



EFFECTS OF SCHEDULED OVERTIME ON LABOR PRODUCTIVITY: A QUANTITATIVE ANALYSIS

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The Construction Industry Institute
The University of Texas at Austin**

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Overtime Task Force**

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EXECUTIVE SUMMARY

Scheduled overtime has been a controversial subject since the mid-1960s. In the early 1970s, the Business Roundtable (BRT) published a report on the effects of scheduled overtime. The BRT report added to the controversy. The purpose of this report is to present the quantitative results of a study into the effects on labor productivity of scheduled overtime. This report is the most comprehensive study of overtime since the BRT report. It is based on 121 weeks of data from four active industrial construction projects. Major contract disputes were not involved in any project, and the labor environment was good. Both union and merit shop labor forces were included in the study. This report is a companion report to an earlier Construction Industry Institute report that surveyed the literature on scheduled overtime (Thomas et al. 1990 [SD-60]).

The initial investigation of overtime is the effect of the number of days worked per week on labor efficiency. Work weeks of 5 and 6 days show losses of efficiency of 12 and 14 percent, respectively. Next, the data is examined for the efficiency trend of working multiple weeks of overtime. The analysis shows that about 25 percent of the time efficiency is not impaired for durations of 2 to 4 weeks. However, on average, there is a likelihood of productivity degradation, even for 1- to 2-week periods. An average curve is calculated and compared to four curves from the literature showing efficiency versus multiple weeks of overtime. The results show that all curves, including the data from this study, are consistent. The conclusion is that the BRT curve is a reasonable average estimate of productivity losses caused by overtime. Since none of the projects in this study are severely impacted with schedule or labor problems, these curves likely represent a lower limit of the losses that can be anticipated. Poorly managed or executed projects will likely experience greater losses.

Efficiency losses are further investigated by examining the influence of disruptions. A normalized disruption frequency is calculated, and it is shown that as the disruption frequency increases, the efficiency decreases. This analysis establishes a causal relationship

between disruptions and efficiency losses. Three disruption categories are defined. Management and rework disruptions show mixed results. That is, there is no clearly established relationship between the disruption frequency and the number of days worked per week. Resource disruptions are defined as the lack of materials, tools, equipment, or information. The frequency of resource disruptions increases sharply for longer workweeks. For the 6-day workweek (60 hours per week), there is almost a three-fold increase in the resource disruption frequency compared to the 4-day workweek (40 hours per week). The conclusion is that working overtime efficiently is a resource management problem.

CHAPTER 1

INTRODUCTION

Scheduled overtime has been the subject of controversy since the Business Roundtable published its overtime study in the early 1970s. It was reissued again in 1983 as part of the Construction Industry Cost Effectiveness (CICE) project (BRT 1980). Some argue that scheduled overtime can be utilized without losing labor efficiency, while others argue that when an overtime schedule is applied, labor efficiency suffers. There are numerous disagreements about the extent of inefficiencies and misunderstandings regarding how overtime schedules affect labor output.

OBJECTIVES

The objectives of this report are:

- To document a procedure for data collection and processing and an analysis methodology that can be used to quantify the effects of scheduled overtime on labor efficiency.
- To detail the results of a study to measure the effects of scheduled overtime on labor efficiency.
- To describe a model explaining how scheduled overtime affects labor productivity. This model can be used as an aid in planning an overtime schedule.

SCOPE

The general scope of this project was on real-time data collection from active construction projects. The focus was on detailed observations of piping and electrical crews, rather than on various crafts. Bulk installations were measured during the early to mid time frame of commodity installations. The projects were completed in a tranquil labor environment. The focus was on labor efficiency, not cost. No significant claims resulted from any of the projects. In these ways, this study differs significantly from previous studies.

BACKGROUND

A literature review and analysis was prepared on scheduled overtime (Thomas et al. 1990). It shows that the literature is very sparse, dated to the late 1960s and earlier, based on small sample sizes, and largely developed from questionable or unknown sources. While there appears to be a number of data sources, this is an illusion because many of the articles and publications quote other sources while providing no new data or insight. Where the data source is known, other pertinent information—such as environmental conditions, quality of management and supervision, and labor situation—is often unknown. The various graphs and data suggest an upper bound on losses of efficiency that might be expected. The literature offers no guidance as to what circumstances may lead to losses of efficiency.

With respect to losses of efficiency as a function of the number of hours per day and number of days per week, the literature often provides strange and unbelievable results. Several studies show that efficiency is not related to the number of hours per day or the number of workdays per week. Since it is not possible to increase the total hours per week in any other way, it is concluded that these studies are flawed.

DEFINITIONS

In this report, the following definitions are used.

Conversion Factors (CF)—The ratio of unit rates based on the earned value concept used to convert quantities of one or more items to equivalent quantities of a standard item.

Disruption—An event that is known or has been reported in the literature to adversely affect labor productivity. Examples include lack of materials, tools, or equipment; congestion; and accidents.

Weekly Disruption Frequency—The number of weekly disruptions per 100 hours worked.

Disruption Index (DI)—The ratio of the performance factor on days when a certain type of disruption occurs divided by the average performance factor on days when no disruption occurs. The index shows the level to which performance and output is reduced because of a particular type of disruption.

Earned Value—This technique is used for calculating the percent complete of a control account. It is a weighted average approach in which the weight assigned to each individual account in the control account is based on the initial workhour estimate for the account compared to the sum of the initial estimated workhours for all accounts included in the control account.

Efficiency—The relative loss of productivity or reduction in performance compared to a baseline period. A value less than unity means less than normal.

Performance Factor (PF)—The ratio of the expected or baseline unit rate divided by the actual unit rate. It is defined such that values greater than unity mean that performance is better than expected.

Productivity—This parameter is defined as the workhours during a specified time frame divided by the quantities installed during the same time frame. The time frame can be daily, weekly, or the entire project duration (cumulative). The workhours per unit is commonly called the unit rate.

Scheduled Overtime—A work schedule that extends more than 40 hours per week. The schedule is planned in advance.

CHAPTER 2

CONCEPTUAL IMPACT ON LABOR PRODUCTIVITY

The overtime environment is greatly misunderstood by many professionals, especially those not familiar with the details of executing a construction contract. This chapter explains a model that aids in the understanding of the construction environment.

BACKGROUND

Prior research has identified that in ordinary situations there are two major factors affecting site labor productivity: *organizational continuity* and *executional continuity* (United Nations 1965). *Organizational continuity* refers to the work that needs to be done and encompasses the physical components of the work, specification requirements, design details, and so forth. *Executional continuity* refers to the work environment and how well the job is planned, organized, managed, and executed. Management aspects covered in this category include weather, material and equipment availability, congestion, out-of-sequence work, etc.

Others have tried to develop models of labor productivity. Unfortunately, these models are often based on erroneous concepts borrowed from industrial engineering (Thomas et al. 1990) or are too complicated to be useful (Brown—Frisby). None of these models have been validated with data.

The conclusions of the United Nations report have been validated by research done at The Pennsylvania State University (Thomas et al. 1989). This research has led to the development of the Factor Model.

FACTOR MODEL

The Factor Model is so named because it is based on the factors that affect labor productivity. A conceptual representation is shown in figure 1. The flow of inputs and outputs is comparable to a pipeline. The work to be done and the work environment are analogous to catalysts in the form of information, resources, and conditions needed to efficiently convert workhours into outputs. Where these are deficient, as would be the case if, say, materials or equipment were not available, inputs cannot be efficiently converted to outputs.

Another element of the Factor Model that is not shown is the ripple effect. This occurs when the project conditions have deteriorated to the point where work on an activity is adversely affected by another activity or by the general deterioration of the site environment. No research has been conducted to measure the ripple effect, although it has been acknowledged quite often by construction professionals. Furthermore, defining when the ripple effect applies is often limited to a post-project analysis.

ORDER OF MAGNITUDE OF IMPACTS

Current practice is reasonably well developed to estimate the added labor hours for the work to be done. Contractor databases that rely on historical information can generally isolate the differences in pipe sizes, design details, or changes in specification or quality requirements. Perhaps the most uncertainty arises when the work scope is affected, as would be the case when a change is added and the quantity of new work is not very large. Here, the startup and mobilization effort cannot be spread over a large scope of work.

Estimating practice can also handle changes in the work environment, although the basis of these estimates is often empirical. All large contractors have rules of thumb about inefficiencies when the work is to be done in winter, the work location is above ground, the work area is congested, or when the facility is in operation. Research has shown that the work environment can cause variations in unit data by as much as 4:1 (Thomas et al. 1989)

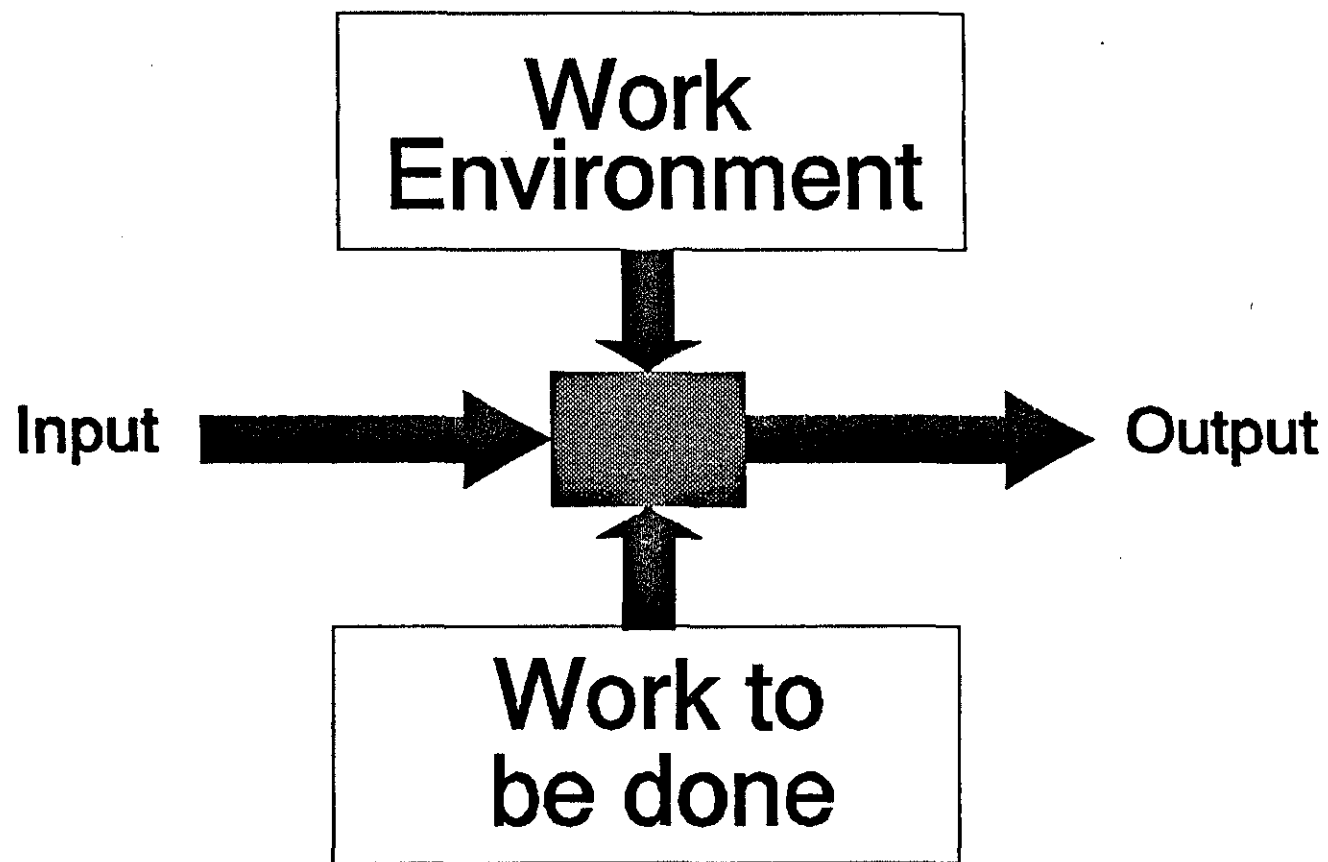


Figure 1. Conceptual representation of the Factor Model.

and in cumulative data by as much as 1.3:1 (Ginther 1994). The magnitude depends on many factors, such as the nature and severity of the condition. There are no firm guidelines for estimating the "markup" for less than satisfactory working conditions.

While much has been said about the ripple effect, there have been little or no quantitative studies showing the magnitude of these effects. Projects where the ripple effect occurs are often involved in litigation, therefore, data are not always available. However, studies at The Pennsylvania State University have documented impacts as high as 5:1 or more. While this figure seems quite large, one must remember that these are very unsatisfactory projects.

HOW OVERTIME AFFECTS LABOR PRODUCTIVITY

A detailed representation of the Factor Model is shown in figure 2. The work environment portion shows 10 variables that can be influential. While there can be many other variables, these 10 are the most common.

Overtime is an indirect factor and causes disruptions in the work environment. In extreme cases overtime can contribute to ripple effects. This is because the view is that **overtime (exclusive of fatigue) itself does not lead to productivity losses**. If it did, the losses would be automatic, which most professionals agree is not the case. Instead, a scheduled overtime situation causes other variables to be activated. Consider the following situation where project management decides to go from a work week consisting of 4 10-hour days to 6 10-hour days. The labor component is thus increased by 50 percent. What else happens? Does the work get finished 50 percent faster? To function efficiently, the entire system must respond to the increase in workhours. Materials must be made available 50 percent faster; equipment will be utilized 50 percent more, and the project staff must respond to 50 percent more questions. Everything is accelerated. **If a project is behind schedule because of one or more of the work environment factors in figure 2, an overtime schedule will only make matters worse.**

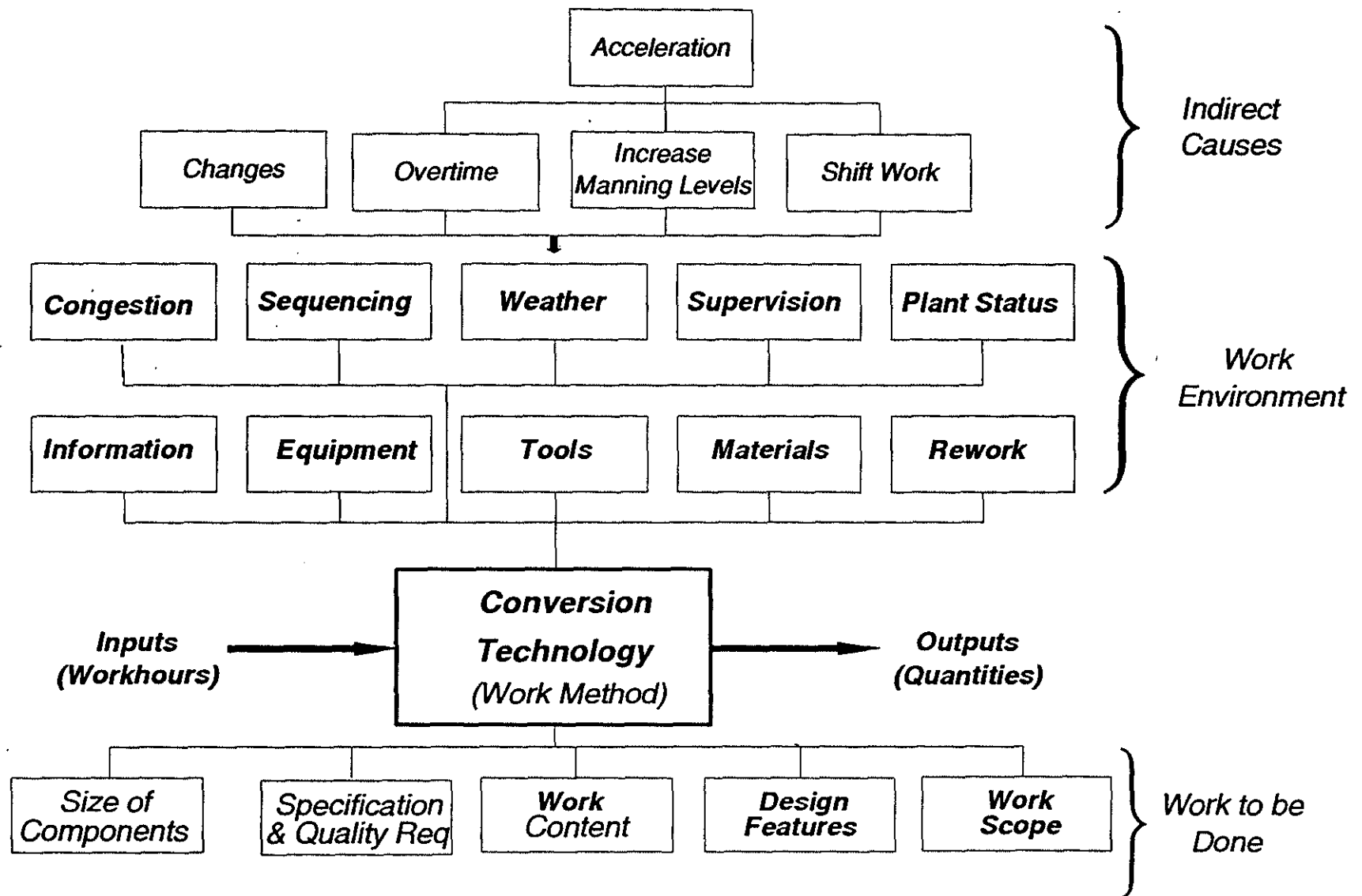


Figure 2. The Factor Model.

CHAPTER 3

OVERVIEW OF DATA COLLECTION AND PROCESSING

This chapter describes conceptually how the data were collected and processed. The detail should be sufficient to duplicate the study. Overall, the analysis process involves accounting for the influence of factors known to affect labor productivity. The process of standardizing the data is shown in figure 3. Each of these steps is briefly described below.

OVERALL ASPECTS OF THE STUDY

This study had several unique aspects that are different from most previous studies. These differences are summarized below.

The smallest manpower unit that produces completed output is the crew. Therefore, the focus is on an average crew. The study includes a crew of electricians and/or pipefitters from four active construction projects. The work of the crews involves bulk installations only, such as cable, conduit, and piping. The stage of construction can also affect labor productivity. The study specifically excludes the early phase of the work and the startup phase. Most previous studies have relied on cumulative productivity data. In this study, unit data are summarized daily and weekly. Cumulative data are also used.

DATA COLLECTION PHASE

Define Study Parameters

In this report, only the electrical and piping crafts are studied. The rationale is that these crafts represent the majority of the work, and they are the crafts most likely to be affected by scheduled overtime. The work performed by these crafts was further narrowed to crews performing production-related work. For electricians, production-related work involves the installation of conduit, cable and wire, terminations and splices, and junction

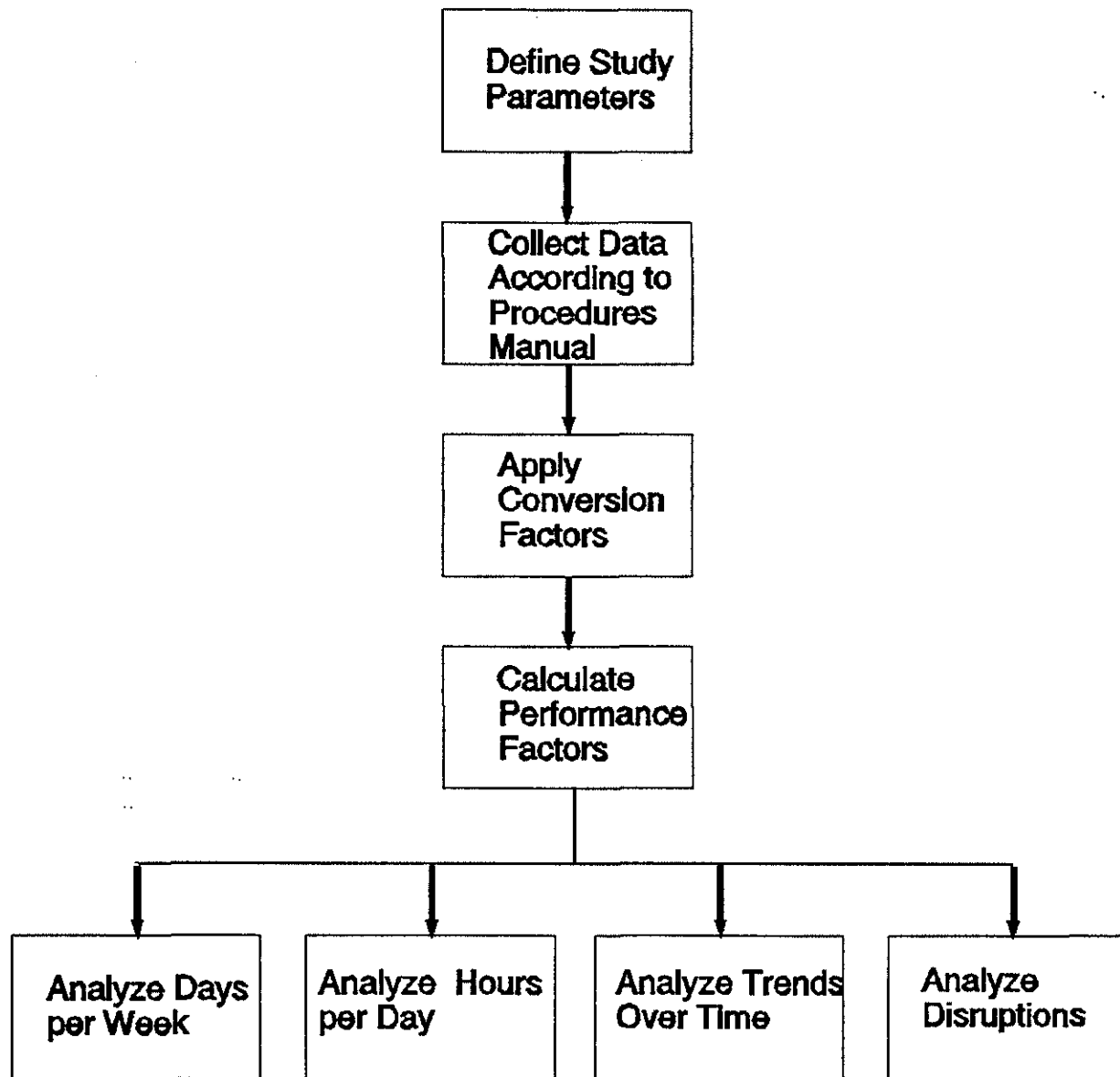


Figure 3. Data collection and analysis procedures.

boxes. For piping, work includes pipe erection and the installation of supports and valves. Crews performing other kinds of work were not considered for study.

Project selection is also an important element for removing other potential influences. The labor environment should be tranquil and there should not be an inordinate number of changes. Experimental, unique, or poorly managed projects should be avoided. In this study, each of these criteria was met. Further, the early phases and the startup phase were not included in the study.

The study duration was sufficient to include a straight-time and an overtime schedule. The performance of a crew on an overtime schedule was compared to the same crew on a straight-time schedule. In this study, a duration of 14 weeks was specified.

Project Descriptions

In this study, productivity data were collected from four active construction projects for the electrical and mechanical crafts as shown in table 1. There were a total of 151 weeks of data collected.

Table 1. Project features.

Crew No.	Description	Craft	No. of Weeks
9181	Process Plant	Mechanical	13
9182	Process Plant	Electrical	14
9183	Manufacturing	Electrical	11
9184	Manufacturing	Mechanical	12
9185	Paper Mill	Electrical	8
9186	Refinery	Mechanical	16
9187	Refinery	Mechanical	15
9188	Refinery	Mechanical	16
9189	Refinery	Mechanical	16
9190	Refinery	Mechanical	15
9191	Refinery	Mechanical	15

The projects were constructed in the 1989-1992 time frame. Each was constructed in a tranquil labor environment and was well managed. None experienced any unusual difficulties that would have caused it to fall behind schedule. Each project was completed in a timely fashion. The overtime schedule was used to maintain schedule, not to attract labor. The manufacturing and paper mill projects were existing facilities where old systems and equipment were removed and new ones installed. Congestion was a concern in each facility. The process plant was a spacious, outdoor, grass-roots facility, and the refinery involved the rebuilding of an existing facility. With respect to owner involvement, design, and construction management, the four projects were considered average industrial projects.