



AN ANALYSIS OF THE METHODS FOR MEASURING
CONSTRUCTION PRODUCTIVITY

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TABLE OF CONTENTS

	<u>Page</u>
CHAPTER I: INTRODUCTION	1
Introduction.	1
Objective	1
Scope of Work	2
Research Methodology.	2
Literature Review.	2
Interviews with Construction Industry Participants	3
CHAPTER II. PRODUCTIVITY MEASUREMENT.	4
Definition of Productivity	4
Productivity Measurement	4
Development of a Productivity Reporting System	5
Reporting of Measured Input and Output	8
Factors Affecting Productivity	11
CHAPTER III. MEASUREMENT OF OUTPUT.	13
Estimated Percent Complete Method	13
Determine the Number of Work Units	13
Estimate the Percentage of Work Units Completed	15
Determine the Number of Work Units Completed	16
Advantages and Disadvantages of the Estimated Percent Complete Method	16
Physical Measurement Method	16
Limitations of the Physical Measurement Method	18
Tracking System	18
Advantages and Disadvantages of the Physical Measurement Method.	20
Earned Value Method	22
Daily Quantity Report	22
Rules of Credit	25
Determination of the Earned Value Quantity	25
Advantage of the Earned Value Method	25
CHAPTER IV. MEASUREMENT OF INPUT.	29
Manhour Method	29
Daily Timesheets	31
Review Requirements	31
Dollar Method	31
Comparison of Manhour vs. Dollar Method	33
Classification of Input	35

CHAPTER V. PERFORMANCE EVALUATION	37
Performance Factors	37
Definition	37
Development of Performance Factors	38
Example of Performance Factor	40
Application of Performance Factors	40
Cost Factors	43
Input Utilization Techniques	44
Work Sampling	44
Delay Surveys and Questionnaires	46
CHAPTER VI. SUMMARY AND CONCLUSIONS	47
Summary	47
Conclusions	50
REFERENCES	53

LIST OF FIGURES

<u>Figure</u>		<u>Page</u>
1	Conceptual productivity measurement process.	6
2	Typical Work Breakdown Structure (WBS)	7
3	Level of detail of reporting as a function of job size	9
4	Frequency of reporting as a function of job size	10
5	Estimated Percent Complete method of measuring output	14
6	A typical detailed WBS structure for pipe fabrication.	19
7	Daily production report from a pipe fabrication shop showing quantities produced.	21
8	Earned Value method of measuring output	23
9	A typical daily quantity report form	24
10	A typical Earned Value report	27
11	Manhour method of measuring input	30
12	A typical foreman's daily timesheet.	32
13	Development of performance factors	39
14	Application of performance factors	42
15	Typical results of a work sampling study	45

LIST OF TABLES

<u>Table</u>		<u>Page</u>
1	Estimated Percent Complete method: example problem	17
2	Piping Rules of Credit	26
3	An evaluation of input required to make a 10-in. (25-cm) ϕ , CS, schedule 40 weld using the Manhour and Dollar methods. .	34
4	Approaches to the classification of work activities.	36
5	A typical manhour performance report	41

PREFACE

This report summarizes the state-of-the-art of productivity measurement systems used by owners and contractors involved in petrochemical and chemical processing construction projects. The report is intended to serve as a basis for establishing a standardized productivity measurement system. The frequency of reporting, level of detail, and techniques of performance evaluation and forecasting are addressed.

Within the construction industry there are many definitions of labor productivity. However, manhours per unit of work, i.e., input divided by output, is the most commonly used measure. Yet there are numerous terms used to describe this parameter. Some of the more often used terms include productivity, unit rate, performance factor, cost factor and production. Also, the definition of productivity is not standard. In addition to manhours per unit of work, some contractors and owners refer to productivity as the number of units of work per manhour. Others define productivity as the comparison of estimated to actual manhours per unit of work. To avoid confusion, this report establishes manhours per unit as the definition of productivity. The performance factor is the estimated productivity divided by the actual productivity, and a cost factor is the inverse of the performance factor. While some readers may disagree with the usage of these terms, they have been carefully selected because they are more widely used in the manner described in the report.

The state-of-the-art of productivity measurement systems is described based upon a study of the approach used by ten industrial owners and contractors. Additional companies were not studied because of the commonality found between the systems. While the state-of-the-art owners and contractors may argue that the report offers no new information, it nevertheless serves two useful purposes. First, it confirms previously unsupported speculation that the various systems are conceptually alike, notwithstanding the apparent definitional differences. Second, there are many contractors that do not use

state-of-the-art systems. These contractors are more likely to be found on future industrial projects where the contract size is smaller and where there is greater use of subcontractors. This report establishes a benchmark for evaluating these contractors.

H. Randolph Thomas, Jr.

CHAPTER I

INTRODUCTION

INTRODUCTION

It is widely accepted that productivity measurement plays an important role in the construction management process. Productivity measurement provides the necessary data for managers to control construction progress and estimate the cost of future construction projects.

It has been appropriately stated [1] that an accurate measurement of productivity provides construction managers with a means of controlling their project by:

1. Determining how effectively their projects are being managed
2. Determining adverse trends quickly so as to facilitate timely corrective action
3. Determining the effects of changed methods or conditions
4. Identifying the reasons for differences in productivity from one project to the next
5. Providing the means for assessing the effects of productivity improvement programs

Productivity measurement plays an equally important role in estimating the cost of future construction projects. The measurement of productivity from past jobs is probably the single best source of information for estimating future project costs.

OBJECTIVE

The objectives of this report are to determine the state-of-the-art of productivity measurement systems and to assess the feasibility of establishing a standardized method of productivity measurement for heavy industrial construction projects. This objective will be accomplished by identifying the common industry practices relative to the measurement of productivity. The methods used to track and account for resources, e.g., manpower and materials, will be documented. The frequency of reporting and level of detail are

important elements of this study. The techniques of performance evaluation and forecasting will also be evaluated.

SCOPE OF WORK

The scope of this study was limited to methods used to measure piping productivity. It is important to note that although the emphasis of this report is upon piping activities, the concepts are identical for all construction activities (concrete, electrical, etc.). Only the units of measurement are different. Additionally, the study was limited to microlevel productivity instead of macrolevel productivity measurements: the productivity measurements discussed in this report are microlevel measurements (manhours per linear foot) used by managers to control construction projects and to estimate future ones, rather than macrolevel industry-wide measurements like manhours per measure of plant capacity [2].

RESEARCH METHODOLOGY

The research methodologies used included the following:

1. Literature Review

- Books and Texts
- Trade Journals and Magazines
- Professional Society Transactions
- Government Documents

2. Interviews with Construction Industry Participants

- General Contractors
- Owners
- Specialty Contractors

Literature Review

A literature review was conducted using a computerized literature data base of recent texts, government documents, trade journals and magazines, and professional society transactions pertaining to methods of

productivity measurement. The results revealed that published texts and government documents were of little help. A review of the trade journals and magazines and professional society transactions yielded only a few papers of direct interest to this study.

Interviews with Construction Industry Participants

The most significant source of information pertaining to methods of measuring productivity in the construction industry was interviews and followup conversations with industrial owners and construction contractors. The interviews with these industry participants not only identified methods of measuring productivity, but provided in-depth details and procedures used in monitoring and forecasting productivity on industrial construction projects. The interviews were conducted with ten companies, of which five were client companies, two were general contractors, two were specialty contractors, and one was a pipe fabrication shop. With the exception of the pipe fabrication shop, the systems identified were found to be quite similar. Therefore, it is felt that the results of this study are valid based upon the ten interviews.

CHAPTER II

PRODUCTIVITY MEASUREMENT

DEFINITION OF PRODUCTIVITY

A situation unique to the construction industry is the use of many different terms to describe productivity. For example, productivity has been defined as the production rate, unit manhour rate, unit cost rate, or performance factor, as well as a number of other terms. In this report it will be defined as the production rate, i.e., the input effort divided by the output quantity (mh/cy, mh/lf).

It is significant to note that most classical sources define productivity as a comparison of the output of the production process to the corresponding input (i.e., $\text{Productivity} = \text{Output}/\text{Input}$) [2]. The construction industry, however, uses input/output as a measurement of productivity, e.g., manhours (input) per linear foot of pipe installed (output). The reason for this appears to be that typically the construction industry places paramount importance upon costs during both estimating and project execution; therefore, if productivity is reported as manhours/unit, the cost engineer can easily determine project costs by multiplying (input/output) productivity times the estimated quantity times the wage rate.

PRODUCTIVITY MEASUREMENT

The construction industry does not typically measure productivity directly; that is, it does not determine production rates from direct measurement techniques such as time and motion studies, as could be done in a manufacturing environment. Instead, the construction industry tracks progress (in terms of work units completed) attained during a given period of time and the associated costs (in terms of manhours or dollars). This report will focus on the methods used to track progress attained and the associated costs.

Since productivity is defined as input/output, the measurement of productivity may be analyzed separately as the measurement of input and the measurement of the associated output. Figure 1 is a simplified flow chart

which conceptualizes the productivity measurement process. For all the organizational entities studied in this report, the basis of the productivity measurement system begins by defining the Work Breakdown Structure (WBS) and the accompanying Chart of Accounts, which provide an organized structure for collecting productivity data. Figure 2 shows part of a typical WBS describing the spool erection of 2-in. and under (5 cm) carbon steel pipe. Careful consideration must be given to the level of detail desired for estimating and reporting purposes. Subsequently, the input effort and the resulting output must be measured and assigned to appropriate account codes that are defined by the Chart of Accounts. This is usually done by field construction personnel. The input and output are usually entered into a computerized reporting system which processes the data and generates productivity reports according to the various levels of detail as defined by the WBS. Figure 2 shows how the cost codes are assigned to each element of the work.

DEVELOPMENT OF A PRODUCTIVITY REPORTING SYSTEM

An important issue pertaining to productivity measurement is the development of the reporting system. The reporting system must provide the construction management team with timely, accurate, and cost-effective productivity information for managing project costs and schedule and for future estimating purposes.

The development of the reporting system requires the resolution of two primary issues: the level of detail in reporting and the frequency of reporting. In the companies interviewed, the level of detail and the frequency of reporting are determined by the project management team as a function of the size of the project. Consideration is also given to other factors like the need for strict control in a particular area. It is important to note a recurring comment made by the companies interviewed that the details of the reporting system must be tailored for each project. Additionally, it was stated that the project manager must define the level of detail and the frequency of the reporting system so that it is consistent with company policy.

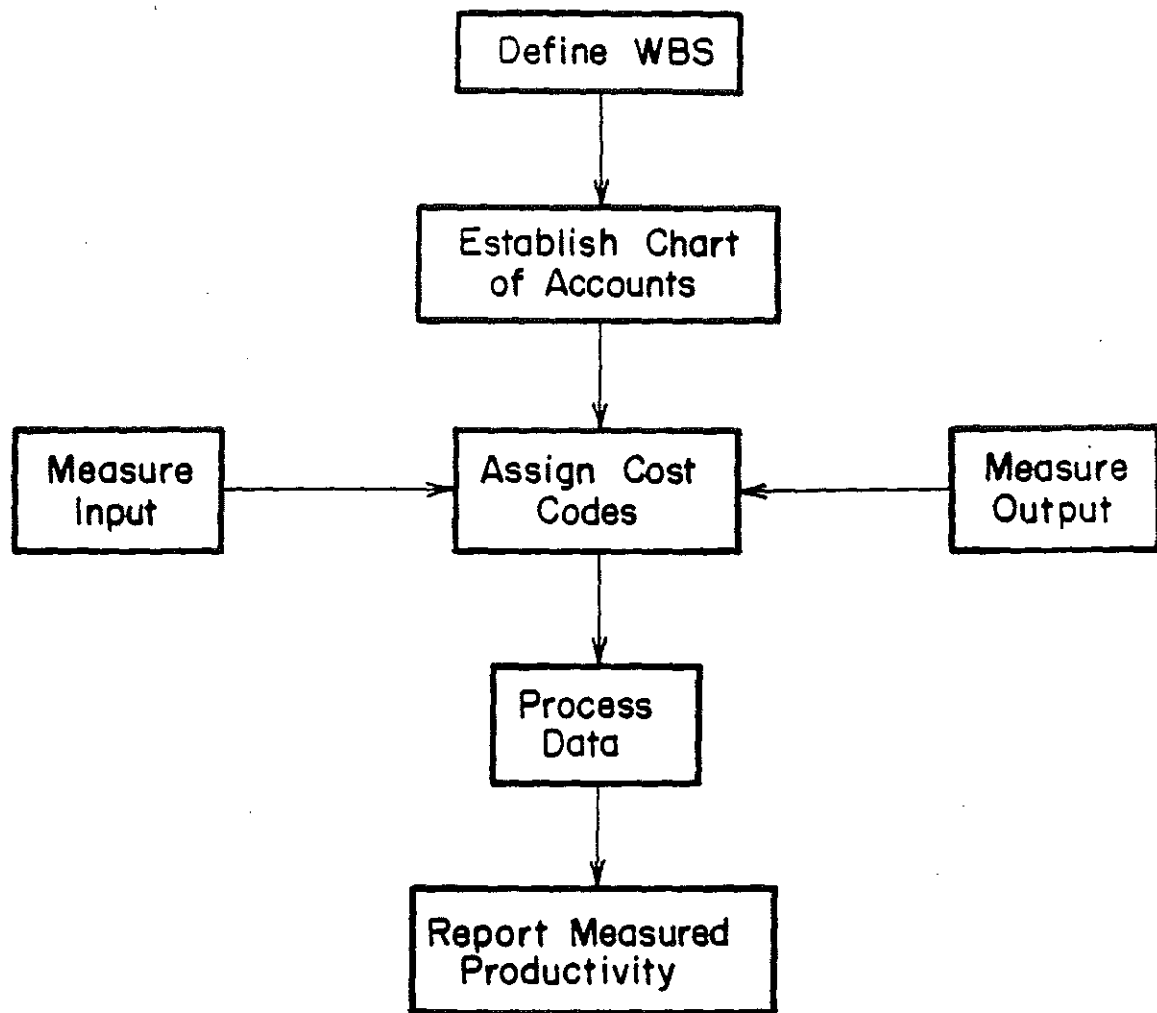


Figure 1. Conceptual productivity measurement process.

LEVEL

1
Project Number

2
Cost Indicators

3
Area

4
Activity Function

5
Activity Feature

6
Activity Subfeature

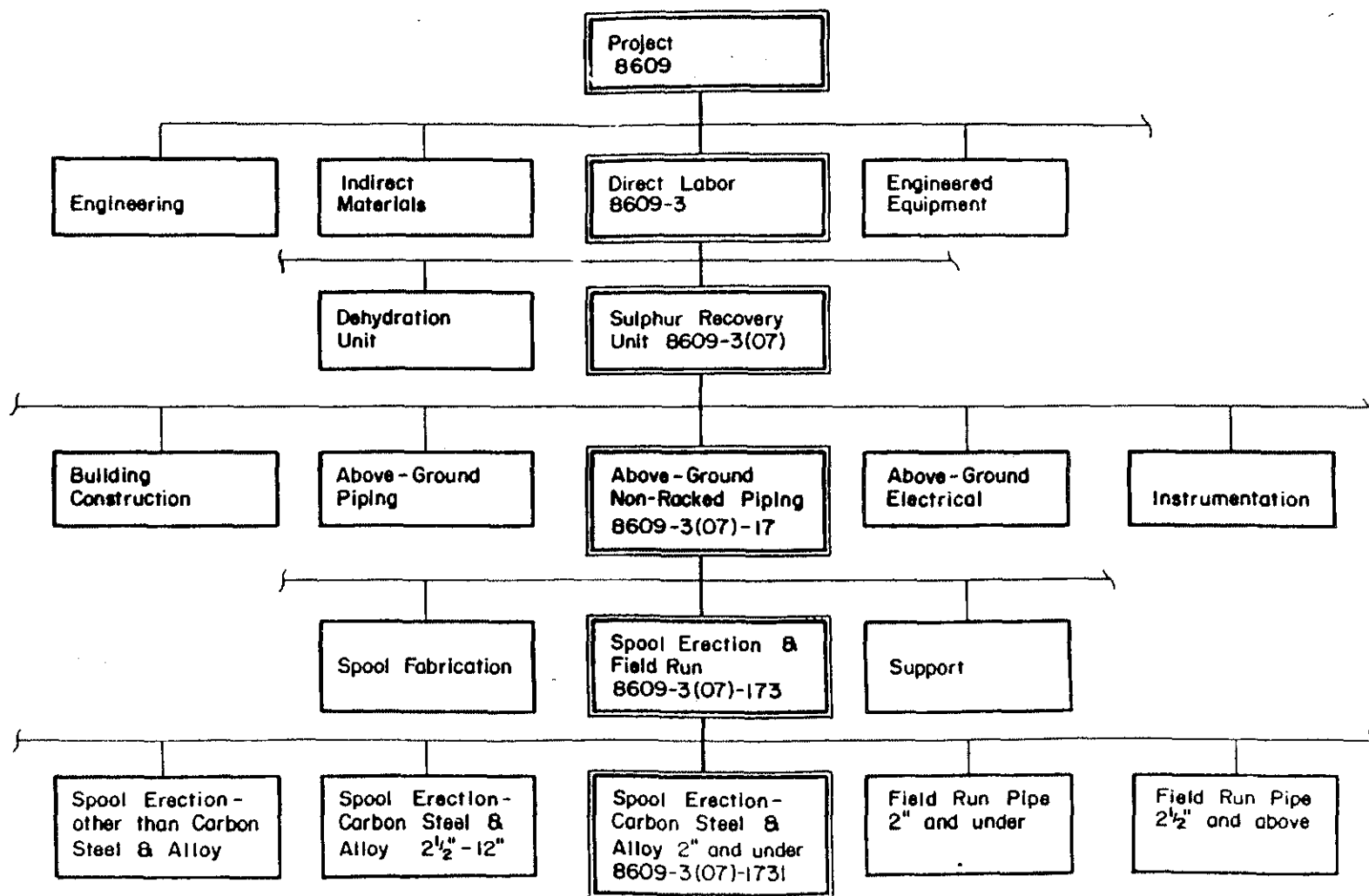


Figure 2. Typical Work Breakdown Structure (WBS).

Figures 3 and 4 show the results of the comments made by the companies interviewed pertaining to the level of detail and the frequency of reporting as a function of the project size. Figure 3 shows that as the project size increases (as measured by dollar volume), the level of detail in reporting becomes greater, and that general and specialty contractors report in greater detail than owners. In relation to the WBS in Figure 2, it should be noted that owners tend to track performance at Levels 4 through 6. General contractors may rely upon this level of detail for projects costing, say, \$30 million or less, but for larger projects, tracking will be done in greater detail according to the specific work task. Specialty contractors tend to track performance at Level 6 and beyond. The incompatibility between Figures 2 and 3 suggests that efforts towards industry standardization must first address the character of the Work Breakdown Structure. Figure 4 shows that the frequency of reporting is generally unchanged as the size of the project decreases. The norm is weekly reporting.

The above observations are not surprising when one considers that:

- 1) the owners tend to be interested in overall costs, whereas the general and specialty contractors are more interested in detailed costs for estimating and control purposes;
- 2) normally one would expect the costs to exceed the benefits of an increased level of detail on a smaller project, and the benefits to exceed the costs on a larger project;
- and 3) the smaller the project size, the shorter the duration and, therefore, there is a need for more frequent reporting than on a longer project.

REPORTING OF MEASURED INPUT AND OUTPUT

Another important issue is who should initiate the source documents used for reporting the input and output. The personnel most commonly used are the project superintendent, the cost engineer, or the foreman.

Typically, on a large project, the foreman reports the input using daily timesheets and the output using a quantity installed report. The foreman is used primarily because he/she is closest to the work (and consequently can best judge the input effort and output quantity) and because the use of the foreman for reporting is much more economical than adding additional overhead

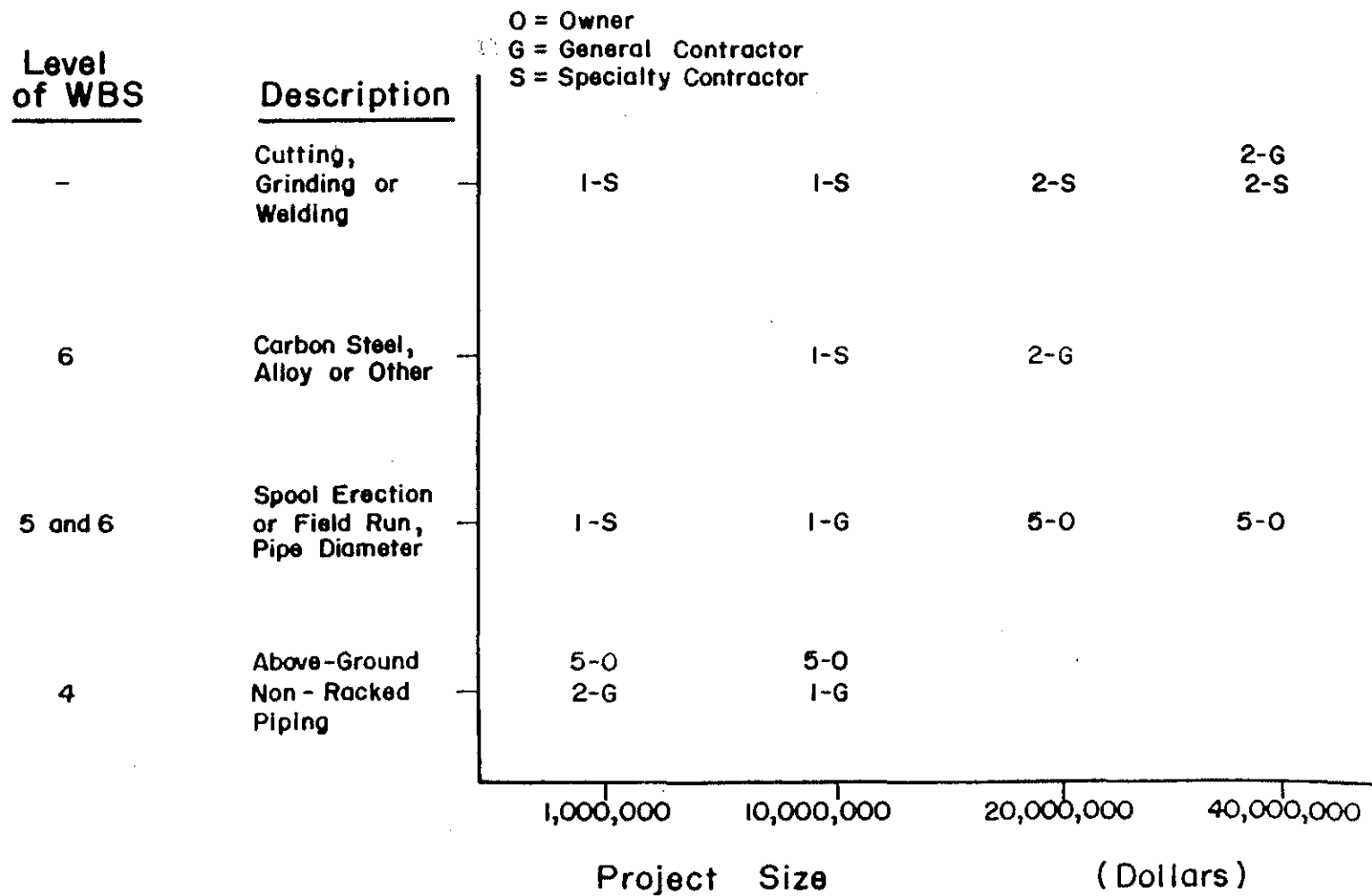


Figure 3. Level of detail of reporting as a function of job size.

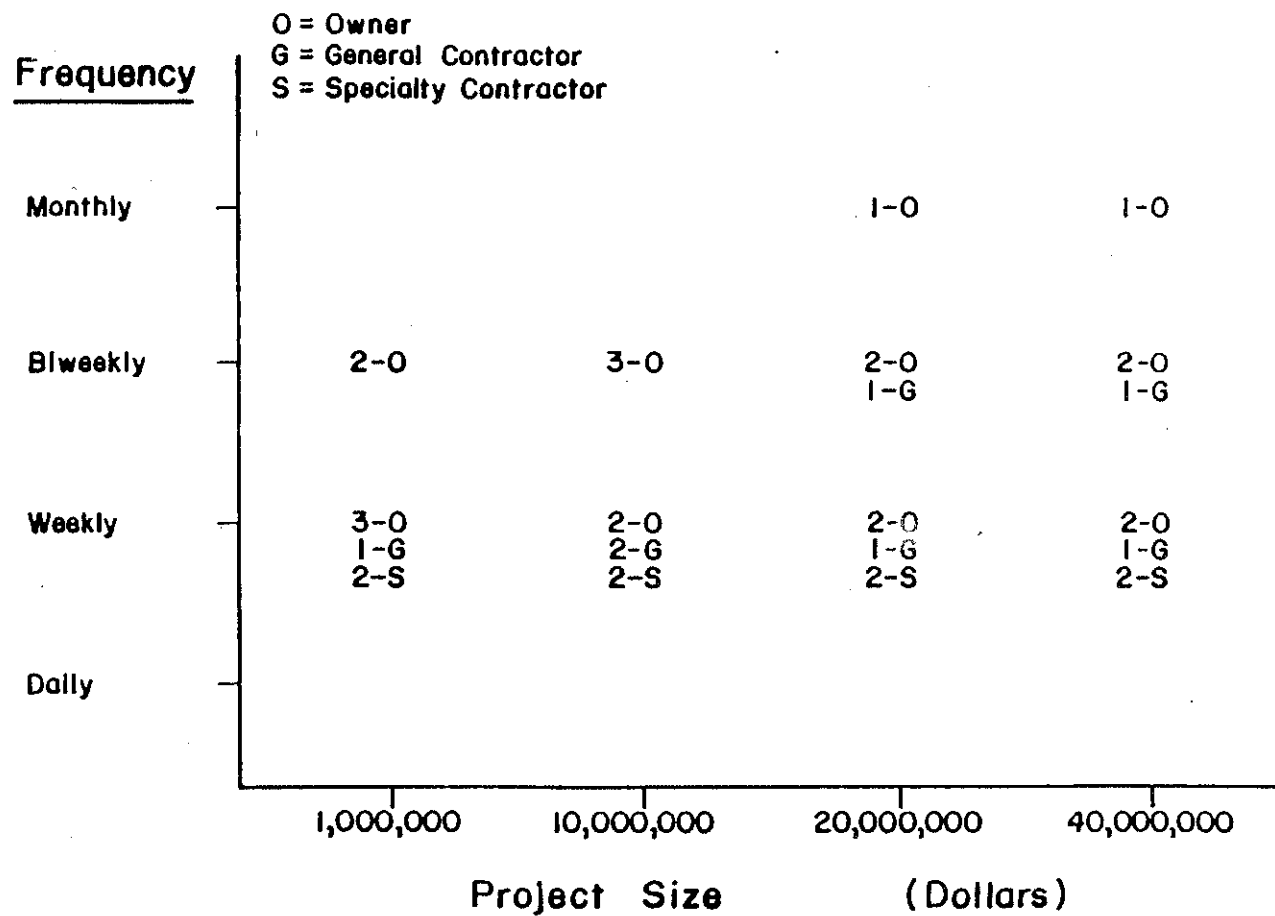


Figure 4. Frequency of reporting as a function of job size.

to the project. It is necessary that the foreman receive some training and indoctrination to provide uniformity in reporting. The foreman should be familiarized with the Chart of Accounts and associated descriptions to ensure proper reporting on the input and output source documents (i.e., the daily timesheets and the quantity installed reports). A key point to be made is that the accuracy of the calculated productivity value is only as accurate as the data used to determine it.

In order to ensure uniformity and accuracy, most firms conduct periodic audits. These audits examine the accuracy of the input effort and the production output reported and check for adherence to reporting procedures, thereby providing uniformity within the project and between projects. Audits are usually performed by the cost engineer.

Whereas the foreman is typically used for reporting the input and output values on large projects, the project superintendent tends to be used for reporting on smaller projects. This is because the project superintendent is better able to keep abreast of the day-to-day construction activities than his/her counterpart on a larger project.

An additional finding of this investigation is that owner companies tend to adapt to the productivity measurement reporting system used by general and specialty contractors. The reason for this appears to be that the contractors have developed relatively sophisticated productivity reporting systems which provide sufficient information to satisfy the owners' needs. As a result, most owners have opted not to support an in-house reporting system which would increase the project overhead costs and would duplicate the efforts of the contractors.

FACTORS AFFECTING PRODUCTIVITY

An important consideration is that the method of measuring productivity should facilitate the identification of certain factors that affect productivity. Historically, the primary means of identifying cause-effect relationships has been to maintain historical records which cross-reference the productivity observed with a characterization of project factors perceived

to be important. Consequently, the method of measuring productivity should, by means of the Chart of Accounts, identify the measured productivity and also characterize at least some of the more important factors affecting it [3].

Some of the factors affecting productivity which have been identified by previous studies [1] are:

1. Geographical location
2. Project size
3. Project schedule (or work week)
4. Expected construction activity in the project area
5. Climate
6. Special site conditions
7. Grassroots vs. addition to existing facility
8. Materials and construction methods
9. Equipment
10. Crew/supervisor experience
11. Overtime and shiftwork
12. Overcrowded work areas
13. Overmanning
14. Absenteeism and turnover
15. Safety and housekeeping
16. Constructability

It should be observed that the WBS in Figure 2 facilitates the isolation of some but not all of these factors. For example, one can isolate project areas but not safety and housekeeping. The effects of absenteeism, turnover and constructability will also be difficult to quantify. The level of detail and reporting frequency are important considerations in establishing cause-effect relationships. Because of the interaction between these factors, the unit-rate reporting system alone cannot account for all of the variables affecting productivity.