 0.156 | S.F. | 15 | 4.25 | 1.41 | 20.66 | 26 |
| 75 | 212 | 2SWK | 10 | 1.6 | Ea. | 154 | 43.5 | 0 | 197.5 | 250 |
| 76 | 223 | 1Carp | 7.2 | 1.111 | Opng | 9.1 | 27.5 | 0 | 36.6 | 53.5 |
| 77 | 224 | 2 Glaz | 95 | 0.168 | S.F. | 4.9 | 4.13 | 0 | 9.03 | 11 |
| 78 | 225 | 2 Glaz | 110 | 0.145 | S.F. | 6.15 | 3.56 | 0 | 9.71 | 12 |
| 79 | 226 | H-1 | 205 | 0.156 | S.F. | 16.2 | 4.03 | 0 | 20.23 | 24.5 |
| 80 | 229 | 1 Lath | 235 | 0.034 | S.F. | 0.29 | 0.83 | 0 | 1.12 | 1.57 |
| 81 | 230 | J-2 | 97 | 0.495 | S.Y. | 7.5 | 11.15 | 0.41 | 19.06 | 26 |
| 82 | 232 | 2 Carp | 2000 | 0.008 | S.F. | 0.17 | 0.2 | 0 | 0.37 | 0.5 |
| 83 | 237 | D-7 | 105 | 0.152 | S.F. | 2.73 | 3.38 | 0 | 6.11 | 8.05 |
| 84 | 240 | 1Carp | 925 | 0.009 | S.F. | 0.25 | 0.21 | 0 | 0.46 | 0.61 |
| 85 | 241 | 1 Carp | 255 | 0.031 | S.F. | 2.05 | 0.77 | 0 | 2.82 | 3.48 |
| 86 | 245 | 1 Tilf | 57 | 0.14 | S.Y. | 12.95 | 3.43 | 0 | 16.38 | 19 |
| 87 | 246 | J-3 | 200 | 0.08 | S.F. | 3.75 | 1.79 | 0.48 | 6.02 | 7.3 |
| 88 | 251 | 1 Pord | 1500 | 0.005 | S.F. | 0.03 | 0.12 | 0 | 0.15 | 0.22 |
| 89 | 254 | 1 Pord | 2040 | 0.004 | S.F. | 0.04 | 0.09 | 0 | 0.13 | 0.18 |
| 90 | 255 | 1 Pape | 480 | 0.017 | S.F. | 1.44 | 0.38 | 0 | 1.82 | 2.18 |
| 91 | 261 | E-4 | 320 | 0.1 | L.F. | 3.15 | 2.77 | 0.24 | 6.16 | 8.85 |
| 92 | 262 | F-1 | 10 | 0.8 | Ea. | 145 | 19.7 | 0.96 | 165 | 193 |
| 93 | 264 | K-1 | 2 | 8 | Ea. | 855 | 178 | 82.5 | 1115 | 1300 |
| 94 | 267 | k-2 | 1.3 | 18.462 | Ea. | 980 | 470 | 127 | 1577 | 2050 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 96 | 317 | M-2 | 0.5 | 32 | Ea. | 2975 | 830 | 38.5 | 3843 | 4575 |
| 97 | 327 | Q-1 | 58 | 0.276 | L.F. | 9.8 | 7.3 | 0 | 17.1 | 22 |
| 98 | 346 | Q-7 | 1.2 | 26.667 | Ea. | 1500 | 745 | 0 | 2245 | 2800 |
| 99 | 357 | Q-5 | 4 | 4 | Ea. | 1450 | 105 | 0 | 1555 | 1750 |
| 100 | 369 | 1 Elec | 150 | 0.053 | L.F. | 3.9 | 1.52 | 0 | 5.42 | 6.6 |
| 101 | 38 | B-7 | 1 | 48 | Acre | | 995 | 1100 | 2095 | 2800 |
| 102 | 36 | A-9 | 235 | 0.272 | L.F. | | 7.65 | 0.93 | 8.58 | 13.4 |
| 103 | 39 | B-10H | 4 | 3 | Day | | 69.5 | 8.05 | 77.55 | 117 |
| 104 | 40 | B-40 | 10.81 | 5.92 | Ton | 685 | 147 | 178 | 1010 | 1200 |
| 106 | 87 | C-1 | 190 | 0.168 | SFCA | 0.99 | 3.92 | 0.15 | 5.06 | 7.5 |
| 107 | 89 | C-2 | 190 | 0.253 | S.F. | 1.1 | 6.1 | 0.2 | 7.4 | 11.1 |
| 108 | 95 | 4Rodm | 1.6 | 20 | Ton | 500 | 540 | | 1040 | 1500 |
| 109 | 100 | C-14 | 8.04 | 17.91 | C.Y. | 288 | 430 | 140 | 858 | 1175 |
| 110 | 103 | C-7 | 100 | 0.64 | C.Y. | | 13.4 | 8.45 | 21.85 | 30.5 |
| 111 | 116 | D-8 | 265 | 0.151 | S.F. | 4.17 | 3.47 | | 7.64 | 10.0 |
| 112 | 119 | C-11 | 500 | 0.144 | S.F. | 7.65 | 3.83 | 3.06 | 14.54 | 18.6 |
| 113 | 120 | D-1 | 90 | 0.178 | L.F. | 4.35 | 3.98 | | 8.33 | 11 |
| 115 | 121 | D-8 | 115 | 0.348 | S.F. | 19.6 | 8 | | 27.6 | 34 |
| 117 | 130 | E-10 | 1030 | 0.016 | Ea. | 0.12 | 0.44 | 0.46 | 1.02 | 1.45 |
| 120 | 135 | E-2 | 600 | 0.093 | L.F. | 5.3 | 2.47 | 1.6 | 9.37 | 11 |
| 121 | 149 | F-1 | 1.5 | 5.333 | C.L.F | 46 | 131 | 6.4 | 183.4 | 267 |
| 122 | 150 | F-2 | 50 | 32 | M.B.F | 590 | 785 | 38.5 | 1413 | 1950 |
| 123 | 151 | F-2 | 0.52 | 30.769 | M.B.F | 890 | 755 | 37 | 1682 | 2225 |
| 124 | 152 | F-2 | 0.53 | 30.189 | M.B.F | 690 | 745 | 36 | 1471 | 1975 |
| 125 | 155 | F-2 | 320 | 0.05 | S.F. | 4.5 | 1.23 | 0.06 | 5.79 | 7 |
| 126 | 156 | F-2 | 1.1 | 14.545 | M.B.F | 1.3 | 360 | 17.45 | 1677 | 2025 |
| 127 | 156 | F-5 | 2400 | 0.013 | SF Flr | 1.37 | 0.33 | 0.01 | 1.71 | 2.05 |
| 128 | 157 | F-2 | 425 | 0.038 | S.F. | 2.6 | 0.93 | 0.05 | 3.58 | 4.39 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 129 | 158 | 1 Carp | 330 | 0.024 | L.F. | 0.16 | 0.6 | | 0.76 | 1.13 |
| 130 | 160 | F-2 | 500 | 0.032 | S.F. | 0.65 | 0.79 | 0.04 | 1.48 | 2.01 |
| 131 | 166 | 2 Carp | 5 | 3.2 | Flight | 145 | 78.5 | | 223.5 | 286 |
| 132 | 169 | 1Rofc | 665 | 0.012 | S.F. | 0.04 | 0.27 | | 0.31 | 0.5 |
| 133 | 174 | J-1 | 295 | 0.136 | S.F. | 1.97 | 3 | 0.13 | 5.1 | 7 |
| 134 | 178 | G-3 | 1100 | 0.029 | S.F. | 0.64 | 0.69 | 0.03 | 1.36 | 1.82 |
| 135 | 182 | G-1 | 22 | 2.545 | Sq. | 30.5 | 52 | 7.15 | 89.65 | 132 |
| 136 | 195 | E-4 | 13 | 2.462 | Ea. | 156 | 68 | 6 | 230 | 305 |
| 137 | 196 | F-2 | 14 | 1.143 | Ea. | 75 | 28 | 1.37 | 104.3 | 129 |
| 138 | 198 | F-2 | 17 | 0.941 | Ea. | 39 | 23 | 1.13 | 63.13 | 81 |
| 139 | 200 | F-2 | 14 | 1.143 | Ea. | 152 | 28 | 1.37 | 181.3 | 214 |
| 140 | 213 | F-2 | 30 | 0.533 | Ea. | 16.9 | 13.1 | 0.64 | 29.64 | 39 |
| 141 | 215 | 1 Carp | 10 | 0.8 | Ea. | 73 | 19.7 | | 92.7 | 112 |
| 142 | 231 | 2 Carp | 1900 | 0.008 | S.F. | 0.18 | 0.21 | | 0.39 | 0.53 |
| 143 | 233 | 2 Carp | 310 | 0.052 | S.F. | 0.85 | 1.27 | | 2.12 | 2.97 |
| 144 | 235 | D-7 | 82 | 0.195 | L.F. | 3.12 | 4.33 | | 7.45 | 9.9 |
| 145 | 239 | 1 Carp | 625 | 0.013 | S.F. | 0.41 | 0.31 | | 0.72 | 0.95 |
| 146 | 242 | D-7 | 60 | 0.267 | S.F. | 4.4 | 5.9 | | 10.3 | 13.65 |
| 147 | 252 | 1 Pord | 20 | 0.4 | Ea. | 1.65 | 9.05 | | 10.7 | 15.75 |
| 148 | 257 | 2 Carp | 8 | 2 | Ea. | 1225 | 49 | | 1274 | 1425 |
| 149 | 258 | 2 Carp | 7 | 2.286 | Ea. | 405 | 56 | | 461 | 535 |
| 150 | 259 | 2 Shee | 5 | 3.2 | Ea. | 515 | 90 | | 605 | 705 |
| 151 | 260 | 1 Carp | 38 | 0.211 | Ea. | 6.75 | 5.2 | | 11.95 | 15.7 |
| 152 | 261 | 1 Sswk | 80 | 0.1 | L.F. | 16.5 | 2.71 | | 19.21 | 23 |
| 154 | 263 | 1 Bric | 8 | 1 | Ea. | 38 | 25.5 | | 63.5 | 81.5 |
| 155 | 263 | F-2 | 1.3 | 12.308 | Ea. | 600 | 305 | 14.75 | 919.7 | 1150 |
| 156 | 265 | 2 Carp | 3 | 5.333 | Ea. | 196 | 131 | | 327 | 425 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 157 | 270 | 2 Carp | 100 | 0.16 | L.F. | 95 | 3.94 | | 98.94 | 111 |
| 158 | 273 | 1 Carp | 13 | 0.615 | Ea. | 24.5 | 15.15 | | 39.65 | 50.5 |
| 159 | 274 | 3 Carp | 0.5 | 48 | Ea. | 4100 | 1175 | | 5275 | 6375 |
| 160 | 315 | 2 Elev | 0.75 | 21.333 | Ea. | 1975 | 620 | | 2595 | 3125 |
| 161 | 315 | 2 Elev | 0.13 | 123 | Ea. | 5000 | 3575 | | 8575 | 10900 |
| 162 | 316 | M-1 | 0.09 | 355 | Ea. | 22900 | 9825 | 920 | 33645 | 41100 |
| 164 | 316 | M-1 | 6.5 | 4.923 | L.F. | 700 | 136 | 12.75 | 848.7 | 990 |
| 165 | 316 | M-1 | 5.27 | 6.072 | L.F. | 1100 | 168 | 15.75 | 1283 | 1500 |
| 169 | 317 | 2 Shee | 3.5 | 4.571 | Floor | 575 | 128 | | 703 | 835 |
| 170 | 318 | 2 Shee | 3.5 | 4.571 | Floor | 1025 | 128 | | 1153 | 1325 |
| 171 | 318 | 2 Stpi | 0.12 | 133 | Total | 4450 | 3900 | | 8350 | 10900 |
| 172 | 318 | 2 Stpi | 37.6 | 0.426 | L.F. | 16.15 | 12.45 | | 28.6 | 37 |
| 173 | 319 | E-4 | 3400 | 0.009 | Lb. | 0.79 | 0.26 | 0.02 | 1.07 | 1.38 |
| 174 | 324 | 1 Plum | 24 | 0.333 | Ea. | 14.85 | 9.75 | | 24.6 | 31.5 |
| 175 | 326 | Q-1 | 70 | 0.229 | L.F. | 22.5 | 6.05 | | 28.55 | 34 |
| 176 | 329 | Q-15 | 93 | 0.172 | L.F. | 2.49 | 4.54 | 0.57 | 7.6 | 10.3 |
| 177 | 329 | 1 Plum | 71 | 0.113 | L.F. | 1.78 | 3.3 | | 5.08 | 7 |
| 178 | 330 | 1 Plum | 24 | 0.333 | Ea. | 5.35 | 9.75 | | 15.1 | 21 |
| 179 | 334 | Q-1 | 4 | 4 | Ea. | 1000 | 106 | | 1106 | 1250 |
| 180 | 335 | 1 Plum | 14 | 0.571 | Ea. | 263 | 16.75 | | 279 | 315 |
| 181 | 338 | Q-1 | 16 | 1 | Ea. | 98 | 26.5 | | 124.5 | 149 |
| 182 | 341 | Q-1 | 1.2 | 13.333 | Ea. | 2150 | 350 | | 2500 | 2925 |
| 183 | 342 | Q-12 | 8 | 2 | Ea. | 81.5 | 55.5 | | 137 | 175 |
| 184 | 345 | Q-19 | 1 | 24 | Ea. | 8350 | 650 | | 9000 | 10200 |
| 185 | 348 | Q-20 | 16 | 1.25 | Ea. | 440 | 32.5 | | 472.5 | 535 |
| 186 | 360 | Q-10 | 75 | 0.32 | Lb. | 3.49 | 8.4 | | 11.89 | 17 |
| 187 | 368 | 1 Elec. | 100 | 0.08 | L.F. | 1 | 2.28 | | 3.28 | 4.54 |
| 188 | 369 | 1 Elec. | 270 | 0.03 | L.F. | 0.35 | 0.84 | | 1.19 | 1.66 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 189 | 370 | 1 Elec. | 20 | 0.4 | L.F. | 55 | 11.4 | | 66.4 | 77.5 |
| 190 | 372 | 1 Elec. | 9 | 0.889 | C.L.F | 16 | 25.5 | | 41.5 | 55.5 |
| 191 | 375 | 1 Elec. | 260 | 0.031 | Ea. | 0.05 | 0.88 | | 0.93 | 1.38 |
| 192 | 376 | 1 Elec. | 8 | 1 | Ea. | 7.05 | 28.5 | | 35.55 | 51 |
| 193 | 378 | 1 Elec. | 40 | 0.2 | Ea. | 3.8 | 5.7 | | 9.5 | 12.8 |
| 194 | 380 | 1 Elec. | 0.5 | 16 | Ea. | 2350 | 455 | | 2805 | 3250 |
| 195 | 382 | 1 Elec. | 1 | 8 | Ea. | 410 | 228 | | 638 | 795 |
| 196 | 384 | R-3 | 0.83 | 24.096 | Ea. | 5750 | 680 | 129 | 6559 | 7500 |
| 197 | 386 | 1 Elec. | 5.7 | 1.404 | Ea. | 50.5 | 40 | | 90.5 | 116 |
| 198 | 388 | R-3 | 2.4 | 8.333 | Ea. | 283 | 235 | 44.5 | 562.5 | 715 |
| 199 | 391 | 1 Elec. | 8 | 1 | Ea. | 75 | 28.5 | | 103.5 | 126 |
| 200 | 393 | 1 Elec. | 1.19 | 6.723 | Ea. | 320 | 192 | | 512 | 640 |

# Appendix B R.S. Means 2009 Cost Estimation Data

| R.S. Means 2009 Data | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Activity # | Page | CREW | DAILY OUT PUT (Units/Crew Day) | MAN-HOURS (Labour hours/unit) | UNIT | BARE COSTS ($) | | | | TOTAL INCL O&P ($) |
| | | | | | | MAT. | LABOR | EQUIP. | TOTAL | |
| 1 | 26 | B-8 | 15300 | 0.004 | C.F. | 0 | 0.15 | 0.19 | 0 | 0 |
| 2 | 554 | 1 Clab | 0.12 | 66.667 | ACRE | 0 | 2100 | 0 | 2100 | 3275 |
| 3 | 564 | B-11C | 135 | 0.119 | C.Y. | 0 | 4.32 | 2.18 | 7 | 9 |
| 4 | 565 | 1 Clab | 14 | 0.571 | L.C.Y. | 0 | 18.05 | 0 | 18 | 28 |
| 5 | 565 | B-10B | 1200 | 0.01 | L.C.Y. | 0 | 0.38 | 0.9 | 1 | 2 |
| 6 | 584 | B-10G | 1300 | 0.009 | E.C.Y | 0 | 0.35 | 0.88 | 1 | 2 |
| 7 | 560 | B-47 | 300 | 0.08 | B.C.Y. | 3 | 2.78 | 4.39 | 10 | 12 |
| 9 | 618 | B-42 | 15 | 4.267 | L.F. | 119 | 152 | 91 | 362 | 470 |
| 10 | 607 | C-17C | 36 | 2.306 | L.F. | 74 | 95 | 13.5 | 183 | 243 |
| 11 | 590 | B-19 | 760 | 0.084 | V.L.F. | 10 | 3.33 | 2.32 | 16 | 19 |
| 12 | 598 | B-26 | 3000 | 0.029 | S.Y. | 22 | 1.04 | 1.02 | 24 | 27 |
| 13 | 44 | C-2 | 470 | 0.102 | S.F. | 5 | 3.97 | 0 | 9 | 11 |
| 14 | 42 | C-2 | 340 | 0.141 | SFCA | 2 | 5.5 | 0 | 8 | 11 |
| 16 | 46 | C-1 | 371 | 0.086 | SFCA | 1 | 3.27 | 0 | 4 | 6 |
| 18 | 60 | C-3 | 2600 | 0.025 | Lb. | 1 | 1.01 | 0.04 | 2 | 3 |
| 19 | 64 | C-20 | 140 | 0.457 | C.Y. | 0 | 15.5 | 5.65 | 21 | 30 |
| 20 | 68 | 2 Clab | 70 | 0.229 | C.S.F | 16 | 7.2 | 0 | 23 | 29 |
| 21 | 69 | C-12 | 525 | 0.091 | L.F. | 71 | 3.6 | 1.46 | 76 | 85 |
| 22 | 70 | C-11 | 288 | 0.25 | S.F. | 15 | 10.95 | 6.55 | 33 | 43 |
| 23 | 71 | C-14 | 200 | 0.72 | L.F. | 24 | 28 | 6.5 | 59 | 77 |
| 25 | 79 | D-4 | 1400 | 0.023 | L.F. | 1 | 0.82 | 0.09 | 2 | 2 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 26 | 79 | 1 Bric | 180 | 0.044 | EA. | 1 | 1.8 | 0 | 3 | 4 |
| 27 | 81 | D-8 | 1.5 | 26.667 | M | 535 | 990 | 0 | 1525 | 2075 |
| 30 | 96 | D-1 | 85 | 0.188 | L.F. | 17 | 6.85 | 0 | 24 | 29 |
| 32 | 95 | D-10 | 130 | 0.246 | S.F. | 17 | 9.7 | 4.63 | 32 | 39 |
| 33 | 95 | D-12 | 85 | 0.376 | L.F. | 15 | 13.85 | 0 | 29 | 38 |
| 35 | 96 | D-1 | 125 | 0.128 | V.L.F. | 4 | 4.65 | 0 | 9 | 12 |
| 37 | 108 | E-10 | 960 | 0.017 | EA. | 1 | 0.76 | 0.39 | 2 | 2 |
| 38 | 111 | E-4 | 350 | 0.091 | L.F. | 2 | 4.13 | 0.38 | 6 | 10 |
| 39 | 102 | E-14 | 150 | 0.053 | L.F. | 0 | 2.49 | 0.89 | 4 | 6 |
| 40 | 160 | 1 Crap | 5.8 | 1.4 | C.L.F. | 75 | 55 | 0 | 130 | 168 |
| 41 | 142 | E-4 | 240 | 0.133 | L.F. | 12 | 6.05 | 0.56 | 18 | 24 |
| 42 | 115 | E-6 | 11 | 11.636 | Ton | 3000 | 515 | 186 | 3701 | 4400 |
| 44 | 124 | E-4 | 1460 | 0.022 | S.F. | 10 | 0.99 | 0.09 | 11 | 13 |
| 45 | 123 | E-4 | 4500 | 0.007 | S.F. | 3 | 0.32 | 0.03 | 3 | 3 |
| 46 | 143 | E-4 | 45 | 0.711 | Riser | 605 | 32 | 2.98 | 640 | 725 |
| 47 | 137 | E-4 | 255 | 0.125 | L.F. | 31 | 5.65 | 0.53 | 37 | 45 |
| 48 | 185 | E-4 | 510 | 0.063 | S.F. | 14 | 2.84 | 0.26 | 17 | 21 |
| 49 | 161 | 2 Carp | 0.81 | 19.704 | M.B.F | 520 | 785 | 0 | 1305 | 1800 |
| 50 | 172 | F-3 | 2560 | 0.016 | SFFlr. | 2 | 0.63 | 0.3 | 3 | 3 |
| 51 | 161 | 1 Carp | 1.3 | 6.154 | C.Pr. | 51 | 246 | 0 | 297 | 435 |
| 52 | 170 | 2 Carp | 1600 | 0.01 | S.F. | 1 | 0.4 | 0 | 1 | 1 |
| 54 | 176 | 1Carp | 17 | 0.471 | Set | 45 | 18.8 | 0 | 64 | 79 |
| 56 | 192 | G-1 | 3000 | 0.019 | S.F. | 0 | 0.6 | 0.15 | 1 | 2 |
| 57 | 516 | 1 Elec | 10 | 0.8 | C.L.F. | 25 | 37.5 | 0 | 63 | 84 |
| 58 | 193 | 1 Carp | 1000 | 0.008 | S.F. | 0 | 0.32 | 0 | 1 | 1 |
| 59 | 221 | G-2 | 3000 | 0.008 | S.F. | 1 | 0.27 | 0.04 | 1 | 1 |
| 61 | 199 | 1 Rofc | 5.5 | 1.455 | Sq. | 50 | 50 | 0 | 100 | 139 |
| 62 | 202 | 1 Rots | 1.35 | 5.926 | Sq. | 97 | 202 | 0 | 299 | 445 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 63 | 203 | G-3 | 1200 | 0.027 | S.F. | 1 | 1.05 | 0 | 2 | 3 |
| 66 | 204 | G-3 | 1000 | 0.032 | S.F. | 2 | 1.26 | 0 | 3 | 4 |
| 67 | 218 | 1 Shee | 120 | 0.067 | L.F. | 2 | 3.15 | 0 | 5 | 7 |
| 68 | 220 | G-3 | 10 | 3.2 | EA. | 500 | 126 | 0 | 626 | 745 |
| 69 | 231 | 2 Carp | 17 | 0.941 | EA. | 295 | 37.5 | 0 | 333 | 385 |
| 70 | 240 | 2 Carp | 15 | 1.067 | EA. | 289 | 42.5 | 0 | 332 | 385 |
| 72 | 242 | 2 Carp | 4 | 4 | Opng. | 1350 | 160 | 0 | 1510 | 1725 |
| 73 | 233 | L-5 | 360 | 0.156 | S.F. | 26 | 6.95 | 2.19 | 35 | 43 |
| 75 | 252 | 2-Sswk | 10 | 1.6 | EA. | 335 | 71.5 | 0 | 407 | 495 |
| 76 | 271 | 1 Carp | 7.2 | 1.111 | Opng. | 12 | 44.5 | 0 | 57 | 83 |
| 77 | 272 | 2 Glaz | 95 | 0.168 | S.F. | 9 | 6.5 | 0 | 15 | 20 |
| 78 | 273 | 2 Glaz | 120 | 0.133 | S.F. | 14 | 5.15 | 0 | 19 | 23 |
| 79 | 251 | H-1 | 205 | 0.156 | S.F. | 31 | 6.5 | 0 | 38 | 46 |
| 80 | 284 | 1 Lath | 235 | 0.034 | S.F. | 0 | 1.21 | 0 | 2 | 2 |
| 81 | 287 | J-2 | 84 | 0.571 | S.Y. | 10 | 19.85 | 1.51 | 31 | 43 |
| 82 | 290 | 2 Carp | 2000 | 0.008 | S.F. | 0 | 0.32 | 0 | 1 | 1 |
| 83 | 294 | D-7 | 110 | 0.145 | L.F. | 6 | 4.96 | 0 | 11 | 13 |
| 84 | 309 | 1 Carp | 925 | 0.009 | S.F. | 0 | 0.35 | 0 | 1 | 1 |
| 85 | 299 | 1 Carp | 255 | 0.031 | S.F. | 3 | 1.25 | 0 | 4 | 5 |
| 86 | 305 | 1 Tilf | 75 | 0.107 | S.Y. | 26 | 4.06 | 0 | 30 | 35 |
| 87 | 304 | J-3 | 200 | 0.08 | S.F. | 5 | 2.74 | 1.27 | 9 | 11 |
| 88 | 316 | 1 Pord | 640 | 0.013 | S.F. | 0 | 0.44 | 0 | 0 | 1 |
| 89 | 320 | 1 Pord | 1350 | 0.006 | S.F. | 0 | 0.21 | 0 | 0 | 0 |
| 90 | 307 | 1 Pape | 480 | 0.017 | S.F. | 2 | 0.59 | 0 | 2 | 3 |
| 91 | 339 | 2 Carp | 160 | 0.1 | L.F. | 6 | 4 | 0 | 10 | 13 |
| 92 | 341 | 1 Carp | 10 | 0.8 | EA. | 244 | 32 | 0 | 276 | 320 |
| 93 | 349 | K-1 | 2 | 8 | EA. | 970 | 284 | 121 | 1375 | 1650 |
| 94 | 348 | K-2 | 1.3 | 18.462 | EA. | 2150 | 755 | 187 | 3092 | 3850 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 96 | 642 | 2 Mill | 0.5 | 32 | EA. | 3150 | 1325 | 0 | 4475 | 5425 |
| 97 | 451 | Q-1 | 59 | 0.271 | L.F. | 3 | 11.9 | 0 | 15 | 22 |
| 98 | 496 | Q-7 | 1.2 | 26.667 | EA. | 1875 | 1250 | 0 | 3125 | 3950 |
| 99 | 505 | Q-5 | 4 | 4 | EA. | 1650 | 178 | 0 | 1828 | 2100 |
| 100 | 521 | 1 Elec | 150 | 0.053 | L.F. | 8 | 2.51 | 0 | 11 | 13 |
| 101 | 553 | B-7 | 1 | 48 | Acre | | 1600 | 1300 | 2900 | 3900 |
| 102 | 33 | A-9 | 235 | 0.272 | L.F. | 1 | 12.05 | | 13 | 20 |
| 103 | 564 | B-10H | 4 | 3 | Day | | 114 | 16.85 | 131 | 192 |
| 104 | 586 | B-40 | 10.81 | 5.92 | Ton | 1225 | 234 | 305 | 1764 | 2050 |
| 106 | 44 | C-1 | 190 | 0.168 | SFCA | 3 | 6.4 | | 10 | 13 |
| 107 | 50 | C-2 | 190 | 0.253 | S.F. | 2 | 9.8 | | 12 | 18 |
| 108 | 58 | 4 Rodm | 1.6 | 20 | Ton | 1550 | 890 | | 2440 | 3150 |
| 109 | 61 | C-14A | 10.13 | 19.743 | S.Y. | 720 | 790 | 75.5 | 1586 | 2100 |
| 110 | 65 | C-7 | 100 | 0.72 | C.Y. | | 24.5 | 11.95 | 36 | 51 |
| 111 | 89 | D-8 | 265 | 0.151 | S.F. | 7 | 5.6 | | 13 | 17 |
| 112 | 119 | C-11 | 500 | 0.144 | S.F. | 11 | 6.3 | 3.78 | 21 | 27 |
| 113 | 84 | D-1 | 90 | 0.178 | L.F. | 10 | 6.45 | | 17 | 22 |
| 115 | 91 | D-8 | 115 | 0.348 | S.F. | 21 | 12.95 | | 33 | 42 |
| 117 | 109 | E-10 | 1120 | 0.014 | Ea. | 0 | 0.65 | 0.34 | 1 | 2 |
| 120 | 113 | E-2 | 600 | 0.93 | L.F. | 17 | 4.06 | 2.9 | 23 | 29 |
| 121 | 161 | 1 Carp | 1.5 | 5.333 | C.L.F | 64 | 213 | | 277 | 400 |
| 122 | 162 | 2 Carp | 0.5 | 32 | M.B.F | 630 | 1275 | | 1905 | 2675 |
| 123 | 162 | 2 Carp | 0.52 | 30.769 | M.B.F | 1175 | 1225 | | 2400 | 3175 |
| 124 | 167 | 2 Carp | 0.53 | 30.189 | M.B.F | 595 | 1200 | | 1795 | 2525 |
| 125 | 169 | 2 Carp | 320 | 0.05 | S.F. | 6 | 2 | | 8 | 10 |
| 126 | 169 | 2 Carp | 1.1 | 14.545 | M.B.F | 1825 | 580 | | 2405 | 2900 |
| 127 | 171 | F-5 | 2400 | 0.013 | SF Flr | 2 | 0.54 | | 3 | 3 |
| 128 | 169 | 2 Carp | 425 | 0.038 | S.F. | 3 | 1.5 | | 5 | 6 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 129 | 175 | 1 Carp | 330 | 0.024 | L.F. | 0 | 0.97 | | 1 | 2 |
| 130 | 177 | 2 Carp | 500 | 0.032 | S.F. | 1 | 1.28 | | 2 | 3 |
| 131 | 178 | 2 Carp | 1.5 | 10.667 | Flight | 3625 | 425 | | 4050 | 4625 |
| 132 | 191 | 1 Rofc | 665 | 0.012 | S.F. | 0 | 0.41 | | 1 | 1 |
| 133 | 198 | J-1 | 295 | 0.136 | S.F. | 3 | 4.69 | 0.43 | 8 | 11 |
| 134 | 204 | G-3 | 1100 | 0.029 | S.F. | 2 | 1.15 | | 3 | 4 |
| 135 | 209 | G-1 | 22 | 2.545 | Sq. | 84 | 81.5 | 20 | 186 | 252 |
| 136 | 231 | E-4 | 13 | 2.462 | Ea. | 270 | 111 | 10.3 | 391 | 505 |
| 137 | 230 | 2 Carp | 14 | 1.143 | Ea. | 153 | 45.5 | | 199 | 240 |
| 138 | 234 | 2 Carp | 17 | 0.941 | Ea. | 33 | 37.5 | | 70 | 94 |
| 139 | 236 | 2 Carp | 14 | 1.143 | Ea. | 320 | 45.5 | | 366 | 420 |
| 140 | 257 | 2 Crap | 30 | 0.533 | Ea. | 32 | 21.5 | | 54 | 68 |
| 141 | 254 | 1 Carp | 10 | 0.8 | Ea. | 184 | 32 | | 216 | 252 |
| 142 | 289 | 2 Carp | 1900 | 0.008 | S.F. | 0 | 0.34 | | 1 | 1 |
| 143 | 282 | 2 Carp | 310 | 0.052 | S.F. | 1 | 2.06 | | 3 | 4 |
| 144 | 293 | D-7 | 82 | 0.195 | L.F. | 5 | 6.65 | | 12 | 15 |
| 145 | 295 | 1 Carp | 625 | 0.013 | S.F. | 1 | 0.51 | | 1 | 2 |
| 146 | 298 | D-7 | 60 | 0.267 | S.F. | 11 | 9.1 | | 20 | 26 |
| 147 | 317 | 1 Pord | 10 | 0.8 | Ea. | 4 | 28 | | 32 | 46 |
| 148 | 327 | 2 Carp | 8 | 2 | Ea. | 1825 | 80 | | 1905 | 2150 |
| 149 | 331 | 2 Carp | 7 | 2.286 | Ea. | 595 | 91.5 | | 687 | 795 |
| 150 | 335 | 2 Shee | 5 | 3.2 | Ea. | 905 | 151 | | 1056 | 1225 |
| 151 | 276 | 1 Carp | 38 | 0.211 | Ea. | 11 | 8.4 | | 19 | 25 |
| 152 | 339 | 1 Sswk | 80 | 0.1 | L.F. | 18 | 4.47 | | 23 | 28 |
| 154 | 341 | 1 Bric | 8 | 1 | Ea. | 52 | 40.5 | | 93 | 119 |
| 155 | 343 | 2 Carp | 1.3 | 12.308 | Ea. | 1125 | 490 | | 1615 | 2000 |
| 156 | 329 | 2 Carp | 3 | 5.333 | Ea. | 242 | 213 | | 455 | 595 |
| 157 | 337 | 2 Carp | 100 | 0.16 | L.F. | 106 | 6.4 | | 112 | 126 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 158 | 340 | 1 Carp | 13 | 0.615 | Ea. | 41 | 24.5 | | 66 | 84 |
| 159 | 351 | 3 Carp | 0.5 | 48 | Ea. | 7275 | 1925 | | 9200 | 11000 |
| 160 | 424 | 2 Elev | 0.75 | 21.333 | Ea. | 2925 | 1200 | | 4125 | 5025 |
| 161 | 424 | 2 Elev | 0.13 | 123 | Ea. | 7375 | 6975 | | 14350 | 18500 |
| 162 | 424 | 2 Elev | 0.05 | 320 | Ea. | 99500 | 18100 | | 117600 | 136500 |
| 164 | 429 | M-1 | 6.5 | 4.923 | L.F. | 850 | 265 | 8.75 | 1124 | 1350 |
| 165 | 429 | M-1 | 5.27 | 6.072 | L.F. | 1575 | 325 | 10.8 | 1911 | 2225 |
| 169 | 430 | 2 Shee | 3.5 | 4.571 | Floor | 1100 | 216 | | 1316 | 1550 |
| 170 | 430 | 2 Shee | 3.5 | 4.571 | Floor | 2350 | 216 | | 2566 | 2900 |
| 171 | 431 | 2 Stpi | 0.12 | 133 | Total | 6600 | 6575 | | 13175 | 17100 |
| 172 | 431 | 2 Stpi | 37.6 | 0.426 | L.F. | 25 | 21 | | 46 | 59 |
| 173 | 642 | E-4 | 3400 | 0.009 | Lb. | 1 | 0.43 | 0.04 | 2 | 2 |
| 174 | 453 | 1 Stpi | 24 | 0.333 | Ea. | 58 | 16.45 | | 74 | 88 |
| 175 | 470 | Q-1 | 70 | 0.229 | L.F. | 35 | 10.05 | | 45 | 53 |
| 176 | 449 | Q-15 | 93 | 0.172 | L.F. | 4 | 7.55 | 0.6 | 12 | 17 |
| 177 | 449 | 1 Plum | 71 | 0.113 | L.F. | 4 | 5.5 | | 9 | 12 |
| 178 | 441 | 1 Plum | 24 | 0.333 | Ea. | 9 | 16.25 | | 25 | 34 |
| 179 | 462 | Q-1 | 4 | 4 | Ea. | 1800 | 176 | | 1976 | 2250 |
| 180 | 459 | 1 Plum | 14 | 0.571 | Ea. | 100 | 28 | | 428 | 480 |
| 181 | 482 | Q-1 | 16 | 1 | Ea. | 172 | 44 | | 216 | 255 |
| 182 | 459 | Q-1 | 1.2 | 13.333 | Ea. | 3600 | 585 | | 4185 | 4825 |
| 183 | 343 | Q-12 | 8 | 2 | Ea. | 124 | 86.5 | | 211 | 267 |
| 184 | 495 | Q-19 | 1 | 24 | Ea. | 5800 | 1075 | | 6875 | 8000 |
| 185 | 505 | Q-20 | 16 | 1.25 | Ea. | 705 | 54 | | 759 | 860 |
| 186 | 483 | Q-10 | 75 | 0.32 | Lb. | 4 | 14.1 | | 18 | 26 |
| 187 | 518 | 1 Elec | 100 | 0.08 | L.F. | 2 | 3.76 | | 6 | 8 |
| 188 | 521 | 1 Elec | 270 | 0.03 | L.F. | 1 | 1.39 | | 2 | 3 |
| 189 | 521 | 2 Elec | 40 | 0.4 | L.F. | 104 | 18.8 | | 123 | 143 |

| | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| 190 | 517 | 1 Elec | 9 | 0.889 | C.L.F | 28 | 42 | | 70 | 92 |
| 191 | 515 | 1 Elec | 260 | 0.031 | Ea. | 0 | 1.45 | | 2 | 2 |
| 192 | 519 | 1 Elec | 8 | 1 | Ea. | 13 | 47 | | 60 | 84 |
| 193 | 534 | 1 Elec | 40 | 0.2 | Ea. | 5 | 9.4 | | 15 | 20 |
| 194 | 529 | 2 Elec | 1 | 16 | Ea. | 4250 | 750 | | 5000 | 5800 |
| 195 | 528 | 1 Elec | 1 | 8 | Ea. | 875 | 375 | | 1250 | 1525 |
| 196 | 536 | R-3 | 0.83 | 24.096 | Ea. | 7700 | 1125 | 156 | 8981 | 10300 |
| 197 | 538 | 1 Elec | 5.7 | 1.404 | Ea. | 53 | 66 | | 119 | 156 |
| 198 | 630 | R-3 | 2.4 | 8.333 | Ea. | 385 | 385 | 54 | 824 | 1050 |
| 199 | 545 | 1 Elec | 8 | 1 | Ea. | 111 | 47 | | 158 | 192 |
| 200 | 523 | 1 Elec | 1.19 | 6.723 | Ea. | 585 | 315 | | 900 | 1100 |

# Appendix C

## Sample Appendix

| Act. | R.S. Means Building Construction Cost Data (Activity Description) | CSI Division |
|---|---|---|
| 1 | Forms in place, elevated slabs, flat plate to 15' high, 1use | Concrete |
| 2 | Forms in place, beams & girders, interior beams, 12" wide, 2 uses | Concrete |
| 3 | Forms in place, columns, round steel, 4 uses/mo, 12" diam | Concrete |
| 4 | Form in place, footing, spreading footing, 2 use | Concrete |
| 5 | Splicing reinforcement bars, column splice clamps, sleeve & wedge, or end bearing, #7 to #8 bars | Concrete |
| 6 | Stressing tendons, Pre stressing steel, post-tensioned in field, grouted bars, 50' span, 42 kips | Concrete |
| 7 | Placing concrete and vibrating, including labor & equipment, Elevated slabs, less than 6" thick, pumped | Concrete |
| 8 | Curing with waterproofing curing paper, 2 ply, reinforced | Concrete |
| 9 | Precast concrete, joists 40 psf, 12" deep for 24' spans | Concrete |
| 10 | Architectural precast, wall panel, high rise 4'x8' | Concrete |
| 11 | Tilt-up precast, column only, site precast, minimum | Concrete |
| 12 | lightweight concrete, concrete plank, lightweight, nailable, T&G, 2" thick | Concrete |
| 13 | Concrete Slab on Grade, 6" thick, 1000 sf, sand fill, per 3-5, p.1 | Concrete |
| 14 | Concrete Walls, Gang forming, 16" thick | Concrete |

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| 15 | Concrete Finish - float with bull float and machine | Concrete |
| 16 | Placing Concrete - Walls | Concrete |
| 17 | Cast in place concrete, wall pour 03300-03310-56300 | Concrete |
| 18 | Sand blasting concrete | Concrete |
| 19 | Concrete Pour - Circular Column | Concrete |
| 20 | Wall Reinforcing #6 bars | Concrete |
| 21 | Steel Trowel Finish Concrete | Concrete |
| 22 | Form Walls - 9' to 17' high | Concrete |
| 23 | Escalators, per single unit, minimum | Conveying |
| 24 | Conveyor, material Handling, horizontal belt, center drive and takeup | Conveying |
| 25 | Commercial steel doors, flush, full panel, hollow metal, 1-3/8", 20 ga, 3'x7' | Doors, windows |
| 26 | Pre-hung doors, ext, wood, combi storms & screen, 6' 9"x2' 6" wide | Doors, windows |
| 27 | Roll-up grille, aluminium, manual uo, mill finish | Doors, windows |
| 28 | Sliding doors, Glass, sliding, vinyl clad, 1" insulated glass, 6'-0"x6'-10" | Doors, windows |
| 29 | Sliding doors, Steel, sliding, up to 50'x18', electric, standard duty, | Doors, windows |
| 30 | Multileaf vertical lift doors, Vertical lift, doors, motor operator, incl. | Doors, windows |
| 31 | Aluminum windows, projected, with screen, 3'-1" x 3"-2" opening | Doors, windows |

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| 32 | Weather strippring/seals, Weatherstripping, windows, double hung, 3'x5', zinc | Doors, windows & glass |
| 33 | Insulating glass, 2 lites, 1/8" float, 1/2" thick under 15SF, clear | Doors, windows & glass |
| 34 | Glass, Spandrel glass 1/4" thick, standard colors, over 2000sf | Doors, windows & glass |
| 35 | Glazed curtain wall, Curtain wall, aluminium, stock, incling glazing, minimum | Doors, windows & glass |
| 36 | 1-1/2 hour. "B" label fire door, 3/0x6/8, per 8-4, p.2 | Doors, windows & glass |
| 37 | Double Hung Window Enclosure, 20"x20" | Doors, windows & glass |
| 38 | Door - 3/8" glass w/frame and hardware | Doors, windows & glass |
| 39 | Window, Aluminum, Casement, 5'-9"x3'-3" | Doors, windows & glass |
| 40 | Glass plate, clear, 1/4" | Doors, windows & glass |
| 41 | Aluminum Doors, Lightweight, double action, clad w/ hardware | Doors, windows & glass |
| 42 | Electrical - Wire, 600 Volt type THW, copper, solid, Stranded #10 | Electrical |
| 43 | Conduits in trench includes terminations & fittings (do not include exc. Or backfill) rigid galv. Steel 2" diam | Electrical |
| 44 | PVC Conduit, 1", per 16-2, p.3 | Electrical |
| 45 | Conduit Systems, Utility Box, per 16-1, p.9 | Electrical |
| 46 | Armored Cable, 3 #4 Conductors & 1 #8 Ground, per 16-22, p.1 | Electrical |
| 47 | Distribution Transformers, 3-phase, dry type, 300 KVA, per 16-42, p.1 | Electrical |
| 48 | 4" Rigid steel, Electrical Conduit installed outside a building, per 16-4, p.1 | Electrical |

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| 49 | Electrical, straight 12" wide cable tray | Electrical |
| 50 | 1'x4', 2 lamp, Recessed fixed fluorescent lighting | Electrical |
| 51 | Aluminum Conduit Exposed, Based on 100' Run with Fittings and Hangers - 2" | Electrical |
| 52 | Electrical Copper Wire | Electrical |
| 53 | Aluminum Cable Tray - 6" | Electrical |
| 54 | Electrical - Wire Connectors - Terminal Lugs - #8 | Electrical |
| 55 | Interior Lighting Fixtures, Fluorescent, C.W. lamps, troffer, recess mounted in grid, 1'wx4'L | Electrical |
| 56 | Furring & lathing, Furring, walls, galvanized, 3/4" channel, 12" OC | Finishes |
| 57 | Gypsum plaster, 2 coats on and incl. 3/8" gypsum lath on steel, on walls | Finishes |
| 58 | Gypsum board systems, drywall, gypsum plasterboard, nailed or screwed to studs, 1/2" thick, on walls, standard, no finish included | Finishes |
| 59 | Quarry tile, base, cove or sanitary, 2" or 5" high, mud set, wainslot 6"x6"x1/2", thin set, red | Finishes |
| 60 | Acoustical insulation, Sound attenuation, blancket 1" thick | Finishes |
| 61 | Wood strip flooring, woode flr, vertical grain, 1"x4", not incl. Finish. B & better | Finishes |
| 62 | Sheet carpet, carpet commercial grades, direct cement, nylon, level loop 26oz, ligth to med traffic | Finishes |
| 63 | Epoxy-marble flooring, Composition flooring epoxy terrazzo, 1/4" thick, chemical resistant, minimum | Finishes |
| 64 | Exterior painting walls, masonry (CMU), smooth surface, brushwork, latex, first coat | Finishes |
| 65 | Interior painting, walls and ceiling, concrete, dry wall or plaster, oil base, primer coat, roller | Finishes |

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| 66 | Wallpaper, wall covering, cork wallpaper, paperbacked, natural | Finishes |
| 67 | Painting, Spray, Interior Concrete Walls, per 9-20, p.1 | Finishes |
| 68 | Wall Paper, Medium Quality, per 9-30, p.1 | Finishes |
| 69 | Gypsum Wallboard, Dry Wall, 1/2" Range Type, Screwed on Metal Studs, per 9-3, p.1 | Finishes |
| 70 | Terrazo Flooring, 2" Cement Terrazo Bonded to Concrete, per 9-11, p.4 | Finishes |
| 71 | Wall - Interior Painting - 2 coats | Finishes |
| 72 | Aluminum Downspouts | Finishes |
| 73 | Gypsum Drywall, including taping - 1/2" | Finishes |
| 74 | Vinyl Wall Covering, 15 oz. | Finishes |
| 75 | Acoustical Tile, Glued, 12"x12", Mineral Fiber | Finishes |
| 76 | Aluminum Strip Siding | Finishes |
| 77 | Wall Papering | Finishes |
| 78 | Veneer, Limestone, 4", sandrub | Finishes |
| 79 | Acoustical Tile 2'x2'x5/8", Mineral Fiber | Finishes |
| 80 | Mortar, grouting, bond bms & lintels, 8" deep, pumped not included, 8" thick, 0.2C.F. per L.F. | Masonry |
| 81 | Masonry accessories, anchor bolts, hooked type with nut, 5/8" diam, 8" long | Masonry |
| 82 | Brick masonry, wall brick, including mortar, 3% brick waste 25% mortar waste, cmmon, 8"x2-2/3"x4", 4" wall, face brick | Masonry |

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| 83 | Brick masonry, coping for 12" wall, stock units, aluminium | Masonry |
| 84 | Sand blast, building face, wet system, minimum | Masonry |
| 85 | Window sill, bluestone, natural cleft, 12" wide, 1.1/2" thick | Masonry |
| 86 | Masonry: Common, 4"x2-2/3"x8", 4" wall, face brick | Masonry |
| 87 | Sanstone or brownstone, sawed face veneer, 2-1/2" thick, to 2'x4' panels | Masonry |
| 88 | Marble, window stools, polished, 7/8" thick, 5" wide | Masonry |
| 89 | Sandstone Veneer, 2'x4', 2" Thick | Masonry |
| 90 | Flue lining, square, including mortar joints, 8"x8" | Masonry |
| 91 | Fireplace for prefabricated fireplace, 30"x24" opening, plain brickwork | Masonry |
| 92 | 4"x12", 100 sf of Brick Masonry Wall, per ASTM C-214 | Masonry |
| 93 | Concrete Block Masonry Walls using 6"x8"x16" block, per 4-1, p.1 | Masonry |
| 94 | Partition Concrete Block - 6" Masonry | Masonry |
| 95 | Furring, on masonry, 1"x3", 12" OC | Masonry |
| 96 | Plastic pipe, fiberglass reinforced, coupling 10' O.C., hanger 3 per 10', high strength, 2" diam | Mechanical |
| 97 | Boiler, oil fired, standard controls, flame retention barrier, cast iron, with insulated flush jacket, 109MBH | Mechanical |
| 98 | Fan coil air conditioning, cabinet mounted, filters, controls chilled water, 3 ton cooling | Mechanical |
| 99 | Ductile Iron Pressure Pipe, 10" dia., per 2-39, p.1 | Mechanical |

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| 100 | Water Chillers, 20 ton, reciprocating water chillers, per 15-1, p.1 | Mechanical |
| 101 | Gas fired boiler, cast-iron, 46.1 MBH, per 15-6, p.2 | Mechanical |
| 102 | A-120 steel piping installed outside a building, 4", per 15-33, p.1 | Mechanical |
| 103 | Pipe Hangers, Insulated A-2 thru G-5 (7/8"), per 15-76, p. 35 | Mechanical |
| 104 | Welded Pipe, p. 15-43, p.29 - Field Erection Joint Butt Welds, A-53 Carbon Steel, 20' lengths, 6", Sch 40, 0.280" wall thickness | Mechanical |
| 105 | Black Steel Pipe - Sch 40 - plain end, w/ weld fittings and hangers and valves | Mechanical |
| 106 | 2" Ball Valve, Bronze | Mechanical |
| 107 | 1/2" Fiberglass Pipe Insulation for 6" dia. Pipe | Mechanical |
| 108 | 500 CFM, Return Air Fan | Mechanical |
| 109 | Black Steel Pipe - w/cast iron fittings and hangers - 5", threaded & couple | Mechanical |
| 110 | Welded shear connectors, 3/4" diameter, 3-3/16" long | Metals |
| 111 | Curb edging, steel angle w/anchors on forms, 1"x1", 0.8#/LF | Metals |
| 112 | Welding, continuous fillet, stick welding, incl. Equip., single pass, 1/8" thick, 0.1#/LF | Metals |
| 113 | Bracing, let-in, T-shaped, 20 ga, galvanized steel, studs at 16" OC | Metals |
| 114 | Columns, aluminium, extruded, stock units, 6" diameter | Metals |
| 115 | Structural steel projects, power stations, fossil fuels, minimum | Metals |
| 116 | Structural steel projects, paints and protective coatings, sprayed, zinc rich primers, self cure, spray, inorganic | Metals |

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| 117 | Metal decking, steel deck, cellular units, galvanized, 2" deep, 20-20 gauge aver 15 squares | Metals |
| 118 | Metal decking, open type, galvanized, 1.1/2" deep, 22 ga., under 50 square | Metals |
| 119 | Metal stair, stair, spiral, cast iron, 4'-0" diameter, ornamental, minimum | Metals |
| 120 | Railing, industrial, welded, 2 rail, 3'-6" high, 1-1/2" pipe | Metals |
| 121 | Floor grating, fiberglass, reinforced polyester, fire retardant, 1"x4" grid, 1" thick | Metals |
| 122 | 6" dia. Steel tube column, per 5-2, p.1 | Metals |
| 123 | Ledger Angles, 3"x3"x1/4", per 5-1, p.1 | Metals |
| 124 | QL-21 20 Ga. Steel Decking, per 5-7, p.3 | Metals |
| 125 | W18X55 Steel Girder, per 5-3, p.9 | Metals |
| 126 | Preformed Metal Roofing and Siding, 20 Ga, , per 7-7, p.2 | Metals |
| 127 | Steel Grating @ grade. Tack weld | Metals |
| 128 | Metal Decking, 1-1/2" thick, 20 ga, 05100-300-00300 | Metals |
| 129 | Aluminum Handrailing | Metals |
| 130 | 4" Steel Square Column | Metals |
| 131 | Building Insulation - Sprayed; Fibruous/cementitous, 3/4" thick | Moisture-thermal control |
| 132 | Sheet membrane, Membrane waterproofing, on slab, 1ply, felt | Moisture-thermal control |
| 133 | Building insulation, wall insulation, rigid, fiberglass 3#/CF, unfaced, 1" thick | Moisture-thermal control |

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| 134 | Fireproofing, sprayed, mineral fiber or cementitious for fireproofing, not incl. Tamping or canvas protection, 1" thick, on flat plate steel | Moisture-thermal control |
| 135 | Roofing tile, clay tile ASTM C1167, gr1, severe weathering | Moisture-thermal control |
| 136 | Shingles, Asphalt shingles, standard strip shingles, inorganic class A, 210-235 lb/square, 3 bundles/square | Moisture-thermal control |
| 137 | Roofing tile, Concrete tile, inclunding installation of accessories, corrugated, 13"x16-1/2", 90 per sq., 950 lb per sq, earthtone color, nailed to wood deck | Moisture-thermal control |
| 138 | Preformed panels, Aluminium roofing, corrugated or ribbed, .0155" thick, natural | Moisture-thermal control |
| 139 | Composite panels, Exposed aggregate panels, polymer concrete matrix, 1/4" thick, small size agg. | Moisture-thermal control |
| 140 | Cladding/siding, Wood product siding, siding, hardboard, 7/18" thick, prime painted, lap, plain or grooved finish | Moisture-thermal control |
| 141 | Fiberglass, corrugated panels, roofing, 8 oz per SF | Moisture-thermal control |
| 142 | Sheet mtl flash & trim, Gutters aluminium, stock units, 5" box, .027" thick, plain | Moisture-thermal control |
| 143 | Roof accessories, Ceiling hatches, 2'-6"x2'-6", single leaf, steel frame & cover | Moisture-thermal control |
| 144 | Moisture Barriers and Pageting, 1 Coat, 1/4" thick, per 7-2, p.6 | Moisture-thermal control |
| 145 | Caulking using a one component butyl caulking material, per 7-13, p.1 | Moisture-thermal control |
| 146 | Blown Insulation - 6" Mineral Wool | Moisture-thermal control |
| 147 | Damp proofing, Asphalt - sprayed, 2 coat | Moisture-thermal control |
| 148 | Building demolition, concrete. | Sitework |
| 149 | Clearing brush by hand | Sitework |
| 150 | Dewatering, Excavate drainage trench, 2' wide, 3' deep, with backhoe loader | Sitework |

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| 151 | Backfill by hand, no compaction, light soil | Sitework |
| 152 | Dozer backfilling, bulk, up to 300' haul, no compaction | Sitework |
| 153 | Compaction, structural, sheepsfoot or wobbly wheel roller, 8" lifts, common fill | Sitework |
| 154 | Drilling and blasting only, rock, open face, over 1500CY | Sitework |
| 155 | Excavating trench by hand with pick and shovel, 2' to 6' deep, heavy soil | Sitework |
| 156 | Horizontal boring, casing only, 100' minimum, railroad work, 24" diameter | Sitework |
| 157 | Retaining walls, concrete gravity wall with vertical face including excavation & backfill, 6' high, level embankment | Sitework |
| 158 | Driven piles, steel, not including mobilization or demobilization, Step tapered, round, concrete filled, 8"tip, 60 ton capacity, 30' depth | Sitework |
| 159 | Concrete pavement, including joints, finishing and curing; fixed formed, 12' pass, reinforced, 6" thick | Sitework |
| 160 | Clear and Grubbing: Remove grass and shrubs: Group 2, per 2-1, p.3 | Sitework |
| 161 | Topsoil Replacing: Group 5, per 2-2, p.2 | Sitework |
| 162 | Site Grading, filling and compacting, 1000' run, class 4 material, per 2-7, p.3 | Sitework |
| 163 | Structurall Excavation - CAT 235 Backhoe, Class 1,A material, per 2-16, p.5 | Sitework |
| 164 | Structurall Excavation Rock - per 2-19, p.1 | Sitework |
| 165 | Asphalt Concrete Paving and Base Materials , 4" Asphalt Concrete, 6" Cement Base, 10" Agg. Base, per 2-43, p.8 | Sitework |
| 166 | 30" RCP, 1000' of ASTM C-76, per 2-33, p.2 | Sitework |
| 167 | trenching, 6'-0" deep, 18" wide, per 2-17, p.4 | Sitework |

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| 168 | structural excavation in class "A" material, CAT 235 Backhoe; per 2-16, p.2 | Sitework |
| 169 | Steel 'H' piling, HP 8x36 | Sitework |
| 170 | 3" ABC Plastic Roof Drains w/ assembly for 12" roof, per 15-31, p.1 | Sitework |
| 171 | Demolition - Remove, wood building | Sitework |
| 172 | Steel "H" 8" piling, 36#, 02360-00300 | Sitework |
| 173 | Remove Slab Concrete - on grade, w/mesh, 6" thick | Sitework |
| 174 | Paving, Bituminous, One Course, 2" | Sitework |
| 175 | 6" Chain Link Fence | Sitework |
| 176 | 18" Reinforced Concrete Pipe | Sitework |
| 177 | Rough Site Grading | Sitework |
| 178 | Porous Fill Underslabs, 6" | Sitework |
| 179 | Wall & corner guards, Corner guards, steel angle w/anchors, 1"x1"x1/4", 1.5#/LF | Specialties |
| 180 | Prefabricated fireplaces, simaluted brick chimney top, 4' high, 16"x16" | Specialties |
| 181 | Ground set flagpoles, Flagpole, not including base or foundation, aluminium, tapered, ground set 20' high | Specialties |
| 182 | Canopies, wall hung, aluminium, prefinished, 8'x10' | Specialties |
| 183 | Urinal, Single Fixture and Trim, per 15-16, p.3 | Specialties |
| 184 | Framing, beams & girders 2"x6", pneumatic nailed | Wood & Plastic |

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| 185 | Glue laminated construction, laminated framing, straight roof beams, 20' clear span, beams 8' OC | Wood & Plastic |
| 186 | Wood framing, bridging wood, for joists 16" O.C., 1"x3" | Wood & Plastic |
| 187 | Sheating, plywood on roof, CDX, 5/16" thick. | Wood & Plastic |
| 188 | Structural panels, Stuned skin plywood roof panel, 3/8" group 1 top, skin, 3/8" exterior AD bottom skin, 1150f stringers, 4'x8' panels, 4.1/4" deep | Wood & Plastic |
| 189 | Millwork moldings, window & door, door moldings, stock, decorative, 1-1/8" wide, plain | Wood & Plastic |
| 190 | Interior Wood Partitions, per 6-2, p.1, 2x3, Concrete floors w/ drive pins, studs, and plate size | Wood & Plastic |
| 191 | Glue Laminated Beams, 3-1/8"x15", 24' long, per 6-7, p.2, Nailed | Wood & Plastic |
| 192 | Gang nail trusses and pitched roof framing, per 6-8, p.3, 2"x4", 20' long | Wood & Plastic |
| 193 | Plywood sheathing, 1000 sf of subflooring, per 6-11, p.1 | Wood & Plastic |
| 194 | Wood wall and partition framing | Wood & Plastic |
| 195 | Wood floor, flat roof joists, 3"x6", per 6-5, p.2 | Wood & Plastic |
| 196 | Wood Framing - Joists 2"x8" | Wood & Plastic |
| 197 | 1/2" Plywood Sheathing Walls | Wood & Plastic |
| 198 | Wood Paneling - Average, 1/4" Thick | Wood & Plastic |
| 199 | Wood Decking - Cedar Plank - 3" | Wood & Plastic |
| 200 | 2"x6" Wood Rafter | Wood & Plastic |

# Bibliography


Abdel-Wahab, M. S., Dainty, A. R. J., Ison, S. G., Bowen, P., & Hazlehurst, G. (2008). Trends of skills and productivity in the UK construction industry. *Engineering, Construction and Architectural Management, 15*(4), 372-382. doi:10.1108/09699980810886865

Allen, S. G. (1985). Why construction industry productivity is declining?, 661-665.

Allmon, E., Haas, C. T., Borcherding, J. D., & Goodrum, P. M. (2000). U.S. construction labor productivity trends, 1970-1998. *Journal of Construction Engineering and Management, 126*(2), 97-104. doi:10.1061/(ASCE)0733-9364(2000)126:2(97)

Bernstein, H. M. (2003). Measuring productivity : An industry challenge. *73*(0885-7024), 46-53.

Eastman, C. M., & Sacks, R. (2008). Relative productivity in the AEC industries in the united states for on-site and off-site activities. *Journal of Construction Engineering and Management, 134*(7), 517-526. doi:10.1061/(ASCE)0733-9364(2008)134:7(517)

Finkel, G. (1997). *The economics of the construction industry*. New York: M.E. Sharpe, Inc.,Armonk, New York.

Goodrum, P. (2009). *Technical change and its impact on construction productivity.* (Academic No. 1). Washington, D.C.: Advancing the Competitiveness and Efficiency of the U.S Construction Industry.

Goodrum, P. M., & Haas, C. T. (2004). Long-term impact of equipment technology on labor productivity in the U.S. construction industry at the activity level. *Journal of Construction Engineering and Management, 130*(1), 124-133. doi:10.1061/(ASCE)0733-9364(2004)130:1(124)

Goodrum, P. M., Haas, C. T., & Glover, R. W. (2002). The divergence in aggregate and activity estimates of US construction productivity. *Construction Management and Economics, 20*(5), 415-423. doi:10.1080/01446190210145868

Greenwood, J. (1997). The third Industrial revolution: Technology, productivity, and income inequality.

Haas, C. (2009). *An international prospective on construction competitiveness and productivity.* (Academic Research No. 1). Washington, D.C.: Advancing the Competitiveness and Efficiency of.

Harrison, P. (2007). *Can measurement error explain the weekness of productivity growth in the canadian construction industry?* (Research No. 2007-01).Center for the Study of Living Standards for the Construction Sector Council.

Harvey M. Bernstein, Andrew C. Lemer. (1996). *Solving the innovation puzzle: Challenges facing the U.S. design & construction industry*. New York: New York, NY: ASCE Press.

Liao, P. -., Thomas, S. R., O'Brien, W. J., Mulva, S. P., & Dai, J. (2009). Development of project level engineering productivity benchmarking index. *2009 Construction Research Congress - Building a Sustainable Future,* Seattle, WA. 1087-1095. doi:10.1061/41020(339)110

Park, H. -., Thomas, S. R., & Tucker, R. L. (2005). Benchmarking of construction productivity. *Journal of Construction Engineering and Management, 131*(7), 772-778. doi:10.1061/(ASCE)0733-9364(2005)131:7(772)

Paul McGinley Goodrum. (2001). *The impact of equipment technology on productivity in the U.S. construction industry.* (Doctor of Philosophy, The University of Texas at Austin).

Pieper, P. (1990). *Construction price statistics.* No. 1). Cambridge, Massachusetts: Technology and Capital Formation.

R.S. Means Company, I. (1995). *Building construction cost data*

R.S. Means Company, I. (2009). In Phillip R. Waier (Ed.), *Building construction cost data*

Rojas, E. M., & Aramvareekul, P. (2003a). Is construction labor productivity really declining? *Journal of Construction Engineering and Management, 129*(1), 41-46. doi:10.1061/(ASCE)0733-9364(2003)129:1(41)

Rojas, E. M., & Aramvareekul, P. (2003b). Labor productivity drivers and opportunities in the construction industry. *Journal of Management in Engineering, 19*(2), 78-82. doi:10.1061/(ASCE)0742-597X(2003)19:2(78)

Teicholz, P. (2000.). *Productivity trends in the construction industry.*Presentation to the 2000 AISC Annual Convention.

Thomas, H., Maloney, W., Horner, R., Smith, G., Handa, V., & Sanders, S. (1990). Modeling construction labor productivity., 705-726.

Thomas, H., & Yiakoumis, I. (1987). Factor model of construction productivity. *113(4)*, 624-644.

Zhai, D., Goodrum, P. M., Haas, C. T., & Caldas, C. H. (2009). Relationship between automation and integration of construction information systems and labor productivity. *Journal of Construction Engineering and Management, 135*(8), 746-753. doi:10.1061/(ASCE)CO.1943-7862.0000024