A PROCEDURE FOR THE ECONOMIC ANALYSIS

OF WORK MEASUREMENT TECHNIQUES

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To my parents,

who have devoted their lives to

the furtherance of education.

PREFACE

This thesis is concerned with developing a procedure whereby the industrial organization is able to determine, within the constraints of its own production environment, the most economical work measurement technique to use to study a particular human task. By application of the Delphi Method of questionnaires and controlled feedback, the various costs and benefits of each available technique may be established. An economic analysis model is then developed to determine the expected net present value of any given labor standard established by any of the different techniques at hand. The resulting information is designed to assist the person responsible for the work measurement function in selecting the economically optimum technique to use to develop the standard time for the job under consideration.

I would like to take this opportunity to express my sincere gratitude and appreciation to the members of my advisory committee: to Professors S. Keith Adams, James E. Shamblin, and G. T. Stevens, Jr., who unselfishly gave so much of their time and talents to the preparation of this thesis, and to Professors Earl J. Ferguson, Hamed K. Eldin, and Frederick M. Black for their personal interest, encouragement, and valued counsel.

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CHAPTER I

INTRODUCTION

The Problem

Throughout industry many resources are devoted to the establishment and maintenance of labor standards. For years administrative decisions and judgments have been made concerning which of the many techniques available should be used to set the standard for a particular task, but no predictive, economic model for this situation has been developed. Some maintain that labor standards should be as accurate as possible. These individuals do not take into account the data acquisition costs. Others say that labor standards should be developed and maintained with a minimum of expense. This argument does not consider the possible advantages to be obtained by a more thorough and, in most cases, more costly investigation of the task under consideration. This thesis will develop a procedure whereby the industrial organization can determine, within the constraints of its own operating environment, the most economical work measurement technique to use to develop the labor standard for any specific job.

It should not be inferred that the economic consequences of work measurement have been ignored in the literature. Indeed, economy of production is at the very heart of such a program. In general, however, publications on this subject may be divided into four categories: (1) those who cite the general economic advantages of work measurement,

(2) those who stress the need for accurate results, (3) those who stress the need for economy of application, and (4) those who have attempted to reduce the cost of applying a particular technique.

The General Advantages of Work Measurement

The general advantages of a work measurement program itself have been cited often. For example, Aquilano (3, p. 51) and Salling (58, p. 63), although their individual figures differ slightly, report that manufacturing operations without labor standards (daywork) experience productivity ranges from 50% to 70% of normal, where "normal" is defined in terms of the productivity that would be expected if the operation had been studied and a labor standard established. Under measured daywork situations, where work measurement has been applied and both the worker and his supervisor know the standard time for the job, but where incentive payment plans are not in force, this productivity increases to 70% to 90% of normal. With the introduction of incentive payments, they report that production ranges of 120% to 135% of normal are observed.

These figures tend to support arguments in favor of establishing a work measurement program, including the introduction of wage incentives. It is not the purpose of this thesis to either justify or condemn such a concept. It will be assumed that this decision has been made previously, that a work measurement program is currently in force, and that it is now desired to economically optimize the application of this program to specific job studies.

Accuracy and/or Economy

Current publications concerning labor standards tend to stress either the need for accuracy or the need for economy. For example, Kadota (40, p. 409) states:

> Standards must be as accurate in measured daywork as in wage incentive plans. One reason is that measurement by an incorrect scale leads to wrong judgements and actions. A second reason is more psychological. In measured daywork ... unless operators and foremen have confidence in the standards, they are not strongly motivated to increase their performance. Thus, the standards must be set accurately, and this accuracy must be 'sold' to the operators and foremen.

The question of whether, in specific individual applications, the costs of wrong judgments, actions and lower motivation may be greater than or less than the cost of obtaining the "accurate" standards is not considered.

Fankhauser (20) reports the results of an experiment comparing the accuracy of MTM (Methods-Time-Measurement) and the stop watch procedure originated by the German Work Study Society (REFA). On page 55 he states:

> Therefore, based on the listed comparisons it may be concluded that the MTM procedure and the REFA stopwatch procedure yield practically the same normal times [author's own emphasis].

In his summary, he concludes on page 60:

> We have also seen that the normal performance established by MTM agrees with that of the REFA stopwatch procedure and that the accuracy of MTM normal times is very good. This latter fact has also been confirmed by others. Consequently, MTM normal times, and therefore MTM standard times, can be used for all industrial work measurement purposes and also as a basis for the payment of wage incentives such as piecework.
>
> We furthermore have seen that the stopwatch procedures known to us are fraught with more than one source of potential error and that they do not yield more accurate results than the MTM procedure. Substituting MTM for these

> procedures could not, therefore, involve disadvantages for either the employers or the workers, contrary to the apprehensions of some stopwatch advocates [emphasis added].

Fankhauser does not present the costs, in terms of application time, for either of the two techniques compared. If, as he indicates, the two procedures result in practically the same normal time, and if the stop watch procedure can be applied in some instances more quickly and easily than MTM, then it is quite reasonable to assume that under these circumstances the added cost of MTM could outweigh the "potential error" of the stop watch. It should be pointed out that in a subsequent article he states, without verification, that one of the advantages of MTM is "Quicker and more accurate development of standard data and time formulas" (21, p. 45). From his experience this may be true. However, the results to be presented later in this thesis do not substantiate this relative speed of MTM application when compared to other techniques available. His neglect of this possibility becomes even more apparent when he states, "Thus work measurement is definitely a practical tool in which unnecessary accuracy must give way to economic considerations" (21, p. 46).

The "economy" viewpoint of work measurement application is to be found in the writings of those practitioners who advertise the allegedly high reductions in cost with the use of a particular procedure. For example, both Beck and Gibson report on the advantages of work sampling in specific instances. Beck (6, p. 22) states, "Productivity was found to improve at approximately the same rate as if standards had been set for every operation but at one-tenth the cost." Gibson (25, p. 13) states that the many

> ... complications and variables in the work of repair shops would make a system of true engineered standards

> inadequate, costly, and subject to unfair measurement practices. The work measurement personnel would be so involved in revising old standards and developing new ones that little time would be available for improving methods, work area layouts, or analyzing performance problems.

It is not clear why the option of increasing the number of work measurement personnel to handle the heavy workload was rejected. Granted that the decision to "engineer" all labor standards would be more "costly" than the described procedure, again the savings to be realized, in terms of reduced production costs, could far outweigh the additional cost of the standards themselves.

Other examples of the attention to economy may be found. Schmidtke and Stier (60, p. 182) state that the development of predetermined elemental time systems sprang in part from the desire to "... determine the time factors of a process more thoroughly and comprehensively than is possible with the very time-consuming stop watch and the chronograph methods ..." In an interview reported in Business Management (37, p. 59), William Hodson, president of H. B. Maynard and Company, Inc., an international management consulting firm, indicates, "A good methods-time-measurement analyst can establish data for chucking and truing up parts in an engine lathe in about four hours. The same job would take a time study engineer a week to complete." Klein (41, p. 17) describes a type of desk calculator designed to calculate element times "at the push of a button," and "take the man-hours out of time study and the drudgery out of industrial engineering." Kopp (43) and Ross (57) describe computer programs to analyze time study data, and Stukey (64) predicts that in 1980 there will be a centralized computer bank of universal time data that all industrial engineers will be able to draw upon to save time in their work measurement applications. An assumption basic to all of these innovations is that the savings in terms of industrial engineering time will more than offset the cost of mechanized data analysis.

The Significance of This Study

It should be apparent that the person charged with the responsibility for practical application of a work measurement program is caught between the desirability of accurate labor standards, with a probable high cost in engineering time but improved productivity in the work area, and the possibility of savings in engineering time, with the concurrent probability of reduced productivity from direct labor. This dilemma is further compounded by the claims and counterclaims of those seeking to prove the point one way or the other. Perhaps the best warning of the attitude of those individuals who try to defend a particular work measurement procedure as the "<u>one</u> best way" is given by Smalley (62, p. 203) who writes:

> ... responses to work measurement criticism are typically reactionary and often irresponsible. This is especially noticeable when doubts are expressed or implied concerning the reliability, validity, or efficacy of particular work measurement plans or schemes in which there are vested proprietary interests. Notable among such interests are various consultants who 'merchandise' their schemes under trade names and who feel impelled to defend them at all costs. And the costs are usually quite high -- antagonism, confusion, and retrogression. These defense campaigns rely heavily upon 'testimonials' from 'satisfied customers,' claims that critics have not been sanctioned or licensed and hence do not understand the schemes, and assertions that in practice the schemes 'work.' The serious student of work measurement has reason to be unimpressed with such unsubstantiated and undocumented pronouncements, whether advanced by individuals, firms, or an association unalterably committed to the 'protection of proprietary rights.'
>
> The positions of individual practitioners in industry are not as easy to identify and describe because they seldom express themselves in the literature. It is likely, however,

> that many practicing Industrial Engineers are influenced by one or the other of the polarized schools of thought such that they become instrumentalities in perpetuating the prevailing confusion ...

Salling (58, p. 64) also recognizes the conflicts in economy when, in his discussion of incentive wage payment plans, he states:

> In contemplating an incentive program, many people mistakenly become preoccupied with the type and cost of the work measurement activity. Our experience has indicated that in the typical metalworking application the actual cost of developing the standard data ranges between 15% to 25% of total program cost with the balance devoted to estimation of the standards, method improvements, utilization of equipment and indoctrination of supervisors, union officials and employees, etc.
>
> Therefore, the work measurement technique employed, whether time study or synthetic data, is not nearly as important to program cost and success as the quality and soundness of the data developed ...
>
> There is no escaping the fact, however, that no matter which program is selected, the installation of it will cost money. The issue, then, is to select the plan with the greatest economic return for each dollar invested ...

<u>The determination of this return per dollar invested is the objective of this thesis</u>.

Every industrial organization operates in its own unique environment. A procedure that is economically justifiable for one firm may be uneconomical for another. It is perhaps for this reason that one encounters varying claims of the desirability of a particular work measurement program over other alternatives. Whereas, in one company MTM may provide the greatest return per dollar invested in work measurement, in another it may prove too costly to even be considered for use. On the other hand, where work sampling has been shown to be the best technique by some, the gross nature of the data obtained in this way may be unacceptable to different users, with the result that the precise elemental breakdown of MTM could be warranted.

Rather than trying to justify the advantages or disadvantages of a specific work measurement technique either as a "universal law" or even as the one best technique to use throughout an entire firm, the fundamental purpose of this study is to describe an investigation procedure that will provide a measure of both the costs and the returns to be expected from the application of any of a set of available technique options. The result of such an investigation will allow the person responsible for the work measurement activity to select, for any particular task to be studied, the work measurement technique that will maximize the expected net present value of the labor standard for that job within that organization's own unique production environment.

CHAPTER II

WORK MEASUREMENT AND THE ORGANIZATION

Introduction to Work Measurement

Definition and Scope of Work Measurement

Work measurement is the appraisal, dimensioning, or evaluation of the work content of a human activity in terms of some unit of time. It is used to determine how long it should take a qualified and well-trained person, working at a normal pace, to complete a specific task under the environmental conditions of the job. As a generic term, work measurement applies to a family of techniques used to establish standards of performance expressed in man-hours, man-minutes, or other appropriate man-time unit, for elements of human labor. The term "time study" is considered synonymous with the term "work measurement;" these terms will be used interchangeably throughout this thesis.

Any work measurement application follows certain principal steps. These steps are common to all techniques currently in use, although they may differ in the details of implementation. The first step is to standardize the work process. This is usually the result of an investigation into the methods that could be used to perform the task with the selection of the most economical method as the standard.

When standardization is considered accomplished, the next step is to select a worker or, in many cases, a group of workers for study.

These workers should be chosen because they are approximately "normal" with regard to their performance of the task on which the standard is being set. In other words, the workers studied should be neither the fastest nor the slowest, but should be those who are as near to representing the pace of the average worker as is possible. Following this, the next phase is to observe the task and take the time study. This includes selecting a work measurement technique and obtaining a measuring instrument and a recording device. During this operation the person making the study is required to follow the sometimes complex and rapid movements of the workers accurately and, at the same time, analyze them to correctly separate the work being performed into its composite motion elements.

Once the readings are taken, the data is usually summarized in terms of some measure of central tendency, such as the mean or modal value. During the observation phase, the time study analyst evaluated the pace of the workers and obtained an appraisal of the rate at which they were working. This appraisal, which should be the result of a refined measurement-judgment process, is now transformed into a rating factor and is used to adjust the data so that it represents what performance ought to be in terms of the so-called normal worker. This normal performance is now once again transformed by adding allowances for fatigue and various types of delays. These added allowances can be based on estimates, actual studies, or, as may often be the case, the outcome of combining the efforts of a sound work measurement program, human factors engineering, and a well-organized company medical program. The final result of all of these operations becomes the standard time for the task under study.

Work Measurement Techniques

In the years since the concept of work measurement was established, many techniques and procedures have been developed and applied to this activity. Some of these methods are quite precise and exact while others often do not result in very accurate labor standards but have the great advantage of ease of application and low cost. Among the most common work measurement techniques are stop-watch time study, work sampling, work measurement sampling, micromotion study, memomotion study, predetermined time systems, standard data, historical data, and estimates. It is not intended that this be an exhaustive enumeration of all techniques available or in use. Many firms undoubtedly have "hybrid" procedures that take advantage of the characteristics of more than one of these techniques; other firms may have developed their own "special" technique. The purpose here has been to present a general idea of the diverse methodology available. For a detailed description of the application procedures, the reader is referred to any of the several excellent references available on work measurement (5, 13, 18, 50, 51, 52, 59, 70).

The Objective of Work Measurement

It is difficult to find a concise statement of the objective or objectives of work measurement in current literature. In many instances attempts to indicate this concept result in a list of the uses or advantages of time study data from the parochial viewpoint under discussion. For example, Barnes (5, p. 659) lists the following purposes of time study:

A. A basis for determining time standards and establishing piecework rates.
B. A basis for establishing a 'standard day's work' for jobs paid on a day-work basis.
C. An aid in improving methods.
D. Production planning and control purposes.
E. Cost-control purposes.

The United States Army Management Engineering Training Agency (70, p. 1-3) states that the objectives of work measurement are threefold:

1. Supply quantitative information to management for programming and planning work and for scheduling the use of manpower and facilities.
2. Provide quantitative information to management for appraising the organization and for evaluating the status of the various operations.
3. Furnish data to management for use in controlling costs, operating effectiveness, and manpower requirements.

It is undoubtedly true that work measurement can serve all of the purposes listed above. However, <u>the basic service provided by any work measurement application is to establish the relationship between the normal time required to perform a task and the work method used in accomplishing that task</u>. Management must base its decisions on facts if results are not to be left to guesses or opinions. A work measurement program provides these facts. It provides a means for comparing what should be produced (the standard) with what was actually produced. It furnishes information that allows supervisors to measure operational effectiveness and to take corrective action in areas where problems are indicated. <u>The fundamental objective of work measurement is, then, the reduction and control of costs</u>. It is a central theme of this thesis that <u>work measurement is an instrument for cost control</u>. The use of any of the various time study techniques should be aimed at reducing operational expenses. Each application of work measurement within the firm should, therefore, be expected to show some measure of return for the costs incurred. It is the determination of this return, or lack of it, that is the objective of this investigation.

The "Credibility" Factor

It was pointed out in the previous chapter that one may find wide disagreement concerning the desirability of any given time study procedure. Behind many of the objections to the use of a particular work measurement technique is what might be called the technique's "credibility." Many types of errors can (and probably do) enter into the final determination of the standard time. Fankhauser (22, p. 67) states that these errors enter into the process in either the determination of the normal time or in the application of allowances. He writes:

> Since a standard time is made up of various components, a loose standard time can, therefore, result from quite different causes. An error in the normal time can thus be attributed to one or more of the following reasons:
>
> (1) Error in the actual measured time,
> (2) Error in performance rating,
> (3) Failure to make an operation analysis to define the work method,
> (4) Failure to follow the prescribed work method,
> (5) Creeping method changes,
> (6) Use of the wrong cutting speeds and feeds,
> (7) Use of the wrong cutting tools,
> (8) Use of the wrong material,
> (9) Design changes in the product,
> Etc.
>
> On the other hand an error in the delay allowances can result from one or more of the following reasons:
>
> (1) Allowances that are incorrect in themselves,
> (2) Allowances that are correct in themselves but are either not required or are only partially needed by the worker because the corresponding 'lost time activities' occur partly or entirely during paid breaks or during periods for which time is included in the normal time such as during process times, or while a relief operator is continuing production

although the regular worker is attending to his personal needs,

(3) Use of unavoidable delay allowances that were determined on the basis of more difficult materials than are currently used,

Etc.

Concerning the reasons for inconsistency in standard times derived from predetermined time systems, Frederick (24, p. 18) states that this may be caused by a number of factors, including:

1. Inexperience of the analyst.
2. The tendency to stray or vary from the motion and classification theories as conceived by the designers of the system being used.
3. Errors or faulty interpretations in application of the motion classifications, such as position, apply pressures, assembly tables, etc.
4. Attempts to interpret motion classifications in the light of the production that the analyst expects the particular operator to achieve.

> In addition, it is still as true with predetermined time systems, as it has been with stop-watch methods, that a major contribution to inconsistent standards is the human inability to determine, in an absolute sense, the 'one best method.' ... Similarly, inadequate or erroneous statistical studies of non-cyclical elements and cyclical occurrences will tend to reduce the accuracy of the standard being established.

To the above sources of error might be added the tendency of the time study analyst to intentionally set a "loose" standard either because he himself does not have confidence in the technique used in its development or because he does not want to have to "defend" the standard should it be criticized for being too "tight" at a later date. Although some time study theoreticians may strongly argue this point, especially in those situations where the work measurement program is allegedly "sound," the only persons who will know for certain whether loose standards are developed in this manner are, of course, the analysts themselves. Therefore, the <u>possibility</u> of this occurring must still be considered, even though it is definitely an undesirable practice.

The errors attributable to work measurement determine, then, the credibility of the labor standard itself. This credibility will generally increase with either an increase in statistical accuracy and/or an increase in the amount of detail inherent in the work measurement technique used. It is one of the contentions of this thesis that <u>the value, or potential value, of time study data is directly related to the credibility of the particular technique</u>. If a technique produces highly credible results, it should be rather accurate; if its credibility is in question, its results are probably less accurate, although there is no definite proof that in specific cases this will be true.

The Value of a Labor Standard

Usefulness Versus Value

As has been indicated, the labor standard, by itself, is simply a measure of the amount of time required to complete a task under a "normal" set of conditions. Within any given organization, there are many <u>uses</u> for this data. All levels of supervision require quantitative information in order to function. The types of information that they require is almost limitless, but one of the most important is concerned with the dimensioning of work in terms of time. Where a formal work measurement program has not existed, these managers have traditionally relied upon rules of thumb, initial experiences, judgment, and even outright guesses to determine this dimension. Regardless of the source of the information, however, this thesis will take the viewpoint that it is <u>not</u> a function of any production activity, <u>other than the</u>

<u>originator of the labor standard</u>, to be concerned with the relative accuracy of that standard. In other words, once the time for a task has been established, either formally or informally, all individuals having a need for this information must use it as though it were "100% accurate." The reasoning behind this assertion is not difficult to see.

There are two mutually exclusive categories of <u>erroneous</u> labor standards: either (1) the standard is too "tight," i.e., not enough time is allowed for the worker to perform his job or (2) the standard is too "loose" and the worker is allowed more time than he needs. In addition, labor standards are used as the basis for either measured daywork or incentive payment production. Regardless of the situation, if the labor standard is <u>too tight</u>, the worker will complain until it is changed. However, if the standard is <u>too loose</u> under the measured daywork condition, it becomes a self-fulfilling prophecy since this is the amount of time that the worker will probably take to do the job. On the other hand, under an incentive payment plan, if the standard is <u>too loose</u> the worker will probably take less time to do the job but the firm will be paying more in incentive premiums than it should. In either case, a loose standard is costly to the organization. However, until it becomes <u>obvious</u> that it is in error, it will not be changed. Therefore, all production functions <u>must</u> use the information as given. If the standard is subsequently found to be incorrect and is adjusted, these activities would <u>then</u> alter, if necessary, any decisions based on the original standard.

It is important for the reader to recognize this difference between the <u>usefulness</u> of the information and the <u>value</u> of the information provided by a labor standard. There are many organization activities, such as inventory control, cost accounting, personnel, etc., that have uses for this data. Where no work measurement program exists, someone must still estimate this dimension in order that these activities may plan and function. There is, however, no tangible value to be found through these activities by increasing the accuracy of this estimate. They must use the best information available, regardless of its origin.

The Source of Value

If the value of a labor standard cannot be derived from its various uses throughout an organization, where, then, does this value lie? It has been stated that the fundamental objective of work measurement is the reduction and control of costs. This objective is attained by attempting to reduce the number of unproductive man-hours in the shop, through the determination of the best method of performing a task and the amount of time that the worker needs to accomplish this task. It is the basic premise of this thesis that the only real measure of the value of a particular labor standard is the number of direct labor man-hours that are saved because the labor standard itself is in force. This value will be directly related to the credibility of the standard, which in turn is directly related to the credibility of the technique used in its development. In order to obtain a measure of this value, then, any procedure used for the economic analysis of work measurement must be able to determine the credibility of any of the various work measurement techniques available. This credibility must then be compared to the credibility of the source of the information if no formal labor standard were developed. The value of the labor standard is then derived from the difference in these credibilities in terms of the savings in unproductive direct labor man-hours that result from the use of the labor standard data.

As an example, consider a production situation where the cost of direct labor is six dollars per hour. It has been stated previously that even where no formal work measurement program exists, someone must still estimate the amount of time that it will take to complete a job. Assume that in this case it is the foreman and that he estimates the job under consideration to take one man-hour. The logic that went into this estimate is of little importance, since barring any information to the contrary, it is the figure that must be used. Now assume that the job is studied by a work measurement analyst and, because of better work methods design among other factors, the standard time for the task is found to be forty minutes. This situation is shown in Figure 1. Using the foreman's estimate, the cost of the job was six dollars per repetition. By application of work measurement, this cost is now reduced to four dollars per repetition. The value of the labor standard, due to the savings in direct labor time, is the difference in these amounts, or two dollars per repetition of the task.

It should be pointed out that the engineered standard is probably not perfect; i. e., if more time had been spent by the analyst studying the job and seeking improvements in the work methods, the standard time could probably have been reduced even further. There is, therefore, a "cost of ignorance" inherent in this labor standard, a cost that the procedure to be developed in this thesis will attempt to determine. However, it is readily seen that even though the standard and the associated work method are not perfect, there is real value accruing to the organization from the knowledge this information supplies.

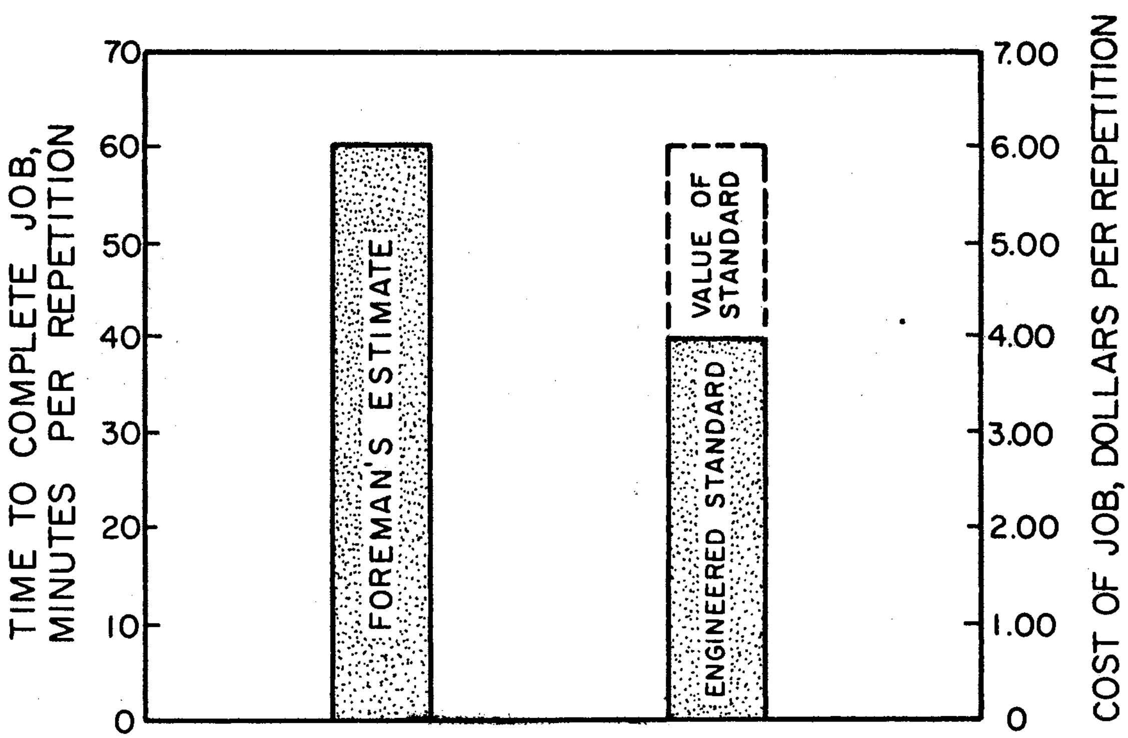


Figure 1. The Value of a Labor Standard

The Costs of Labor Standards

A labor standard in use did not come about automatically. Someone must have investigated the job, developed the standard, and recorded the results. The development and maintenance of labor standards results in a cost to the organization. The purpose of this section is to discuss the areas of these costs.

Methods Design and Methods Improvement in Perspective

In determining any labor standard by any of the various techniques available, some amount of methods design (or at least methods analysis) is needed. Methods design is the name given to the procedure used "... for finding the preferred method of doing work" (5, p. 4). Before any time study is made, the analyst determines, with varying amounts of detail depending on the situation, what he considers to be the best way to perform the operation under study. This determination is the methods design phase of the work measurement activity. Its purpose is to find "... the ideal method, or the one nearest to the ideal that can actually be used. We call this the preferred method" (5, p. 8). It is this method that the operator uses when the analyst studies the job to determine the standard time.

The anticipated result of methods design is to save the operator time, reduce the amount of work required by him, increase his productivity, lower labor costs, improve product quality, or any combination of these. Methods design is an integral part of work measurement. The different techniques available for work measurement each have different requirements for detail in the methods design phase, ranging from quite general "impressions" concerning what work procedure should be used to an extensively detailed analysis of finger movements.

Methods improvement, on the other hand, is the process of finding a better way to do a job that has already been studied and has a standard time set. The purpose and anticipated results of methods improvement are the same as those for methods design. The difference between the two concepts is their temporal order. Methods design occurs prior to the determination of the labor standard. Methods improvement occurs after a standard has been set and is an attempt to further improve the existing method. It is an application of the philosophy that "... there are always opportunities for improvement" (5, p. 50).

Although some may take exception to the definitions offered above, for the purposes of this thesis methods design will be considered an integral part (and, therefore, an integral cost) of initially setting any particular time standard. Methods improvement will be considered a subsequent function, possibly a "target of opportunity" which may be taken advantage of by formal directive or simply by "inspiration" on the part of the time study analyst some time after he has set the original labor standard. Methods improvement will be treated as an additional cost of the work measurement function, occurring in the future, and considered to be a part of labor standard revision costs.

Initial Standard Development Cost

Each of the various work measurement techniques has associated with it a procedure for determining the standard time. The determination of the standard time for a task requires time. The time taken is a cost to the organization in terms of the salary of the person who establishes the standard. This time, and therefore cost, is a function of the procedure and detail inherent in the technique used, which in turn dictates the amount of time required to make a methods design investigation of the job.

There is, therefore, in the establishment of any labor standard, an "initial investment" by the organization in terms of the time taken by some employee and the salary he receives for this time. The size of this investment is directly related to the length and complexity of the job studied, the detail of the methods design, and the work measurement technique used.

Labor Standard Revision Costs

Frequently, after a labor standard has been developed, the need arises to change the standard due to a methods change. This methods change may come about because of a methods improvement action on the part of someone involved in the process, or because of a change in the process itself, such as new instruction manuals or procedures developed in an attempt to improve product or service quality. Regardless of the origin of the methods change, part or all of the original standard must be restudied to update the standard time. In the same manner as the initial development cost, these standard revisions require the time of a paid employee to accomplish. This is in addition to the investment that the company has in the original standard and is, again, directly related to the length or complexity of the part (or all) of the task to be restudied, the detail of the methods analysis, and the work measurement technique used.

Labor Standards Maintenance Costs

Labor standards require periodic auditing to insure compliance and accuracy. How often the audit is performed on a particular standard may depend on its frequency of use, company policy, or other factors, such as operator complaints concerning overwork or underpayment, excessively high or low paychecks, or when it is apparent that workers can control their earnings artificially. These last factors apply principally in companies using incentive pay plans.

It should be pointed out that it is not absolutely necessary for an audit of a particular standard to ever be accomplished. The standard may have been reviewed as a result of a procedural change in the operation or a change due to the study and improvement of the method used. When either of these actions occur, the entire labor standard may be restudied and a new standard placed on record. If either or both of these actions happen with sufficient frequency, an audit of the standard may never be necessary.

The periodic auditing of standards is, however, an additional cost in the work measurement program. The magnitude of this cost is in direct proportion to the same set of variables as the cost of labor standard revision, and again represents an additional investment in the particular standard concerned.

Other Costs

Depending on the situation, there are probably many other costs associated with the work measurement program of an organization. If the standards-setting personnel undergo a training program before they become active in this function, the cost of this training must be considered. Those organizations with a large group of people setting labor standards probably have a person designated as a supervisor, who may or may not actively determine standards himself. In addition to the supervisor, there may be a secretarial staff assigned to this function. These and similar overhead costs are part of the investment in the over-all work measurement program of the organization, as are such items as keypunch operators and electronic data processing costs if the firm maintains its standards by machine records.

Although many costs of the work measurement function are not readily apparent in the shop, if an adequate analysis of the investments due to labor standards is to be made, these additional costs must be searched out and considered.

Summary

Work measurement and its results, time standards, are intimately involved in the proper functioning of an industrial organization, or any organization that relies heavily on human work to produce goods or services. It is the intent of this thesis to provide a procedure that will maximize the expected return while minimizing the expected cost of this activity. It is realized that the <u>objective</u> determination of these factors would be an extremely difficult chore in most organizations. The next chapter will discuss the topic of subjectivity or "expert judgments" as a means for quantifying such hard-to-determine concepts.

CHAPTER III

THE USE OF EXPERT JUDGMENT

Human behavior is a fundamental ingredient in any work measurement program. For this reason, the precise determination of either the cost or the value of a particular labor standard could be exceedingly difficult. An investigator would almost certainly find a decided lack of quantitative information concerning these factors as they apply in any given situation. This dilemma could be circumvented by an exhaustive analysis of company records and a complete investigation of the workers and time study personnel involved. Such an effort would most likely still lead to incomplete information due to the "human element" incorporated in human work and the inability of the analyst to recognize and classify all of the variables of concern. In addition, such a study would probably be expensive, the cost of which might negate any anticipated benefits.

Given, then, that the precise and complete determination of the costs and benefits of a work measurement program would be at best quite difficult and expensive, an alternate source of information is needed. The source to be proposed by this thesis is the wealth of knowledge inherent in the experience of the members of the organization. In those cases where complete, or nearly complete, records have been maintained that would reveal in quantitative form the necessary data, then of course this source should be exploited. But for those situations where this type of information is not readily available, a practical substitute is the judgment of those persons considered most knowledgeable in the area. The remainder of this chapter will be devoted to a justification of such a process and the description of a technique that has shown itself to be valuable in arriving at a consensus of opinion from a group of experts.

Subjective and Objective Information

Perhaps the greatest discussion of the relative worth of subjective and objective information has occurred between statisticians in the assessment of probability values. Whereas:

> ... the 'objectivist' or 'relative frequency' point of view ... defines probability as the long-run relative frequency limit of the ratio of the observed number of favorable events to the total number of observed instances associated with the outcomes of a random physical process ..., the 'subjectivist' or 'personalistic' point of view defines probability as a numerical coefficient purporting to measure a particular human being's subjective belief about the outcomes of some physical phenomenon. ... [This is] a characteristic of human beings -- a component part of a particular individual's attitude toward a physical phenomenon (63, p. xii).

The subjectivist point of view is, however, receiving ever greater support as described by Suppes (65, p. 503) who writes:

> Although many philosophers and statisticians believe that only an objectivistic theory of probability can have serious application in the sciences, there is a growing number of physicists and statisticians, if not philosophers, who advocate a subjective theory of probability. The increasing advocacy of subjective probability is surely due to the increasing awareness that the foundations of statistics are most properly constructed on the basis of a general theory of decision-making.

The procedure to be developed in this thesis for the determination of the costs and benefits of a labor standard will incorporate the subjectivist viewpoint.

The Use of Expertise

The use of expert judgment makes certain assumptions concerning the qualifications of the individuals involved. The first assumption is that, at an acceptable minimum, he has some vague partial knowledge concerning the true value of the information and cannot be characterized as having complete ignorance of the subject. The better the quality of his knowledge, of course, the better the quality of his judgments. A second assumption concerning the expert is that he is rational. Rationality requires that (1) his judgments are consistent or, when inconsistencies are brought to his attention, he is willing to correct them, (2) his judgments are reasonably stable over a period of time, provided he receives no new relevant information, and (3) his judgments are affected in the "right" direction by new relevant information. The use of an expert to predict information about some subject matter, then, assumes that he is rational in the above sense, has the background knowledge in the field, and has or will have a record of comparative predictive successes in the long run (33, p. 36).

It has been stated that the <u>precise</u> determination of the costs and benefits of work measurement is an impractical goal. What is needed is a close, but possibly <u>inexact</u>, approximation of these values that can be used for decision-making purposes. This inexact approximation is to be the function of the chosen experts. It will make use of their background knowledge, which may be intuitive in scope or rely strictly on the vague recognition of certain underlying regularities in the production processes of men. It will be the task of these experts to translate this background knowledge and intuitive feeling into quantitative data.

The trouble with human judgments is that they are subject to errors. Is there, then, something inherent in the use of the judgment of an expert that destroys objective scientific methods and substitutes rank subjectivity? The answer to this question, under appropriate conditions, is an emphatic "no" as attested to by the writings of several authors, including Churchman and Eisenberg (14), Lord (46), and the following from Helmer and Rescher (33, pp. 42-43):

> ... The reasons why our reliance on the expert is objectively justified are not difficult to see. For one thing, the selection of appropriate experts is not a matter of mere personal preference but is a procedure governed by objective criteria ... most importantly, the past diagnostic performance record makes the diagnostician an objectively reliable indicator ...
>
> Even if the expert's explicit record of past performance is unknown, reliance upon his predictions may be objectively justified on the basis of general background knowledge as to his reputation as an expert. The objective reliability of experts' pronouncements may also be strongly suggested by the fact that they often exhibit a high degree of agreement with one another, which -- at least if we have reason to assume the pronouncements to be independent -- precludes subjective whim.
>
> ... [Hence] the incorporation of expert judgment into the structure of our investigation is made subject to the same safeguards which are used to assure objectivity in other scientific investigations. <u>The use of expertise is therefore no retreat from objectivity or reversion to a reliance on subjective taste</u> [emphasis added].

The use of expert opinion to gather information, when done properly, requires the investigator to guard against introducing less objectivity than is necessary. It should be realized that expert judgments, although usually subjective, may be the best available means of obtaining data.

> ... From the standpoint of the researcher, the expert is an objective indicator of the predicted variable, and therefore, a systematic approach to extracting expert information will maintain scientific objectivity (11, p. 11).

Historical Uses of Inexact Data

It is recognized that the use of subjectively determined information for planning or decision-making purposes is an accepted approach in those areas where either very little or no historical data exist (61, p. 20). Even in those situations that purport to give exact answers, the results of the mathematical models are inexact:

> The laws of nature are obscure. Their effects are so numerous and complex that it's usually hopeless to attempt an exact mathematical analysis of a physical phenomenon. Instead the scientist visualizes a simplified model which approximates reality and he then proceeds to study that model mathematically (68, p. 5).

> No model, physical, schematic, mathematical or other is the real world, though some scientists become so devoted to their model (mathematical or verbal) that they will insist that this model is the real world, and at best, it's useful. Usefulness is the proper criterion for judging a model [emphasis added]. A model is neither true or false. The standard for comparing models is, therefore, dependent on the situation in which it is used, it is not intrinsic (i.e., dependent only on the model itself) (8, p. 5).

The major concern of this thesis is to provide a practical methodology for determining the "hard-to-obtain" information about the costs and benefits of a work measurement program, and a model for mathematical manipulation of this information into usable form. No claim of "exactness" will be made for the results of this model. Rather, it is an attempt to introduce an optimum amount of order into the making and recording of the human judgments that are, in most cases, essential to the determination of the most economical work measurement technique to use in a given situation. This model may, thus, be classified as an "estimating function."

The Concept of an Estimating Function

The difficulty of classifying all of the variables inherent in the work measurement process and of obtaining an exact analytical model to represent their relationships has already been discussed. In lieu of this form of precise analytical model, with its correspondingly precise results, an estimating function is often used. This function may be regarded:

> ... as a convenient gadget for getting quick provisional answers for problems too demanding of a foresight and prediction to figure out the hard way. It must always be remembered that a formula does not solve the real problem the the analyst confronts but rather a shadow problem defined by its own assumptions, projective structure and data and stipulations the analyst supplies. The results are valid only insofar as this shadow problem resembles the real one. The extent of this resemblance is up to management to judge (66, p. 5).
>
> Nevertheless, the estimating function is an aid to decision making when it is treated with respect, when its shortcomings, its overoptimisms, are recognized, and in particular when the development and derivation are understood. Its use should be encouraged. Its development to fit unusual situations should be constant practice. Traditional estimating functions should be used whenever possible and practicable, but little hesitancy should be exhibited by the engineer when unusual situations arise. He should have no fear but confidence that after having analyzed the situation, he will be able to determine a suitable estimating function to fit the situation. In fact, the estimating function should be a 'tool' for the engineer to use sensibly and not the source of 'perplexities' (10, p. 7).

Any given time standard is only an estimate of the true value of this time. The process used in its determination is in itself an estimating function (10, p. 7). It is not inappropriate, then, that an estimating function be used in the analysis of the costs and benefits of time study. The precision of this estimating function will be dictated by the precision of the model's formulation, which in turn is dependent upon one or any combination of the following factors:

1. The available data,
2. The nature of the situation,
3. The time available for making the decision, or
4. The cost of making the estimating function (10, p. 5).

The usefulness of the results derived by the methodology of this thesis will be largely subject to the nature of the organization (second factor above) in concert with the other three factors. Each organization is unique in itself; each study of work measurement costs and benefits will, therefore, be as unique as the organization.

Prior to presenting the proposed model for determining the costs and values of time study techniques, an explanation of the procedure for obtaining the consensus of expert opinions on these matters is in order.

The Delphi Method

Once it has been determined that data will be generated for problem-solving purposes from expert opinions, a decision must be made concerning how these opinions will be collected. There are a number of ways that this might be accomplished including (1) the selection of a single "favored" expert and the acceptance of his judgment alone, (2) a combination of opinions from various experts, using the mean, weighted mean, median or other indicator of central tendency as the pooled value of their estimates, (3) a committee confrontation of experts, requiring that they reach a group consensus, or (4) a post-discussion revision of the individual estimates to diminish the effects of group pressure on the individual involved (11, p. 14).

Under the assumption that the opinions of a group are more likely to be accurate than the opinion of a single individual (an assumption that can only be proved after the fact), many instances of group judgment formulation use the committee approach. This technique has come under attack for many reasons.

> ... In particular the outcome is apt to be a compromise between divergent views, arrived at, all too often, under the undue influence of certain psychological factors such as specious persuasion by the member with the greatest supposed authority, or even merely the loudest voice; the unwillingness to abandon publicly expressed opinions; and the bandwagon effect of majority opinion (35, p. 120).

In addition, "Committees ... often fail to make their assumptions and reasoning explicit since their findings are obtained through bargaining" (55, p. 9).

The Delphi Method is an attempt to overcome these difficulties. Its object is to obtain the best consensus of judgments from a group of experts. It replaces committee activity among the chosen experts with a carefully designed set of questionnaires, containing controlled information and opinion feedback. It avoids the direct confrontation of the experts with one another, and therefore the disadvantages of round-table discussions and committee action. The method should "... be more conducive to independent thought on the part of the experts and ... aid them in the gradual formation of a considered opinion ..." (16, p. 459).

In a typical Delphi investigation, the participants are presented with a sequence of questionnaires, usually four in number. On the first they are likely to be asked to <u>independently</u> provide their judgments as to the most probable value of some variable. These initial responses normally reveal a spectrum of opinion. This range of answers is then divided into intervals such that the central range contains the middle 50% of the estimates. This range, along with some measure of central tendency, such as the mean or median value is then presented to the respondents on the second questionnaire. On this questionnaire, they are given the opportunity to revise their previous estimates (as they are in all questionnaires subsequent to the first) in the light of the response of the group as a whole. Those whose second-round estimates fall outside of the given central range are asked to provide the reason(s) for their position. These reasons, along with the new set of estimates for the group are then collated and sent back to the participants on the third questionnaire. They are again asked to reconsider their earlier estimates in view of this new set of responses and the reasons provided. Critiques of these reasons from the other participants are encouraged and are included in the fourth questionnaire along with the third-round group estimates. On this fourth questionnaire, each person surveyed is asked to consider all previous information presented and give his final estimate. Through this process, the respondents are stimulated to consider information or factors they may have neglected or dismissed as unimportant originally, or to reconsider the importance of factors they weighted heavily in their previous estimates.

Several variations of this method have been proposed. One of these (the one that will be used in this thesis) is to require each participant to rate himself as to how relatively accurate he feels his individual answers are. On the basis of this information, it is possible to evaluate divergent views in the light of the individual's own concept of his knowledge. The use of this procedure assumes that the individual's rating is directly correlated with his estimating ability, and that the best judge of a person's knowledge is the person himself. Since the participant was chosen because of his assumed knowledge and rationality, this does not appear to be an illogical assumption.

The Delphi Method has drawn some criticism. Opponents maintain that the weakness in the procedure is the assumption that the experts do indeed have the required wisdom. They say that "Collected errors, though mathematically manipulated and elegantly modified, are still errors ..." (9, p. 56). Even the advocates of the use of the method admit to shortcomings in their applications. Included in these fallibilities are: (1) the experts' responses are not always independent, particularly when they are required to associate with each other because of their working assignments, (2) some "leading" by the investigator is almost inevitable from the selection and wording of the questions asked, (3) in an attempt to minimize this leading, some questions often become vague making responses to them of questionable value, (4) the necessity of oversimplification of the subject matter introduced in the questions, and (5) the dissatisfaction of the participants with the process in general, which may have resulted in less than thoroughly considered judgments on their part (16, pp. 466-467) (31, pp. 54-55).

In spite of these apparent pitfalls, the Delphi Method has shown itself to be a valuable tool in the collection and evaluation of expert opinions. Campbell (11, pp. 165-167), in a study of the forecasting accuracy of a Delphi-processed group, compared to a group that was allowed direct confrontation reports:

> Group participants who were administered the Delphi process forecasted more accurately, as a group and as individuals, than did group participants functioning under the uncontrolled-interaction method ...
>
> ... Delphi-processed participants consistently improved their group forecasts during the experimental period and exhibited decreased dispersions of individual forecasts within the group ...

> Some evidence in this study suggests that the central value estimators of distributions of individual forecasts are more accurate, on the average, than are the individual forecasts of the participants. It might be inferred, therefore, that a group will forecast more accurately than will a randomly chosen member of the group, especially where the variables forecasted are somewhat nebulous and where consistent relative forecasting accuracy among the participants does not prevail over a large number of forecasting trials ...
>
> The conclusions arrived at in this study strongly support the desirability of Delphi-process applications in business forecasting. However, the strength of these conclusions is also a function of the statistical power of the [present] experiment which, in turn, is based on the experimental design ...

A major contribution to the information-gathering function of the Delphi Method appears to be its tendency to produce a convergence of opinion in the majority of cases to which it has been applied (11, 16, 30, 31, 34, 35, 55). In cases for which convergence to a relatively narrow interval did not occur, the opinions usually polarized around two distinct values, implying two schools of thought on the subject matter, two interpretations of the same set of data, or decisions based on different sets of data. It is possible that this polarization could have been eliminated by several more rounds of questionnaires, which would have pinpointed the exact cause of the discrepancy, and thus caused the formation of a true consensus. However, even though this was not done, the Delphi Method served to crystallize the reasoning processes that led to the positions that were taken and helped to clarify the issue involved (35, p. 121).

The major application of the Delphi Method to date has been in the area of long-range forecasting of expected technological and societal developments concerned with such subjects as political alliances, technological potentials, war prevention techniques, economic indices, and medical developments. The results have been described as generally favorable; in many cases a reasonable consensus was obtained and the predicted potential developments provided a basis for subsequent analysis, planning and action (31, pp. 134-135).

The success of the Delphi Method in obtaining a consensus of expert opinion in the field of forecasting makes it a valid technique for collecting the opinions of a group of experts about other so-called nebulous areas. Even though this technique has met with success and is accepted in some circles, it should not be viewed as a device that produces the "truth." "The Delphi Method is designed to produce consensus judgments in inexact fields; it would be a mistake to consider such judgments as complete or precise descriptions ..." (31, p. 4). This procedure should, however, provide acceptable data for use in an estimating function of the costs and benefits of a work measurement program and its associated techniques.

CHAPTER IV

THE PROPOSED MODEL

The Variation of Costs and Benefits

There is neither a unique value for the cost of setting a labor standard by a particular technique nor a unique value for the benefits to be derived from the use of this information. Even within the same shop, no two jobs are exactly alike. The time taken to develop the standard for a particular task by a specified technique will be a function of the length of the task and its complexity. Since the complexity of tasks varies, the time required to study the tasks, and therefore the costs, will vary, even if the same technique is used for all jobs and all jobs have the same standard time. In a similar manner, the value of the benefits to be derived from the results of a time study will depend on the environmental conditions of the shop and the credibility of the particular standard. Therefore, in attempting to specify the costs and benefits of a labor standard, there will be an amount of uncertainty in the expressed values. The problem is not whether this uncertainty exists, but how to determine its magnitude and nature.

One common method of pointing out uncertainty in estimates is to state the expected value and footnote it with a statement about the possibility of error. This procedure serves notice that the value given is subject to deviation, and helps bring attention to this uncertainty.

It does not, however, indicate the extent to which the actual value is likely to deviate from the expected value.

In order to provide at least some guess as to the variance of the estimate, many analysts will attempt to intuitively derive this value and record it for the decision maker's use. This intuitive value is obtained by the mental operation of assessing all of the sources of uncertainty and combining them into a single quantity. For more than a small number of factors, this procedure could easily tax the ability of even the best analyst, leaving a result with questionable validity.

One further technique used to provide better information about the variability of an estimate is to specify a probable range for the value of the variable. This provides two additional measures, the lowest possible value and the highest. Although there is now a range of the analyst's beliefs concerning the limits of the variable, there is very little information concerning the relative probability of any particular value (63, pp. 4-5).

What is needed, then, to describe the uncertainty or variability in the cost and benefit estimates is a procedure that will result in an approximate distribution for each of the variables. This distribution should take into account the differences in complexities of jobs that could be studied, for cost purposes, and the credibility of the resulting data for benefit-determination purposes.

Obtaining the Cost and Benefit Distributions

All costs and benefits associated with or derived from a labor standard will be assumed to be <u>independent random variables</u> that may be approximately described by a beta distribution of the form

$$f(x{:}\alpha,\beta) = \frac{(\alpha+\beta+1)!\ (x-L)^{\alpha}\ (H-x)^{\beta}}{\alpha!\ \beta!\ (H-L)^{\alpha+\beta+1}} \tag{4-1}$$

where

x = the particular variable of interest,

H = the upper limit of the value of x,

L = the lower limit of the value of x, and

α and β = beta parameters.

This function is also commonly written

$$f(x{:}\alpha,\beta) = \frac{\Gamma(\alpha+\beta+2)\ (x-L)^{\alpha}\ (H-x)^{\beta}}{\Gamma(\alpha+1)\ \Gamma(\beta+1)\ (H-L)^{\alpha+\beta+1}}\ . \tag{4-2}$$

Expressions for the mean (μ), variance (σ^2), mode (M), and α and β parameters of this distribution are given by Cole and Mikasa (15, pp. A-2, A-7) as

$$\mu = \frac{(H-L)\ (\alpha+1)}{(\alpha+\beta+2)} + L\ , \tag{4-3}$$

$$\sigma^2 = \frac{(H-L)^2\ (\alpha+1)\ (\beta+1)}{(\alpha+\beta+2)^2\ (\alpha+\beta+3)}\ , \tag{4-4}$$

$$M = \frac{(H-L)\alpha}{(\alpha+\beta)} + L \qquad (\text{for } \alpha,\ \beta \geq 0)\ , \tag{4-5}$$

$$\alpha = \frac{(\mu-L)^2\left(1-\frac{\mu-L}{H-L}\right)}{\sigma^2} - \left(\frac{\mu-L}{H-L}\right) - 1\ , \tag{4-6}$$

and

$$\beta = \frac{\left(\frac{\mu-L}{H-L}\right)(H-\mu)^2}{\sigma^2} + \left(\frac{\mu-L}{H-L}\right) - 2\ . \tag{4-7}$$

The use of beta distributions to describe the uncertainty inherent in the costs and benefits of a work measurement program seems logical. This family of distributions has many characteristics that would be expected in the actual variables themselves, such as a finite range ($L \leq x \leq H$), continuity, and unimodality (when α and β are both greater than zero). In addition, it can, as opposed to the normal distribution, describe various forms of skewness and peakedness, which is desirable in the context of the present problem. It is for these reasons that this function was selected to depict the subjective inputs for the economic analysis model developed in this chapter.

The Use of the Delphi Method

As has been stated previously, when explicit data is not available concerning the costs and benefits of work measurement, the analyst must rely on expert judgment to describe these distributions. It should be noted here that it may not be possible to find more than one expert to provide data for some of these factors. In this case, of course, the analyst will have to rely solely on the judgment of this single individual. To simplify the data-collection task, the following procedure adapted from Dienemann (19) has been developed.

In conjunction with the Delphi Method of questionnaires and controlled feedback, the analyst asks the chosen experts to specify three values for each of the cost and benefit factors: the lowest possible, the most likely, and the highest possible values. Since ordinarily it would be expected that the expert furnish the most likely value, he is now really only required to specify two additional estimates, an opportunity he might welcome in order to qualify his position on the matter. Following the specification of these values, the expert is asked to choose, from the nine probability distributions shown in Figure 2, the distribution that he feels best describes the nature of each factor. (Although the α and β parameters are shown on this figure, they probably should not be included on the figure used with the survey since they add nothing to the subjective "feel" of the distributions and could cause some confusion as to their meaning.) The selection of a distribution must be based on whether the expert feels the value of the variable under consideration is skewed left, symmetric, or skewed right, and whether the variance is low, medium, or high. Although these nine types are only a few of the infinite number of beta distributions available, "... the selection should suffice since it is unlikely that an analyst could accurately distinguish between more variations anyway" (19, p. 13).

One point should be made clear concerning the nine distributions selected. The modal value of the variable is always at the first quarter, midpoint, or third quarter of the range depending on whether the distribution is skewed or symmetric. In addition, any calculated value of the high or low point may differ to some extent from those specified by the expert, as might the mode. However, since these values are estimates to begin with, this discrepancy is not considered critical.

Another method has been suggested for accomplishing the same result. Sobel (63) developed a procedure whereby the expert would provide the lowest possible, highest possible and most probable values, <u>and</u> an 80 per cent central range. From these values, the resulting distribution and its parameters are determined by the use of a series of three computer programs. However, as Husic (38, p. 11) reports:

> ... Experience with analysts at RAC [Research Analysis Corporation] indicates that the analyst seems better able to pick a particular distribution from a fixed set than to estimate a number like the 80 per cent central range.

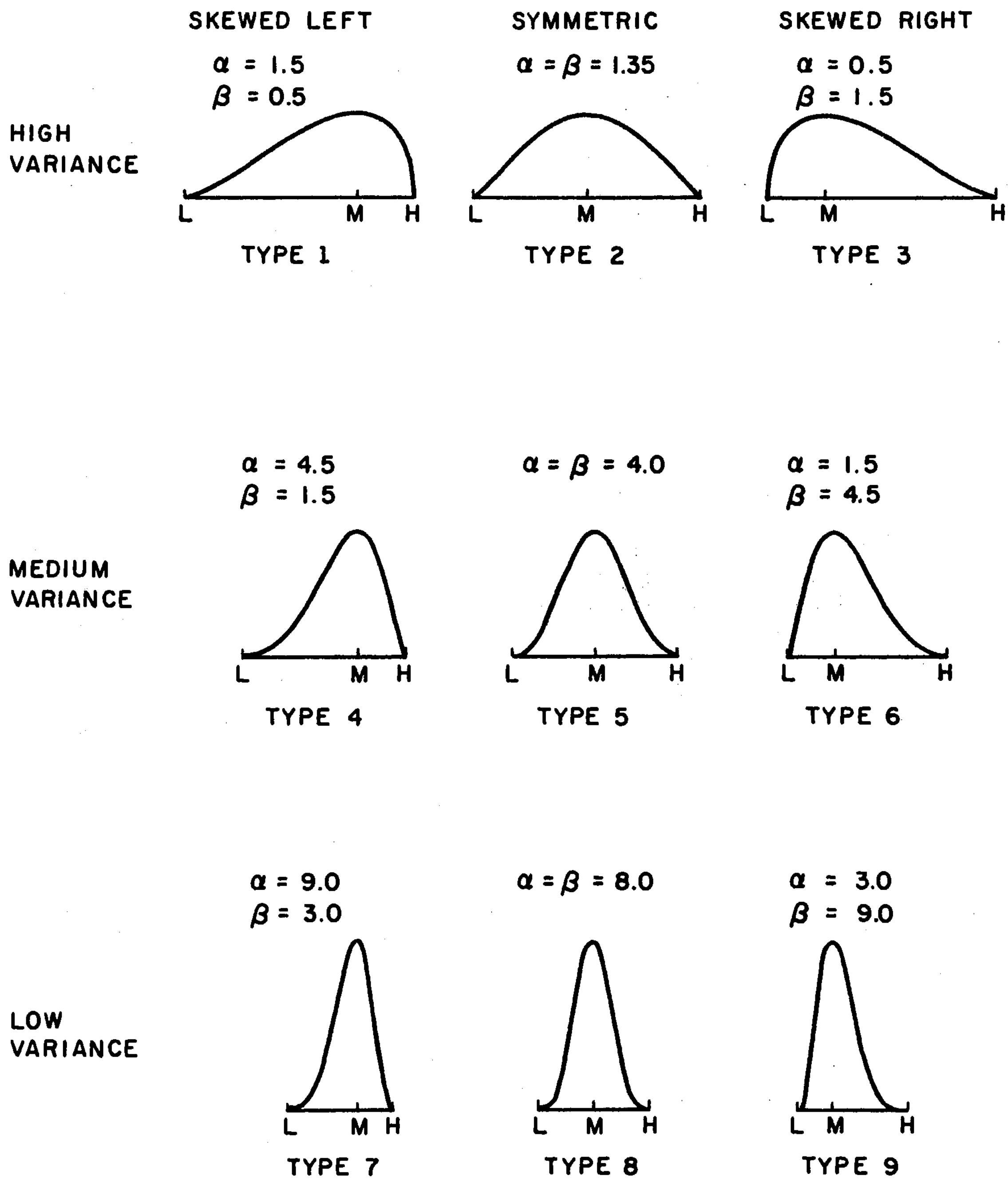


Figure 2. Beta Distributions Used With the Delphi Method

It is for this reason that the "fixed set" approach was selected for the model to be developed here.

Weighting the Results of the Delphi Method

It is highly probable that an attempt to obtain complete agreement about the lowest, highest, and most likely values of any particular distribution would be extremely difficult without unduly influencing the judgments of some experts. It can be expected, therefore, that upon completion of the Delphi process each individual value surveyed will have a distribution of its own. The usual Delphi procedure has been to use the median value as the predicted value. This technique can have a serious impact on the predicted value, however, since it does not allow for unequal expertise among the respondents. To provide for this range of expertise, the participants are asked to provide a "confidence rating" for each answer, thus giving a measure of how competent they feel they are to answer the particular question. The rating scale used in the study described in Chapter V is given below, the numbers preceding the statements indicating the relative weight to be given to that particular answer:

5 - I feel that this answer is probably within ±20% of the true value.

4 - I feel that this answer is probably within ±40% of the true value.

3 - I feel that this answer is probably within ±60% of the true value.

2 - I feel that this answer is probably within ±80% of the true value.

1 - I feel that this answer is probably within ±100% or more of the true value.

At the conclusion of the Delphi survey procedure, then, the analyst will have obtained various estimates of the lowest, most likely, and highest values (L, M, and H) of certain variables along with individual confidence ratings for each estimate. Assume for the moment that all participants have agreed upon the same curve-type from Figure 2 to represent the distribution of some variable. Since the α and β parameters of a distribution are implicit in the selection of that distribution, it is apparent that the specification of any two of the remaining three parameters, L, M, or H, will completely describe the distribution in question. The analyst should, therefore, use those two parameters that have the least "disagreement" or "relative dispersion" in order to obtain the final function. The procedure proposed here for accomplishing this task is to make use of the confidence ratings to obtain weighted means and variances for each of the three estimated parameters.

Let $w_1, w_2, \ldots, w_n$ be the confidence ratings obtained from n experts concerning their estimates $h_1, h_2, \ldots, h_n$ of the value H. The weighted mean, μ_H, and the weighted variance, σ_H^2, of these estimates for this highest value are

$$\mu_H = \frac{w_1 h_1 + w_2 h_2 + \ldots + w_n h_n}{w_1 + w_2 + \ldots + w_n} \tag{4-8}$$

and

$$\sigma_H^2 = \frac{w_1 (h_1 - \mu_H)^2 + w_2 (h_2 - \mu_H)^2 + \ldots + w_n (h_n - \mu_H)^2}{w_1 + w_2 + \ldots + w_n} \tag{4-9}$$

(49, p. 197). In a similar manner, the weighted means and variances of

L and M may be obtained.

To determine which two of the three estimated values have the least "disagreement," the ratio of the standard deviation to the mean for each parameter is calculated,

$$r_L = \frac{\sigma_L}{\mu_L} , \tag{4-10}$$

$$r_M = \frac{\sigma_M}{\mu_M} , \tag{4-11}$$

and

$$r_H = \frac{\sigma_H}{\mu_H} , \tag{4-12}$$

and the two parameters with the smallest ratios are selected. Equation (4-5) may then be used to solve for the third value in terms of the other two.

The possibility also exists that all experts surveyed about a particular cost or benefit value will not agree upon a common distribution from the nine presented. When agreement <u>is</u> obtained, the analyst should use the procedure outlined above. When the participants <u>do not</u> agree on the same curve-type, a distribution other than the nine presented must be used to describe the variable in question. To determine the characteristics of this new distribution, the procedure previously described is followed <u>for each different curve-type chosen</u>. Then, using Equations (4-3) and (4-4), the mean and variance of each different curve-type selection can be calculated.

Let W_1, W_2, ..., W_m be the <u>over-all sums</u> of the individual confidence ratings of the <u>two</u> parameters L, M, or H with the smallest ratios found from Equations (4-10), (4-11), and (4-12) for m different curve-types selected to represent a particular variable. Then, the weighted mean, variance, lower limit, and upper limit of the composite distribution, μ_c, σ_c^2, L_c, and H_c are found from

$$\mu_c = \frac{W_1\mu_1 + W_2\mu_2 + \ldots + W_m\mu_m}{W_1 + W_2 + \ldots + W_m}, \tag{4-13}$$

$$\sigma_c^2 = \frac{W_1^2\sigma_1^2 + W_2^2\sigma_2^2 + \ldots + W_m^2\sigma_m^2}{(W_1 + W_2 + \ldots + W_m)^2}, \tag{4-14}$$

$$L_c = \frac{W_1 L_1 + W_2 L_2 + \ldots + W_m L_m}{W_1 + W_2 + \ldots + W_m}, \tag{4-15}$$

and

$$H_c = \frac{W_1 H_1 + W_2 H_2 + \ldots + W_m H_m}{W_1 + W_2 + \ldots + W_m} \tag{4-16}$$

(49, p. 321). With this information, Equations (4-6) and (4-7) may be used to solve for the α and β parameters, and Equation (4-5) may be used to find the mode of the composite beta distribution that best represents the over-all weighted estimates of the variable in question.

One further situation must be considered: when only <u>one</u> individual has selected a particular curve-type, or when only <u>one</u> expert can be found to provide estimates. In this case, the analyst should use those two values of L, M, or H with the highest confidence ratings in order to find the third. When ties occur in these confidence ratings, <u>or</u> when ties occur in the ratios obtained through Equations (4-10), (4-11), and (4-12), the assumption is made here that the estimated values for M, L, and H are the most accurate, second most accurate, and least accurate, respectively, in order to determine which parameter should be recalculated.

The Time Value of Costs and Benefits

It is the objective of this thesis to provide a procedure that will allow for the selection of a work measurement technique to be used to study a particular job that will maximize the expected net present value of the time standard obtained. This presentation will take the viewpoint that the costs of establishing and maintaining a labor standard and the benefits to be obtained from this standard can be represented as a cash flow problem. In other words, the costs represent expenditures of the firm; the benefits represent savings in the expected expenditures for production purposes due to having the labor standard data available for use. It is the values of these cash flows that must be determined.

The Planning Horizon

The life expectancy of a given labor standard is a critical variable in determining the net present value of that standard. Present and future expenditures for the establishment and maintenance of the standard must be weighed against the future savings expected. For example, it would be foolish to spend $1,000 to establish a labor standard for which the organization expects to save $100 per month if the standard is only going to be in use for three months. In this case, it would probably be better to either use a different, and less expensive, technique or not set the standard at all.

Another variable that must be considered in the selection of a work measurement technique is the frequency of performance of the task in question. Once again, it would probably be foolish to use a very precise and costly technique to engineer the labor standard for a job that is carried out only once or twice a month, even though the standard will be used for years to come.

These two factors, therefore, the expected life of a standard and its frequency of use, are variables that highly influence the expected net present values of the work measurement techniques under consideration.

The Interest Rate Problem

The use of expected net present values to compare work measurement techniques requires that all future cash flows be discounted to the present by the use of some rate of interest. The selection of the proper interest rate to use in any given situation is a matter of disagreement among many economists. It is beyond the scope of this thesis to enter into this controversy. It will be assumed that for any organization a suitable discount rate can be found that may realistically be used for this purpose.

A Common Unit of Measurement

The economic analysis of work measurement techniques requires that <u>all initial costs</u> be presented for final analysis in terms of <u>dollars per standard hour developed</u>. Likewise, <u>all anticipated future costs and benefits</u> must be in terms of <u>dollars per standard hour developed per appropriate time period</u>. These units may not, however, be the best units to use in determining the cost and benefit values by the Delphi Method. The units used in the survey will depend to a large extent on the characteristics of the organization, the type of experts chosen, and how they can best relate their knowledge. It can be expected, therefore, that some or all of the data obtained will have to be converted to the above units. The purpose of this section is to introduce four statistical theorems that provide a means for accomplishing this goal.

THEOREM 1. Let x be a random variable with mean μ_x and variance σ_x^2. Let c be a constant. Then, the mean and variance of the product cx are

$$\mu_{cx} = c\mu_x \tag{4-17}$$

and

$$\sigma_{cx}^2 = c^2\sigma_x^2 \, , \tag{4-18}$$

and the mean and variance of the sum x + c are

$$\mu_{x+c} = \mu_x + c \tag{4-19}$$

and

$$\sigma_{x+c}^2 = \sigma_x^2 \tag{4-20}$$

(49, pp. 178, 190).

THEOREM 2. Let x and y be two independent random variables with means μ_x and μ_y and variances σ_x^2 and σ_y^2, respectively. Then, the mean of the sum x + y is

$$\mu_{x+y} = \mu_x + \mu_y \, , \tag{4-21}$$

the mean of the difference x - y is

$$\mu_{x-y} = \mu_x - \mu_y \, , \tag{4-22}$$

and the variance of either the sum x + y or the difference x - y is

$$\sigma_{x\pm y}^2 = \sigma_x^2 + \sigma_y^2 \tag{4-23}$$

(49, pp. 214, 322, 326).

THEOREM 3. If x_1, x_2, ..., x_n are independently and identically distributed random variables with means $\mu_{x_i} = \mu$ and variances $\sigma^2_{x_i} = \sigma^2$ ($i = 1, \ldots, n$), and if $t = x_1 + x_2 + \ldots + x_n$, then

$$\mu_t = n\mu \tag{4-24}$$

and

$$\sigma^2_t = n\sigma^2 \tag{4-25}$$

(49, pp. 326-327).

THEOREM 4. Let x and y be two independent random variables with means μ_x and μ_y and variances σ^2_x and σ^2_y, respectively. Then, the mean and variance of the product xy are given by

$$\mu_{xy} = \mu_x\mu_y \tag{4-26}$$

and

$$\sigma^2_{xy} = \mu^2_x\sigma^2_y + \mu^2_y\sigma^2_x + \sigma^2_x\sigma^2_y \tag{4-27}$$

(49, p. 217) (29, p. 709).

By appropriate use of the above theorems, recognizing, of course, the assumptions inherent in their application, the values obtained through the Delphi survey procedure may be converted to the units required for economic comparisons.

The Discounted Cash Flows

With the exception of the initial cost of developing a labor standard, all cash flows, both costs and benefits, will occur at some time in the future. A procedure for discounting these future cash flows to the present is needed.

It will be assumed that all individual cash flows concerning a particular labor standard occur at the end of their respective time periods. Furthermore, all <u>future</u> cash flow elements will be assumed to be both independent and identically distributed from one time period to the next. Let

$$\mu_p = \sum_{j=1}^{k} \mu_j \,, \tag{4-28}$$

$$\sigma_p^2 = \sum_{j=1}^{k} \sigma_j^2 \,, \tag{4-29}$$

$$\mu_r = \sum_{s=1}^{t} \mu_s \,, \tag{4-30}$$

and

$$\sigma_r^2 = \sum_{s=1}^{t} \sigma_s^2 \,, \tag{4-31}$$

where

μ_j and σ_j^2 = the mean and variance, respectively, of the j^{th} initial (time = 0) development cost distribution, for a particular work measurement technique, in dollars per standard hour set ($j = 1, \ldots, k$),

and

μ_s and σ_s^2 = the mean and variance, respectively, of the s^{th} individual future cash flow distribution, for a particular work measurement technique, in dollars per standard hour set per time period (s = 1, ..., t).

The expected net present value (ENPV) and the variance of the net present value of a particular labor standard developed by a particular work measurement technique may then be written

$$\text{ENPV} = \mu_p + \sum_{r=1}^{n} \frac{\mu_r}{(1+i)^r} \tag{4-32}$$

and

$$\text{Var(NPV)} = \sigma_p^2 + \sum_{r=1}^{n} \frac{\sigma_r^2}{(1+i)^{2r}} , \tag{4-33}$$

where

n = the number of time periods that the standard will be in use,

i = the appropriate interest rate,

and where the means of all cost distributions are taken to be negative quantities while the means of all benefit distributions are taken to be positive. Since the future cash flow distributions were assumed to be independent and identically distributed, Equations (4-32) and (4-33) may be rewritten

$$\text{ENPV} = \mu_p + \mu_r \left[\frac{(1+i)^n - 1}{i(1+i)^n} \right] \tag{4-34}$$

and

$$\text{Var(NPV)} = \sigma_p^2 + \sigma_r^2 \sum_{r=1}^{n} \frac{1}{(1+i)^{2r}} . \tag{4-35}$$

Although the above expressions provide the mean and variance of the net present value of a particular labor standard developed by a particular work measurement technique, they say nothing about the type of distribution that results. The following section will furnish this answer.

The Distribution of Net Present Value

It is well known that when independent random variables are added the distribution of their sum may be found either by convolving the component distributions or by using moments to generate the final distribution. In either case, since the input data concerning these distributions are only estimates, such elaborate operations are not warranted.

The Bounded Liapounov Theorem provides a necessary and sufficient condition for the sum of finite independent random variables to have a limiting normal distribution. Its proof may be found in Fisz (23, p. 206) and Loeve (45, p. 200). In essence, this theorem states that if $\{X_k\}$ ($k = 1, \ldots, n$) is a set of independent random variables with each X_k having both an upper and lower limit ($-\infty < X_k < +\infty$ for all k), a variance that exists ($\sigma_k^2 \neq 0$ for all k), and if

$$Z = \sum_{k=1}^{n} X_k , \tag{4-36}$$

then a necessary and sufficient condition for the distribution function of the random variable Z to approach a normal distribution function is that

$$\lim_{n \to \infty} \sum_{k=1}^{n} \sigma_k^2 = \infty. \tag{4-37}$$

Since the net present value of a labor standard results from the sum of supposed mutually independent random variables, since these random variables are in fact bounded by upper and lower limits, and since their variances do exist, the constraints of the theorem are satisfied. It will be assumed, therefore, that the individual cash flows are present in a large enough number, n, such that the effect of any one cash flow will be slight with respect to their sum and that the distribution law followed by this sum will not differ significantly from the normal distribution law.

The Selection of the Most Desirable Technique

The determination of the expected net present value for each of the work measurement techniques under consideration is a large step toward economically optimizing a work measurement program. However, the selection of a particular technique to use to study a given job based <u>only</u> on its expected net present value does not make full use of the information available; the possibility of incurring a loss should be considered, and the techniques should be compared against each other before the final selection is made.

<u>The Possibility of Incurring a Loss With a Particular Technique</u>

With the assumption that the net present value of a labor standard is normally distributed, the probability of a loss and the expected loss given that a loss occurs may be calculated for any work measurement technique under consideration. The probability of a loss is the probability that a particular occurrence of the net present value of the labor standard, developed by the technique concerned, will be less than or equal to zero. This probability is shown by the shaded area of Figure 3 and may be found from

$$P(\text{loss}) = P\left(z \leq \frac{0 - \text{ENPV}}{\sqrt{\text{Var(NPV)}}}\right), \tag{4-38}$$

where z is the standard normal deviate with zero mean and unit variance which is commonly tabulated.

The expected loss given that a loss occurs may also be calculated. Define u to be the number of standard deviations between NPV = 0 and the ENPV, or

$$u = \frac{\text{ENPV} - 0}{\sqrt{\text{Var(NPV)}}}. \tag{4-39}$$

Then, the expected loss given that a loss occurs is

$$E(\text{loss} \mid \text{loss occurs}) = \frac{\sqrt{\text{Var(NPV)}}}{P(\text{loss})} \int_u^\infty (z-u) \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}z^2} dz \tag{4-40}$$

(69, pp. 57-60).

Now, let

$$L(u) = \int_u^\infty (z-u) \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}z^2} dz \tag{4-41}$$

$$= \text{"unit-normal linear-loss integral."}$$

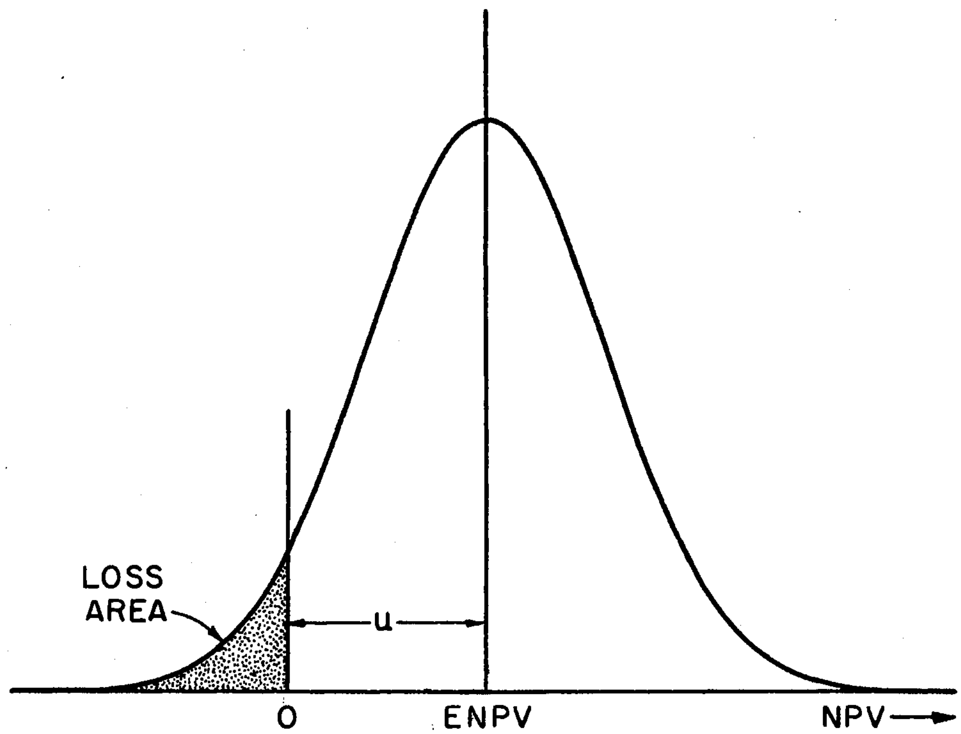


Figure 3. Distribution of the Net Present Value of a Labor Standard

A table of this integral for various values of u can be found in Raiffa and Schlaifer (56, p. 356). Therefore,

$$E(\text{loss} \mid \text{loss occurs}) = \frac{\sqrt{Var(NPV)}}{P(\text{loss})} L(u). \tag{4-42}$$

With the information supplied by the above expressions, the decision maker can further evaluate the desirability of a particular work measurement technique to be used to develop the labor standard for a given task. Before the final decision is made, however, competing techniques should be compared against each other.

Paired Comparisons of the Competing Techniques

Assume that techniques 1 and 2 have the largest expected net present values of all techniques under consideration, with $ENPV_1 > ENPV_2$ as shown in Figure 4(a). Under the assumption that the two techniques are mutually independent, the difference of these expected net present values, $ENPV_d$, and the variance of this difference, $Var(NPV_d)$, may be found from

$$ENPV_d = ENPV_1 - ENPV_2 \tag{4-43}$$

and

$$Var(NPV_d) = Var(NPV_1) + Var(NPV_2). \tag{4-44}$$

The distribution of this difference is shown in Figure 4(b). Since NPV_1 and NPV_2 are normally distributed and independent of each other, NPV_d is also normally distributed.

With the information supplied by $ENPV_d$ and $Var(NPV_d)$, the "probability of reversal" may be calculated. The probability of reversal is

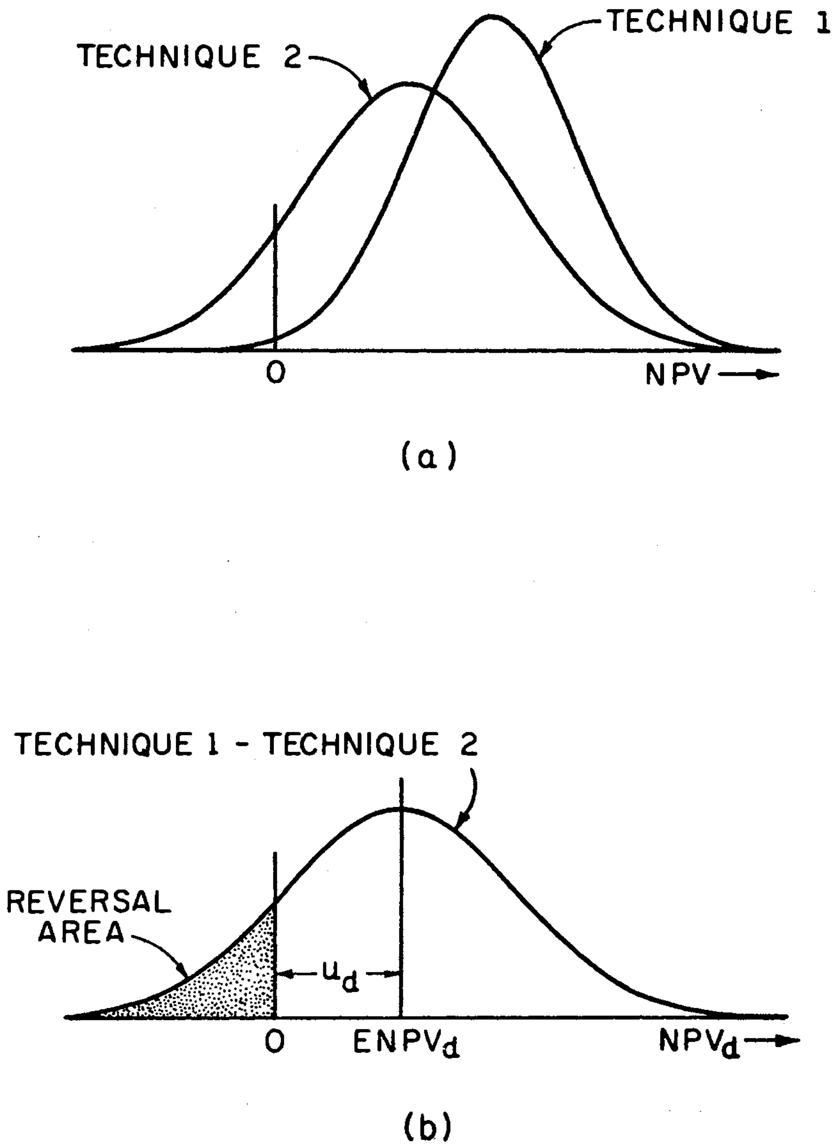


Figure 4. Comparison of the Net Present Values of Two Competing Work Measurement Techniques

the probability that between two competing techniques, the one with the greater ENPV will actually be found to be not as good as the other (12, p. 35). Although technique 1 has a higher ENPV than technique 2, there is a probability that a single occurrence of NPV_1 will be less than NPV_2. The probability of reversal, the probability that $NPV_d \leq 0$, is shown by the shaded area of Figure 4(b). This probability is given by

$$P(\text{reversal}) = P\left(z \leq \frac{0 - ENPV_d}{\sqrt{Var(NPV_d)}}\right), \qquad (4\text{-}45)$$

where again z is the standard normal deviate with zero mean and unit variance (12, p. 36).

The expected loss given that a reversal occurs may also be calculated. Here, define u_d to be the number of standard deviations between $NPV_d = 0$ and the $ENPV_d$, or

$$u_d = \frac{ENPV_d - 0}{\sqrt{Var(NPV_d)}}. \qquad (4\text{-}46)$$

The expected loss given a reversal occurs becomes

$$E(\text{loss} \mid \text{reversal occurs}) = \frac{\sqrt{Var(NPV_d)}}{P(\text{reversal})} \int_{u_d}^{\infty} (z - u_d) \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}z^2} dz , \qquad (4\text{-}47)$$

or using Equation (4-41),

$$E(\text{loss} \mid \text{reversal occurs}) = \frac{\sqrt{Var(NPV_d)}}{P(\text{reversal})} L(u_d). \qquad (4\text{-}48)$$

In the comparison of two work measurement techniques, the expected loss given a reversal occurs is a measure of how much could be saved, on the average, if the occurrence of a reversal could be perfectly predicted and the technique with the highest ENPV were not chosen if this reversal were going to occur (12, p. 36). In practice this value and the probability of reversal can be used, together with a qualitative judgment of other pertinent factors to make a better decision concerning which of the two techniques should be applied.

Although the procedure outlined is applicable only to a two-way comparison, it may be used to further evaluate other techniques under consideration. Once the more preferable of the two techniques just evaluated has been selected, this technique may be compared with the technique having the next smaller ENPV, by repeating the process just described. These two-way comparisons can be repeated until it is determined that further consideration is not warranted, or until all possible technique combinations have been exhausted. The final choice should be the technique that has the most positive ENPV <u>and</u> which has not been judged to be less desirable than some other technique due to the loss information calculated or other pertinent factors (12, p. 36).

The Validity and Usefulness of the Results

With the explicit information determined by the proposed model, the decision maker is aided in two ways. First, the extent that the net present value of a particular work measurement technique could differ from its expected value can be <u>anticipated and evaluated in advance</u>. With this quantitative measure, the decision maker is better able to judge, in concert with other pertinent factors, the desirability of each alternative technique. Secondly, the decision maker is more apt to choose the preferable alternative when this type of information is available, especially in those situations when competing techniques have almost equal expected net present values, but differing dispersions.

It is obvious, however, that the final estimate of the expected net present value for any particular work measurement technique is no better than the quality of its inputs. The analyst's thoroughness in attempting to identify and survey all contributing elements has a direct relationship to the validity of the resultant distribution. Likewise, in describing each element's distribution, there is no substitute for accurate data. It is true that the inputs proposed here are mostly subjective. However, any information, even if only in the form of an educated guess, is a <u>departure</u> from total ignorance, a departure that could prove profitable to the organization.

CHAPTER V

AN APPLICATION OF THE PROPOSED MODEL

The economic model developed in Chapter IV was actually applied to a working industrial organization. The various quantities provided in this chapter have been taken from the results of that investigation. The reader is cautioned to remember that these specific results are applicable only to the specific situation described; they should not be interpreted as being valid data for use under all other conditions.

The Organization Studied

One branch of a large organization, operating under a measured day-work condition, and specializing in the maintenance and repair of aircraft parts and accessories was the subject of this study. At the time, 24 industrial engineering technicians, out of a total of 134 employed by the parent organization itself, were assigned to this branch. These 24 technicians were responsible for the establishment and maintenance of over 4,000 active labor standards. In addition, three supervisors and two clerk-secretaries were assigned to this function.

Categories of Labor Standards Within the Organization

Labor standards developed within the subject organization are classified according to one of the following four types:

Type A: A labor standard developed by a recognized work measurement technique and backed up by sufficient data to statistically support an accuracy of plus or minus 10% of the mean, with 95% confidence,

Type B: A labor standard developed by a recognized work measurement technique and backed up by sufficient data to statistically support an accuracy of plus or minus 25% of the mean, with 95% confidence,

Type 2: A labor standard developed by a recognized work measurement technique, but which lacks sufficient data to satisfy the requirements for classification as either a Type A or Type B standard, or

Type 3: An estimate of the standard time arrived at through coordination between an industrial engineering technician and one or more representatives from production control, quality control, shop supervision, etc.

The industrial engineering technicians employed by this organization have the ability to establish labor standards by any of six basic techniques: MTM, standard data, stop-watch time study, work sampling, engineered estimates, and coordinated estimates. For clarification of the terminology used in this chapter and in the appendixes, it should be pointed out that the standard data is maintained by an electronic data processing procedure, known as the Automated Standard Data (ASD) System. A labor standard developed using this information is termed an "ASD standard."

When the technique options are combined with the various type classifications, the result is that any given labor standard would have been developed by one of the following twelve technique-types:

MTM (Type A),

ASD (Type A),

ASD (Type B),

ASD (Type 2),

Stop Watch (Type A),

Stop Watch (Type B),

Stop Watch (Type 2),

Work Sampling (Type A),

Work Sampling (Type B),

Work Sampling (Type 2),

Engineered Estimate (Type 2), or

Coordinated Estimate (Type 3).

The Costs and Benefits of the Work Measurement Program

There are three different sources of costs associated with the work measurement program of the subject organization. The first is attributable to the time required by the industrial engineering technicians to develop and maintain the labor standards. The second stems from the practice of processing the labor standards by electronic computer. This cost may also be divided into two categories: (1) The cost of initially establishing the labor standard and (2) the periodic cost of maintaining that standard as part of the mechanized records. The source of the third type of cost is the four work measurement training courses conducted by the organization. The subjects covered in these courses are: (1) general work methods and standards, (2) MTM procedures, (3) the Automated Standard Data System, and (4) the programming of labor standards for electronic data processing.

The benefits of the work measurement program to the organization are derived from the savings in unproductive direct labor that results from the use of the labor standards themselves.

The Participants in the Study

Eight industrial engineering technicians assigned to the branch studied were administered the Delphi questionnaires included in Appendix A. Of these eight, three had previous experience as production-shop supervisors.

Each of the four training courses had only one individual assigned to develop and conduct the respective class presentations. In addition, only one individual could be identified as having sufficient knowledge of electronic data processing (EDP) of labor standards to provide the costs associated with this procedure. Hence, the Delphi Method could not be used to gather this information. However, objective historical records were available to aid these persons in providing their answers. The questionnaires concerning these costs are included in Appendixes B and C.

The Results of the Study

The remainder of this chapter will be devoted to an example of the application of the proposed economic model. Again, the reader is reminded that the various quantities that follow, although obtained from an actual investigation, apply only to the particular situation studied.

Obtaining the Composite Distributions

At the conclusion of the survey procedure, the analyst will have obtained several estimates of the lowest, most likely, and highest values (L, M, and H) of certain variables, individual confidence ratings (CR) for each estimate, and various curve-type selections to represent the values. Table I shows the estimates obtained from the eight industrial engineering technicians, on the fourth-round questionnaire, for the number of hours required to develop a one-standard-hour labor standard using MTM. As defined in the study, a "one-standard-hour labor standard" is a standard set on a job that will be charged for one man-hour of work. In other words, after the task has been studied, and the appropriate fatigue, delay, personal, etc., allowances have been added, the resulting labor standard shows a standard time (not normal time) of one man-hour to accomplish.

Since the technicians did not agree on the same curve-type to represent this variable, a composite distribution must be developed. By using the following equations:

$$\mu_H = \frac{w_1 h_1 + w_2 h_2 + \dots + w_n h_n}{w_1 + w_2 + \dots + w_n}, \tag{4-8}$$

and

$$\sigma_H^2 = \frac{w_1 (h_1 - \mu_H)^2 + w_2 (h_2 - \mu_H)^2 + \dots + w_n (h_n - \mu_H)^2}{w_1 + w_2 + \dots + w_n}, \tag{4-9}$$

and substituting for L and M when appropriate, the weighted mean and variance of each estimated parameter for each curve-type selection may be found. For curve Type 3:

TABLE I

ESTIMATES OF THE TIME REQUIRED BY AN INDUSTRIAL ENGINEERING TECHNICIAN TO DEVELOP A ONE-STANDARD-HOUR LABOR STANDARD USING MTM

Technician	L (hrs)	CR_L	M (hrs)	CR_M	H (hrs)	CR_H	Curve-Type Selection
1	45	4	80	4	140	4	3
2	30	3	50	3	80	2	3
3	40	2	70	2	120	2	3
4	40	4	65	4	110	4	3
5	49	5	55	5	119	5	3
6	30	5	35	5	40	5	8
7	20	5	30	4	40	4	8
8	40	4	80	4	125	4	2

$$\mu_L = \frac{4(45) + 3(30) + 2(40) + 4(40) + 5(49)}{4 + 3 + 2 + 4 + 5} = 41.944 \text{ hrs},$$

$$\sigma_L^2 = \frac{4(45 - 41.944)^2 + 3(30 - 41.944)^2 + 2(40 - 41.944)^2}{4 + 3 + 2 + 4 + 5}$$

$$+ \frac{4(40 - 41.944)^2 + 5(49 - 41.944)^2}{4 + 3 + 2 + 4 + 5}$$

$$= 40.941 \text{ hrs}^2,$$

$$\sigma_L = 6.399 \text{ hrs},$$

$$\mu_M = \frac{4(80) + 3(50) + 2(70) + 4(65) + 5(55)}{4 + 3 + 2 + 4 + 5} = 63.611 \text{ hrs},$$

$$\sigma_M^2 = \frac{4(80 - 63.611)^2 + 3(50 - 63.611)^2 + 2(70 - 63.611)^2}{4 + 3 + 2 + 4 + 5}$$

$$+ \frac{4(65 - 63.611)^2 + 5(55 - 63.611)^2}{4 + 3 + 2 + 4 + 5}$$

$$= 116.126 \text{ hrs}^2,$$

$$\sigma_M = 10.776 \text{ hrs},$$

$$\mu_H = \frac{4(140) + 2(80) + 2(120) + 4(110) + 5(119)}{4 + 2 + 2 + 4 + 5} = 117.353 \text{ hrs},$$

$$\sigma_H^2 = \frac{4(140 - 117.353)^2 + 2(80 - 117.353)^2 + 2(120 - 117.353)^2}{4 + 2 + 2 + 4 + 5}$$

$$+ \frac{4(110 - 117.353)^2 + 5(119 - 117.353)^2}{4 + 2 + 2 + 4 + 5}$$

$$= 299.170 \text{ hrs}^2,$$

and

$$\sigma_H = 17.297 \text{ hrs}.$$

Now using this information, the following ratios are determined:

$$r_L = \frac{\sigma_L}{\mu_L} = \frac{6.399}{41.944} = 0.153, \tag{4-10}$$

$$r_M = \frac{\sigma_M}{\mu_M} = \frac{10.776}{63.611} = 0.169 \ , \tag{4-11}$$

and

$$r_H = \frac{\sigma_H}{\mu_H} = \frac{17.297}{117.353} = 0.147 \ . \tag{4-12}$$

Since r_M is greater than both r_L and r_H, the most likely value (M) is recalculated, and the over-all weighting factor to use for curve Type 3 is the sum of the individual confidence ratings for L and H:

$$M = \frac{(H - L)\alpha}{(\alpha + \beta)} + L \tag{4-5}$$

$$= \frac{(117.353 - 41.944)0.5}{(0.5 + 1.5)} + 41.944 = 60.797 \text{ hrs}$$

and

$$W_1 = (4 + 3 + 2 + 4 + 5) + (4 + 2 + 2 + 4 + 5) = 35 \ .$$

For curve Type 8:

$$\mu_L = \frac{5(30) + 5(20)}{5 + 5} = 25 \text{ hrs} \ ,$$

$$\sigma_L^2 = \frac{5(30 - 25)^2 + 5(20 - 25)^2}{5 + 5} = 25 \text{ hrs}^2 \ ,$$

$$\sigma_L = 5 \text{ hrs},$$

$$\mu_M = \frac{5(35) + 4(30)}{5 + 4} = 32.778 \text{ hrs},$$

$$\sigma_M^2 = \frac{5(35 - 32.778)^2 + 4(30 - 32.778)^2}{5 + 4} = 6.173 \text{ hrs}^2 \ ,$$

$$\sigma_M = 2.484 \text{ hrs} \ ,$$

$$\mu_H = \frac{5(40) + 4(40)}{5 + 4} = 40 \text{ hrs} \ ,$$

$$\sigma_H^2 = \frac{5(40 - 40)^2 + 4(40 - 40)^2}{5 + 4} = 0 \text{ hrs}^2 \ ,$$

$$\sigma_H = 0 \text{ hrs} ,$$

$$r_L = \frac{5}{25} = 0.200 ,$$

$$r_M = \frac{2.484}{32.778} = 0.076 ,$$

and

$$r_H = \frac{0}{40} = 0 .$$

Since r_L is greater than both r_M and r_H, Equation (4-5) is solved in terms of L. The over-all weighting factor to use for curve Type 8 becomes the sum of the individual confidence ratings for M and H:

$$L = \frac{M(\alpha + \beta) - H\alpha}{\beta}$$

$$= \frac{32.778(8 + 8) - 40(8)}{8} = 25.556 \text{ hrs}$$

and

$$W_2 = (5 + 4) + (5 + 4) = 18.$$

For curve Type 2:

Inasmuch as only one individual selected this curve-type and since the confidence ratings are equal for all three estimates, the assumption is made that H is the least accurate. Equation (4-5) is now solved for H, and the over-all weighting factor to use for curve Type 2 is the sum of the confidence ratings for L and M:

$$H = \frac{M(\alpha + \beta) - L\beta}{\alpha}$$

$$= \frac{80(1.35 + 1.35) - 40(1.35)}{1.35} = 120.000 \text{ hrs}$$

and

$$W_3 = (4) + (4) = 8 \; .$$

The mean and variance of a beta distribution are

$$\mu = \frac{(H - L)\ (\alpha + 1)}{(\alpha + \beta + 2)} + L \tag{4-3}$$

and

$$\sigma^2 = \frac{(H - L)^2\ (\alpha + 1)\ (\beta + 1)}{(\alpha + \beta + 2)^2\ (\alpha + \beta + 3)} \; . \tag{4-4}$$

Using these equations, the mean and variance of each curve-type selection is found. For curve Type 3:

$$\mu_1 = \frac{(117.353 - 41.944)\ (0.5 + 1)}{(0.5 + 1.5 + 2)} + 41.944 = 70.223 \text{ hrs}$$

and

$$\sigma_1^2 = \frac{(117.353 - 41.944)^2\ (0.5 + 1)\ (1.5 + 1)}{(0.5 + 1.5 + 2)^2\ (0.5 + 1.5 + 3)} = 266.552 \text{ hrs}^2 .$$

For curve Type 8:

$$\mu_2 = \frac{(40 - 25.556)\ (8 + 1)}{(8 + 8 + 2)} + 25.556 = 32.778 \text{ hrs}$$

and

$$\sigma_2^2 = \frac{(40 - 25.556)^2\ (8 + 1)\ (8 + 1)}{(8 + 8 + 2)^2\ (8 + 8 + 3)} = 2.745 \text{ hrs}^2 \; .$$

For curve Type 2:

$$\mu_3 = \frac{(120 - 40)\ (1.35 + 1)}{(1.35 + 1.35 + 2)} + 40 = 80.000 \text{ hrs}$$

and

$$\sigma_3^2 = \frac{(120 - 40)^2\ (1.35 + 1)\ (1.35 + 1)}{(1.35 + 1.35 + 2)^2\ (1.35 + 1.35 + 3)} = 280.702 \text{ hrs}^2 .$$

To find the weighted mean, variance, lower limit, upper limit, and α and β parameters of the composite distribution, the following expressions are used:

$$\mu_c = \frac{W_1\mu_1 + W_2\mu_2 + \ldots + W_m\mu_m}{W_1 + W_2 + \ldots + W_m} \tag{4-13}$$

$$= \frac{35(70.223) + 18(32.778) + 8(80)}{35 + 18 + 8} = 60.456 \text{ hrs} ,$$

$$\sigma_c^2 = \frac{W_1^2\sigma_1^2 + W_2^2\sigma_2^2 + \ldots + W_m^2\sigma_m^2}{(W_1 + W_2 + \ldots + W_m)^2} \tag{4-14}$$

$$= \frac{(35)^2(266.552) + (18)^2(2.745) + (8)^2(280.702)}{(35 + 18 + 8)^2} = 92.819 \text{ hrs}^2 ,$$

$$L_c = \frac{W_1 L_1 + W_2 L_2 + \ldots + W_m L_m}{W_1 + W_2 + \ldots + W_m} \tag{4-15}$$

$$= \frac{35(41.944) + 18(25.556) + 8(40)}{35 + 18 + 8} = 36.853 \text{ hrs} ,$$

$$H_c = \frac{W_1 H_1 + W_2 H_2 + \ldots + W_m H_m}{W_1 + W_2 + \ldots + W_m} \tag{4-16}$$

$$= \frac{35(117.353) + 18(40) + 8(120)}{35 + 18 + 8} = 94.875 \text{ hrs} ,$$

$$\alpha_c = \frac{(\mu_c - L_c)^2\left(1 - \frac{\mu_c - L_c}{H_c - L_c}\right)}{\sigma_c^2} - \left(\frac{\mu_c - L_c}{H_c - L_c}\right) - 1 \tag{4-6}$$

$$= \frac{(60.456 - 36.853)^2\left(1 - \frac{60.456 - 36.853}{94.875 - 36.853}\right)}{92.819} - \left(\frac{60.456 - 36.853}{94.875 - 36.853}\right) - 1$$

$$= 2.153 ,$$

and

$$\beta_c = \frac{\left(\frac{\mu_c - L_c}{H_c - L_c}\right)(H_c - \mu_c)^2}{\sigma_c^2} + \left(\frac{\mu_c - L_c}{H_c - L_c}\right) - 2 \tag{4-7}$$

$$= \frac{\left(\frac{60.456 - 36.853}{94.875 - 36.853}\right)(94.875 - 60.456)^2}{92.819} + \left(\frac{60.456 - 36.853}{94.875 - 36.853}\right) - 2$$

$$= 3.599.$$

The previous calculations are summarized in Table II.

A similar procedure was used to determine the composite distribution of each of the remaining variables identified on the questionnaires. All of the preceding calculations and decision rules have been incorporated in Computer Program 1 of Appendix D. Tables III through VIII show the resultant distribution characteristics.

Conversion to a Common Unit of Measurement

The economic analysis of work measurement techniques requires that <u>all initial costs</u> be presented for final analysis in terms of <u>dollars per standard hour developed</u>. Likewise, <u>all anticipated future costs and benefits</u> must be in terms of <u>dollars per standard hour developed per appropriate time period</u>. Due to the characteristics of the subject organization, three months was considered to be a suitable time period for subsequent analysis of the work measurement techniques. Some of the information collected on the questionnaires can be applied directly in these analyses; other data require conversion to the appropriate units.

<u>The Costs of Employee Services</u>

The amount of pay received by both the industrial engineering

TABLE II

SUMMARY OF THE WEIGHTED ESTIMATES OF THE TIME REQUIRED BY AN INDUSTRIAL ENGINEERING TECHNICIAN TO DEVELOP A ONE-STANDARD-HOUR LABOR STANDARD USING MTM

Curve	L (hrs)	M (hrs)	H (hrs)	μ (hrs)	σ^2 (hrs)^2	σ (hrs)	α	β	W
Type 3	41.944	60.797	117.353	70.223	266.552	16.326	0.500	1.500	35
Type 8	25.556	32.778	40.000	32.778	2.745	1.657	8.000	8.000	18
Type 2	40.000	80.000	120.000	80.000	280.702	16.754	1.350	1.350	8
Composite	36.853	58.575	94.875	60.456	92.819	9.634	2.153	3.599	

TABLE III

DISTRIBUTIONS OF THE TIME REQUIRED BY AN INDUSTRIAL ENGINEERING TECHNICIAN TO DEVELOP A ONE-STANDARD-HOUR LABOR STANDARD BY VARIOUS TECHNIQUE-TYPES

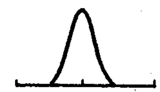
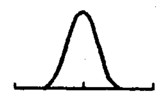
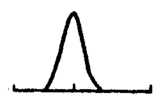
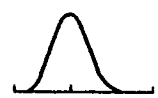
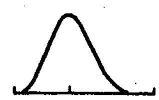
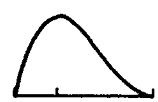
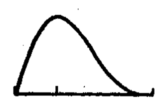
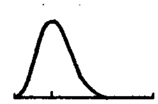
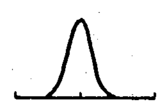
Technique-Type	L (hrs)	M (hrs)	H (hrs)	μ (hrs)	σ^2 (hrs)^2	α	β	Distribution Shape
MTM (A)	36.853	58.575	94.875	60.456	92.819	2.153	3.599	
ASD (A)	4.628	8.916	13.719	8.931	0.609	14.552	16.301	
ASD (B)	2.998	6.158	9.319	6.158	0.394	11.183	11.183	
ASD (2)	2.211	4.678	7.867	4.695	0.185	17.291	22.352	
Stop Watch (A)	6.596	12.051	20.030	12.202	2.478	5.972	8.735	
Stop Watch (B)	5.535	8.892	14.182	9.062	1.456	3.649	5.750	
Stop Watch (2)	1.554	2.363	3.493	2.371	0.021	16.944	23.661	
Work Sampling (A)	18.120	32.251	62.256	35.248	73.462	1.056	2.242	
Work Sampling (B)	10.474	16.667	30.330	17.826	12.349	1.386	3.058	
Work Sampling (2)	4.900	10.387	14.906	10.280	2.481	3.856	3.176	
Engineered Estimate (2)	0.687	1.233	2.713	1.294	0.052	3.619	9.810	
Coordinated Estimate (3)	0.460	0.902	1.417	0.904	0.006	16.173	18.805	

TABLE IV

DISTRIBUTIONS OF THE TIME REQUIRED BY AN INDUSTRIAL ENGINEERING TECHNICIAN EVERY TWO YEARS TO MAINTAIN A ONE-STANDARD-HOUR LABOR STANDARD BY VARIOUS TECHNIQUE-TYPES

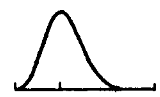
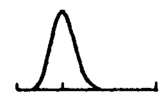
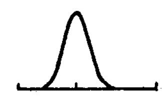
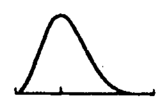
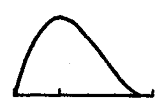
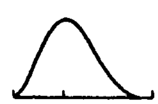
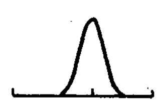
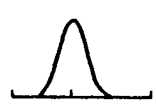
Technique-Type	L (hrs)	M (hrs)	H (hrs)	μ (hrs)	σ^2 (hrs)^2	α	β	Distribution Shape
MTM (A)	1.164	22.576	46.876	22.693	20.220	10.656	12.093	
ASD (A)	1.213	4.527	11.369	4.790	1.635	3.720	7.679	
ASD (B)	1.279	3.114	7.020	3.179	0.225	9.423	20.059	
ASD (2)	1.045	3.398	6.645	3.426	0.233	12.537	17.297	
Stop Watch (A)	0.000	3.597	10.040	3.777	1.825	4.393	7.033	
Stop Watch (B)	0.471	2.596	7.008	2.819	0.875	2.677	5.559	
Stop Watch (2)	0.420	1.671	4.138	1.846	0.410	1.672	3.295	
Work Sampling (A)	2.401	7.953	16.646	8.247	4.206	3.381	5.294	
Work Sampling (B)	2.001	5.201	11.673	5.782	3.355	1.204	2.435	
Work Sampling (2)	1.121	2.852	5.746	3.000	0.582	2.196	3.670	
Engineered Estimate (2)	0.493	2.166	3.461	2.156	0.056	20.285	15.694	
Coordinated Estimate (3)	0.421	0.754	1.192	0.758	0.005	11.224	14.729	

TABLE V

DISTRIBUTIONS OF THE AMOUNT OF UNPRODUCTIVE DIRECT LABOR TIME PER 160 REPETITIONS OF A ONE-MAN-HOUR TASK BY VARIOUS TECHNIQUE-TYPES

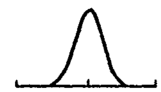
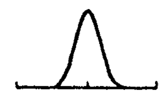
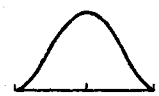
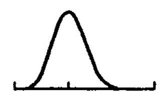
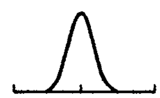
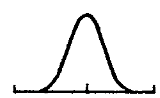
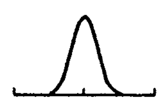
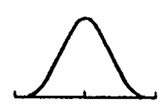
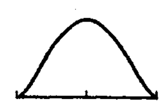
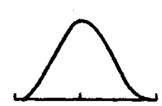
Technique-Type	L (hrs)	M (hrs)	H (hrs)	μ (hrs)	σ^2 (hrs)^2	α	β	Distribution Shape
No Standard	17.766	39.706	61.645	39.706	77.650	1.599	1.599	
MTM (A)	3.653	8.094	12.155	8.080	0.632	13.352	12.208	
ASD (A)	4.353	8.757	12.912	8.750	0.532	16.156	15.238	
ASD (B)	5.273	12.399	19.172	12.342	6.737	2.136	2.030	
ASD (2)	10.111	20.064	36.164	20.393	8.247	6.366	10.297	
Stop Watch (A)	4.663	9.448	14.742	9.463	0.740	14.826	16.400	
Stop Watch (B)	5.894	12.575	18.985	12.561	2.209	8.366	8.025	
Stop Watch (2)	8.935	21.241	33.839	21.266	12.363	4.714	4.826	
Work Sampling (A)	4.953	9.656	14.359	9.656	0.649	15.532	15.532	
Work Sampling (B)	6.879	14.227	21.576	14.227	4.843	4.075	4.075	
Work Sampling (2)	8.094	22.578	37.062	22.578	33.346	1.646	1.646	
Engineered Estimate (2)	12.228	24.749	42.156	24.998	10.608	7.387	10.269	
Coordinated Estimate (3)	18.194	28.920	40.742	29.053	13.739	2.968	3.271	

TABLE VI

DISTRIBUTIONS OF THE TOTAL COST OF ESTABLISHING A ONE-STANDARD-HOUR LABOR STANDARD IN THE EDP RECORDS BY VARIOUS TECHNIQUE-TYPES

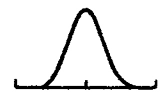
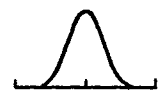
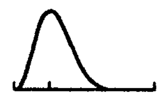
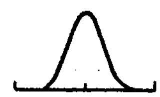
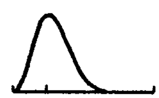
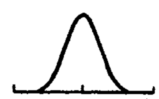
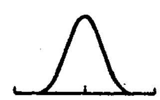
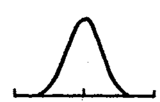
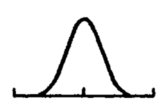
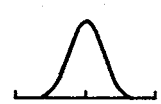
Technique-Type	L ($)	M ($)	H ($)	μ ($)	σ^2 ($)^2	α	β	Distribution Shape
MTM (A)	130.000	154.000	178.000	154.000	30.316	8.000	8.000	
ASD (A)	22.000	27.000	32.000	27.000	1.316	8.000	8.000	
ASD (B)	14.000	16.000	22.000	16.286	0.871	3.000	9.000	
ASD (2)	5.500	6.750	8.000	6.750	0.082	8.000	8.000	
Stop Watch (A)	22.000	27.000	32.000	27.000	1.316	8.000	8.000	
Stop Watch (B)	14.000	16.000	22.000	16.286	0.871	3.000	9.000	
Stop Watch (2)	5.500	6.750	8.000	6.750	0.082	8.000	8.000	
Work Sampling (A)	1.500	2.000	2.500	2.000	0.013	8.000	8.000	
Work Sampling (B)	1.500	2.000	2.500	2.000	0.013	8.000	8.000	
Work Sampling (2)	1.500	2.000	2.500	2.000	0.013	8.000	8.000	
Engineered Estimate (2)	5.500	6.750	8.000	6.750	0.082	8.000	8.000	
Coordinated Estimate (3)	1.500	2.000	2.500	2.000	0.013	8.000	8.000	

TABLE VII

DISTRIBUTIONS OF THE TOTAL COST OF MAINTAINING A
ONE-STANDARD-HOUR LABOR STANDARD
EVERY TWO YEARS IN THE EDP RECORDS
BY VARIOUS TECHNIQUE-TYPES

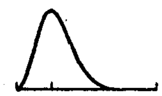
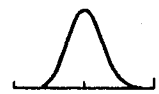
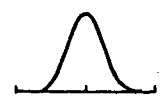
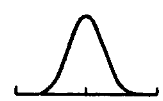
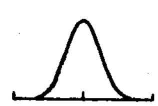
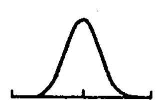
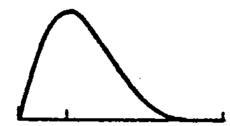
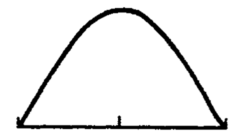
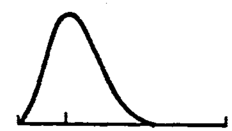
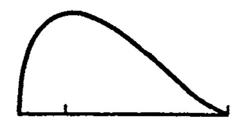
Technique-Type	L ($)	M ($)	H ($)	μ ($)	σ^2 ($)^2	α	β	Distribution Shape
MTM (A)	780.000	824.000	956.000	830.286	421.442	3.000	9.000	
ASD (A)	132.000	162.000	192.000	162.000	47.368	8.000	8.000	
ASD (B)	84.000	96.000	108.000	96.000	7.579	8.000	8.000	
ASD (2)	33.000	40.500	48.000	40.500	2.961	8.000	8.000	
Stop Watch (A)	132.000	162.000	192.000	162.000	47.368	8.000	8.000	
Stop Watch (B)	84.000	96.000	108.000	96.000	7.579	8.000	8.000	
Stop Watch (2)	33.000	40.500	48.000	40.500	2.961	8.000	8.000	
Work Sampling (A)	9.000	12.000	15.000	12.000	0.474	8.000	8.000	
Work Sampling (B)	9.000	12.000	15.000	12.000	0.474	8.000	8.000	
Work Sampling (2)	9.000	12.000	15.000	12.000	0.474	8.000	8.000	
Engineered Estimate (2)	33.000	40.500	48.000	40.500	2.961	8.000	8.000	
Coordinated Estimate (3)	9.000	12.000	15.000	12.000	0.474	8.000	8.000	

TABLE VIII

DISTRIBUTIONS OF THE TOTAL QUARTERLY COST OF EACH WORK MEASUREMENT TRAINING COURSE

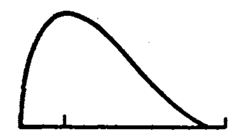
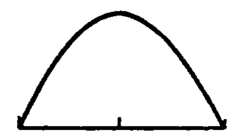
Training Course	L ($)	M ($)	H ($)	μ ($)	σ^2 $(\$)^2$	α	β	Distribution Shape
Work Methods and Standards	0	3,248	12,992	4,060	4,029,324	1.500	4.500	
MTM Procedures	0	8,000	16,000	8,000	11,228,060	1.350	1.350	
ASD System	0	500	2,000	571	54,422	3.000	9.000	
Labor Standards Programming	2,458	4,038	8,775	4,828	1,870,499	0.500	1.500	

technicians and the direct labor employees is determined by each individual's level on his respective wage scale. It follows, then, that neither of these factors may be considered a constant. Computer Program 2 (Appendix D) was used to determine the characteristics of the beta function that best represented the distributions of these variables. The input information included not only the basic hourly wages, but also the cost to the organization of the various fringe benefits, such as paid vacations, sick leave, contributions to retirement plans, etc. In addition, the hourly direct-labor cost included the various charges for working materials, shop, branch, and organization supervision, and other overhead costs, with the sole exception of the work measurement function, such that the result incorporated the <u>total cost</u> of one man-hour of production to the branch of the organization studied. The characteristics of the distributions of these costs are shown in Table IX. It should be pointed out that it is <u>not</u> necessary to assume that these costs are beta distributed. Inasmuch as both variables are in fact bounded by upper and lower limits, the constraints of the Bounded Liapounov Theorem are satisfied. Likewise, any time that information is obtained from <u>empirical</u> sources concerning a <u>bounded</u> variable, the "beta" assumption is unnecessary since all that is required in the subsequent analyses are the means and variances of these values. However, for illustrative purposes, these factors were assumed to be represented by beta functions.

Although the hourly cost of direct labor is complete as shown, the hourly cost of industrial engineering technician time is not. The cost of the three supervisors and the two clerk-secretaries assigned to this function must be included, as must the cost of the four training

TABLE IX

DISTRIBUTIONS OF THE COST OF DIRECT LABOR AND INDUSTRIAL ENGINEERING TECHNICIAN TIME

Source of Cost	L ($/hr)	M ($/hr)	H ($/hr)	μ ($/hr)	σ^2 ($/hr)^2	α	β	Distribution Shape
Direct Labor	8.819	9.107	9.998	9.234	0.055	0.666	2.062	
Industrial Engineering Technicians*	5.000	7.008	9.100	7.027	0.791	1.132	1.180	

*Does not include overhead costs of the work measurement function.

courses. The over-all cost to the organization of the supervisors and clerk-secretaries is \$71,134.44 per year. Each industrial engineering technician works 48 weeks per year at 40 hours per week, or 1,920 hours per year. Therefore, the 24 technicians assigned to the branch studied work

$$(24)(1{,}920) = 46{,}080 \text{ hrs/yr.}$$

The additional cost, per hour of technician time, of supervision and secretarial services, c, becomes

$$c = \frac{71{,}134.44}{46{,}080} = 1.544 \text{ \$/hr.}$$

The mean and variance, μ_x and σ_x^2, of the previously determined cost per hour of industrial engineering time were given in Table IX as 7.027 \$/hr and 0.791 $(\$/\text{hr})^2$, respectively. Using

$$\mu_{x+c} = \mu_x + c \tag{4-19}$$

and

$$\sigma_{x+c}^2 = \sigma_x^2, \tag{4-20}$$

the new mean and variance of this cost is

$$\mu_{x+c} = 7.027 + 1.544 = 8.571 \text{ \$/hr}$$

and

$$\sigma_{x+c}^2 = 0.791 \ (\$/\text{hr})^2.$$

To determine the added cost of the training courses, all 134 technicians employed by the parent organization must be considered. Since the costs of these courses were obtained in terms of dollars per three-month period (quarter), the total number of technician-hours available per quarter, T_{hq}, must be found:

$$T_{hq} = \frac{(134)(1{,}920)}{4} = 64{,}320 \text{ hrs/qtr.}$$

Then, from

$$\mu_{cx} = c\,\mu_x \tag{4-17}$$

and

$$\sigma^2_{cx} = c^2 \sigma^2_x \ , \tag{4-18}$$

where

$$c = \frac{1}{T_{hq}} \ ,$$

μ_x = mean cost of each training course, \$/qtr ,

σ^2_x = variance of the cost of each training course, $(\$/\text{qtr})^2$,

μ_{cx} = mean cost, \$/hour of technician time, of each training course ,

and

σ^2_{cx} = variance of the cost, ($/hour of technician time)^2, of each training course,

the effect of the cost of each training course on the hourly cost of industrial engineering technician time may be found. Table X shows these values for each of the four courses.

The mean and variance of the total cost to the organization of an hour of industrial engineering technician time, μ_t and σ^2_t, may be obtained from an expansion of Equations (4-21) and (4-23):

$$\mu_t = \mu_1 + \mu_2 + \dots + \mu_n$$

TABLE X

ADDITIONAL COSTS OF TRAINING COURSES TO THE COST OF INDUSTRIAL ENGINEERING TECHNICIAN TIME

Training Course	Cost of Course		Additional Cost to Technician Time	
	μ_x (\$/qtr)	σ^2_x (\$/qtr)^2	μ_{cx} (\$/hr)	σ^2_{cx} (\$/hr)^2
Work Methods and Standards	4060	4,029,324	0.063	0.001
MTM Procedures	8000	11,228,060	0.124	0.003
ASD System	571	54,422	0.009	0.00001
Labor Standards Programming	4828	1,870,499	0.075	0.0005

and

$$\sigma_t^2 = \sigma_1^2 + \sigma_2^2 + \ldots + \sigma_n^2,$$

or

$$\mu_t = 8.571 + 0.063 + 0.124 + 0.009 + 0.075 = 8.842 \text{ \$/hr}$$

and

$$\sigma_t^2 = 0.791 + 0.001 + 0.003 + 0.00001 + 0.0005 \approx 0.796 \text{ (\$/hr)}^2.$$

Initial Standard Development Costs

With the mean and variance of the hourly cost of industrial engineering technician time, the mean and variance of the cost of using each of the various technique-type options may be determined. Let

μ_x = mean cost of technician time = 8.842 \$/hr ,

σ_x^2 = variance of the cost of technician time = 0.796 $(\$/\text{hr})^2$,

μ_y = mean time required to develop a labor standard by the y^{th} technique-type, hrs/std-hr ,

and

σ_y^2 = variance of the time required to develop a labor standard by the y^{th} technique-type, $(\text{hrs/std-hr})^2$.

Then, the mean and variance of the technician cost of developing a one-standard-hour labor standard using the y^{th} technique-type is

$$\mu_{xy} = \mu_x \mu_y \tag{4-26}$$

and

$$\sigma_{xy}^2 = \mu_x^2\sigma_y^2 + \mu_y^2\sigma_x^2 + \sigma_x^2\sigma_y^2 . \tag{4-27}$$

Implicit in the use of these expressions is the assumption that the time required by a technician to develop a labor standard is independent of his pay scale.

From Table III, the mean and variance of the time required to develop a standard hour using MTM is

$$\mu_y = 60.456 \text{ hrs/std-hr}$$

and

$$\sigma_y^2 = 92.819 \text{ (hrs/std-hr)}^2.$$

Then,

$$\mu_{xy} = (8.842)(60.456) = 534.552 \text{ \$/std-hr},$$

$$\sigma_{xy}^2 = (8.842)^2(92.819) + (60.456)^2(0.796) + (0.796)(92.819)$$

$$= 10{,}239.889 \text{ (\$/std-hr)}^2,$$

and

$$\sigma_{xy} = 101.192 \text{ \$/std-hr}.$$

In a similar manner, the initial technician cost of establishing a one-standard-hour labor standard may be found for each of the remaining technique-type options. These costs are shown in Table XI. Since the initial EDP costs were obtained directly in the units required, no conversion is necessary. These values are also shown in Table XI.

Quarterly Standard Maintenance Costs

The costs associated with the maintenance of the various labor standards were obtained on the questionnaires using a two-year reference period. This basic time unit was selected because organization policy

TABLE XI

INITIAL COSTS OF ESTABLISHING A ONE-STANDARD-HOUR LABOR STANDARD BY VARIOUS TECHNIQUE-TYPES

Technique-Type	Industrial Engineering Cost			EDP Cost		
	μ_{xy} (\$/std-hr)	σ^2_{xy} (\$/std-hr)^2	σ_{xy} (\$/std-hr)	μ (\$/std-hr)	σ^2 (\$/std-hr)^2	σ (\$/std-hr)
MTM (A)	534.552	10,239.889	101.192	154.000	30.316	5.506
ASD (A)	78.967	111.588	10.563	27.000	1.316	1.147
ASD (B)	54.449	61.302	7.829	16.286	0.871	0.933
ASD (2)	41.513	32.156	5.670	6.750	0.082	0.287
Stop Watch (A)	107.890	314.220	17.726	27.000	1.316	1.147
Stop Watch (B)	80.126	180.357	13.429	16.286	0.871	0.933
Stop Watch (2)	20.964	6.133	2.476	6.750	0.082	0.287
Work Sampling (A)	311.662	6,790.773	82.406	2.000	0.013	0.115
Work Sampling (B)	157.617	1,228.228	35.046	2.000	0.013	0.115
Work Sampling (2)	90.895	280.061	16.735	2.000	0.013	0.115
Engineered Estimate (2)	11.441	5.439	2.332	6.750	0.082	0.287
Coordinated Estimate (3)	7.993	1.124	1.060	2.000	0.013	0.115

required that each labor standard be audited at least once every two years. Thus, even if no other effort on the part of the industrial engineering technician was necessary, he would at least have had to perform an audit on the labor standard during this time.

If it is assumed that the estimated values for the two-year period represent the sum of eight independently and identically distributed quarterly random variables, then Equations (4-24) and (4-25) may be used to find the mean and variance of these quarterly values. Let

μ_t = mean of the estimated value for a two-year period,

σ_t^2 = variance of the estimated value for a two-year period,

μ_q = mean of the estimated value for a three-month period,

and

σ_q^2 = variance of the estimated value for a three-month period.

Then,

$$\mu_q = \frac{\mu_t}{n} \tag{4-24}$$

and

$$\sigma_q^2 = \frac{\sigma_t^2}{n} . \tag{4-25}$$

Table VII shows that the two-year EDP maintenance cost of a one-standard-hour labor standard developed by MTM has the following mean and variance:

$$\mu_t = 830.286 \text{ \$/std-hr}$$

and

$$\sigma_t^2 = 421.442 \ (\$/\text{std-hr})^2 \ .$$

In terms of a three-month period, these values become

$$\mu_q = \frac{830.286}{8} = 103.786 \ \$/\text{std-hr} \ ,$$

$$\sigma_q^2 = \frac{421.442}{8} = 52.680 \ (\$/\text{std-hr})^2 \ ,$$

and

$$\sigma_q = 7.258 \ \$/\text{std-hr}.$$

The same procedure is used to find the number of hours required of an industrial engineering technician each quarter to maintain the various types of labor standards. Again using a one-standard-hour MTM standard as the example, from Table IV

$$\mu_t = 22.693 \ \text{hrs/2-yrs}$$

and

$$\sigma_t^2 = 20.220 \ (\text{hrs/2-yrs})^2 \ .$$

Then,

$$\mu_q = \frac{22.693}{8} = 2.837 \ \text{hrs/qtr}$$

and

$$\sigma_q^2 = \frac{20.220}{8} = 2.528 \ (\text{hrs/qtr})^2 \ .$$

To convert these values to dollars per quarter, the distribution of technician cost per hour and Equations (4-26) and (4-27) are again used:

$$\mu_{xq} = (8.842)(2.837) = 25.084 \ \$/\text{qtr} \ ,$$

$$\sigma^2_{xq} = (8.842)^2(2.528) + (2.837)^2(0.796) + (0.796)(2.528)$$

$$= 206.060\ (\$/\text{qtr})^2 \ ,$$

and

$$\sigma_{xq} = 14.354\ \$/\text{qtr}.$$

In a similar manner, the quarterly maintenance costs of the remaining technique-type options may be found. These values are summarized in Table XII.

The Costs of Unproductive Direct Labor

To determine the costs of unproductive direct labor that might result if each of the various work measurement technique-type options were used, an "average" shop consisting of 20 direct-labor employees working eight hours per day was used as the base of reference. This figure was selected under the assumption that the industrial engineering technicians would be better able to estimate the amount of over-all "wasted time" inherent in the particular labor standard classifications for a group working a full day than, for example, a single individual working only one hour. This assumption is strictly based on the judgment of the author; there is no way to determine whether it provided more or less valid data than would another reference figure.

Table V shows the estimates of the number of unproductive direct labor man-hours, out of the 160 man-hours available in the 20-man shop each day, that might result if <u>all</u> labor standards in that shop were set in the manner indicated. As stated in the study, these values were to be determined by considering the amount of time that the workers would get that was over and above what they should <u>need</u> to perform their

TABLE XII

QUARTERLY COSTS OF MAINTAINING A ONE-STANDARD-HOUR LABOR STANDARD BY VARIOUS TECHNIQUE-TYPES

Technique-Type	Industrial Engineering Cost			EDP Cost		
	μ_{xq} (\$/qtr)	σ^2_{xq} (\$/qtr)^2	σ_{xq} (\$/qtr)	μ_q (\$/qtr)	σ^2_q (\$/qtr)^2	σ_q (\$/qtr)
MTM (A)	25.084	206.060	14.354	103.786	52.680	7.258
ASD (A)	5.296	16.396	4.049	20.250	5.921	2.433
ASD (B)	3.510	2.336	1.528	12.000	0.947	0.973
ASD (2)	3.784	2.436	1.560	5.063	0.370	0.608
Stop Watch (A)	4.173	18.184	4.264	20.250	5.921	2.433
Stop Watch (B)	3.112	8.707	2.950	12.000	0.947	0.973
Stop Watch (2)	2.042	4.070	2.017	5.063	0.370	0.608
Work Sampling (A)	9.116	42.387	6.510	1.500	0.059	0.243
Work Sampling (B)	6.392	33.507	5.788	1.500	0.059	0.243
Work Sampling (2)	3.315	5.877	2.424	1.500	0.059	0.243
Engineered Estimate (2)	2.387	0.610	0.781	5.063	0.370	0.608
Coordinated Estimate (3)	0.839	0.054	0.233	1.500	0.059	0.243

duties either because of the poor method definition or "looseness" of the technique used to set the standards. Time lost due to personal needs, official break periods, cleanup, minor maintenance, or other recognized delays and allowances was <u>not</u> to be considered unproductive. In effect, these values represent estimates of the inherent accuracy or credibility of each of the various work measurement technique-types, as applied in the subject organization branch.

Assuming that the estimated values represent the sum of 160 independent and identically distributed random variables, let

μ_y = mean number of unproductive direct labor man-hours per repetition of a one-man-hour task established by the y^{th} technique-type,

σ_y^2 = variance of the number of unproductive direct labor man-hours per repetition of a one-man-hour task established by the y^{th} technique-type,

μ_{ty} = mean of the total number of unproductive direct labor man-hours (out of the 160 man-hours available in the 20-man shop each day) that would result if all standards were established by the y^{th} technique-type.

σ_{ty}^2 = variance of the total number of unproductive direct labor man-hours (out of the 160 man-hours available in the 20-man shop each day) that would result if all standards were established by the y^{th} technique-type,

μ_x = mean cost per direct-labor-hour = 9.234 \$/hr,

and

σ_x^2 = variance of the cost per direct-labor-hour = 0.055 (\$/hr)^2.

Then, assuming that all of the standards were established using MTM,

$$\mu_y = \frac{\mu_{ty}}{n} = \frac{8.080}{160} = 0.051 \text{ hrs/rep} \tag{4-24}$$

and

$$\sigma_y^2 = \frac{\sigma_{ty}^2}{n} = \frac{0.632}{160} = 0.004 \text{ (hrs/rep)}^2 \ . \tag{4-25}$$

From Equations (4-26) and (4-27)

$$\mu_{xy} = (9.234)(0.051) = 0.470 \text{ \$/rep} \ ,$$

$$\sigma_{xy}^2 = (9.234)^2(0.004) + (0.051)^2(0.055) + (0.055)(0.004)$$
$$= 0.341 \text{ (\$/rep)}^2 \ ,$$

and

$$\sigma_{xy} = 0.584 \text{ \$/rep} \ .$$

Again, an assumption implicit in the preceding calculations is that the number of unproductive man-hours per repetition of the task is independent of the worker's pay scale. The per cent of the mean cost per direct-labor hour represented by the mean cost of unproductive direct labor for an MTM standard is

$$\frac{\mu_{xy}}{\mu_x} = \frac{0.470}{9.234} = 0.051 = 5.1\% \ .$$

The interpretation of this value is that, <u>in the long run</u>, the branch can expect to receive approximately 94.9% labor effectiveness when MTM is used to establish labor standards.

In a similar manner, the cost of unproductive direct labor per repetition of a one-man-hour task may be obtained for each of the remaining technique-types, including the option of setting no standard at all. These values are shown in Table XIII.

The Net Present Value of a Labor Standard

With the information determined, the net present value of any labor standard to be developed may be found.

The Interest Rate

From the economic characteristics of the organization it was determined that a suitable discount rate was 10% per year, compounded per year. In order to make use of this information, however, this value must be converted to a quarterly rate. Let

$$i_{eff} = \text{effective annual interest rate}$$
$$= 10\% \text{ per year, compounded per year,}$$
$$i_{nom} = \text{nominal annual interest rate,}$$

and

$$i_q = \text{quarterly interest rate.}$$

Then,

$$i_{eff} = \left(1 + \frac{i_{nom}}{4}\right)^4 - 1 = 0.10 \ ,$$

$$i_{nom} = 0.0964$$
$$= 9.64\% \text{ per year, compounded quarterly,}$$

and

$$i_q = \frac{i_{nom}}{4} = \frac{0.0964}{4} = 0.0241$$
$$= 2.41\% \text{ per quarter, compounded per quarter}$$

(67, p. 80).

TABLE XIII

COST OF UNPRODUCTIVE DIRECT LABOR PER REPETITION OF A ONE-MAN-HOUR TASK BY VARIOUS TECHNIQUE-TYPES

Technique-Type	Cost			Direct-Labor Effectiveness (%)
	μ_{xy} (\$/rep)	σ_{xy}^2 (\$/rep)^2	σ_{xy} (\$/rep)	
No Standard	2.290	41.384	6.433	75.2
MTM (A)	0.470	0.341	0.584	94.9
ASD (A)	0.507	0.256	0.506	94.5
ASD (B)	0.711	3.583	1.893	92.3
ASD (2)	1.172	4.437	2.106	87.3
Stop Watch (A)	0.544	0.426	0.653	94.1
Stop Watch (B)	0.729	1.194	1.093	92.1
Stop Watch (2)	1.228	6.570	2.563	86.7
Work Sampling (A)	0.554	0.341	0.584	94.0
Work Sampling (B)	0.821	2.560	1.600	91.1
Work Sampling (2)	1.301	17.748	4.212	85.9
Engineered Estimate (2)	1.440	5.632	2.373	84.4
Coordinated Estimate (3)	1.680	7.339	2.709	81.8

The Task to be Studied

Assume that it is desired to determine the most economical work measurement technique-type to use to study a task that has an expected life of 18 months (6 quarters). Further assume that the task will be performed twice a week, or 26 times per quarter, and that the technique-type being considered is Stop Watch (Type 2).

In order to determine the value of a labor standard, the costs of that standard must be compared to the costs of having no standard at all. These values are summarized in Table XIV.

The mean and variance of the initial development costs for a Stop Watch (2) labor standard are

$$\mu_p = \sum_{j=1}^{k} \mu_j = -20.964 - 6.750 = -27.714 \text{ \$/std-hr} \tag{4-28}$$

and

$$\sigma_p^2 = \sum_{j=1}^{k} \sigma_j^2 = 6.133 + 0.082 = 6.215 \text{ (\$/std-hr)}^2 \ . \tag{4-29}$$

The value of a labor standard is derived from the savings in unproductive direct labor costs as a result of the use of the standard. Assuming that these values are independent and identically distributed from one repetition of the task to another, and remembering that the task is to be repeated 26 times per quarter, by using Equations (4-22), (4-23), (4-24), and (4-25) the mean and variance of the quarterly distribution of value of the Stop Watch (2) labor standard becomes

$$\mu_s = n(\mu_2 - \mu_1) = 26(2.290 - 1.228) = 27.612 \text{ \$/qtr} \ ,$$

TABLE XIV

COMPARISON OF THE COSTS OF A STOP WATCH (TYPE 2) LABOR STANDARD WITH NO STANDARD AT ALL

Technique-Type	Industrial Engineering Costs				EDP Costs				Cost of Unproductive Direct Labor Per Repetition	
	Development		Maintenance Per Quarter		Development		Maintenance Per Quarter			
	μ_J (\$/std-hr)	σ_J^2 (\$/std-hr)^2	μ_s (\$/std-hr)	σ_s^2 (\$/std-hr)^2	μ_J (\$/std-hr)	σ_J^2 (\$/std-hr)^2	μ_s (\$/std-hr)	σ_s^2 (\$/std-hr)^2	μ_s (\$/std-hr)	σ_s^2 (\$/std-hr)^2
Stop Watch (2)	20.964	6.133	2.042	4.070	6.750	0.082	5.063	0.370	1.228	6.570
No Standard	---	---	---	---	---	---	---	---	2.290	41.384

and

$$\sigma_s^2 = n(\sigma_2^2 + \sigma_1^2) = 26(41.384 + 6.570) = 1{,}246.804 \ (\$/\text{qtr})^2 \ .$$

The mean and variance of the quarterly cash flows is obtained from

$$\mu_r = \sum_{s=1}^{t} \mu_s = -2.042 - 5.063 + 27.612 = 20.507 \ \$/\text{qtr} \tag{4-30}$$

and

$$\sigma_r^2 = \sum_{s=1}^{t} \sigma_s^2 = 4.070 + 0.370 + 1{,}246.804 = 1{,}251.244 \ (\$/\text{qtr})^2 \ . \tag{4-31}$$

Then, the expected net present value and the variance of the net present value of the labor standard are

$$\text{ENPV} = \mu_p + \mu_r \left[\frac{(1 + i_q)^n - 1}{i_q(1 + i_q)^n}\right] \tag{4-34}$$

$$= -27.714 + 20.507 \left[\frac{(1 + .0241)^6 - 1}{.0241(1 + .0241)^6}\right]$$

$$= 85.579 \ \$/\text{std-hr}$$

and

$$\text{Var(NPV)} = \sigma_p^2 + \sigma_r^2 \sum_{r=1}^{n} \frac{1}{(1 + i_q)^{2r}} \tag{4-35}$$

$$= 6.215 + 1{,}251.244 \sum_{r=1}^{6} \frac{1}{(1 + .0241)^{2r}}$$

$$= 6{,}382.003 \ (\$/\text{std-hr})^2 .$$

The desired loss information is

$$P(\text{loss}) = P\left(z \leq \frac{0 - \text{ENPV}}{\sqrt{\text{Var(NPV)}}}\right) \tag{4-38}$$

$$= P\left(z \leq \frac{-85.579}{\sqrt{6,382.003}}\right) = 0.1424 \ ,$$

$$u = \frac{\text{ENPV} - 0}{\sqrt{\text{Var(NPV)}}} \tag{4-39}$$

$$= \frac{85.579}{\sqrt{6,382.003}} = 1.07 \ ,$$

and

$$E(\text{loss} \mid \text{loss occurs}) = \frac{\sqrt{\text{Var(NPV)}}}{P(\text{loss})} \ L(u) \tag{4-42}$$

$$= \frac{\sqrt{6,382.003}}{0.1424} \ (0.07279)$$

$$= 40.850 \ \$/\text{std-hr} \ .$$

In a like manner, each of the other competing technique-types may be evaluated. Table XV is a summary of this information obtained for <u>all</u> options available. It is interesting to note that in <u>this</u> case, if MTM were the <u>only</u> technique available, the organization would stand to lose more than $800 in expected net present value by developing the standard for this task.

<u>Paired Comparisons of the Techniques</u>

Before determining that a Stop Watch (Type 2) labor standard will be developed for the task under consideration (Stop Watch (2) has the

TABLE XV

COMPARISON OF THE VALUE CHARACTERISTICS OF A LABOR STANDARD WITH AN EXPECTED LIFE OF 18 MONTHS FOR A TASK TO BE REPEATED 26 TIMES PER QUARTER BY VARIOUS TECHNIQUE-TYPES

Technique-Type	ENPV ($/std-hr)	Var(NPV) ($/std-hr)^2	P(loss)	E(loss | loss occurs) ($/std-hr)
Stop Watch (2)	85.579	6,382.003	0.1424	40.850
ASD (B)	70.385	6,036.335	0.1830	42.298
Coordinated Estimate (3)	64.705	6,456.757	0.2109	45.497
ASD (2)	63.449	6,117.109	0.2092	44.180
Engineered Estimate (2)	62.744	6,239.406	0.2141	44.918
Stop Watch (B)	44.321	5,871.347	0.2823	47.543
Work Sampling (2)	22.563	8,144.398	0.4024	64.396
ASD (A)	9.010	5,743.277	0.4539	57.309
Work Sampling (B)	7.789	7,221.179	0.4647	65.050
Stop Watch (A)	-19.023	5,977.542	0.5961	69.356
Work Sampling (A)	-122.954	12,534.980	0.8636	151.329
No Standard	-328.934	5,482.742	0.9999	328.935
MTM (A)	-1,139.081	17,116.540	1.0000	1,139.081

largest ENPV), the technique-types should be compared against each other. Considering the Stop Watch (2) and ASD (B) techniques,

$$ENPV_d = ENPV_1 - ENPV_2 \tag{4-43}$$

$$= 85.579 - 70.385 = 15.194 \text{ \$/std-hr} ,$$

and

$$Var(NPV_d) = Var(NPV_1) + Var(NPV_2) \tag{4-44}$$

$$= 6,382.003 + 6,036.335 = 12,418.338 \text{ (\$/std-hr)}^2 .$$

Then,

$$P(\text{reversal}) = P\left(z \leq \frac{0 - ENPV_d}{\sqrt{Var(NPV_d)}}\right) \tag{4-45}$$

$$= P\left(z \leq \frac{-15.194}{\sqrt{12,418.338}}\right) = 0.4470 ,$$

$$u_d = \frac{ENPV_d - 0}{\sqrt{Var(NPV_d)}} \tag{4-46}$$

$$= \frac{15.194}{\sqrt{12,418.338}} = 0.136 ,$$

and

$$E(\text{loss} \mid \text{reversal occurs}) = \frac{\sqrt{Var(NPV_d)}}{P(\text{reversal})} L(u_d) \tag{4-48}$$

$$= \frac{\sqrt{12,418.338}}{0.4470} (0.3354)$$

$$= 83.616 \text{ \$/std-hr} .$$

Table XVI shows selected paired comparisons of the Stop Watch (2) and ASD (B) technique-types with other options available. The preceding

TABLE XVI

SELECTED PAIRED COMPARISONS OF THE STOP WATCH (TYPE 2) AND ASD (TYPE B) TECHNIQUE-TYPES WITH OTHER OPTIONS AVAILABLE FOR A LABOR STANDARD WITH AN EXPECTED LIFE OF 18 MONTHS SET ON A TASK TO BE REPEATED 26 TIMES PER QUARTER

Stop Watch (2) Versus	P(Reversal)	E(Loss | Reversal Occurs) ($/std-hr)	ASD (B) Versus	P(Reversal)	E(Loss | Reversal Occurs) ($/std-hr)
ASD (B)	0.4470	83.616	Coordinated Estimate (3)	0.4810	87.150
Coordinated Estimate (3)	0.4281	83.229	ASD (2)	0.4762	85.489
ASD (2)	0.4227	81.624	Engineered Estimate (2)	0.4738	85.684
Engineered Estimate (2)	0.4206	81.830	Stop Watch (B)	0.4067	78.247
Stop Watch (B)	0.3556	74.894	Work Sampling (2)	0.3449	79.580

calculations and decision rules have all been incorporated into Computer Program 3 of Appendix D. The output of this program provides not only the information shown in Table XV, but also the information shown in Table XVI for all possible pairs of technique-type options.

Although the ENPV's obtained in this example are relatively small, the reader should not be left with the impression that this is always the case. The expected life of the standard and the number of times that the task is to be repeated are the two factors that primarily influence the magnitude of these values. For example, consider a one-hour task to be performed by one man every hour that he works, or, in other words, the task is to be performed 40 times per week. Further, assume that the task has an anticipated life of ten years. The expected net present value of an ASD (A) labor standard for this task is $22,873.59. If the number of men performing this task is increased to twelve, the expected net present value of an MTM (A) standard established for the task is more than $285,000. In both cases, the probability of incurring a loss is negligible. The value of a labor standard can, therefore, become quite large, particularly in those situations where the life and/or frequency of occurrence of the task are great.

Further Comments on the Study

The reader will note that the questionnaires contained in Appendix A ask that confidence ratings be provided for both the first-round and the fourth-round responses. Although only the fourth-round ratings are used in the preceding analysis, they were included on the first questionnaire for three reasons: (1) to introduce the concept of confidence ratings, (2) to get the technicians thinking in terms of the accuracy of their estimates, and (3) to cause as little confusion and misunderstanding as possible on the final questionnaire. Again, this was a matter of judgment on the part of the author; whether or not it is a necessary procedure is a matter of opinion.

Part II of the questionnaire administered to the individuals responsible for the training courses (Appendix C) asked for estimates of the total quarterly dollar cost of the course that could be eliminated if each of the six basic work measurement techniques were never going to be used to establish labor standards in the organization. This information was to be used to adjust the hourly cost of industrial engineering technician time if it could be shown that any of the techniques was economically inferior to all of the others. A review of the information presented in Tables III through VII shows that none of the six basic techniques is inferior to all other techniques in all respects. Therefore, none of them may be unilaterally discarded without further investigation. However, if it were decided that, for example, MTM would never be used to establish labor standards in this organization, an average savings of $32,000 per year, or $0.124 per technician-hour (see Tables VIII and X) could be realized simply from the elimination of the MTM course. Additional savings from the other three training courses would amount to $0.002 per technician-hour from this decision. It is beyond the scope of this thesis to either recommend or not recommend such a course of action. The point is, however, that any time an overhead cost can be directly identified with a specific work measurement technique, the characteristics of that cost should be investigated with the understanding that the technique may be shown by subsequent analysis to be economically unjustifiable in any application.

Summary

Any future application of the proposed economic model must be designed to specifically take into account the characteristics of the organization to be studied. A large measure of judgment must be used by the analyst in planning his investigation to fit the existing situation. The questionnaires contained in Appendixes A, B, and C should be considered as a guide to subsequent studies; there is no absolute requirement to use the exact phraseology contained on these instruments. Likewise, the mathematical analysis of the resulting data will depend on the manner and the units in which it is collected. The model itself is rather flexible. The usefulness and validity of the results of any subsequent studies will largely rely on the amount of good common sense that went into each investigation. Figure 5 contains a summary of the steps required to apply this procedure.

Step 1: Identify all cost and benefit elements of the work measurement program.

Step 2: Using Delphi questionnaires or empirical records, obtain data concerning each cost and benefit element as it applies to each work measurement procedure available.

Step 3: Determine the composite beta distribution of each cost and benefit element for each work measurement procedure (see pages 66-73, and Computer Program 1, Appendix D).

Step 4: Convert the cost and benefit elements into the units required for economic analysis (see pages 73-94).

Step 5: Determine the applicable discount rate (see page 95).

Step 6: For the labor standard to be developed, determine the expected life of the task and the number of repetitions of the task per time period.

Step 7: Make an economic analysis of each competing work measurement procedure (see pages 97-104, and Computer Program 3, Appendix D).

Step 8: Select the "best" work measurement procedure based on the economic analysis and other pertinent factors.

Step 9: Repeat Steps 6 through 8 for each new labor standard to be developed.

Figure 5. Steps Required to Apply the Proposed Economic Model

CHAPTER VI

CONCLUSIONS AND RECOMMENDATIONS

The Usefulness of the Model

The selection of a work measurement technique to use to study a given human task has been frequently based on administrative judgment, supported, perhaps, by rules of thumb, previous experiences, or the claims of those who have allegedly demonstrated the "value" of a particular procedure. Although the economic importance of a general work measurement program has often been cited in literature, a method for comparing the costs and benefits of specific application procedures within each individual production environment has been virtually ignored.

The model developed in Chapter IV furnishes, in essence, a cost-effectiveness analysis, for a particular industrial organization, of the various work measurement techniques as they are applied within that organization. It adds a measure of objectivity to what has previously been a rather subjective decision, by providing a procedure whereby the person responsible for this function is aided in selecting the most economically effective technique to apply to a given job study. It is an effort to make systematic and efficient use of the judgments required in this situation; it is not an attempt to determine the exact economic impact of any particular work measurement technique.

Although there are some definite precautions to be taken in the use of this model, its

> ... function is, after all, to give operational advice to a decision-maker. ... its justification should derive from the fact that recommended actions based on it have a good chance of being more appropriate than actions selected without use of the model (34, p. 7).
>
> ... [It is] used to predict future events and, in particular, to make conditional predictions of the consequences of alternative courses of action. The ability to make contingency predictions of this kind gives us a measure of control over the future ... (34, pp. 4-5).

Any reduction of uncertainty in estimating the anticipated value of work measurement applications is beneficial and profitable, regardless of whether the decision data and methods are subjective (as in this model) or actually based on empirically measured information. In addition, the results obtained from <u>any</u> model "... still cannot fail to depend indirectly on the expert judgment that went into the construction of the model" (34, pp. 97-98).

The proposed procedure is a <u>predictive</u> tool -- the answer regarding present and future costs and benefits can be anticipated and evaluated in advance. Even though it provides only estimates of these quantities, the value of such a tool lies in whether it enables a <u>correct</u> choice or decision to be made. The absolute or relative error inherent in the model is unimportant, so long as the model leads the decision maker to choose the appropriate technique. If the information provided by the solution to any engineering or economy problem allows the more or most economical alternative to be selected, it has served its purpose. A discrete choice must be made in selecting a work measurement technique to study a given task. <u>As long as the measures provided in the model allow for this choice, the model is useful</u>. The method developed provides such measures. Much of the guesswork involved in technique selection can be removed. The best choice can be made on a consistent basis.

It is true with any cost-effectiveness model, however, that the results, although quite useful, should be given no more, and no less, than is their due. The limitations and pitfalls of the procedure must be as fully recognized and considered as the advantages, when decisions are to be based on the results.

Pitfalls in the Model

The Survey Procedure

The application of the Delphi Method is an attempt to gather facts concerning the costs and benefits of the work measurement techniques. In this respect, the environmental conditions of the survey must be conducive to obtaining these facts. The questions must be carefully worded to insure that they do not lead to improper responses. The person conducting the study must be readily available to discuss the questions with the respondents to be certain that they are fully understood; yet he must take precautions against influencing the results.

Work measurement personnel are often required to make decisions under pressure. Some organizations provide more pressure in the form of consequences than others, and hence these individuals learn to be bold, non-committed, conservative, etc. The selection of a person to take part in a Delphi survey implies that he is (if rational) unaffected by any pressures resulting from past experiences. The participants should, therefore, be assured that their answers will not result in punitive action at a later date. The use of an analyst from outside the subject organization to conduct the study, and guaranteed anonymity of replies is perhaps the best approach to obtaining honest judgments.

Another assumption inherent in the selection of a survey participant is that he is impartial. Work measurement analysts, particularly those with many years of experience, are not necessarily impartial. Thus, respondents must be carefully selected to insure that the over-all answers are not unjustifiably biased either for or against a particular technique.

Finally, even under the best of conditions, a survey will be somewhat of a nuisance for the participants. A proper foundation must be established to convince those taking part that their answers will most likely lead to definite improvements in the work measurement function. They must be encouraged to provide thoughtful, honest answers. Hasty, unconsidered responses may be worse than no information at all.

The Mathematical Results

The economic model presented in this thesis is a predictive technique. It is designed to determine, in advance, which of the various work measurement procedures available, if applied to a given human task, will result in the greatest expected value to the organization. As is true with any mathematical treatment of a real world phenomenon, however, the role of the decision maker is quite important. The analysis must always be supplemented by judgment.

The future course of events may take many forms. The user of the model must guard against concentrating on the statistical uncertainties, emphasized by the mathematical procedures, to the neglect of the real uncertainties. He must beware of the tendency to overlook the simplifications made in the model to achieve its precision, and the temptation to overemphasize the calculations, while omitting the pertinent qualitative factors.

A cost-effectiveness study must be given no more influence than it can legitimately claim. The responsibilities of the decision maker must not be transferred to the model. The study and analysis may be scientific, but its application is an art; an art based on scientific analysis supported by judgment and experience. The value of the model, therefore, depends heavily on the sense of restraint with which it is applied and its product appreciated (42, pp. 1-5) (54, pp. 4-15) (55, p. 7).

Conclusions Based on the Study

Although the results of the investigation presented in Chapter V are applicable only to the specific organization studied, the following conclusions may be drawn from the information obtained:

1. The Delphi Method may be advantageously used to evaluate the costs and benefits of a work measurement program. The results obtained from this study strongly support the desirability of this procedure when making such an investigation. Taken as a whole, the participants in the survey showed increasing enthusiasm as the study progressed, with many of them commenting favorably on the fact that they were required to re-evaluate their original biases in the light of the responses of the other participants.
2. There is real value to be obtained from a properly

applied work measurement program. The expected net present value of a <u>single</u> labor standard can reach into the hundreds of thousands of dollars. Even in the largest of corporations, returns of this magnitude are extremely significant, particularly when one considers the vast number of time standards that may be in force in any one firm.

3. Although a properly applied work measurement program can be quite valuable, on the other hand, an improperly applied program can be quite costly. An emphasis on either accuracy or economy of application <u>alone</u> can result in a significant economic loss to the organization with the development of each labor standard. The results of this study dramatically demonstrate the wisdom of judiciously selecting the work measurement technique to be applied to a specific task, based on the expected net present value (and other factors) of the resulting labor standard.

4. The results of this study tend to support the contention that the MTM procedure produces quite accurate labor standards. However, in many cases the added cost of MTM can outweigh the potential errors inherent in the other techniques, and, contrary to Fankhauser's assertion (see page 3 of this thesis), substituting MTM for the stop watch (or any other technique) might be disadvantageous to the organization. The primary cause of this disadvantage is that, at least in the organization studied,

MTM does <u>not</u> produce quicker time studies than the other options available; in fact, it is five times as costly, on the average, as the best stop watch labor standard (see Table XI).

5. The credibility or accuracy of a given work measurement technique is not necessarily proportional to the amount of time (cost) required to develop the standard. For example, the average Work Sampling (Type A) labor standard takes almost three times as long to develop, in the subject organization, as the average Stop Watch (Type A) labor standard; yet the results of the stop watch study are considered the more accurate. One may not unilaterally infer, then, that the more costly the technique, the better the results. It should be pointed out, however, that work sampling is not a frequently used technique in the subject organization, and that the application of this technique is not aided by such devices as a memomotion activity camera. A large portion of the cost of this procedure may, thus, be attributed to the time required of the technician to travel from work place to work place to make the observations. The implementation of more modern sampling devices would doubtless reduce this cost.

6. The apparent accuracy and economy of the Automated Standard Data (ASD) System would tend to justify a similar process for other large organizations. Such a decision would, however, have to be based on the

expected return for the investment required, which in turn would be derived from such factors as the number of labor standards developed each year and whether the characteristics of the work of the organization would lend themselves to a standard data procedure.

7. The results of the study imply that the stop watch technique, although frequently criticized, does produce rather accurate labor standards. This fact could justify investment in more sophisticated measuring instruments, such as portable electronic data recorders, to eliminate the "crudeness" of the stop watch itself and some of the associated errors. Again, before an investment of this nature is undertaken, a feasibility study should be made. Such a study could incorporate the Delphi Method to determine whether the results obtained from these innovations would, in fact, result in more accurate standards.

8. Finally, it should be apparent that the economic optimization of a work measurement program may dictate a change in the number of time study analysts employed by the organization. If it is shown that more sophisticated, and, therefore, more time-consuming techniques should be used, it would be false economy not to hire more personnel to establish labor standards. Likewise, if, on the average, less time-consuming procedures are indicated, a reduction in the number of analysts employed is warranted. The person responsible for the work measurement

function must be prepared for the possibility of drastic changes in his organization, if such changes are suggested by the results of the investigation.

Recommendations for Future Studies

Possible extensions of this thesis may be classified into two general categories: (1) additional studies of the economic consequences of the work measurement function itself and (2) applications of all or part of the proposed model to other "estimating" situations.

Work Measurement Investigations

The model developed in Chapter IV and applied in Chapter V is an attempt to economically optimize the work measurement function as it presently exists. No effort has been made toward improving specific technique applications. The information obtained from the Delphi survey procedure is assumed to provide the necessary accuracy to form the basis for subsequent decisions. Additional studies suggested by the results include:

1. Experimental investigations, under actual production conditions, to verify the relative accuracy of the various work measurement techniques.
2. A study to determine whether the costs of unproductive direct labor attributed to each of the various techniques is a result of poor work methods definition, the inherent inaccuracy of the timing procedure, or both.
3. An investigation to determine the characteristics of the jobs that best lend themselves to study by each of the

various techniques; i.e., does a particular technique, although generally less economical than another, become more economical when applied to jobs that have certain identifiable traits, and vice versa?

4. A model that would indicate the best combination of techniques that should be used to study each part of a long task, to even further optimize the expected value of the labor standard.
5. An investigation to determine how to identify a task that should be restudied for methods improvement; i.e., is there some quantitative or qualitative measure that would indicate how much might be saved in unproductive direct-labor costs before the methods improvement action is begun to provide for a decision concerning whether such an effort is justified?

Other Estimating Situations

The procedure developed in this thesis should lend itself to many other areas of investigation where data is obtained from estimates. In particular, some of these applications include:

1. The incorporation of a "fixed set" of beta distributions into the well-known PERT (Program Evaluation and Review Technique) procedure, which might lead to better estimates of the mean and variance of project durations than are obtained by the rather crude formulas presently in use.
2. An investigation to determine whether the Delphi Method

could be used in conjunction with Cardinal Utility Theory to determine the characteristics of the utility function of an organization.

3. The use of the proposed model with almost any economic study in which estimates of present and future costs and returns are required; the results obtained from such a procedure could prove quite useful to any large-scale investment decision in which there are competing alternatives.

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APPENDIX A

DELPHI METHOD QUESTIONNAIRES ADMINISTERED TO THE INDUSTRIAL ENGINEERING TECHNICIANS

FIRST-ROUND QUESTIONNAIRE

Please read these instructions carefully.

You have been selected to participate in a study to determine the cost-benefit relationships of the various work measurement techniques available for setting time standards. This questionnaire is the first of a series of four questionnaires designed to gather information that only you and your fellow workers can provide. The answers you give to the questions could become the basis for possible improvement in the current work measurement program. You are asked to adhere to the following rules during this study:

1. Please read the instructions for each part carefully, determine that you know exactly what is being asked, and give thorough consideration to all aspects of the question before answering.

2. Please do not discuss your answers with any other person engaged in the study until after the fourth questionnaire is completed. This is a critical requirement. Any violation could seriously distort the results.

3. You are allowed to use any records, files, or other source of information available to aid you in answering the questions; in fact, you are encouraged to do so. The only exception is that you are not to discuss the questions or your answers with any other person taking the survey.

Although your name has been identified with this particular answer sheet, you should understand that this is required only to compare answers between yourself and the other participants as a group in the following questionnaires. No one but yourself and the person conducting the survey will know how you answered any particular question. You are asked, then, to give honest answers, not the answers that you think someone else would like to see. This study is an attempt to gather facts, not to falsely justify or condemn any particular policy or procedure. Please provide answers that you sincerely feel are as accurate as you can make them.

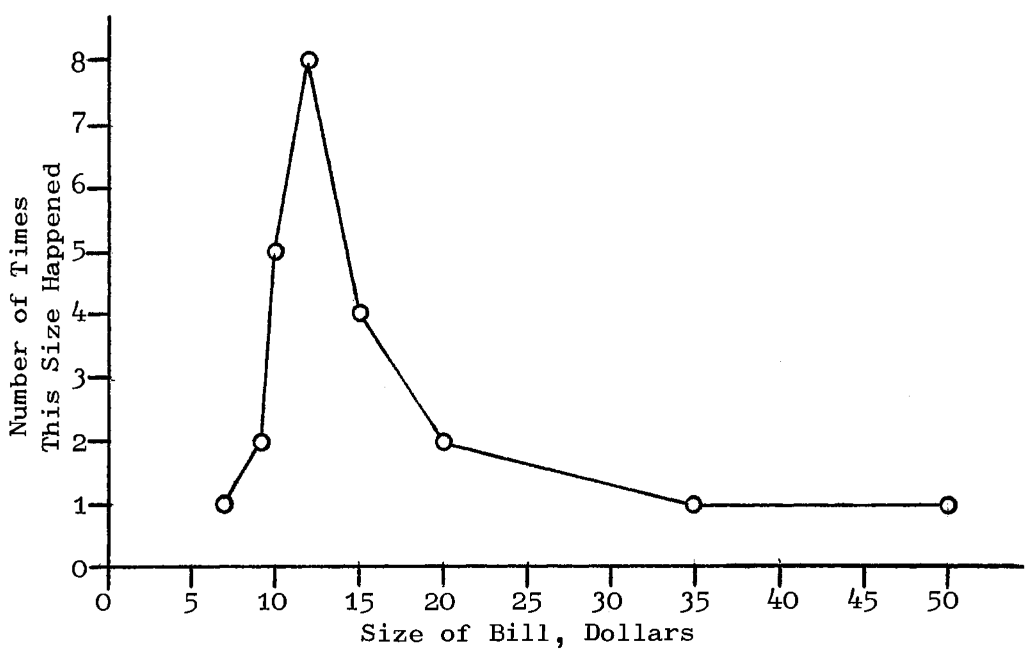
Instructions for Providing Answers.

In the questions associated with this study, you will be asked to estimate three values for each quantity. These three values will be the lowest (L), the highest (H), and the most common (M) values. The lowest value will be the smallest value that you think the quantity could have. The highest value is the biggest value that you think the quantity could have. The most common value is the value that you think might happen more often than any other value. In addition to providing these three values, you will also be asked to choose from the nine curves shown on the last page the one that you think best describes the way the values of the quantity would look if they were plotted on graph paper. The procedure to use in selecting a particular curve can best be explained by a couple of examples.

Example 1. Suppose that you were asked how much your telephone bill is each month. If you and the rest of your family make no long-distance calls during any month, your bill is $7.00. Therefore, the lowest value, L, of your phone bill is $7.00. Now if you were to check your records for the past two years you might find that there was only one month when no long-distance calls were made, and that normally two or three long-distance calls are made each month. You might also find that the largest bill you received was for $50.00, and that this happened during Christmas one year when you called all of your relatives. Therefore the highest value, H, of your phone bill is $50.00. If you were to round-off all of the 24 phone bills for the past two years to the nearest whole dollar and then list them in order of their size, you might have something like the following:

Size of Bill	Number of Times This Size Happened
$7.00	1
$9.00	2
$10.00	5
$12.00	8
$15.00	4
$20.00	2
$35.00	1
$50.00	1

Now if you were to plot these values on a graph, and draw straight lines between the points, your graph would look like this:



When asked about the size of your phone bill, you would state that the lowest value (L) was $7.00, the highest value (H) was $50.00, and that the most common value (M) was $12.00 since it occurred more often than any other value. Referring to the figure on the last page, since the most common value is closer to the lowest value than either the middle or highest values, the curve to choose must be either Type 3, Type 6, or Type 9. Notice that the only difference between these three curves is how spread out they are around the most common value. Type 3 shows a wide spread, Type 6 a medium spread, and Type 9 a narrow spread. Since the graph of your phone bill size is rather narrow around the most common value, you would choose curve Type 9.

Example 2. Now suppose that you are asked to indicate how much you spend each month for food for your family. Also suppose that you always pay cash at the grocery store and that you have no records, such as checkbook stubs, to give you this information. Even though you have no records, you still have some idea about this cost. You might estimate that you spend at least $100.00 each month. This would be your lowest value, L. You also know that you have never spent more than $200.00 in any month for food. Your estimate of the highest value, H, would then be $200.00. Most of the time, however, you think you spend between $120.00 and $180.00 with an average perhaps of $145.00. Your estimate of the most common value, M, would then be $145.00.

Referring again to the figure on the last page, since the most common value lies about half way between the lowest and highest values, you would be choosing between Type 2, Type 5, or Type 8 as the curve to represent your monthly food cost. However, you estimated that most of the time you would spend anywhere between $120.00 and $180.00 for food. This is a spread of $60.00 compared to a total spread of only $100.00 between the lowest and highest values. This indicates that your monthly grocery bills are quite spread out around the most common value. You would, therefore, probably pick curve Type 2. If, after some thought, you felt that the range of $120.00 to $180.00 was too large and that it should be $130.00 to $170.00, you might change your choice to curve Type 5, since this shows a smaller spread around the most common value.

These two examples should have given you an understanding of how to select a curve-type to represent certain quantities. The questions you will be asked in this study will require you to estimate a low (L), high (H), and most common (M) value for each quantity, in addition to selecting a curve-type from those on the last page to represent the quantity. In some cases you may have records that will assist you in answering the questions. In other cases you will have to rely on your experience to provide the answers. For still other questions a combination of both your records and experience may provide the best estimates.

Instructions for Providing Confidence Ratings.

Within each question that asks for a lowest, highest, or most common value, you will be asked to provide a confidence rating for that answer. This is a numerical rating of 5, 4, 3, 2, or 1 that indicates how confident you are in that particular answer. In making this evaluation, you should indicate one of the following:

5 - I feel that this answer is probably within ± 20% of the true value.

4 - I feel that this answer is probably within ± 40% of the true value.

3 - I feel that this answer is probably within ± 60% of the true value.

2 - I feel that this answer is probably within ± 80% of the true value.

1 - I feel that this answer is probably within ± 100% or more of the true value.

Your confidence rating should be an indication of how much faith you have in that answer. Once again, you are asked to be honest in these ratings. You are the best judge of the accuracy of your answers. No one can do this for you.

Miscellaneous Instructions.

Your comments concerning this questionnaire are invited. Additional sheets of paper have been provided for this purpose. Please indicate the part and question number(s) to which you are referring, if you have any comments to make.

Please complete this questionnaire and have it ready to be picked up by the morning of ________________.

Your cooperation in this study is greatly appreciated.

PART I

Listed below are the work measurement techniques that could currently be used to establish different types of labor standards within this branch. For each technique and labor-standard type (A, B, 2, or 3) you are asked to provide the lowest (L), most common (M), and highest (H) amount of time you might spend establishing a labor standard for a one-hour job. In other words, if you were to develop a labor standard that is exactly one hour long, that meets the statistical accuracy requirements for the type standard being set, and were to use the technique indicated, what is the lowest amount of time it might take you, what is the most common amount of time it might take you, and what is the highest amount of time it might take you? For each of these three values, you are also asked to provide a confidence rating for your answer. In addition, you are to indicate, from the nine curves shown on the last page, the type of curve that best describes the way you think these times would look if you were to set one-hour labor standards in that manner over and over and were to plot the amount of time it took you horizontally and the number of times it took you this long vertically.

	Amount of time it might take you to set a one-hour standard this way.	Confidence Rating
1. MTM (Type A)		
(a) Lowest (L)	________ Hours	________
(b) Most Common (M)	________ Hours	________
(c) Highest (H)	________ Hours	________
(d) Curve-Type ______		
2. ASD (Type A)		
(a) Lowest (L)	________ Hours	________
(b) Most Common (M)	________ Hours	________
(c) Highest (H)	________ Hours	________
(d) Curve-Type ______		

3. ASD (Type B)		
(a) Lowest (L)	________ Hours	________
(b) Most Common (M)	________ Hours	________
(c) Highest (H)	________ Hours	________
(d) Curve-Type ______		
4. ASD (Type 2)		
(a) Lowest (L)	________ Hours	________
(b) Most Common (M)	________ Hours	________
(c) Highest (H)	________ Hours	________
(d) Curve-Type ______		
5. Stop Watch (Type A)		
(a) Lowest (L)	________ Hours	________
(b) Most Common (M)	________ Hours	________
(c) Highest (H)	________ Hours	________
(d) Curve-Type ______		
6. Stop Watch (Type B)		
(a) Lowest (L)	________ Hours	________
(b) Most Common (M)	________ Hours	________
(c) Highest (H)	________ Hours	________
(d) Curve-Type ______		

7. Stop Watch (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
8. Work Sampling (Type A) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
9. Work Sampling (Type B) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
10. Work Sampling (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______

11. Engineered Estimate (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 __________ Hours __________ Hours __________ Hours	 __________ __________ __________
12. Coordinated Estimate (Type 3) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 __________ Hours __________ Hours __________ Hours	 __________ __________ __________

PART II

Even though a labor standard has been established, the industrial engineering technician is still responsible for maintaining that standard. In this part of the questionnaire, you are to consider all of the reasons that might require additional work by you after the original labor standard has been developed, to keep it current. These reasons include such causes as changes in all or part of the labor standard because of a change in the instruction manual, changes in all or part of the labor standard due to a methods-improvement action, or simply the requirement for a periodic review of the standard because of its age.

Listed below are the same work measurement technique-type combinations as in Part I. In this part, however, you are asked to indicate the lowest (L), most common (M) and highest (H) amount of total time you might spend in any two-year period following the original standard-development date to keep that standard current. This, of course, assumes that the standard will be in existance for two years or more. In other words, what is desired is an indication of how much extra work is required of you every two years to keep a labor standard up-to-date. As in Part I of this questionnaire, all times apply to maintaining a labor standard that is exactly one hour long.

	Amount of time required every 2 years to maintain a one-hour labor standard set this way.	Confidence Rating
1. MTM (Type A)		
(a) Lowest (L)	______ Hours	______
(b) Most Common (M)	______ Hours	______
(c) Highest (H)	______ Hours	______
(d) Curve-Type ______		
2. ASD (Type A)		
(a) Lowest (L)	______ Hours	______
(b) Most Common (M)	______ Hours	______
(c) Highest (H)	______ Hours	______
(d) Curve-Type ______		

3. ASD (Type B) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
4. ASD (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
5. Stop Watch (Type A) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
6. Stop Watch (Type B) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______

7. Stop Watch (Type 2)		
(a) Lowest (L)	______ Hours	______
(b) Most Common (M)	______ Hours	______
(c) Highest (H)	______ Hours	______
(d) Curve-Type ______		
8. Work Sampling (Type A)		
(a) Lowest (L)	______ Hours	______
(b) Most Common (M)	______ Hours	______
(c) Highest (H)	______ Hours	______
(d) Curve-Type ______		
9. Work Sampling (Type B)		
(a) Lowest (L)	______ Hours	______
(b) Most Common (M)	______ Hours	______
(c) Highest (H)	______ Hours	______
(d) Curve-Type ______		
10. Work Sampling (Type 2)		
(a) Lowest (L)	______ Hours	______
(b) Most Common (M)	______ Hours	______
(c) Highest (H)	______ Hours	______
(d) Curve-Type ______		

11. Engineered Estimate (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 ________ Hours ________ Hours ________ Hours	 ________ ________ ________
12. Coordinated Estimate (Type 3) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 ________ Hours ________ Hours ________ Hours	 ________ ________ ________

PART III

One of the objectives of a work measurement program is to reduce the amount of unproductive man-hours in the shop. This is accomplished by attempting to determine how long it should take a properly trained and supervised worker, working at a normal pace, to accomplish a particular task. Even when labor standards are in force, however, there is probably still some wasted time if only because the labor standard itself is either "loose" or just "too high."

This part of the questionnaire is an attempt to determine how many wasted man-hours might result if there were no labor standards at all, or if the various techniques and labor-standard types were in use. You are to assume that the questions pertain to a shop that has 20 direct-labor employees, being paid for an 8-hour day (160 direct man-hours per day), and that these 20 workers are properly supervised by their foreman. In addition, you are to assume that all labor standards in that shop have been established by the technique indicated and with the statistical accuracy required by that type standard.

Listed below are the same standard technique-types as in the previous two parts of this questionnaire. There has been added, however, the situation when no labor standards are in use. You are asked to indicate the lowest (L), most common (M), and highest (H) number of man-hours (out of the 160 man-hours available in this 20-man shop each day) that might be wasted or not fully utilized if all labor standards in that shop were set in the manner indicated. Time lost due to personal needs, official break periods, cleanup, minor maintenance, or other recognized delays and allowances is not to be considered wasted. Wasted man-hours, as used here, is the amount of time the worker would get that is over and above what he should have to perform his duties either because of the poor method definition or "looseness" of the technique used to set his standard. Remember that you are to estimate these values on a daily basis.

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.	Confidence Rating
1. No Standards at all		
(a) Lowest (L)	________ Hours	________
(b) Most Common (M)	________ Hours	________
(c) Highest (H)	________ Hours	________
(d) Curve-Type ______		

2. MTM (Type A) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 __________ Hours __________ Hours __________ Hours	 __________ __________ __________
3. ASD (Type A) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 __________ Hours __________ Hours __________ Hours	 __________ __________ __________
4. ASD (Type B) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 __________ Hours __________ Hours __________ Hours	 __________ __________ __________
5. ASD (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 __________ Hours __________ Hours __________ Hours	 __________ __________ __________

6. Stop Watch (Type A) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
7. Stop Watch (Type B) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
8. Stop Watch (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
9. Work Sampling (Type A) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______

10. Work Sampling (Type B) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
11. Work Sampling (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
12. Engineered Estimate (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______
13. Coordinated Estimate (Type 3) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	______ Hours ______ Hours ______ Hours	______ ______ ______

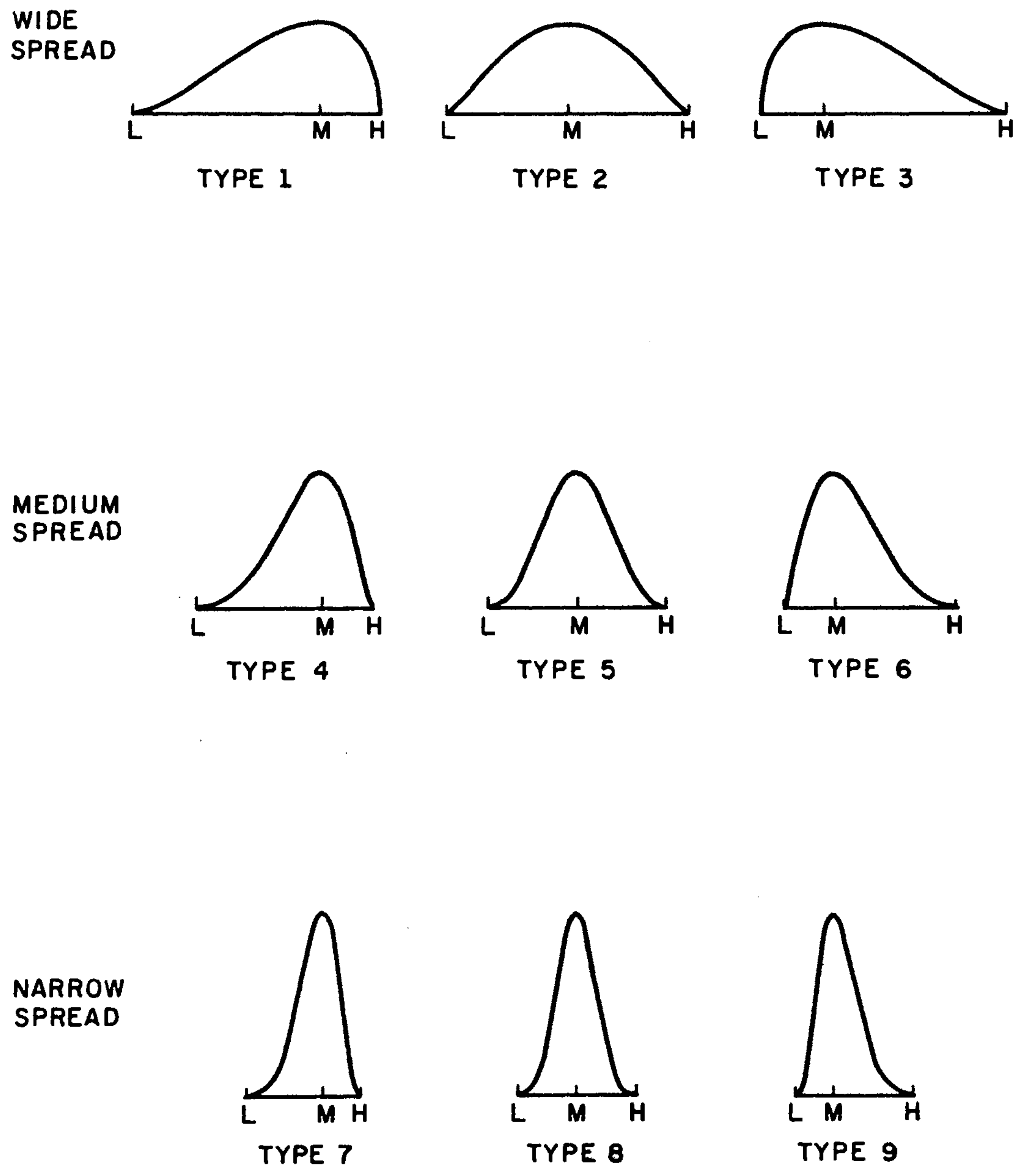


Figure 6. Nine Survey Curves

SECOND-ROUND QUESTIONNAIRE

Please read these instructions carefully.

This is the second of a series of four questionnaires designed to gather information concerning the cost-benefit relationships of the various work measurement techniques available in this branch. The same questions that appeared in the first questionnaire are repeated here. During the first round you submitted estimates of various time values and selected a curve-type to represent your concept of how these values would look if they were plotted on graph paper. This questionnaire gives you the opportunity to revise any of these estimates if you feel they can be improved.

For each work measurement technique-type combination the following information is presented: your first-round estimate, the average of the estimates made by all participants, and the central range of the estimates made by all participants. The central range is chosen so that 25% of the estimates lie below the lower value and 25% of the estimates lie above the upper value. Therefore, the central range itself contains the middle 50% of the estimates made for that particular value. In addition, the curve-type chosen by more respondents than any other type is also given, along with the number of persons (out of the eight participating in this study) who selected that type curve.

You are asked to reconsider each of your previous answers, possibly revise them, and write your new answer in the space provided. For each question, if your new estimate lies outside the central range, or if the new curve-type you select does not agree with the curve-type selected by the most persons previously, you are asked to state briefly but clearly, in the space provided, the major reason or reasons why you feel the estimate should be lower (or higher) than those within the central range, or why the curve-type selected by more participants than any other type does not adequately represent your concept of those particular values. These reasons may include, of course, such things as relevant information of any kind from any source, and/or your own personal reasoning that went into the new estimate. If additional space is needed, you may use the paper attached to this questionnaire. Please be sure to indicate the part and question number that you are referring to.

It should be pointed out that your "new" estimates do not have to be different from your first-round estimates. If, after considering the responses of the other persons participating in this study, you still feel that your previous estimate is valid, then of course you may hold to that answer. The purpose of this and the following questionnaires is to give you a chance to reconsider your responses in the light of new information. It is not mandatory that you change any estimate. Changes should be made only when you honestly feel they might improve the accuracy of your answers, not simply to "go along with the crowd."

A few points may require further clarification:

1. A "labor standard that is exactly one hour long" is a standard set on a job that will be charged for one man-hour of work. In other words, after the task has been studied, and the appropriate fatigue, delay, personal, etc. allowances have been added, the resulting labor standard shows a standard time (not normal time) of one man-hour to accomplish.

2. ASD Standards (Types A, B, and 2). It is recognized that in establishing a particular labor standard some elements of the work cycle may not be available in the ASD file. In these situations, the industrial engineering technician must develop the data for these elements on his own. In some cases, the effect of these "other" elements will be such that the standard may still be classified as Type A. In other cases, the effect of the data for these elements may require that the standard be classified Type B. In still other situations, the added uncertainty of this data may be so great that the standard must be classified Type 2. In your answers to questions concerning ASD standards, you should consider those situations where the major portion of the data, but not all of the data, is obtained through the ASD system, in addition to those situations where the standard could be set using ASD information alone.

3. Part III. The term "properly supervised" is meant to imply that the worker is not allowed to waste time or "goof off" and that he is kept supplied with work to be done and the materials to accomplish this work. In other words, the foreman is there to insure that in the long run (not isolated or special situations) the worker meets the standard time for his task as set by the technique indicated with the appropriate statistical accuracy.

4. The word "need" has been inserted in the instructions for Part III to further clarify the definition of "wasted man-hours."

It is essential that you continue not discussing your answers with any other person engaged in the study. You are still encouraged to use any records, files, or other source of information to aid you in answering the questions. Again, please read the instructions for each part carefully, determine that you know exactly what is being asked, and give thorough consideration to all aspects of the question before answering.

Please complete this questionnaire and have it ready to be picked up by the morning of ______________________.

PART I

Listed below are the work measurement techniques that could currently be used to establish different types of labor standards within this branch. For each technique and labor-standard type (A, B, 2, or 3) you are asked to provide the lowest (L), most common (M), and highest (H) amount of time you might spend establishing a labor standard for a one-hour job. In other words, if you were to develop a labor standard that is exactly one hour long, that meets the statistical accuracy requirements for the type standard being set, and were to use the technique indicated, what is the lowest amount of time it might take you, what is the most common amount of time it might take you, and what is the highest amount of time it might take you? In addition, you are to indicate, from the nine curves shown on the last page, the type of curve that best describes the way you think these times would look if you were to set one-hour labor standards in that manner over and over and were to plot the amount of time it took you horizontally and the number of times it took you this long vertically.

	Amount of time it might take you to set a one-hour labor standard this way.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, if your new estimate lies outside the central range or you do not agree with the curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
1. MTM (Type A)					
(a) Lowest (L)	Hours	41.25	28 - 50	___ Hours	
(b) Most Common (M)	Hours	64.75	35 - 80	___ Hours	
(c) Highest (H)	Hours	110.00	50 - 160	___ Hours	
(d) Curve-Type	Type	4 Persons: Type 3		Type ___	
2. ASD (Type A)					
(a) Lowest (L)	Hours	6.81	6 - 8	___ Hours	
(b) Most Common (M)	Hours	11.53	10 - 16	___ Hours	
(c) Highest (H)	Hours	18.88	15 - 25	___ Hours	
(d) Curve-Type	Type	3 Persons: Type 9		Type ___	
3. ASD (Type B)					
(a) Lowest (L)	Hours	4.67	4 - 5	___ Hours	
(b) Most Common (M)	Hours	8.67	6 - 10	___ Hours	
(c) Highest (H)	Hours	13.25	8 - 20	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 8		Type ___	
4. ASD (Type 2)					
(a) Lowest (L)	Hours	2.95	1.75 - 5	___ Hours	
(b) Most Common (M)	Hours	6.25	2.25 - 15	___ Hours	
(c) Highest (H)	Hours	8.35	2.75 - 18	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 3		Type ___	

	Amount of time it might take you to set a one-hour labor standard this way.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, if your new estimate lies outside the central range or you do not agree with the curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
5. Stop Watch (Type A)					
(a) Lowest (L)	Hours	8.25	5 - 8	___ Hours	
(b) Most Common (M)	Hours	15.50	12 - 16	___ Hours	
(c) Highest (H)	Hours	25.75	20 - 25	___ Hours	
(d) Curve-Type	Type	2 Persons:	Type 2 2 Persons: Type 3	Type ___	
6. Stop Watch (Type B)					
(a) Lowest (L)	Hours	5.50	4 - 6	___ Hours	
(b) Most Common (M)	Hours	9.88	8 - 12	___ Hours	
(c) Highest (H)	Hours	17.75	16 - 20	___ Hours	
(d) Curve-Type	Type	3 Persons:	Type 3	Type ___	
7. Stop Watch (Type 2)					
(a) Lowest (L)	Hours	1.75	1.5 - 2	___ Hours	
(b) Most Common (M)	Hours	2.63	2 - 3	___ Hours	
(c) Highest (H)	Hours	4.88	3 - 6	___ Hours	
(d) Curve-Type	Type	2 Persons:	Type 6 2 Persons: Type 8	Type ___	
8. Work Sampling (Type A)					
(a) Lowest (L)	Hours	32.38	12 - 21	___ Hours	
(b) Most Common (M)	Hours	48.00	24 - 30	___ Hours	
(c) Highest (H)	Hours	78.75	40 - 50	___ Hours	

	Amount of time it might take you to set a one-hour labor standard this way.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, <u>if</u> your new estimate lies outside the central range <u>or</u> you do not agree with the curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
8. Work Sampling (Type A) (Continued)					
(d) Curve-Type	Type	2 Persons: Type 3 2 Persons: Type 6		Type ____	
9. Work Sampling (Type B)					
(a) Lowest (L)	Hours	13.25	8 - 16	____ Hours	
(b) Most Common (M)	Hours	28.88	16 - 25	____ Hours	
(c) Highest (H)	Hours	47.25	30 - 40	____ Hours	
(d) Curve-Type	Type	3 Persons: Type 3		Type ____	
10. Work Sampling (Type 2)					
(a) Lowest (L)	Hours	6.29	4 - 9	____ Hours	
(b) Most Common (M)	Hours	10.57	8 - 16	____ Hours	
(c) Highest (H)	Hours	14.57	14 - 20	____ Hours	
(d) Curve-Type	Type	2 Persons: Type 3		Type ____	
11. Engineered Estimate (Type 2)					
(a) Lowest (L)	Hours	0.81	0.5 - 1	____ Hours	
(b) Most Common (M)	Hours	1.56	1 - 1.5	____ Hours	
(c) Highest (H)	Hours	3.34	2 - 4	____ Hours	
(d) Curve-Type	Type	3 Persons: Type 9		Type ____	

	Amount of time it might take you to set a one-hour labor standard this way.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, <u>if</u> your new estimate lies outside the central range <u>or</u> you do not agree with the curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
12. Coordinated Estimate (Type 3)					
(a) Lowest (L)	Hours	0.55	0.4 - 1	___ Hours	
(b) Most Common (M)	Hours	1.01	0.6 - 1	___ Hours	
(c) Highest (H)	Hours	1.73	1 - 1.5	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 3 2 Persons: Type 8		Type ___	

PART II

Even though a labor standard has been established, the industrial engineering technician is still responsible for maintaining that standard. In this part of the questionnaire, you are to consider all of the reasons that might require additional work by you after the original labor standard has been developed, to keep it current. These reasons include such causes as changes in all or part of the labor standard because of a change in the instruction manual, changes in all or part of the labor standard due to a methods-improvement action, or simply the requirement for a periodic review of the standard because of its age.

Listed below are the same work measurement technique-type combinations as in Part I. In this part, however, you are asked to indicate the lowest (L), most common (M) and highest (H) amount of total time you might spend in any two-year period following the original standard-development date to keep that standard current. This, of course, assumes that the standard will be in existance for two years or more. In other words, what is desired is an indication of how much extra work is required of you every two years to keep a labor standard up to date. As in Part I of this questionnaire, all times apply to maintaining a labor standard that is exactly one hour long.

	Amount of time required every 2 years to maintain a one-hour labor standard set this way.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, if your new estimate lies outside the central range or you do not agree with this curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
1. MTM (Type A)					
(a) Lowest (L)	Hours	11.09	2 - 16	___ Hours	
(b) Most Common (M)	Hours	21.34	4.25 - 35	___ Hours	
(c) Highest (H)	Hours	44.25	4.5 - 80	___ Hours	
(d) Curve-Type	Type	3 Persons: Type 6		Type ___	
2. ASD (Type A)					
(a) Lowest (L)	Hours	2.66	2 - 4	___ Hours	
(b) Most Common (M)	Hours	5.47	3 - 8	___ Hours	
(c) Highest (H)	Hours	10.50	5 - 16	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 8 2 Persons: Type 9		Type ___	
3. ASD (Type B)					
(a) Lowest (L)	Hours	1.43	0.8 - 2	___ Hours	
(b) Most Common (M)	Hours	3.58	1 - 5	___ Hours	
(c) Highest (H)	Hours	8.50	1.25 - 16	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 5 2 Persons: Type 9		Type ___	
4. ASD (Type 2)					
(a) Lowest (L)	Hours	0.97	0.125 - 2	___ Hours	
(b) Most Common (M)	Hours	2.53	0.25 - 8	___ Hours	
(c) Highest (H)	Hours	6.02	0.5 - 16	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 5		Type ___	

	Amount of time required every 2 years to maintain a one-hour labor standard set this way.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, if your new estimate lies outside the central range or you do not agree with this curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
5. Stop Watch (Type A)					
(a) Lowest (L)	Hours	4.66	1 - 5	___ Hours	
(b) Most Common (M)	Hours	8.28	2 - 6.5	___ Hours	
(c) Highest (H)	Hours	17.56	3 - 10	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 8 2 Persons: Type 9		Type ___	
6. Stop Watch (Type B)					
(a) Lowest (L)	Hours	1.82	0.8 - 3	___ Hours	
(b) Most Common (M)	Hours	5.61	1.5 - 5	___ Hours	
(c) Highest (H)	Hours	8.59	3 - 8	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 5 2 Persons: Type 8 2 Persons: Type 9		Type ___	
7. Stop Watch (Type 2)					
(a) Lowest (L)	Hours	0.60	0.5 - 1	___ Hours	
(b) Most Common (M)	Hours	3.26	0.6 - 1.5	___ Hours	
(c) Highest (H)	Hours	13.90	1 - 2	___ Hours	
(d) Curve-Type	Type	3 Persons: Type 2 3 Persons: Type 8		Type ___	
8. Work Sampling (Type A)					
(a) Lowest (L)	Hours	22.28	3 - 6	___ Hours	
(b) Most Common (M)	Hours	31.09	6 - 9	___ Hours	

	Amount of time required every 2 years to maintain a one-hour labor standard set this way.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, if your new estimate lies outside the central range or you do not agree with this curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
8. Work Sampling (Type A) (Continued)					
(c) Highest (H)	Hours	85.94	12 - 16	___ Hours	
(d) Curve-Type	Type	2 Persons: 2 Persons:	Type 2 Type 9	Type ___	
9. Work Sampling (Type B)					
(a) Lowest (L)	Hours	6.09	2 - 4.5	___ Hours	
(b) Most Common (M)	Hours	16.94	4 - 8	___ Hours	
(c) Highest (H)	Hours	45.75	9 - 16	___ Hours	
(d) Curve-Type	Type	2 Persons: 2 Persons: 2 Persons:	Type 3 Type 5 Type 9	Type ___	
10. Work Sampling (Type 2)					
(a) Lowest (L)	Hours	3.36	0.5 - 3	___ Hours	
(b) Most Common (M)	Hours	7.41	1.1 - 4	___ Hours	
(c) Highest (H)	Hours	14.59	1.6 - 6	___ Hours	
(d) Curve-Type	Type	2 Persons: 2 Persons:	Type 2 Type 8	Type ___	
11. Engineered Estimate (Type 2)					
(a) Lowest (L)	Hours	0.75	0.25 - 1	___ Hours	
(b) Most Common (M)	Hours	1.91	0.5 - 2	___ Hours	
(c) Highest (H)	Hours	5.14	1 - 3	___ Hours	
(d) Curve-Type	Type	3 Persons:	Type 9	Type ___	

	Amount of time required every 2 years to maintain a one-hour labor standard set this way.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, <u>if</u> your new estimate lies outside the central range <u>or</u> you do not agree with this curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
12. Coordinated Estimate (Type 3)					
(a) Lowest (L)	Hours	0.48	0.25 - 0.50	___ Hours	
(b) Most Common (M)	Hours	1.03	0.5 - 1	___ Hours	
(c) Highest (H)	Hours	1.58	0.5 - 2	___ Hours	
(d) Curve-Type	Type	4 Persons: Type 8		Type ___	

PART III

One of the objectives of a work measurement program is to reduce the amount of unproductive man-hours in the shop. This is accomplished by attempting to determine how long it should take a properly trained and supervised worker, working at a normal pace, to accomplish a particular task. Even when labor standards are in force, however, there is probably still some wasted time if only because the labor standard itself is either "loose" or just "too high."

This part of the questionnaire is an attempt to determine how many wasted man-hours might result if there were no labor standards at all, or if the various techniques and labor-standard types were in use. You are to assume that the questions pertain to a shop that has 20 direct-labor employees, being paid for an 8-hour day (160 direct man-hours per day), and that these 20 workers are properly supervised by their foreman. In addition, you are to assume that all labor standards in that shop have been established by the technique indicated and with the statistical accuracy required by that type standard.

Listed below are the same standard technique-types as in the previous two parts of this questionnaire. There has been added, however, the situation when no labor standards are in use. You are asked to indicate the lowest (L), most common (M), and highest (H) number of man-hours (out of the 160 man-hours available in this 20-man shop each day) that might be wasted or not fully utilized if all labor standards in that shop were set in the manner indicated. Time lost due to personal needs, official break periods, cleanup, minor maintenance, or other recognized delays and allowances is not to be considered wasted. Wasted man-hours, as used here, is the amount of time the worker would get that is over and above what he should need to perform his duties either because of the poor method definition or "looseness" of the technique used to set his standard. Remember that you are to estimate these values on a daily basis.

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, if your new estimate lies outside the central range or you do not agree with this curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
1. No Standards at all					
(a) Lowest (L)	Hours	21.56	10 - 32	___ Hours	
(b) Most Common (M)	Hours	43.13	32 - 48	___ Hours	
(c) Highest (H)	Hours	74.19	56 - 80	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 2 2 Persons: Type 8		Type ___	
2. MTM (Type A)					
(a) Lowest (L)	Hours	6.06	0.5 - 8	___ Hours	
(b) Most Common (M)	Hours	10.19	7 - 10	___ Hours	
(c) Highest (H)	Hours	17.00	10 - 24	___ Hours	
(d) Curve-Type	Type	4 Persons: Type 8		Type ___	
3. ASD (Type A)					
(a) Lowest (L)	Hours	5.88	1 - 8	___ Hours	
(b) Most Common (M)	Hours	9.44	7.5 - 12	___ Hours	
(c) Highest (H)	Hours	14.00	10 - 20	___ Hours	
(d) Curve-Type	Type	5 Persons: Type 8		Type ___	
4. ASD (Type B)					
(a) Lowest (L)	Hours	9.67	6 - 13	___ Hours	
(b) Most Common (M)	Hours	15.33	8 - 20	___ Hours	
(c) Highest (H)	Hours	24.50	11 - 40	___ Hours	
(d) Curve-Type	Type	3 Persons: Type 2		Type ___	

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, <u>if</u> your new estimate lies outside the central range <u>or</u> you do not agree with this curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
5. ASD (Type 2)					
(a) Lowest (L)	Hours	15.30	6 - 32	___ Hours	
(b) Most Common (M)	Hours	21.60	8 - 40	___ Hours	
(c) Highest (H)	Hours	32.30	12.5 - 65	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 6		Type ___	
6. Stop Watch (Type A)					
(a) Lowest (L)	Hours	5.69	4 - 8	___ Hours	
(b) Most Common (M)	Hours	10.63	8 - 15	___ Hours	
(c) Highest (H)	Hours	15.81	16 - 20	___ Hours	
(d) Curve-Type	Type	4 Persons: Type 8		Type ___	
7. Stop Watch (Type B)					
(a) Lowest (L)	Hours	8.06	8 - 12	___ Hours	
(b) Most Common (M)	Hours	12.94	12 - 16	___ Hours	
(c) Highest (H)	Hours	22.44	16 - 32	___ Hours	
(d) Curve-Type	Type	3 Persons: Type 5		Type ___	
8. Stop Watch (Type 2)					
(a) Lowest (L)	Hours	13.81	9 - 16	___ Hours	
(b) Most Common (M)	Hours	22.81	13 - 32	___ Hours	
(c) Highest (H)	Hours	36.31	20 - 48	___ Hours	

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, if your new estimate lies outside the central range or you do not agree with this curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
8. Stop Watch (Type 2) (Continued) (d) Curve-Type	Type	3 Persons: Type 5		Type ___	
9. Work Sampling (Type A) (a) Lowest (L)	Hours	7.06	5.5 - 9	___ Hours	
(b) Most Common (M)	Hours	12.00	8 - 14	___ Hours	
(c) Highest (H)	Hours	18.44	16 - 22	___ Hours	
(d) Curve-Type	Type	4 Persons: Type 8		Type ___	
10. Work Sampling (Type B) (a) Lowest (L)	Hours	10.19	9 - 13	___ Hours	
(b) Most Common (M)	Hours	17.06	13 - 20	___ Hours	
(c) Highest (H)	Hours	25.31	18 - 36	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 5 2 Persons: Type 8		Type ___	
11. Work Sampling (Type 2) (a) Lowest (L)	Hours	12.71	8 - 15	___ Hours	
(b) Most Common (M)	Hours	20.43	11 - 25	___ Hours	
(c) Highest (H)	Hours	30.71	18 - 40	___ Hours	
(d) Curve-Type	Type	3 Persons: Type 2		Type ___	

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.				Major reason(s) why you feel the estimate should be lower (or higher) than those within the central range or why the curve-type selected by more persons than any other type does not adequately represent the values, <u>if</u> your new estimate lies outside the central range <u>or</u> you do not agree with this curve-type.
	Your first-round estimate	Group Estimates		Your new estimate	
		Average	Central Range		
12. Engineered Estimate (Type 2)					
(a) Lowest (L)	Hours	13.56	7.5 - 20	___ Hours	
(b) Most Common (M)	Hours	24.75	13 - 40	___ Hours	
(c) Highest (H)	Hours	42.81	20 - 60	___ Hours	
(d) Curve-Type	Type	2 Persons: Type 2 2 Persons: Type 3 2 Persons: Type 5		Type ___	
13. Coordinated Estimate (Type 3)					
(a) Lowest (L)	Hours	17.38	9 - 28	___ Hours	
(b) Most Common (M)	Hours	38.69	16 - 50	___ Hours	
(c) Highest (H)	Hours	61.13	40 - 70	___ Hours	
(d) Curve-Type	Type	3 Persons: Type 2		Type ___	

The set of curves attached to this questionnaire was identical to the set attached to the first-round questionnaire (see page 142).

THIRD-ROUND QUESTIONNAIRE

Please read these instructions carefully.

This is the third in the series of four questionnaires designed to gather information concerning the cost-benefit relationships of the various work measurement techniques available in this branch. The same questions that appeared on the first two questionnaires are repeated here. During the second round you submitted "new" estimates of various time values and selected a curve-type to represent your concept of how these values would look if they were plotted on graph paper. This questionnaire once again gives you the opportunity to revise any of these estimates if you feel they can be improved.

For each work measurement technique-type combination the following information is presented: your second-round estimate, the average of the estimates made by all participants during the second round, the central range of these second-round estimates, and the major relevant reasons, in the opinion of some of the participants, why the estimated values should be lower (or higher) than those within the central range, or why the curve-type selected by more participants than any other type does not adequately represent the values under consideration. You are again asked to reconsider your previous estimates in the light of the group information, using the stated reasons for what you think they are worth. For each reason that you find unacceptable in making your own estimate, please give your opinion, as briefly and clearly as possible, as to why it is unacceptable. If you need additional space, use the extra paper attached to this questionnaire, being sure to identify the part and question number to which you are referring. Following this procedure, please reconsider each of your estimates once more, possibly revise it, and write your new estimate in the space provided.

Please continue not discussing your answers with any other person engaged in this study. Once again, read the instructions for each part carefully to determine that you fully understand the question before answering.

Please complete this questionnaire and have it ready to be picked up by the morning of ________________________.

PART I

Listed below are the work measurement techniques that could currently be used to establish different types of labor standards within this branch. For each technique and labor-standard type (A, B, 2, or 3) you are asked to provide the lowest (L), most common (M), and highest (H) amount of time you might spend establishing a labor standard for a one-hour job. In other words, if you were to develop a labor standard that is exactly one hour long, that meets the statistical accuracy requirements for the type standard being set, and were to use the technique indicated, what is the lowest amount of time it might take you, what is the most common amount of time it might take you, and what is the highest amount of time it might take you? In addition, you are to indicate, from the nine curves shown on the last page, the type of curve that best describes the way you think these times would look if you were to set one-hour labor standards in that manner over and over and were to plot the amount of time it took you horizontally and the number of times it took you this long vertically.

	Amount of time it might take you to set a one-hour labor standard this way. Your second-round estimate	Group Estimates: Average	Group Estimates: Central Range	Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
1. MTM (Type A)						
(a) Lowest (L)	Hours	45.75	30 - 50			___ Hours
(b) Most Common (M)	Hours	81.38	50 - 80			___ Hours
(c) Highest (H)	Hours	140.88	80 - 130			___ Hours
(d) Curve-Type	Type	5 Persons:	Type 3	Comments in favor of Type 8: Personnel familiar with MTM could not possibly agree with a type 3 curve. Comments in favor of Type 9: The skew should be more sharply defined. Type 3 indicates a greater lack of self-confidence.		Type ___
2. ASD (Type A)						
(a) Lowest (L)	Hours	6.06	3 - 7	Comments in favor of a smaller L, M, & H: Proficiency in the use of ASD elements would lower these values. Comments in favor of a greater L & M: The smaller values must be the result of greater familiarity with the use of ASD which is not typical.		___ Hours
(b) Most Common (M)	Hours	11.03	7 - 14			___ Hours
(c) Highest (H)	Hours	15.88	10 - 20			___ Hours
(d) Curve-Type	Type	3 Persons:	Type 8	Comments in favor of Type 1: The spread should be more pronounced in all cases. Comments in favor of Type 8: The spread of the central range indicates there would be very little skew.		Type ___
3. ASD (Type B)						
(a) Lowest (L)	Hours	4.14	4 - 5	Comments in favor of a greater L, M, & H: An ASD standard with some elements derived from other techniques should still require a time similar to a Type A standard. Comments in favor of a greater L & M: The smaller values must be the result of greater familiarity with the use of ASD which is not typical.		___ Hours
(b) Most Common (M)	Hours	7.29	6 - 9			___ Hours
(c) Highest (H)	Hours	11.57	10 - 16			___ Hours

	Amount of time it might take you to set a one-hour labor standard this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates				
		Average	Central Range			
3. ASD (Type B) (Continued)						
(d) Curve-Type	Type	4 Persons: Type 8				Type ____
4. ASD (Type 2)						
(a) Lowest (L)	Hours	2.96	2 - 4	Comments in favor of a greater L, M, & H: An ASD standard with some elements derived from other techniques should still require a time similar to a Type A standard.		____ Hours
(b) Most Common (M)	Hours	5.61	4 - 7			____ Hours
(c) Highest (H)	Hours	8.25	7 - 10			____ Hours
(d) Curve-Type	Type	2 Persons: Type 2 2 Persons: Type 3		Comments in favor of Type 2: Type 3 represents M closer to L. This is not borne out by the estimates. Comments in favor of Type 4: A medium spread is more in keeping with this type standard.		Type ____
5. Stop Watch (Type A)						
(a) Lowest (L)	Hours	7.75	5 - 8	Comments in favor of a smaller L: It appears that some were influenced by an old rule of thumb that required at least a 5-cycle study. Statistically this is not so. A Type "A" study can be made with less than 5 cycles. A minimum of 3 cycles could be statistically sound. Then add one hour for preparation and computation.		____ Hours
(b) Most Common (M)	Hours	13.63	12 - 14			____ Hours
(c) Highest (H)	Hours	20.88	20 - 24			____ Hours
(d) Curve-Type	Type	3 Persons: Type 2				Type ____
6. Stop Watch (Type B)						
(a) Lowest (L)	Hours	5.38	4 - 6	Comments in favor of a smaller M: A "B" standard with a stop watch will take an average of 5 to 6 cycles, with one more hour required to setup and compute.		____ Hours
(b) Most Common (M)	Hours	9.25	7 - 10			____ Hours

	Amount of time it might take you to set a one-hour labor standard this way. Your second-round estimate	Group Estimates: Average	Group Estimates: Central Range	Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
6. Stop Watch (Type B) (Continued)						
(c) Highest (H)	Hours	15.63	12 - 20	<u>Comments in favor of a smaller H:</u> A "B" standard with a stop watch might take 8 to 10 cycles with one hour to setup and compute.		___ Hours
(d) Curve-Type	Type	5 Persons: Type 3				Type ___
7. Stop Watch (Type 2)						
(a) Lowest (L)	Hours	1.75	1.5 - 2	<u>Comments in favor of a smaller L:</u> The lowest Type 2 stopwatch standard could be an incomplete 1-cycle study.		___ Hours
(b) Most Common (M)	Hours	2.63	2 - 3	<u>Comments in favor of a smaller H:</u> A 1-cycle study will result in a Type 2 standard classification. Then add one hour for preparation and computation.		___ Hours
(c) Highest (H)	Hours	4.13	3 - 5	Two times the labor standard = study time to complete one cycle. This is not always true, however, I don't think I have ever used more than this on a repetitive or non-repetitive type study. <u>Comments in favor of a greater H:</u> The question is speculative. However, conceivably a person could spend many more hours than this and still not have an A or B study.		___ Hours
(d) Curve-Type	Type	3 Persons: Type 8				Type ___
8. Work Sampling (Type A)						
(a) Lowest (L)	Hours	18.75	16 - 20	<u>Comments in favor of a greater L:</u> 100 observations made in one hour with 1700 observations required = 17 hours minimum plus computation time.		___ Hours
(b) Most Common (M)	Hours	32.63	27 - 30			___ Hours

	Amount of time it might take you to set a one-hour labor standard this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates				
		Average	Central Range			
8. Work Sampling (Type A) (Continued)						
(c) Highest (H)	Hours	56.38	40 - 50	<u>Comments in favor of a greater M & H:</u> As work sampling constitutes random times of the day, it seldom can be accomplished in short periods of time. This type of work consumes a lot of time. <u>Comments in favor of a greater H:</u> One observation made in 5 minutes with 1700 observations required = 1700 x 5 = 8500 minutes = 143 hours plus computation time.		___ Hours
(d) Curve-Type	Type	3 Persons: Type 3				Type ___
9. Work Sampling (Type B)						
(a) Lowest (L)	Hours	12.13	10 - 15	<u>Comments in favor of a smaller L:</u> 100 observations made in one hour with 480 observations required = 4.8 hours plus computation time.		___ Hours
(b) Most Common (M)	Hours	19.38	18 - 20			___ Hours
(c) Highest (H)	Hours	36.25	30 - 40	<u>Comments in favor of a greater M & H:</u> As work sampling constitutes random times of the day, it seldom can be accomplished in short periods of time. This type of work consumes a lot of time. <u>Comments in favor of a greater H:</u> One observation made in 5 minutes with 480 observations required = 480 x 5 = 2400 minutes = 40 hours plus computation time.		___ Hours
(d) Curve-Type	Type	4 Persons: Type 3				Type ___

	Amount of time it might take you to set a one-hour labor standard this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates				
		Average	Central Range			
10. Work Sampling (Type 2)						
(a) Lowest (L)	Hours	6.29	5 - 9			___ Hours
(b) Most Common (M)	Hours	12.86	12 - 16			___ Hours
(c) Highest (H)	Hours	18.14	18 - 20			___ Hours
(d) Curve-Type	Type	5 Persons: Type 3				Type ___
11. Engineered Estimate (Type 2)						
(a) Lowest (L)	Hours	0.70	0.5 - 0.75	<u>Comments in favor of a smaller H:</u> One hour is an ample amount of time.		___ Hours
(b) Most Common (M)	Hours	1.63	1.0 - 1.5	<u>Comments in favor of a greater M:</u> The research of tech orders and other related material will consume more time.		___ Hours
(c) Highest (H)	Hours	3.50	2 - 4	<u>Comments in favor of a greater H:</u> Considering a new end item with no previous experience on overhaul, 8 hours is not unreasonable.		___ Hours
(d) Curve-Type	Type	6 Persons: Type 9				Type ___
12. Coordinated Estimate (Type 3)						
(a) Lowest (L)	Hours	0.53	0.4 - 0.5	<u>Comments in favor of a greater M:</u> If shops and personnel were readily available, this could be lower. However experience shows this not to be the case.		___ Hours
(b) Most Common (M)	Hours	1.05	0.75 - 1.0			___ Hours
(c) Highest (H)	Hours	1.79	1.0 - 1.5	<u>Comments in favor of a greater H:</u> Again, considering unfamiliar end items, 4 hours is not unreasonable.		___ Hours
(d) Curve-Type	Type	3 Persons: Type 8				Type ___

PART II

Even though a labor standard has been established, the industrial engineering technician is still responsible for maintaining that standard. In this part of the questionnaire, you are to consider all of the reasons that might require additional work by you after the original labor standard has been developed, to keep it current. These reasons include such causes as changes in all or part of the labor standard because of a change in the instruction manual, changes in all or part of the labor standard due to a methods-improvement action, or simply the requirement for a periodic review of the standard because of its age.

Listed below are the same work measurement technique-type combinations as in Part I. In this part, however, you are asked to indicate the lowest (L), most common (M) and highest (H) amount of total time you might spend in any two-year period following the original standard-development date to keep that standard current. This, of course, assumes the standard will be in existance for two years or more. In other words, what is desired is an indication of how much extra work is required of you every two years to keep a labor standard up to date. As in Part I of this questionnaire, all times apply to maintaining a labor standard that is exactly one hour long.

	Amount of time required every two years to maintain a one-hour labor standard set this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates				
		Average	Central Range			
1. MTM (Type A)						
(a) Lowest (L)	Hours	6.33	2 - 8	Comments in favor of a smaller L: The minimum review time could be ½ hour. A standard could only require an update. Comments in favor of a greater L, M, & H: Some estimates apparently do not consider the quantity of data to be reviewed.		___ Hours
(b) Most Common (M)	Hours	25.28	18 - 35			___ Hours
(c) Highest (H)	Hours	52.06	30 - 80			___ Hours
(d) Curve-Type	Type	4 Persons: Type 6				Type ___
2. ASD (Type A)						
(a) Lowest (L)	Hours	1.77	1 - 2	Comments in favor of a smaller L: The minimum review time could be ½ hour. A standard could only require an update.		___ Hours
(b) Most Common (M)	Hours	5.53	3 - 8			___ Hours
(c) Highest (H)	Hours	13.44	8 - 16			___ Hours
(d) Curve-Type	Type	3 Persons: Type 6				Type ___
3. ASD (Type B)						
(a) Lowest (L)	Hours	1.35	0.8 - 2	Comments in favor of a smaller L: A standard could only require an update.		___ Hours
(b) Most Common (M)	Hours	3.60	2.2 - 5			___ Hours
(c) Highest (H)	Hours	10.04	6 - 16			___ Hours
(d) Curve-Type	Type	3 Persons: Type 9				Type ___
4. ASD (Type 2)						
(a) Lowest (L)	Hours	1.05	0.7 - 2	Comments in favor of a smaller L: A standard could only require an update.		___ Hours
(b) Most Common (M)	Hours	3.39	1.5 - 6			___ Hours

	Amount of time required every two years to maintain a one-hour labor standard set this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates				
		Average	Central Range			
4. ASD (Type 2) (Continued)						
(c) Highest (H)	Hours	8.30	4.5 - 12			___ Hours
(d) Curve-Type	Type	2 Persons: Type 5		Comments in favor of Type 9: The greatest difference should be between the highest and most common values.		Type ___
5. Stop Watch (Type A)						
(a) Lowest (L)	Hours	1.38	0.5 - 1.0	Comments in favor of a smaller L: The minimum review time could be ½ hour. A standard could only require an update.		___ Hours
(b) Most Common (M)	Hours	4.11	2 - 6.5			___ Hours
(c) Highest (H)	Hours	12.00	4 - 17			___ Hours
(d) Curve-Type	Type	3 Persons: Type 8		Comments in favor of Type 5: The amount of time spent on each standard will have a larger spread due to work content change. Comments in favor of Type 2: The spread of values should be more gradual.		Type ___
6. Stop Watch (Type B)						
(a) Lowest (L)	Hours	0.99	0.5 - 1.0	Comments in favor of a smaller L: If a technician is familiar with a job through daily contact, ½ hour is not unreasonable. A standard could only require an update.		___ Hours
(b) Most Common (M)	Hours	2.93	2 - 5			___ Hours
(c) Highest (H)	Hours	8.13	4 - 8			___ Hours
(d) Curve-Type	Type	2 Persons: Type 5 2 Persons: Type 8 2 Persons: Type 9				Type ___

	Amount of time required every two years to maintain a one-hour labor standard set this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates				
		Average	Central Range			
7. Stop Watch (Type 2)						
(a) Lowest (L)	Hours	0.64	0.5 - 1.0	<u>Comments in favor of a smaller L:</u> The minimum review time could be ½ hour. The standard could only require an update.		___ Hours
(b) Most Common (M)	Hours	1.51	1 - 1.5			___ Hours
(c) Highest (H)	Hours	4.09	1 - 2			___ Hours
(d) Curve-Type	Type	3 Persons: Type 2 3 Persons: Type 8				Type ___
8. Work Sampling (Type A)						
(a) Lowest (L)	Hours	2.57	0.5 - 3	<u>Comments in favor of a smaller L:</u> The minimum review time could be ½ hour. A standard could only require an update.		___ Hours
(b) Most Common (M)	Hours	6.19	6 - 8			___ Hours
(c) Highest (H)	Hours	24.08	12 - 16			___ Hours
(d) Curve-Type	Type	2 Persons: Type 2 2 Persons: Type 3 2 Persons: Type 9		<u>Comments in favor of Type 3</u>: The estimates indicate that M is closer to L.		Type ___
9. Work Sampling (Type B)						
(a) Lowest (L)	Hours	2.27	2 - 3	<u>Comments in favor of a smaller L:</u> The minimum review time could be ½ hour. A standard could only require an update.		___ Hours
(b) Most Common (M)	Hours	4.69	4 - 6			___ Hours
(c) Highest (H)	Hours	15.38	9 - 14			___ Hours
(d) Curve-Type	Type	3 Persons: Type 3				Type ___

	Amount of time required every two years to maintain a one-hour labor standard set this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates				
		Average	Central Range			
10. Work Sampling (Type 2)						
(a) Lowest (L)	Hours	1.29	0.5 - 3	<u>Comments in favor of a smaller L:</u> A standard could only require an update.		___ Hours
(b) Most Common (M)	Hours	2.87	1.5 - 4			___ Hours
(c) Highest (H)	Hours	6.09	2 - 6			___ Hours
(d) Curve-Type	Type	2 Persons: Type 2 2 Persons: Type 8		<u>Comments in favor of Type 9</u>: The long slope should be to the high side rather than equal as shown by Types 2 and 8.		Type ___
11. Engineered Estimate (Type 2)						
(a) Lowest (L)	Hours	0.60	0.4 - 0.5	<u>Comments in favor of a smaller L:</u> The minimum review time could be ½ hour. A standard could only require an update.		___ Hours
(b) Most Common (M)	Hours	1.94	0.5 - 2			___ Hours
(c) Highest (H)	Hours	5.33	1 - 3	<u>Comments in favor of a greater H:</u> We have standards that are changed several times. The average estimate appears far too low.		___ Hours
(d) Curve-Type	Type	6 Persons: Type 9				Type ___
12. Coordinated Estimate (Type 3)						
(a) Lowest (L)	Hours	0.40	0.3 - 0.5	<u>Comments in favor of a smaller L:</u> A standard could only require an update.		___ Hours
(b) Most Common (M)	Hours	0.83	0.5 - 1.0			___ Hours
(c) Highest (H)	Hours	1.39	0.6 - 2			___ Hours
(d) Curve-Type	Type	5 Persons: Type 8		<u>Comments in favor of Type 9</u>: The long slope should be to the high side rather than equal.		Type ___

PART III

One of the objectives of a work measurement program is to reduce the amount of unproductive man-hours in the shop. This is accomplished by attempting to determine how long it should take a properly trained and supervised worker, working at a normal pace, to accomplish a particular task. Even when labor standards are in force, however, there is probably still some wasted time if only because the labor standard itself is either "loose" or just "too high."

This part of the questionnaire is an attempt to determine how many wasted man-hours might result if there were no labor standards at all, or if the various techniques and labor-standard types were in use. You are to assume that the questions pertain to a shop that has 20 direct-labor employees, being paid for an 8-hour day (160 direct man-hours per day), and that these 20 workers are properly supervised by their foreman. In addition, you are to assume that all labor standards in that shop have been established by the technique indicated and with the statistical accuracy required by that type standard.

Listed below are the same standard technique-types as in the previous two parts of this questionnaire. There has been added, however, the situation when no labor standards are in use. You are asked to indicate the lowest (L), most common (M), and highest (H) number of man-hours (out of the 160 man-hours available in this 20-man shop each day) that might be wasted or not fully utilized if all labor standards in that shop were set in the manner indicated. Time lost due to personal needs, official break periods, cleanup, minor maintenance, or other recognized delays and allowances is not to be considered wasted. Wasted man-hours, as used here, is the amount of time the worker would get that is over and above what he should need to perform his duties either because of the poor method definition or "looseness" of the technique used to set his standard. Remember that you are to estimate these values on a daily basis.

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates				
		Average	Central Range			
1. No standards at all						
(a) Lowest (L)	Hours	23.93	16 - 32	Comments in favor of a smaller L, M, & H: I have found that most people like to produce. If they have good facilities and if the product and parts are there, they will produce. They love to say "we did this" or "records are set to be broken." Proper planning and supervision produces and cuts cost.		___ Hours
(b) Most Common (M)	Hours	37.86	32 - 48			___ Hours
(c) Highest (H)	Hours	57.36	48 - 80			___ Hours
(d) Curve-Type	Type	4 Persons: Type 2		Comments in favor of Type 4: I feel all of these should be skewed to the high side because of bias.		Type ___
2. MTM (Type A)						
(a) Lowest (L)	Hours	4.13	2 - 5	Comments in favor of a smaller L, M, & H: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards. Comments in favor of a greater M & H: The inherent inaccuracy of an MTM standard leaves these very conservative estimates.		___ Hours
(b) Most Common (M)	Hours	9.06	7.5 - 10			___ Hours
(c) Highest (H)	Hours	16.75	10 - 24			___ Hours
(d) Curve-Type	Type	6 Persons: Type 8				Type ___
3. ASD (Type A)						
(a) Lowest (L)	Hours	4.88	3 - 8	Comments in favor of a smaller L, M, & H: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore,		___ Hours
(b) Most Common (M)	Hours	9.44	8 - 12			___ Hours

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates: Average	Group Estimates: Central Range			
3. ASD (Type A) (Continued)						
(c) Highest (H)	Hours	14.00	12 - 18	under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.		___ Hours
(d) Curve-Type	Type	7 Persons:	Type 8			Type ___
4. ASD (Type B)						
(a) Lowest (L)	Hours	6.86	6 - 10	Comments in favor of a smaller L, M, & H: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.		___ Hours
(b) Most Common (M)	Hours	11.86	9 - 20			___ Hours
(c) Highest (H)	Hours	16.86	12 - 24			___ Hours
(d) Curve-Type	Type	5 Persons:	Type 2			Type ___
5. ASD (Type 2)						
(a) Lowest (L)	Hours	12.21	7 - 16			___ Hours
(b) Most Common (M)	Hours	18.00	10 - 32			___ Hours
(c) Highest (H)	Hours	27.79	15 - 40			___ Hours
(d) Curve-Type	Type	3 Persons:	Type 6	Comments in favor of Type 7: The difference between the lowest and most common values should be the greater.		Type ___

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates				
		Average	Central Range			
6. Stop Watch (Type A)						
(a) Lowest (L)	Hours	5.31	4 - 7	<u>Comments in favor of a smaller L, M, & H:</u> There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.		___ Hours
(b) Most Common (M)	Hours	9.75	8 - 12			___ Hours
(c) Highest (H)	Hours	15.06	16 - 18			___ Hours
(d) Curve-Type	Type	6 Persons: Type 8				Type ___
7. Stop Watch (Type B)						
(a) Lowest (L)	Hours	7.56	8 - 10	<u>Comments in favor of a smaller L, M, & H:</u> There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.		___ Hours
(b) Most Common (M)	Hours	13.06	12 - 16			___ Hours
(c) Highest (H)	Hours	20.81	16 - 32			___ Hours
(d) Curve-Type	Type	4 Persons: Type 5		<u>Comments in favor of Type 6:</u> This type is more appropriate due to the spread from M to H.		Type ___
8. Stop Watch (Type 2)						
(a) Lowest (L)	Hours	14.44	9 - 16			___ Hours
(b) Most Common (M)	Hours	22.31	12 - 32			___ Hours
(c) Highest (H)	Hours	35.19	16 - 48			___ Hours

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates				
		Average	Central Range			
8. Stop Watch (Type 2) (Continued)						
(d) Curve-Type	Type	4 Persons: Type 5		<u>Comments in favor of Type 2</u>: The values should be more wide spread than Type 5 shows.		Type ____
9. Work Sampling (Type A)						
(a) Lowest (L)	Hours	6.31	5.5 - 8	<u>Comments in favor of a smaller L, M, & H</u>: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.		____ Hours
(b) Most Common (M)	Hours	10.13	8 - 13			____ Hours
(c) Highest (H)	Hours	15.06	16 - 18			____ Hours
(d) Curve-Type	Type	5 Persons: Type 8				Type ____
10. Work Sampling (Type B)						
(a) Lowest (L)	Hours	9.31	9 - 10	<u>Comments in favor of a smaller L, M, & H</u>: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.		____ Hours
(b) Most Common (M)	Hours	15.31	13 - 20			____ Hours
(c) Highest (H)	Hours	23.06	18 - 27			____ Hours
(d) Curve-Type	Type	4 Persons: Type 5				Type ____

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Your opinion, for each reason you find unacceptable in making your own estimate(s), as to why it is unacceptable.	Your new estimate
	Your second-round estimate	Group Estimates				
		Average	Central Range			
11. Work Sampling (Type 2)						
(a) Lowest (L)	Hours	13.14	9 - 15	Comments in favor of a greater L, M, & H: I don't agree that a type 2 work sampling would be a better management tool than a type 2 time study. The averages should have increased.		___ Hours
(b) Most Common (M)	Hours	19.71	13 - 25			___ Hours
(c) Highest (H)	Hours	29.00	20 - 40			___ Hours
(d) Curve-Type	Type	5 Persons:	Type 2			Type ___
12. Engineered Estimate (Type 2)						
(a) Lowest (L)	Hours	14.50	7.5 - 20	Comments in favor of a smaller L: It is possible to set this type standard at or below the actual time required -- I have done so.		___ Hours
(b) Most Common (M)	Hours	24.75	13 - 40			___ Hours
(c) Highest (H)	Hours	42.75	20 - 60			___ Hours
(d) Curve-Type	Type	2 Persons: 2 Persons: 2 Persons:	Type 2 Type 3 Type 5			Type ___
13. Coordinated Estimate (Type 3)						
(a) Lowest (L)	Hours	15.13	9 - 22	Comments in favor of a smaller L: It is possible to set this type standard at or below the actual time required -- I have done so.		___ Hours
(b) Most Common (M)	Hours	26.81	13 - 37			___ Hours
(c) Highest (H)	Hours	40.88	18 - 48			___ Hours
(d) Curve-Type	Type	4 Persons:	Type 2	Comments in favor of Type 9: This type standard would have to be represented by a Type 7, 8 or 9.		Type ___

The set of curves attached to this questionnaire was identical to the set attached to the first-round questionnaire (see page 142).

FOURTH- (and FINAL-) ROUND QUESTIONNAIRE

Please read these instructions carefully.

This is the last in the series of questionnaires concerning the cost-benefit relationships of the various work measurement techniques. The same questions that appeared previously are presented once more. The purpose of this questionnaire is to give you one final opportunity to revise your estimates in the light of the relevant information collected during the first three rounds.

For each work measurement technique-type combination the following information is presented: your third-round estimate, the average of the estimates made by all participants during the third round, the central range of these third-round estimates, the major relevant reasons (identical to those presented in the third round) why the estimated values should be lower (or higher) than those within the central range or why the most popular curve-type does not adequately represent the values under consideration, and the critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire. You are once again asked to reconsider each of your previous estimates using the collected group answers, the stated reasons, and the critiques of these reasons for what you feel they are worth, possibly revise your previous estimate, and write your final estimate in the space provided, remembering that you are to be honest in making your evaluations. Following this, you are asked once more to provide a confidence rating for each lowest, most common, and highest value. In making this appraisal, you should indicate one of the following in the space provided at the far right-hand side of the paper:

5 - I feel that this answer is probably within ± 20% of the true value.

4 - I feel that this answer is probably within ± 40% of the true value.

3 - I feel that this answer is probably within ± 60% of the true value.

2 - I feel that this answer is probably within ± 80% of the true value.

1 - I feel that this answer is probably within ± 100% or more of the true value.

Your confidence rating should be an indication of how much faith you have in that answer. Once again, you are asked to be honest in these ratings. You are the best judge of the accuracy of your answers. No one can do this for you.

Please continue not discussing your answers with any other person engaged in this study until this questionnaire is picked up. Once again read the instructions for each part carefully to determine that you fully understand the question before answering.

Please complete this questionnaire and have it ready to be picked up by the afternoon of ______________________.

The cooperation and interest of the industrial engineering technicians, both individually and collectively, has been most gratifying during the conduct of this study. It is sincerely hoped that the information obtained through the four questionnaires will prove beneficial to your work in the future. Each of you is to be commended for your efforts. Thank you very much for your time and trouble.

PART I

Listed below are the work measurement techniques that could currently be used to establish different types of labor standards within this branch. For each technique and labor-standard type (A, B, 2, or 3) you are asked to provide the lowest (L), most common (M), and highest (H) amount of time you might spend establishing a labor standard for a one-hour job. In other words, if you were to develop a labor standard that is exactly one hour long, that meets the statistical accuracy requirements for the type standard being set, and were to use the technique indicated, what is the lowest amount of time it might take you, what is the most common amount of time it might take you, and what is the highest amount of time it might take you? In addition, you are to indicate, from the nine curves shown on the last page, the type of curve that best describes the way you think these times would look if you were to set one-hour labor standards in that manner over and over and were to plot the amount of time it took you horizontally and the number of times it took you this long vertically.

	Amount of time it might take you to set a one-hour labor standard this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
1. MTM (Type A)							
(a) Lowest (L)	Hours	39.25	30 - 49		<u>Comments in favor of a smaller L, M & H:</u> My estimates are strictly guesses, but not without thought. We do not set standards with MTM. However if we did, we technicians would be familiar with the elements and the times would be less. The larger estimates are surely based on training which consumed more time. If we were proficient in MTM usage, the times would be lower. It is the <u>ability</u> to recognize motions and apply the related values that controls the time expended. The averages are much too high.	___ Hours	____
(b) Most Common (M)	Hours	62.50	50 - 80			___ Hours	____
(c) Highest (H)	Hours	103.00	80 - 125			___ Hours	____
(d) Curve-Type	Type	5 Persons: Type 3		<u>Comments in favor of Type 8</u>: Personnel familiar with MTM could not possibly agree with a type 3 curve. <u>Comments in favor of Type 9</u>: The skew should be more sharply defined. Type 3 indicates a greater lack of self-confidence.	<u>Comments in favor of Type 3</u>: The indicated ranges of values can hardly be called anything but a wide spread.	Type ____	
2. ASD (Type A)							
(a) Lowest (L)	Hours	5.81	2.5 - 7	<u>Comments in favor of a smaller L, M, & H:</u> Proficiency in the use of ASD elements would lower these values. <u>Comments in favor of a greater L & M:</u> The smaller values must be the result of greater familiarity with the use of ASD which is not typical.	<u>Comments in favor of a smaller L, M & H:</u> The smaller values are "not typical" to the extent that ASD is an existing tool but not used. <u>Comments in favor of a greater L & M:</u> The lower estimates in this category would indicate a failure to consider the extensive information research required to utilize ASD. In many cases this equals the ASD application time. <u>Comments in favor of a greater L, M & H:</u> Proficiency in the use of ASD may be the key to the larger	___ Hours	____
(b) Most Common (M)	Hours	10.28	6 - 12			___ Hours	____
(c) Highest (H)	Hours	15.31	11.5 - 20			___ Hours	____

	Amount of time it might take you to set a one-hour labor standard this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates: Average	Group Estimates: Central Range				
2. ASD (Type A) (Continued)					times, however, there will always be technicians less familiar with the system.		
(d) Curve-Type	Type	5 Persons:	Type 8	Comments in favor of Type 1: The spread should be more pronounced in all cases. Comments in favor of Type 8: The spread of the central range indicates there would be very little skew.		Type ___	
3. ASD (Type B)							
(a) Lowest (L)	Hours	3.75	2 - 4	Comments in favor of a greater L, M, & H: An ASD standard with some elements derived from other techniques should still require a time similar to a Type A standard. Comments in favor of a greater L & M: The smaller values must be the result of greater familiarity with the use of ASD which is not typical.	Comments in favor of a smaller L, M & H: Most of the dilution would be by estimates. This would not take as long. The smaller values are "not typical" to the extent that ASD is an existing tool but not used.	___ Hours	___
(b) Most Common (M)	Hours	6.75	6 - 8			___ Hours	___
(c) Highest (H)	Hours	10.25	10 - 13			___ Hours	___
(d) Curve-Type	Type	6 Persons:	Type 8			Type ___	
4. ASD (Type 2)							
(a) Lowest (L)	Hours	2.52	2 - 3	Comments in favor of a greater L, M, & H: An ASD standard with some elements derived from other techniques should still require a time similar to a Type A standard.	Comments in favor of a greater H: The time required to set this type standard would depend on ASD proficiency and the technician's familiarity with the work to be accomplished. From one extreme to the other, 14 hours is not inaccurate.	___ Hours	___
(b) Most Common (M)	Hours	5.03	4 - 6			___ Hours	___
(c) Highest (H)	Hours	9.09	7 - 10			___ Hours	___

	Amount of time it might take you to set a one-hour labor standard this way. Your third-round estimate	Group Estimates: Average	Group Estimates: Central Range	Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
4. ASD (Type 2) (Continued)							
(d) Curve-Type	Type	2 Persons: Type 2		<u>Comments in favor of Type 2</u>: Type 3 represents M closer to L. This is not borne out by the estimates. <u>Comments in favor of Type 4</u>: A medium spread is more in keeping with this type standard.		Type ___	
5. Stop Watch (Type A)							
(a) Lowest (L)	Hours	7.13	5 - 8	<u>Comments in favor of a smaller L</u>: It appears that some were influenced by an old rule of thumb that required at least a 5-cycle study. Statistically this is not so. A Type "A" study can be made with less than 5 cycles. A minimum of 3 cycles could be statistically sound. Then add one hour for preparation and computation.	<u>Comments in favor of a greater L</u>: I agree that a 3-cycle study will give you a Type A standard if only the total standard is classified. However, the variation of the elements within the study will not let the study be classified as a type A. Therefore, 10 or more cycles are required. <u>Comments in favor of a greater L, M & H</u>: I agree that a type "A" could be set in a minimum of 3 cycles. However, time to research tech orders, determine work requirements, establish methods, set up time study, etc., was evidently not considered. In many "repair as necessary" type work, where the amount of work varies considerably from item to item, 10 to 20 cycles might be required.	___ Hours	___
(b) Most Common (M)	Hours	12.50	12 - 13			___ Hours	___
(c) Highest (H)	Hours	21.00	20 - 24			___ Hours	___
(d) Curve-Type	Type	4 Persons: Type 2				Type ___	
6. Stop Watch (Type B)							
(a) Lowest (L)	Hours	5.00	4 - 6	<u>Comments in favor of a smaller M</u>: A "B" standard with a stop watch will take an average of 5 to 6 cycles, with one more hour required to setup and compute.	<u>Comments in favor of a greater M & H</u>: Most "B" time studies occur when the technician is attempting to make an "A" study and realizes the range is too great. In many	___ Hours	___
(b) Most Common (M)	Hours	8.88	7 - 10			___ Hours	___

	Amount of time it might take you to set a one-hour labor standard this way. Your third-round estimate	Group Estimates: Average	Group Estimates: Central Range	Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
6. Stop Watch (Type B) (Continued)							
(c) Highest (H)	Hours	15.63	12 - 20	<u>Comments in favor of a smaller H:</u> A "B" standard with a stop watch might take 8 to 10 cycles with one hour to setup and compute.	cases he has as many cycles as an "A" standard.	___ Hours	_____
(d) Curve-Type	Type	5 Persons: Type 3				Type ____	
7. Stop Watch (Type 2)							
(a) Lowest (L)	Hours	1.63	1 - 2	<u>Comments in favor of a smaller L:</u> The lowest Type 2 stopwatch standard could be an incomplete 1-cycle study.		___ Hours	_____
(b) Most Common (M)	Hours	2.63	2 - 3	<u>Comments in favor of a smaller H:</u> A 1-cycle study will result in a Type 2 standard classification. Then add one hour for preparation and computation.		___ Hours	_____
(c) Highest (H)	Hours	4.00	3 - 5	Two times the labor standard = study time to complete one cycle. This is not always true, however, I don't think I have ever used more than this on a repetitive or non-repetitive type study. <u>Comments in favor of a greater H:</u> The question is speculative. However, conceivably a person could spend many more hours than this and still not have an A or B study.		___ Hours	_____
(d) Curve-Type	Type	4 Persons: Type 8			<u>Comments in favor of Type 6:</u> My experience with time study shows this to be the more accurate curve.	Type ____	

	Amount of time it might take you to set a one-hour labor standard this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
8. Work Sampling (Type A)							
(a) Lowest (L)	Hours	18.00	16 - 20	Comments in favor of a greater L: 100 observations made in one hour with 1700 observations required = 17 hours minimum plus computation time.	Comments in favor of a smaller L: It is possible to establish an "A" standard with as few as 100 observations.	___ Hours	___
(b) Most Common (M)	Hours	32.13	28 - 30			___ Hours	___
(c) Highest (H)	Hours	56.38	40 - 50	Comments in favor of a greater M & H: As work sampling constitutes random times of the day, it seldom can be accomplished in short periods of time. This type of work consumes a lot of time. Comments in favor of a greater H: One observation made in 5 minutes with 1700 observations required = 1700 x 5 = 8500 minutes = 143 hours plus computation time.	Comments in favor of a smaller L, M & H: The amount of time consumed relates to observations. Average time for observing 5 or more persons is 2 minutes per person. The real value in the sampling technique is the partial use of technician time.	___ Hours	___
(d) Curve-Type	Type	4 Persons: Type 3				Type ___	
9. Work Sampling (Type B)							
(a) Lowest (L)	Hours	10.38	10 - 12	Comments in favor of a smaller L: 100 observations made in one hour with 480 observations required = 4.8 hours plus computation time.		___ Hours	___
(b) Most Common (M)	Hours	16.00	15 - 20			___ Hours	___
(c) Highest (H)	Hours	32.75	30 - 40	Comments in favor of a greater M & H: As work sampling constitutes random times of the day, it seldom can be accomplished in short periods of time. This type of work consumes a lot of time. Comments in favor of a greater H: One observation made in 5 minutes with 480 observations required = 480 x 5 = 2400 minutes = 40 hours plus computation time.		___ Hours	___
(d) Curve-Type	Type	4 Persons: Type 3				Type ___	

	Amount of time it might take you to set a one-hour labor standard this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
10. Work Sampling (Type 2)							
(a) Lowest (L)	Hours	4.93	4 - 6		Comments in favor of a smaller L: Using the basic requirement of 50 observations, 50 x 2 minutes = 1.7 hours.	___ Hours	_____
(b) Most Common (M)	Hours	11.73	12 - 14			___ Hours	_____
(c) Highest (H)	Hours	16.40	18 - 20			___ Hours	_____
(d) Curve-Type	Type	5 Persons:	Type 2			Type ____	
11. Engineered Estimate (Type 2)							
(a) Lowest (L)	Hours	0.66	0.5 - 0.75	Comments in favor of a smaller H: One hour is an ample amount of time. Comments in favor of a greater M: The research of tech orders and other related material will consume more time. Comments in favor of a greater H: Considering a new end item with no previous experience on overhaul, 8 hours is not unreasonable.	Comments in favor of a smaller M & H: The technician must be familiar with similar end items or he is not qualified to set a type 2 standard. He must be able to look at the end item or tech order and establish the labor standard.	___ Hours	_____
(b) Most Common (M)	Hours	1.50	1 - 1.5			___ Hours	_____
(c) Highest (H)	Hours	3.00	2 - 4			___ Hours	_____
(d) Curve-Type	Type	7 Persons:	Type 9			Type ____	
12. Coordinated Estimate (Type 3)							
(a) Lowest (L)	Hours	0.53	0.4 - 0.5	Comments in favor of a greater M: If shops and personnel were readily available, this could be lower. However, experience shows this not to be the case. Comments in favor of a greater H: Again, considering unfamiliar end items, 4 hours is not unreasonable.	Comments in favor of a greater L, M & H: I find it impossible to conceive of any technician in this or any other organization setting standards in the ranges indicated. Even the most familiar work would require more than the indicated range.	___ Hours	_____
(b) Most Common (M)	Hours	1.05	0.75 - 1			___ Hours	_____
(c) Highest (H)	Hours	1.79	1 - 1.5			___ Hours	_____
(d) Curve-Type	Type	4 Persons:	Type 8			Type ____	

PART II

Even though a labor standard has been established, the industrial engineering technician is still responsible for maintaining that standard. In this part of the questionnaire, you are to consider all of the reasons that might require additional work by you after the original labor standard has been developed, to keep it current. These reasons include such causes as changes in all or part of the labor standard because of a change in the instruction manual, changes in all or part of the labor standard due to a methods-improvement action, or simply the requirement for a periodic review of the standard because of its age.

Listed below are the same work measurement technique-type combinations as in Part I. In this part, however, you are asked to indicate the lowest (L), most common (M) and highest (H) amount of total time you might spend in any two-year period following the original standard development date to keep that standard current. This, of course, assumes that the standard will be in existance for two years or more. In other words, what is desired is an indication of how much extra work is required of you every two years to keep a labor standard up to date. As in Part I of this questionnaire, all times apply to maintaining a labor standard that is exactly one hour long.

	Amount of time required every two years to maintain a one-hour labor standard set this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
1. MTM (Type A)							
(a) Lowest (L)	Hours	4.96	2 - 5	<u>Comments in favor of a smaller L:</u> The minimum review time could be ½ hour. A standard could only require an update. <u>Comments in favor of a greater L, M & H:</u> Some estimates apparently do not consider the quantity of data to be reviewed.	<u>Comments in favor of a greater L:</u> Some part of the motion sequence will have to be changed to match current procedures due to tech order change, modification, etc. The mass of material involved in an MTM standard would require more than 2 hours reading time. Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures, layout changes, additional work requirements, or deletions of work requirements.	___ Hours	___
(b) Most Common (M)	Hours	23.63	18 - 25			___ Hours	___
(c) Highest (H)	Hours	45.88	30 - 49			___ Hours	___
(d) Curve-Type	Type	4 Persons: Type 6				Type ___	
2. ASD (Type A)							
(a) Lowest (L)	Hours	1.71	1 - 2	<u>Comments in favor of a smaller L:</u> The minimum review time could be ½ hour. A standard could only require an update.	<u>Comments in favor of a greater L:</u> Some part of the ASD elements will have to be changed to match the current procedure due to tech order change, modifications, etc. Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures, layout changes, additional work requirements, or deletions in work requirements.	___ Hours	___
(b) Most Common (M)	Hours	4.91	3 - 6			___ Hours	___
(c) Highest (H)	Hours	13.06	10 - 16			___ Hours	___
(d) Curve-Type	Type	7 Persons: Type 6				Type ___	
3. ASD (Type B)							
(a) Lowest (L)	Hours	1.24	0.8 - 2	<u>Comments in favor of a smaller L:</u> A standard could only require an update.	<u>Comments in favor of a greater L:</u> Some part of the ASD elements will have to be changed to match the current procedure due to tech order change, modifications, etc.	___ Hours	___
(b) Most Common (M)	Hours	3.53	2 - 4			___ Hours	___

	Amount of time required every two years to maintain a one-hour labor standard set this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
3. ASD (Type B) (Continued)							
(c) Highest (H)	Hours	9.71	4 - 16		0.8 hours is unrealistic. This allows no time for revision of any standard. Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures, layout changes, additional work requirements, or deletions in work requirements.	___ Hours	_____
(d) Curve-Type	Type	3 Persons: Type 9				Type ___	
4. ASD (Type 2)							
(a) Lowest (L)	Hours	1.04	0.7 - 1	<u>Comments in favor of a smaller L</u>: A standard could only require an update.	<u>Comments in favor of a greater L</u>: Some part of the ASD elements will have to be changed to match the current procedure due to tech order change, modification, etc. Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures, layout changes, additional work requirements, or deletions in work requirements.	___ Hours	_____
(b) Most Common (M)	Hours	3.63	2 - 4			___ Hours	_____
(c) Highest (H)	Hours	8.19	3 - 10			___ Hours	_____
(d) Curve-Type	Type	3 Persons: Type 5		<u>Comments in favor of Type 9</u>: The greatest difference should be between the highest and most common values.		Type ___	
5. Stop Watch (Type A)							
(a) Lowest (L)	Hours	1.27	0.5 - 1	<u>Comments in favor of a smaller L</u>: The minimum review time could be ½ hour. A standard could only require an update.	<u>Comments in favor of a greater L</u>: Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures,	___ Hours	_____
(b) Most Common (M)	Hours	3.31	2 - 4			___ Hours	_____

	Amount of time required every two years to maintain a one-hour labor standard set this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
5. Stop Watch (Type A) (Continued)							
(c) Highest (H)	Hours	10.25	4 - 9		layout changes, additional work requirements, or deletions in work requirements. <u>Comments in favor of a greater H:</u> Using approximately 10 hours each six months does not seem overly excessive when all variables are considered.	___ Hours	___
(d) Curve-Type	Type	5 Persons: Type 8		<u>Comments in favor of Type 5:</u> The amount of time spent on each standard will have a larger spread due to work content change. <u>Comments in favor of Type 2:</u> The spread of values should be more gradual.		Type ___	
6. Stop Watch (Type B)							
(a) Lowest (L)	Hours	0.99	0.5 - 1	<u>Comments in favor of a smaller L:</u> If a technician is familiar with a job through daily contact, ½ hour is not unreasonable. A standard could only require an update.	<u>Comments in favor of a greater L:</u> Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures, layout changes, additional work requirements, or deletions in work requirements.	___ Hours	___
(b) Most Common (M)	Hours	2.55	2 - 2			___ Hours	___
(c) Highest (H)	Hours	6.25	4 - 6			___ Hours	___
(d) Curve-Type	Type	2 Persons: Type 3 2 Persons: Type 5 2 Persons: Type 8 2 Persons: Type 9				Type ___	
7. Stop Watch (Type 2)							
(a) Lowest (L)	Hours	0.58	0.5 - 0.5	<u>Comments in favor of a smaller L:</u> The minimum review time could be ½ hour. A standard could only require an update.	<u>Comments in favor of a greater L:</u> Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures,	___ Hours	___
(b) Most Common (M)	Hours	1.58	1 - 1.5			___ Hours	___

	Amount of time required every two years to maintain a one-hour labor standard set this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
7. Stop Watch (Type 2) (Continued)							
(c) Highest (H)	Hours	4.21	1.5 - 2		layout changes, additional work requirements, or deletions in work requirements. <u>Comments in favor of a greater H:</u> Considering all variables, the average is far too low.	___ Hours	_____
(d) Curve-Type	Type	3 Persons: Type 2 3 Persons: Type 8				Type ___	
8. Work Sampling (Type A)							
(a) Lowest (L)	Hours	2.64	2.5 - 3	<u>Comments in favor of a smaller L:</u> The minimum review time could be ½ hour. A standard could only require an update.	<u>Comments in favor of a greater L:</u> Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures, layout changes, additional work requirements, or deletions of work requirements. <u>Comments in favor of a greater H:</u> This could involve a completely new study.	___ Hours	_____
(b) Most Common (M)	Hours	7.19	6 - 8			___ Hours	_____
(c) Highest (H)	Hours	27.75	12 - 16			___ Hours	_____
(d) Curve-Type	Type	3 Persons: Type 3		<u>Comments in favor of Type 3:</u> The estimates indicate that M is closer to L.		Type ___	
9. Work Sampling (Type B)							
(a) Lowest (L)	Hours	2.14	2 - 3	<u>Comments in favor of a smaller L:</u> The minimum review time could be ½ hour. A standard could only require an update.	<u>Comments in favor of a greater L:</u> Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures, layout changes, additional work requirements, or deletions in work requirements.	___ Hours	_____
(b) Most Common (M)	Hours	4.75	4 - 6			___ Hours	_____

	Amount of time required every two years to maintain a one-hour labor standard set this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
9. Work Sampling (Type B) (Continued)							
(c) Highest	Hours	17.75	9 - 14		Comments in favor of a greater H: This could involve a completely new study.	___ Hours	___
(d) Curve-Type	Type	6 Persons: Type 3				Type ___	
10. Work Sampling (Type 2)							
(a) Lowest (L)	Hours	1.19	0.5 - 1	Comments in favor of a smaller L: A standard could only require an update.	Comments in favor of a greater L: Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures, layout changes, additional work requirements, or deletions in work requirements.	___ Hours	___
(b) Most Common (M)	Hours	2.61	1.5 - 4			___ Hours	___
(c) Highest (H)	Hours	5.48	2 - 6			___ Hours	___
(d) Curve-Type	Type	2 Persons: Type 2 2 Persons: Type 3 2 Persons: Type 8 2 Persons: Type 9		Comments in favor of Type 9: The long slope should be to the high side rather than equal as shown by Types 2 and 8.		Type ___	
11. Engineered Estimate (Type 2)							
(a) Lowest (L)	Hours	0.63	0.5 - 0.5	Comments in favor of a smaller L: The minimum review time could be ½ hour. A standard could only require an update. Comments in favor of a greater H: We have standards that are changed several times. The average estimate appears far too low.	Comments in favor of a greater L: Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures, layout changes, additional work requirements, or deletions in work requirements. Comments in favor of a greater H: Updating of some standards could mean redevelopment of a large standard. This should have a higher average.	___ Hours	___
(b) Most Common (M)	Hours	1.94	0.5 - 2			___ Hours	___
(c) Highest (H)	Hours	5.33	1 - 3			___ Hours	___

	Amount of time required every two years to maintain a one-hour labor standard set this way.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
11. Engineered Estimate (Type 2) (Continued)							
(d) Curve-Type	Type	6 Persons: Type 9				Type ___	
12. Coordinated Estimate (Type 3)							
(a) Lowest (L)	Hours	0.43	0.4 - 0.5	Comments in favor of a smaller L: A standard could only require an update.	Comments in favor of a greater L: Proper review and updating requires complete re-evaluation of the standard to determine changes in requirements, procedures, layout changes, additional work requirements, or deletions in work requirements.	___ Hours	___
(b) Most Common (M)	Hours	0.83	0.5 - 1			___ Hours	___
(c) Highest (H)	Hours	1.34	0.6 - 1.5			___ Hours	___
(d) Curve-Type	Type	7 Persons: Type 8		Comments in favor of Type 9: The long slope should be to the high side rather than equal.		Type ___	

PART III

One of the objectives of a work measurement program is to reduce the amount of unproductive man-hours in the shop. This is accomplished by attempting to determine how long it should take a properly trained and supervised worker, working at a normal pace, to accomplish a particular task. Even when labor standards are in force, however, there is probably still some wasted time if only because the labor standard itself is either "loose" or just "too high."

This part of the questionnaire is an attempt to determine how many wasted man-hours might result if there were no labor standards at all, or if the various techniques and labor-standard types were in use. You are to assume that the questions pertain to a shop that has 20 direct-labor employees, being paid for an 8-hour day (160 direct man-hours per day), and that these 20 workers are <u>properly supervised</u> by their foreman. In addition, you are to assume that <u>all</u> labor standards in that shop have been established by the technique indicated and with the statistical accuracy required by that type standard.

Listed below are the same standard technique-types as in the previous two parts of this questionnaire. There has been added, however, the situation when <u>no</u> labor standards are in use. You are asked to indicate the lowest (L), most common (M), and highest (H) number of man-hours (out of the 160 man-hours available in this 20-man shop each day) that might be wasted or not fully utilized if <u>all</u> labor standards in that shop were set in the manner indicated. Time lost due to personal needs, official break periods, cleanup, minor maintenance, or other recognized delays and allowances is <u>not</u> to be considered wasted. Wasted man-hours, as used here, is the amount of time the worker would get that is over and above what he should <u>need</u> to perform his duties either because of the poor method definition or "looseness" of the technique used to set his standard. Remember that you are to estimate these values on a <u>daily</u> basis.

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates: Average	Group Estimates: Central Range				
1. No standards at all							
(a) Lowest (L)	Hours	20.94	10 - 32	Comments in favor of a smaller L, M & H: I have found that most people like to produce. If they have good facilities and if the product and parts are there, they will produce. They love to say "we did this" or "records are set to be broken." Proper planning and supervision produces and cuts cost.	Comments in favor of a smaller H: 80 hours "goof off" reflects 4 hours per man per day which is too much.	___ Hours	_____
(b) Most Common (M)	Hours	43.13	32 - 48		Comments in favor of a greater L, M & H: Personnel become bored with their everyday routine, start thinking that their pay scale is too low, and develop poor attitudes toward supervision and production rates.	___ Hours	_____
(c) Highest (H)	Hours	70.19	48 - 80		Comments in favor of a greater M & H: "Proper supervision" would keep people occupied. Misapplied effort could be as much as 160 hours per day.	___ Hours	_____
(d) Curve-Type	Type	5 Persons: Type 2		Comments in favor of Type 4: I feel all of these should be skewed to the high side because of bias.		Type ___	
2. MTM (Type A)							
(a) Lowest (L)	Hours	3.75	2 - 5	Comments in favor of a smaller L, M & H: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.	Comments in favor of a smaller L & M: "Proper supervision" will keep shop loaded and people working. Maximum variance will be ± 10% of the mean.	___ Hours	_____
(b) Most Common (M)	Hours	8.31	8 - 10	Comments in favor of a greater M & H: The inherent inaccuracy of an MTM standard leaves these very conservative estimates.	Comments in favor of a smaller M & H: A type A standard has a 95% confidence level. Therefore the labor standard should be within 10% of the actual time required to perform the operation. This is why an MTM or ASD study must be verified with a stop watch study. This should cover any "inherent inaccuracy" of MTM.	___ Hours	_____
(c) Highest (H)	Hours	13.63	10 - 16			___ Hours	_____

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
2. MTM (Type A) (Continued)					<u>Comments in favor of a greater L & M</u>: There will never be a condition where a shop can operate at 99% effectiveness even with the best of standards.		
(d) Curve-Type	Type	6 Persons: Type 8				Type ____	
3. ASD (Type A)							
(a) Lowest (L)	Hours	4.63	3 - 7	<u>Comments in favor of a smaller L, M & H</u>: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.	<u>Comments in favor of a greater H</u>: "Proper supervision" will keep shop loaded and people working. Maximum variance will be ± 10% of the mean.	____ Hours	____
(b) Most Common (M)	Hours	9.19	8 - 12			____ Hours	____
(c) Highest (H)	Hours	13.50	12 - 16			____ Hours	____
(d) Curve-Type	Type	7 Persons: Type 8				Type ____	
4. ASD (Type B)							
(a) Lowest (L)	Hours	5.63	6 - 7	<u>Comments in favor of a smaller L, M & H</u>: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.	<u>Comments in favor of a greater M & H</u>: "Proper supervision" will keep shop loaded and people working. Maximum variance will be ± 25% of the mean.	____ Hours	____
(b) Most Common (M)	Hours	12.25	9 - 15			____ Hours	____
(c) Highest (H)	Hours	19.25	12 - 20			____ Hours	____
(d) Curve-Type	Type	5 Persons: Type 2				Type ____	

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
5. ASD (Type 2)							
(a) Lowest (L)	Hours	10.69	7 - 10		Comments in favor of a greater M & H: "Proper supervision" will keep shop loaded and people working. Maximum variance will be ± 50% of the mean.	___ Hours	___
(b) Most Common (M)	Hours	20.13	10 - 26			___ Hours	___
(c) Highest (H)	Hours	34.31	15 - 40			___ Hours	___
(d) Curve-Type	Type	4 Persons: Type 6		Comments in favor of Type 7: The difference between the lowest and most common values should be the greater.		Type ___	
6. Stop Watch (Type A)							
(a) Lowest (L)	Hours	4.81	4 - 7	Comments in favor of a smaller L, M & H: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.	Comments in favor of a greater H: "Proper supervision" will keep shop loaded and people working. Maximum variance will be ± 10% of the mean.	___ Hours	___
(b) Most Common (M)	Hours	9.50	8 - 12			___ Hours	___
(c) Highest (H)	Hours	14.56	16 - 16			___ Hours	___
(d) Curve-Type	Type	6 Persons: Type 8				Type ___	
7. Stop Watch (Type B)							
(a) Lowest (L)	Hours	6.31	6.5 - 8	Comments in favor of a smaller L, M & H: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.	Comments in favor of a greater M & H: "Proper supervision" will keep shop loaded and people working. Maximum variance will be ± 25% of the mean.	___ Hours	___
(b) Most Common (M)	Hours	12.81	12 - 16			___ Hours	___
(c) Highest (H)	Hours	19.44	16 - 20			___ Hours	___

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
7. Stop Watch (Type B) (Continued)							
(d) Curve-Type	Type	4 Persons: Type 5		Comments in favor of Type 6: This type is more appropriate due to the spread from M to H.		Type ___	
8. Stop Watch (Type 2)							
(a) Lowest (L)	Hours	8.56	7.5 - 9		Comments in favor of a smaller L: There should be no difference between a type 2 ASD and a type 2 stop watch as concerns lost time.	___ Hours	_____
(b) Most Common (M)	Hours	22.31	12 - 32			___ Hours	_____
(c) Highest (H)	Hours	35.19	20 - 48		Comments in favor of a greater M & H: "Proper supervision" will keep shop loaded and people working. Maximum variance will be ± 50% of the mean.	___ Hours	_____
(d) Curve-Type	Type	5 Persons: Type 5		Comments in favor of Type 2: The values should be more wide spread than Type 5 shows.		Type ___	
9. Work Sampling (Type A)							
(a) Lowest (L)	Hours	5.69	5.5 - 8	Comments in favor of a smaller L, M & H: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.	Comments in favor of a greater H: "Proper supervision" will keep shop loaded and people working. Maximum variance will be ± 10% of the mean.	___ Hours	_____
(b) Most Common (M)	Hours	10.25	8 - 13			___ Hours	_____
(c) Highest (H)	Hours	14.94	16 - 18			___ Hours	_____
(d) Curve-Type	Type	6 Persons: Type 8				Type ___	

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards. Your third-round estimate	Group Estimates: Average	Group Estimates: Central Range	Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
10. Work Sampling (Type B)							
(a) Lowest (L)	Hours	8.06	7.5 - 10	Comments in favor of a smaller L, M & H: There will be very little variance in the total man-hours of a good type A or B labor standard regardless of the method used to establish the standard. Therefore, under the working conditions stated on the first page of Part III, there would be no wasted man-hours if the shop was operating under type A or B labor standards.	Comments in favor of a greater M & H: "Proper supervision" will keep shop loaded and people working. Maximum variance will be ± 25% of the mean.	___ Hours	___
(b) Most Common (M)	Hours	15.31	13 - 20			___ Hours	___
(c) Highest (H)	Hours	23.06	18 - 27			___ Hours	___
(d) Curve-Type	Type	3 Persons: Type 5				Type ___	
11. Work Sampling (Type 2)							
(a) Lowest (L)	Hours	11.50	8 - 12	Comments in favor of a greater L, M & H: I don't agree that a type 2 work sampling would be a better management tool than a type 2 time study. The averages should have increased.	Comments in favor of a greater M & H: "Proper supervision" will keep shop loaded and people working. Maximum variance will be ± 50% of the mean.	___ Hours	___
(b) Most Common (M)	Hours	22.25	13 - 25			___ Hours	___
(c) Highest (H)	Hours	35.38	20 - 40			___ Hours	___
(d) Curve-Type	Type	6 Persons: Type 2				Type ___	
12. Engineered Estimate (Type 2)							
(a) Lowest (L)	Hours	13.25	7.5 - 12	Comments in favor of a smaller L: It is possible to set this type standard at or below the actual time required -- I have done so.	Comments in favor of a greater M & H: "Proper supervision" will keep shop loaded and people working. Maximum variance will be ± 50% of the mean.	___ Hours	___
(b) Most Common (M)	Hours	24.75	13 - 40			___ Hours	___
(c) Highest (H)	Hours	42.75	20 - 60			___ Hours	___
(d) Curve-Type	Type	4 Persons: Type 5				Type ___	

	Number of "wasted" man-hours each day for 20 men working 8 hours, if this method was used to set their standards.			Major reason(s) why the estimate(s) should be lower (or higher) than the central range or why the curve-type selected does not adequately represent the values.	Critiques of these reasons given by those participants who found them to be unacceptable in making their own estimates and/or any new comments volunteered on the third-round questionnaire.	Your final estimate	Confidence Rating
	Your third-round estimate	Group Estimates					
		Average	Central Range				
13. Coordinated Estimate (Type 3)							
(a) Lowest (L)	Hours	17.00	10 - 22	Comments in favor of a smaller L: It is possible to set this type standard at or below the actual time required -- I have done so.	Comments in favor of a smaller L, M & H: Type 3 is usually a standard with a smaller than normal variance from the average. Maximum variance would probably not exceed 10%. Comments in favor of a greater L, M & H: The predominant experience in this area is that the standard will be 25% to 50% high.	___ Hours	___
(b) Most Common (M)	Hours	28.31	13 - 37			___ Hours	___
(c) Highest (H)	Hours	40.88	18 - 48			___ Hours	___
(d) Curve-Type	Type	4 Persons: Type 2		Comments in favor of Type 9: This type standard would have to be represented by a Type 7, 8 or 9.		Type ___	

The set of curves attached to this questionnaire was identical to the set attached to the first-round questionnaire (see page 142).

APPENDIX B

QUESTIONNAIRE ADMINISTERED TO THE PERSON

RESPONSIBLE FOR ELECTRONIC

DATA PROCESSING (EDP) OF

LABOR STANDARDS

EDP QUESTIONNAIRE

Please read these instructions carefully.

You have been selected to participate in a study to determine the cost-benefit relationships of the various work measurement techniques available for setting time standards. This questionnaire is designed to gather information that can best be provided by you. The answers you give to these questions could become the basis for possible improvement in the current work measurement program. You are asked to adhere to the following rules during this study:

1. Please read the instructions for each part carefully, determine that you know exactly what is being asked, and give thorough consideration to all aspects of the question before answering.

2. In answering these questions, please remember that your responses are to apply only to the electronic data processing costs of maintaining labor standards by machine records.

3. You are allowed to use any records, files, or other source of information available to aid you in answering these questions; in fact, you are encouraged to do so.

4. Since you are the one best source of information for this questionnaire, you are asked to give honest answers. This study is an attempt to gather facts, not to falsely justify or condemn any particular policy or procedure. Please provide answers that you sincerely feel are as accurate as you can make them.

One point may require clarification. A "labor standard that is exactly one hour long" is a standard set on a job that will be charged for one man-hour of work. In other words, after the task has been studied, and the appropriate fatigue, delay, personal, etc. allowances have been added, the resulting labor standard shows a standard time (not normal time) of one man-hour to accomplish.

Instructions for Providing Answers.

These instructions were identical to the instructions included with the first-round questionnaire administered to the industrial engineering technicians (see page 126).

Instructions for Providing Confidence Ratings.

These instructions were identical to the instructions included with the first-round questionnaire administered to the industrial engineering technicians (see page 128).

Miscellaneous Instructions.

Your comments concerning this questionnaire are invited. Additional sheets of paper have been provided for this purpose. Please indicate the part and question number(s) to which you are referring, if you have any comments to make.

Please complete this questionnaire and have it ready to be picked up by the morning of __________.

Your cooperation in this study is _greatly_ appreciated.

PART I

Listed below are the work measurement techniques that could currently be used to establish different types of labor standards within this organization. For each technique and standard type (A, B, 2, or 3) you are asked to provide the lowest (L), most common (M), and highest (H) dollar cost of entering a new one-hour labor standard into the data bank. In other words, a new labor standard that is exactly one hour long has been developed and coded by an industrial engineering technician. Considering all subsequent cost factors, such as keypunch operator time, clerical time, debugging costs, machine time costs, etc., what are the lowest, most common, and highest total dollar costs that might be incurred in establishing that labor standard on the EDP records? In addition to providing these three estimates, you are asked to indicate, from the nine curves shown on the last page, the type of curve that best describes the way you think these costs would look if one-hour labor standards were to be set in that manner over and over and you were to plot these costs horizontally and the number of times it cost this much vertically.

	Total dollar cost that might be incurred in establishing a new one-hour labor standard, set in this manner, on the EDP records.	Confidence Rating
1. MTM (Type A)		
(a) Lowest (L)	$________	________
(b) Most Common (M)	$________	________
(c) Highest (H)	$________	________
(d) Curve-Type ______		
2. ASD (Type A)		
(a) Lowest (L)	$________	________
(b) Most Common (M)	$________	________
(c) Highest (H)	$________	________
(d) Curve-Type ______		

3. ASD (Type B)		
(a) Lowest (L)	$______	______
(b) Most Common (M)	$______	______
(c) Highest (H)	$______	______
(d) Curve-Type ______		
4. ASD (Type 2)		
(a) Lowest (L)	$______	______
(b) Most Common (M)	$______	______
(c) Highest (H)	$______	______
(d) Curve-Type ______		
5. Stop Watch (Type A)		
(a) Lowest (L)	$______	______
(b) Most Common (M)	$______	______
(c) Highest (H)	$______	______
(d) Curve-Type ______		
6. Stop Watch (Type B)		
(a) Lowest (L)	$______	______
(b) Most Common (M)	$______	______
(c) Highest (H)	$______	______
(d) Curve-Type ______		

7. Stop Watch (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type _______	 $ ________ $ ________ $ ________	 ________ ________ ________
8. Work Sampling (Type A) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type _______	 $ ________ $ ________ $ ________	 ________ ________ ________
9. Work Sampling (Type B) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type _______	 $ ________ $ ________ $ ________	 ________ ________ ________
10. Work Sampling (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type _______	 $ ________ $ ________ $ ________	 ________ ________ ________

11. Engineered Estimate (Type 2)		
(a) Lowest (L)	$________	________
(b) Most Common (M)	$________	________
(c) Highest (H)	$________	________
(d) Curve-Type ______		
12. Coordinated Estimate (Type 3)		
(a) Lowest (L)	$________	________
(b) Most Common (M)	$________	________
(c) Highest (H)	$________	________
(d) Curve-Type ______		

PART II

Even though a labor standard has been established and entered in the data bank, there are still some additional EDP costs of maintaining that standard. In this part of the questionnaire, you are to consider all of the reasons that might cause additional costs after the original labor standard has been established in the machine records, for maintenance of that standard. These reasons may include such causes as changes in all or part of the labor standard due to a change in the instruction manual or a methods-improvement action, the requirement for a periodic review of the standard because of its age, machine and key-punch costs incurred by these two actions, costs of periodic publication of the standard, or simply the cost of storage of that record on tape or disc.

Listed below are the same work measurement technique-type combinations as in Part I. In this part, however, you are asked to indicate the lowest (L), most common (M), and highest (H) number of total dollars that might be spent in any two-year period following the original standard establishment as a machine record, to maintain that standard. In other words, what is desired is an indication of how much extra cost is incurred every two years due solely to the electronic data processing of that one particular standard. As in Part I of this questionnaire, all costs apply to maintaining a labor standard that is exactly one hour long.

	Total dollar cost that might be incurred every 2 years to maintain a single one-hour labor standard, set in this manner, by electronic data processing.	Confidence Rating
1. MTM (Type A)		
(a) Lowest (L)	$________	______
(b) Most Common (M)	$________	______
(c) Highest (H)	$________	______
(d) Curve-Type _____		

2. ASD (Type A) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type _______	 $ ______________ $ ______________ $ ______________	 __________ __________ __________
3. ASD (Type B) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type _______	 $ ______________ $ ______________ $ ______________	 __________ __________ __________
4. ASD (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type _______	 $ ______________ $ ______________ $ ______________	 __________ __________ __________
5. Stop Watch (Type A) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type _______	 $ ______________ $ ______________ $ ______________	 __________ __________ __________

6. Stop Watch (Type B)		
(a) Lowest (L)	$______	______
(b) Most Common (M)	$______	______
(c) Highest (H)	$______	______
(d) Curve-Type ______		
7. Stop Watch (Type 2)		
(a) Lowest (L)	$______	______
(b) Most Common (M)	$______	______
(c) Highest (H)	$______	______
(d) Curve-Type ______		
8. Work Sampling (Type A)		
(a) Lowest (L)	$______	______
(b) Most Common (M)	$______	______
(c) Highest (H)	$______	______
(d) Curve-Type ______		
9. Work Sampling (Type B)		
(a) Lowest (L)	$______	______
(b) Most Common (M)	$______	______
(c) Highest (H)	$______	______
(d) Curve-Type ______		

10. Work Sampling (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 $ ______ $ ______ $ ______	 ______ ______ ______
11. Engineered Estimate (Type 2) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 $ ______ $ ______ $ ______	 ______ ______ ______
12. Coordinated Estimate (Type 3) (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 $ ______ $ ______ $ ______	 ______ ______ ______

The set of curves attached to this questionnaire was identical to the set attached to the first-round questionnaire administered to the industrial engineering technicians (see page 142).

APPENDIX C

QUESTIONNAIRE ADMINISTERED TO THE PERSON RESPONSIBLE FOR EACH WORK MEASUREMENT TRAINING COURSE

TRAINING QUESTIONNAIRE

____
(Name of Course)

Please read these instructions carefully.

You have been selected to participate in a study to determine the cost-benefit relationships of the various work measurement techniques available for setting time standards. This questionnaire is designed to gather information that can best be provided by you. The answers you give to these questions could become the basis for possible improvement in the current work measurement program. You are asked to adhere to the following rules during this study:

1. Please read the instructions for each part carefully, determine that you know exactly what is being asked, and give thorough consideration to all aspects of the question before answering.

2. In answering these questions, please remember that your responses are to apply only to the training course named above.

3. You are allowed to use any records, files, or other source of information available to aid you in answering these questions; in fact, you are encouraged to do so.

4. Since you are the one best source of information for this questionnaire, you are asked to give honest answers. This study is an attempt to gather facts, not to falsely justify or condemn any particular policy or procedure. Please provide answers that you sincerely feel are as accurate as you can make them.

Instructions for Providing Answers.

These instructions were identical to the instructions included with the first-round questionnaire administered to the industrial engineering technicians (see page 126).

Instructions for Providing Confidence Ratings.

These instructions were identical to the instructions included with the first-round questionnaire administered to the industrial engineering technicians (see page 128).

Miscellaneous Instructions.

Your comments concerning this questionnaire are invited. Additional sheets of paper have been provided for this purpose. Please indicate the part and question number(s) to which you are referring, if you have any comments to make.

Please complete this questionnaire and have it ready to be picked up by the morning of ________________.

Your cooperation in this study is greatly appreciated.

PART I

In this part you are asked to estimate the lowest (L), most common (M), and highest (H) quarterly cost in dollars of this particular work measurement training course. In making these estimates, you should consider all cost factors, including such items as the salaries (or appropriate parts of the salaries) of those persons engaged in preparing and/or conducting the training, the salaries paid to students while attending class, course materials, training aids, etc. In other words, what are the lowest, most common, and highest total costs in any three-month period that can be directly attributed to this particular course. In addition to these estimates, you are to indicate, from the nine curves shown on the last page, the type of curve that best describes your concept of how these costs would look if they could be obtained over and over every three months and you were to plot the cost horizontally and the number of times it cost this much vertically.

	Total quarterly dollar cost of this training course.	Confidence Rating
1. (a) Lowest (L)	$________	________
(b) Most Common (M)	$________	________
(c) Highest (H)	$________	________
(d) Curve-Type ______		

PART II

Listed below are the work measurement techniques that could currently be used to establish labor standards within this organization. For each technique you are asked to provide the lowest (L), most common (M), and highest (H) aggregate part of the total cost you provided in Part I that could be eliminated from the total cost of this course if this organization did not maintain the capability to develop labor standards by that technique. What is desired here is the amount of the total quarterly cost of this course that can be directly attributed to, and only to, the present potential capability of the industrial engineering technicians to set labor standards by the technique indicated. In other words, if it were decided that this technique would never be used to set labor standards in this organization, what is the lowest, most common, and highest amount of the total quarterly cost, if any, of this course that could be eliminated because instruction concerning that technique would not be necessary?

It is recognized that some parts of the material covered in this course may apply to all phases of work measurement and that they serve to broaden the student's background and general knowledge of this subject. However, the only costs that you are to consider in this part are those costs that can be directly attributed to the understanding of the particular labor-standard-development technique under consideration.

	Amount of the total quarterly dollar cost of this course that could be eliminated if this technique were never going to be used to establish labor standards in this organization.	Confidence Rating
1. MTM		
(a) Lowest (L)	$________	________
(b) Most Common (M)	$________	________
(c) Highest (H)	$________	________
(d) Curve-Type ______		

2. ASD (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 $ __________ $ __________ $ __________	 __________ __________ __________
3. Stop-Watch Time Study (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 $ __________ $ __________ $ __________	 __________ __________ __________
4. Work Sampling (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 $ __________ $ __________ $ __________	 __________ __________ __________
5. Engineered Estimate (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 $ __________ $ __________ $ __________	 __________ __________ __________

6. Coordinated Estimate (a) Lowest (L) (b) Most Common (M) (c) Highest (H) (d) Curve-Type ______	 $ ____________ $ ____________ $ ____________	 ____________ ____________ ____________

The set of curves attached to this questionnaire was identical to the set attached to the first-round questionnaire administered to the industrial engineering technicians (see page 142).

APPENDIX D

COMPUTER PROGRAMS

This appendix contains four programs written in FORTRAN IV for execution on the IBM System 360/Model 65 computer in use at Oklahoma State University. The results presented in Chapter V were obtained from these programs.

Program 1

Program 1 was used to determine the characteristics of the composite beta distribution that best represented the over-all weighted estimates of the variables identified on the questionnaires contained in Appendixes A, B, and C.

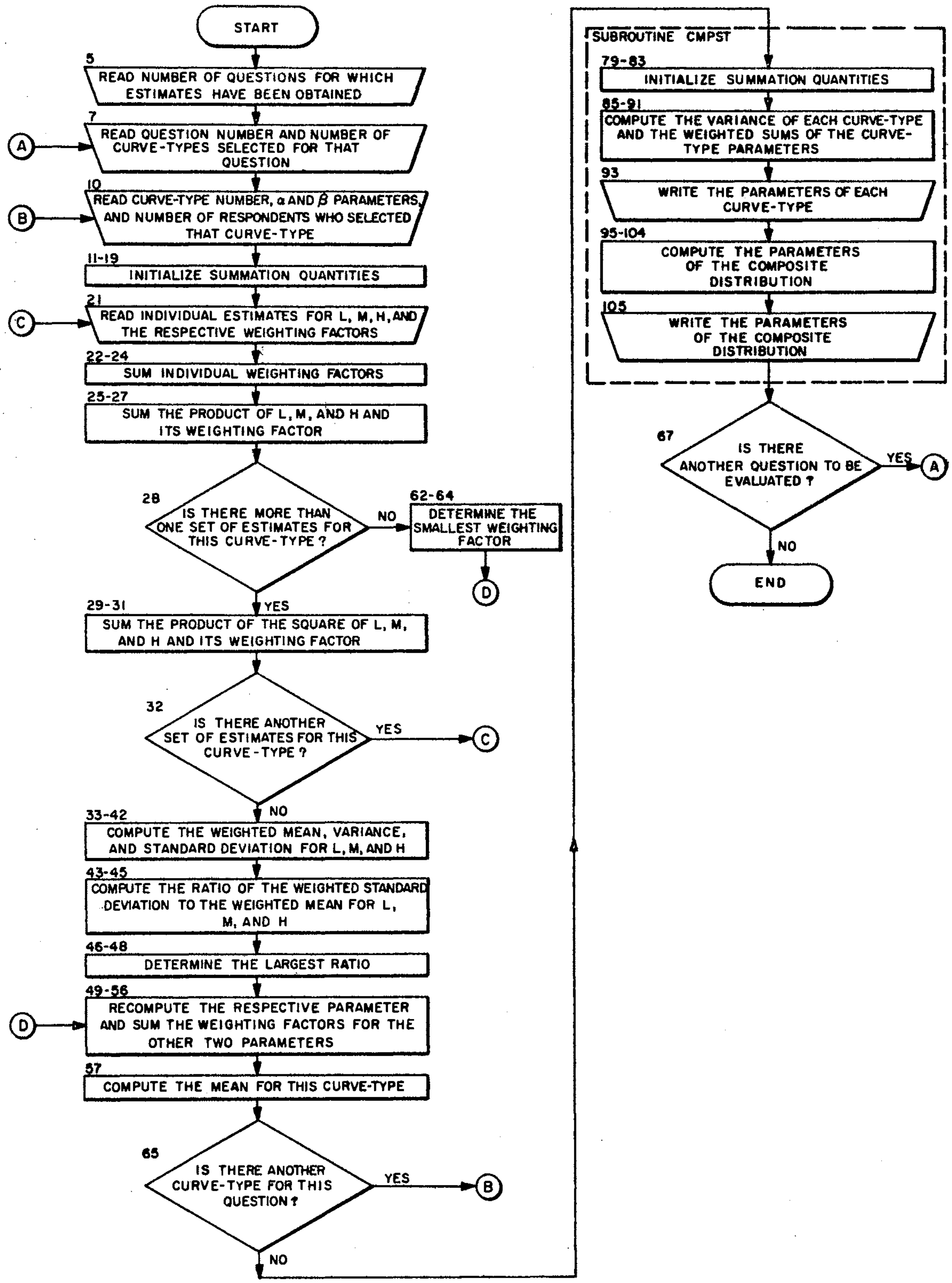


Figure 7. Flow Chart for Program 1

TABLE XVII

PROGRAM 1

```
$JOB
C PROGRAM 1
C
C
C THIS PROGRAM UTILIZES THE INFORMATION OBTAINED FROM SURVEY QUESTIONNAIRES TO
C CALCULATE WEIGHTED AVERAGES OF L, M, AND H (FOR EACH CURVE-TYPE WITH MULTIPLE
C ESTIMATES OF THESE VALUES) OR A NEW VALUE FOR L, M, OR H (FOR THOSE CURVE-
C TYPES WITH SINGLE ESTIMATES OF THESE VALUES).  IT THEN DETERMINES, FOR
C MULTIPLE-ESTIMATE CURVES, THE TWO PARAMETERS WITH THE LEAST 'DISAGREEMENT' AND
C COMPUTES THE THIRD PARAMETER.  FOR SINGLE-ESTIMATE CURVES, IT DETERMINES THE
C TWO PARAMETERS WITH THE HIGHEST CONFIDENCE RATINGS AND COMPUTES THE THIRD.  IN
C BOTH CASES, WHEN TIES OCCUR, THE PROGRAM ASSUMES THAT THE ESTIMATED VALUES FOR
C M, L, AND H ARE THE MOST ACCURATE, SECOND MOST ACCURATE, AND LEAST ACCURATE,
C RESPECTIVELY, IN ORDER TO DETERMINE WHICH PARAMETER SHOULD BE RECALCULATED.
C USING THE 'NEW' VALUES OF L AND H IT THEN CALCULATES THE MEAN (MU) OF EACH
C CURVE-TYPE IN QUESTION, AND PASSES THE NECESSARY INFORMATION TO SUBROUTINE
C CMPST.
C
C
      IMPLICIT REAL(L,M)
      INTEGER C
      DIMENSION L(9),M(9),H(9),LW(9),MW(9),HW(9),C(9),A(9),B(9),MU(9),
     C  WT(9),LL(9),MM(9),HH(9)
      WRITE(6,1)
      READ(5,2) NQ
C NQ = TOTAL NUMBER OF QUESTIONS FOR WHICH ESTIMATES HAVE BEEN OBTAINED.
      DO 30 INQ = 1,NQ
      READ(5,2) J,K,NC
C J = SURVEY PART NUMBER, K = PART QUESTION NUMBER, NC = NUMBER OF DIFFERENT
C CURVE-TYPES SELECTED BY RESPONDENTS TO THAT QUESTION.
      WRITE(6,3) J,K
      DO 20 INC = 1,NC
      READ(5,4) C(INC),NR,A(INC),B(INC)
C C(INC) = CURVE-TYPE NUMBER,  NR = NUMBER OF RESPONDENTS WHO SELECTED THAT
C CURVE-TYPE ON THIS QUESTION,  A(INC) = CURVE-TYPE ALPHA PARAMETER,  B(INC) =
C CURVE-TYPE BETA PARAMETER.
      SUML = 0.
      SUMM = 0.
      SUMH = 0.
      SUMSQL = 0.
      SUMSQM = 0.
      SUMSQH = 0.
      LWT = 0.
      MWT = 0.
      HWT = 0.
      DO 10 INR = 1,NR
      READ(5,5) L(INR),LW(INR),M(INR),MW(INR),H(INR),HW(INR)
C L(INR), M(INR) AND H(INR) ARE THE INDIVIDUAL ESTIMATES OF L, M, AND H, AND
C LW(INR), MW(INR) AND HW(INR) ARE THE RESPECTIVE WEIGHTING FACTORS.
      LWT = LWT + LW(INR)
      MWT = MWT + MW(INR)
      HWT = HWT + HW(INR)
      SUML = SUML + L(INR)*LW(INR)
      SUMM = SUMM + M(INR)*MW(INR)
      SUMH = SUMH + H(INR)*HW(INR)
      IF (NR.EQ.1) GO TO 10
      SUMSQL = SUMSQL + (L(INR)**2)*LW(INR)
      SUMSQM = SUMSQM + (M(INR)**2)*MW(INR)
      SUMSQH = SUMSQH + (H(INR)**2)*HW(INR)
   10 CONTINUE
      LBAR = SUML/LWT
      MBAR = SUMM/MWT
      HBAR = SUMH/HWT
      IF (NR.EQ.1) GO TO 15
      VARL = ((LWT*SUMSQL)-(SUML**2))/(LWT*(LWT-1.))
      VARM = ((MWT*SUMSQM)-(SUMM**2))/(MWT*(MWT-1.))
      VARH = ((HWT*SUMSQH)-(SUMH**2))/(HWT*(HWT-1.))
      STDL = SQRT(VARL)
      STDM = SQRT(VARM)
      STDH = SQRT(VARH)
      LR = STDL/LBAR
      MR = STDM/MBAR
      HR = STDH/HBAR
      IF ((HR.GE.LR).AND.(HR.GE.MR)) GO TO 12
      IF (LR.GE.MR) GO TO 11
      GO TO 13
   11 LBAR = ((MBAR*(A(INC)+B(INC)))-(A(INC)*HBAR))/B(INC)
      WT(INC) = MWT + HWT
      GO TO 14
   12 HBAR = ((MBAR*(A(INC)+B(INC)))-(B(INC)*LBAR))/A(INC)
      WT(INC) = LWT + MWT
      GO TO 14
   13 MBAR = (((HBAR-LBAR)*A(INC))/(A(INC)+B(INC))) + LBAR
      WT(INC) = LWT + HWT
   14 MU(INC) = (((HBAR-LBAR)*(A(INC)+1.))/(A(INC)+B(INC)+2.)) + LBAR
      LL(INC) = LBAR
      MM(INC) = MBAR
      HH(INC) = HBAR
      GO TO 20
   15 IF ((HWT.LE.LWT).AND.(HWT.LE.MWT)) GO TO 12
      IF (LWT.LE.MWT) GO TO 11
      GO TO 13
   20 CONTINUE
      CALL CMPST(INC,C,LL,MM,HH,A,B,MU,WT)
   30 CONTINUE
    5 FORMAT(3(F6.2,F1.0))
    4 FORMAT(2I2,2F3.2)
    3 FORMAT(1H0,I1,1X,I2)
    2 FORMAT(3I2)
    1 FORMAT(1H1,99HPART  CURVE       L          M          H       A       B
     C     (A+B+1)      MU             VAR        STD    WT)
      STOP
      END
```

TABLE XVII (Continued)

```
      SUBROUTINE CMPST(NC,C,L,M,H,A,B,MU,WT)
C
C
C THIS SUBROUTINE USES THE INFORMATION GENERATED BY THE MAIN PROGRAM FOR EACH
C INDIVIDUAL CURVE-TYPE SELECTION AND COMPUTES THE CHARACTERISTICS OF THE
C COMPOSITE DISTRIBUTION THAT BEST REPRESENTS THE OVERALL WEIGHTED ESTIMATES
C OF THE VARIABLE ASSOCIATED WITH THAT QUESTI ON.
C
C
      IMPLICIT REAL(L,M)
      INTEGER C
      DIMENSION C(9),L(9),H(9),A(9),B(9),VAR(9),STD(9),MU(9),M(9),
     C WT(9)
      VART = 0.
      WTT = 0.
      MUT = 0.
      HT = D.
      LT = 0.
      DO 40 I = 1,NC
      VAR(I)=(((H(I)-L(I))**2)*((A(I)+1.)*(B(I)+1.)))/(((A(I)+B(I)+2.)**
     C2)*(A(I)+B(I)+3.))
      STD(I) = SORT(VAR(I))
      HT = HT + (WT(I)*H(I))
      VART = VART + (VAR(I)*(WT(I)**2))
      LT = LT + (WT(1)*L(I))
      WTT = WTT + WT(I)
      MUT = MUT + (WT(I)*MU(I))
      IWT = WT(I)
      WRITE(6,6) C(I),L(I),M(I),H(I),A(I),B(I),MU(I),VAR(I),STC(I),IWT
   40 CONTINUE
      VARBAR = VART/(WTT**2)
      MUBAR = MUT/WTT
      HBAR = HT/WTT
      LBAR = LT/WTT
      X = (MUBAR - LBAR)/(HBAR - LBAR)
      AA =((((MUBAR - LBAR)**2)*(1.-X))/VARBAR) - X - 1.
      BB =((((HBAR - MUBAR)**2)*(X))/VARBAR) + X - 2.
      AB1 = AA + BB + 1.
      MBAR = (((HBAR - LBAR)*AA)/(AA+BB)) + LBAR
      STDBAR = SORT(VARBAR)
      WRITE(6,7) LBAR,MBAR,HBAR,AA,BB,AB1,MUBAR,VARBAR,STCBAR
      RETURN
    7 FORMAT(1HO,11H  COMPOSITE,3(F10.3),3(F7.3),1X,F10.3,F12.3,F10.3)
    6 FORMAT(1X,8X,I1,2X,3(F10.3),2(F7.3),8X,F10.3,F12.3,F10.3,I4)
      END

$ENTRY
```

Program 2

Program 2 computes the parameters of the beta distribution that best represents the characteristics of a set of empirical data points.

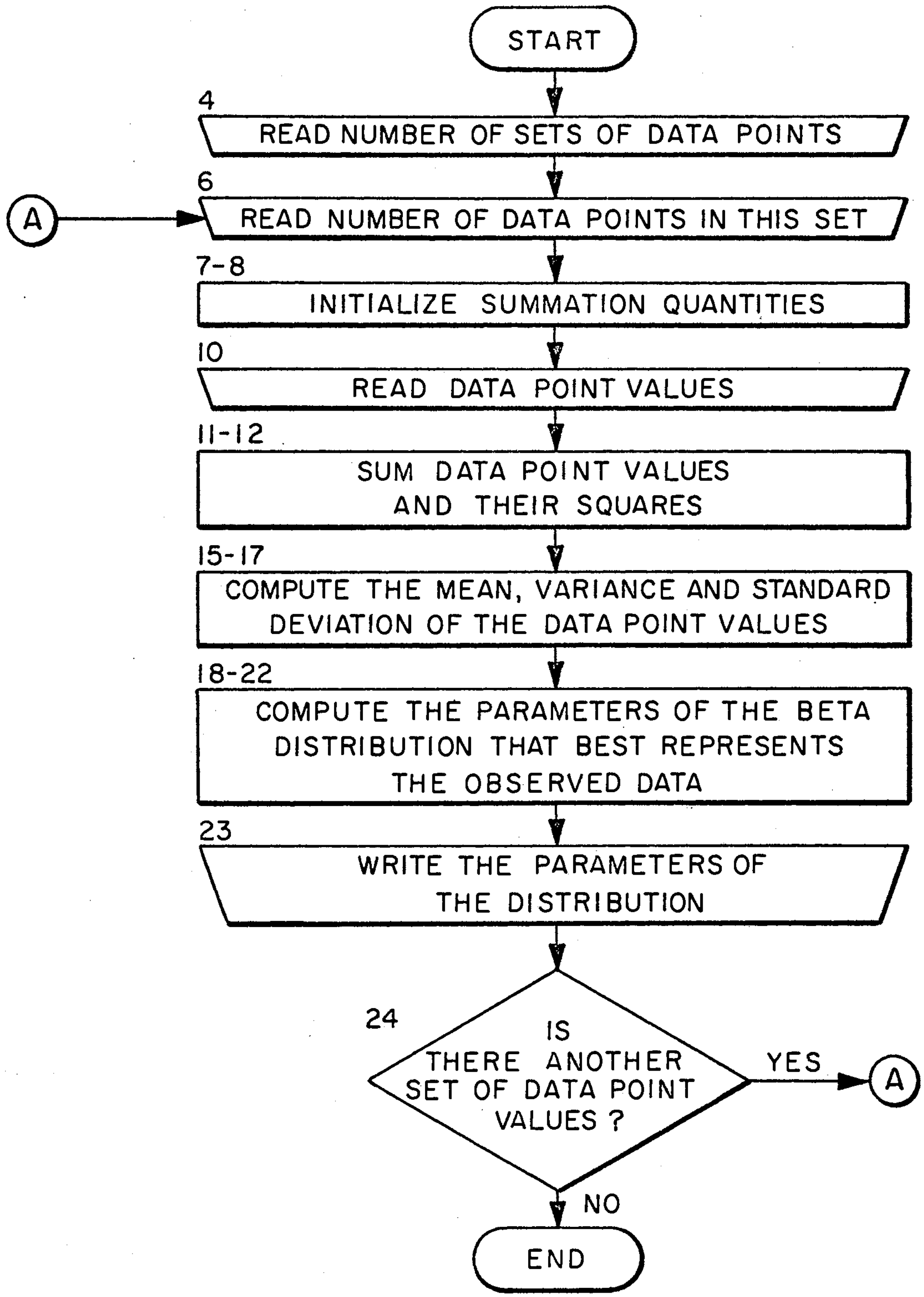


Figure 8. Flow Chart for Program 2

TABLE XVIII

PROGRAM 2

```
$JOB
C PROGRAM 2
C
C
C THIS PROGRAM USES EMPIRICAL DATA POINTS TO COMPUTE THE CHARACTERISTICS OF THE
C BETA DISTRIBUTION THAT BEST REPRESENTS THE OBSERVED DATA.
C
C
      REAL M,MU
      DIMENSION Y(1000)
      WRITE(6,1)
      READ(5,2) NS
C NS = THE NUMBER OF SETS OF DATA POINTS (NUMBER OF CURVES DESIRED).
      DO 20 INS = 1,NS
      READ(5,2) NDP
C NDP = THE NUMBER OF DATA POINTS IN THIS PARTICULAR SET.
      SUM = 0.
      SUMSQ = 0.
      DO 10 I = 1,NDP
      READ(5,3) Y(I)
C Y(I) = EACH INDIVIDUAL DATA POINT VALUE.  NOTE: THE LOGIC OF THIS PROGRAM
C REQUIRES THAT Y(1) BE THE SMALLEST DATA POINT VALUE, AND Y(NDP) BE THE
C LARGEST DATA POINT VALUE.  THE INPUT ORDER OF THE REMAINING VALUES IS
C UNIMPORTANT.
      SUM = SUM + Y(I)
      SUMSQ = SUMSQ + (Y(I)**2)
   10 CONTINUE
      Z = NDP
      MU = SUM/Z
      VAR = ((Z*SUMSQ)-(SUM**2))/(Z*(Z-1.))
      STD = SQRT(VAR)
      R = (MU-Y(1))/(Y(NDP)-Y(1))
      A = ((((MU-Y(1))**2)*(1.-R))/VAR) - R - 1.
      B = ((((Y(NDP)-MU)**2)*(R))/VAR) + R - 2.
      AB1 = A + B + 1.
      M = (((Y(NDP)-Y(1))*A)/(A+B)) + Y(1)
      WRITE(6,4) INS,Y(1),M,Y(NDP),A,B,AB1,MU,VAR,STD
   20 CONTINUE
    4 FORMAT(1H0,1X,I2,2X,3(F10.3),3(F7.3),1X,F10.3,F12.3,F10.3)
    3 FORMAT(F9.3)
    2 FORMAT(I3)
    1 FORMAT(1H1,87HCURVE       L          M          H       A       B     (A
     C+B+1)      MU          VAR        STD)
      STOP
      END

$ENTRY
```

Program 3

Program 3 provides the desired economic analysis of the labor standard to be developed for a given task. The probability statements of Equations (4-38), (4-40), (4-45), and (4-47) require that two integrals be evaluated. The approximations of these integrals are explained below.

Approximation of the Normal Integral

The normal integral may be written

$$F(x) = \int_{-\infty}^{x} \frac{1}{\sigma\sqrt{2\pi}} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} dx .$$

Let

$$z = \frac{x - \mu}{\sigma} = \frac{x}{\sigma} - \frac{\mu}{\sigma} .$$

Then,

$$dz = \frac{1}{\sigma} dx - 0 = \frac{dx}{\sigma}$$

and

$$F(x) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{1}{2}\left(\frac{x-\mu}{\sigma}\right)^2} \frac{dx}{\sigma}$$

$$= \frac{1}{\sqrt{2\pi}} \int_{-\infty}^{x} e^{-\frac{1}{2}z^2} dz .$$

Now, let

$$Z(z) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}z^2} .$$

Then, when $0 \leq z < \infty$,

$$F(x) = 1 - Z(z)(a_1 t + a_2 t^2 + a_3 t^3) + \epsilon ,$$

where

$$t = \frac{1}{1 + p(z)} ,$$

$$p = 0.33267 ,$$

$$a_1 = 0.4361836 ,$$

$$a_2 = -0.1201676 ,$$

$$a_3 = 0.9372980 ,$$

$$\frac{1}{\sqrt{2\pi}} \approx 0.4 ,$$

and

$$|\epsilon| < 10^{-5}$$

(1, pp. 931-933).

When $-\infty < z < 0$, $$t = \frac{1}{1 + p(-z)}$$

and

$$F(x) = Z(z)(a_1 t + a_2 t^2 + a_3 t^3) + \epsilon .$$

This approximation is performed by Function F(z) of Program 3.

Approximation to the Unit-Normal

Linear-Loss Integral

The unit-normal linear-loss integral is written

$$L(u) = \int_u^\infty (z-u) \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}z^2} dz$$

$$= \frac{1}{\sqrt{2\pi}} \int_u^\infty z\ e^{-\frac{1}{2}z^2} dz - \frac{u}{\sqrt{2\pi}} \int_u^\infty e^{-\frac{1}{2}z^2} dz$$

$$= \frac{-1}{\sqrt{2\pi}} \int_u^\infty -z\ e^{-\frac{1}{2}z^2} dz - \frac{u}{\sqrt{2\pi}} \int_u^\infty e^{-\frac{1}{2}z^2} dz ,$$

where $u = \frac{\mu}{\sigma}$ and $z = \frac{x-\mu}{\sigma}$.

Now, $de^{-\frac{1}{2}z^2} = -z\ e^{-\frac{1}{2}z^2} dz$.

Therefore,

$$L(u) = \frac{-1}{\sqrt{2\pi}} e^{-\frac{1}{2}z^2} \Bigg|_u^\infty - \frac{u}{\sqrt{2\pi}} \int_u^\infty e^{-\frac{1}{2}z^2} dz$$

$$= \frac{-1}{\sqrt{2\pi}} \left[\lim_{z\to\infty} e^{-\frac{1}{2}z^2} - e^{-\frac{1}{2}u^2} \right] - \frac{u}{\sqrt{2\pi}} \int_u^\infty e^{-\frac{1}{2}z^2} dz$$

$$= \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2} - \frac{u}{\sqrt{2\pi}} \int_u^\infty e^{-\frac{1}{2}z^2} dz$$

$$= \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2} - u \left[1 - \frac{1}{\sqrt{2\pi}} \int_{-\infty}^u e^{-\frac{1}{2}z^2} dz \right] .$$

Now, let

$$F(u) = \frac{1}{\sqrt{2\pi}} \int_{-\infty}^u e^{-\frac{1}{2}z^2} dz$$

and

$$Z(u) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2} .$$

Then, when $0 \leq u < \infty$, $t = \dfrac{1}{1 + p(u)}$

and

$$F(u) = 1 - Z(u)(a_1 t + a_2 t^2 + a_3 t^3) + \epsilon ,$$

and when $-\infty < u < 0$, $t = \dfrac{1}{1 + p(-u)}$

and

$$F(u) = Z(u)(a_1 t + a_2 t^2 + a_3 t^3) + \epsilon ,$$

where the values of the constants are the same as those given for the normal integral. Therefore,

$$L(u) = \frac{1}{\sqrt{2\pi}} e^{-\frac{1}{2}u^2} - u[1 - F(u)]$$

and

$$E(\text{loss} \mid \text{loss occurs}) = \frac{\sigma}{P(\text{loss})} L(u) .$$

The same procedure is applicable for evaluating the $E(\text{loss} \mid \text{reversal occurs})$.

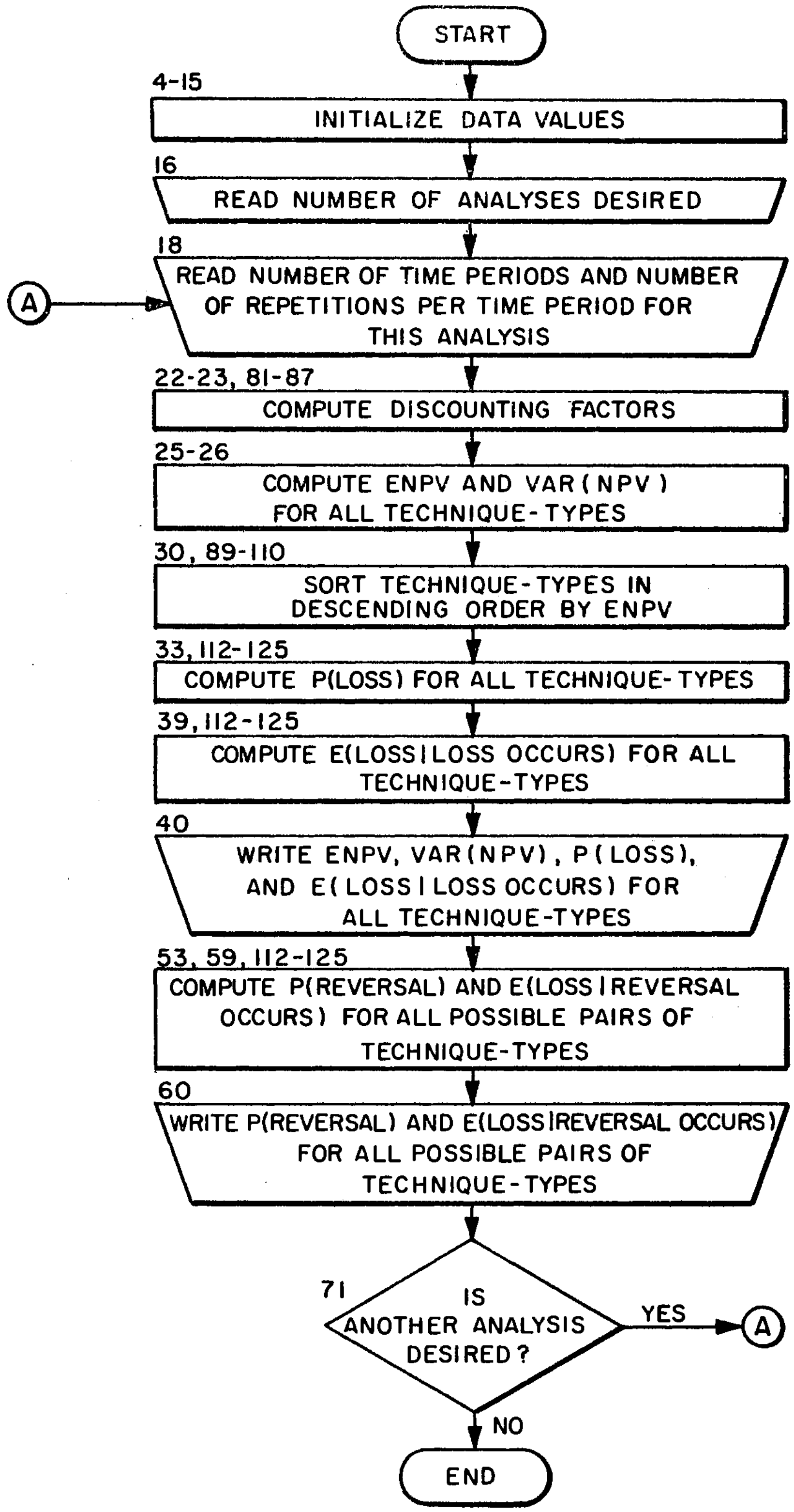


Figure 9. Flow Chart for Program 3

TABLE XIX

PROGRAM 3

```
      $JOB
      C PROGRAM 3
      C
      C
      C GIVEN THE NUMBER OF TIME PERIODS THAT A LABOR STANDARD WILL BE IN FORCE AND
      C THE NUMBER OF TIMES THAT THE TASK (FOR WHICH THE STANDARD IS TO BE SET) WILL
      C BE PERFORMED EACH TIME PERIOD, THIS PROGRAM COMPUTES THE EXPECTED NET PRESENT
      C VALUE, THE VARIANCE OF THE NET PRESENT VALUE, THE PROBABILITY OF A LOSS, AND
      C THE EXPECTED LOSS GIVEN THAT A LOSS OCCURS, FOR EACH WORK MEASUREMENT
      C TECHNIQUE-TYPE INCLUDING THE OPTION OF NOT SETTING A LABOR STANDARD AT ALL.
      C IT THEN CALCULATES, FOR ALL POSSIBLE PAIRS OF TECHNIQUE-TYPES, THE PROBABILITY
      C OF REVERSAL AND THE EXPECTED LOSS GIVEN THAT REVERSAL OCCURS.
      C
      C
1           IMPLICIT REAL (M)
2           REAL INT
3           DIMENSION TYPE(13,6),MUIIE(13),VIIE(13),MUIEM(13),VIEM(13),
         C  MUIEDP(13),VIEDP(13),MUEDPM(13),VEDPM(13),MUTWP(13),VTWP(13),
         C  ENPV(13),VNPV(13),SYPE(13,6)
      C THE FIRST SUBSCRIPT OF 'TYPE' AND THE SUBSCRIPTS OF THE REMAINING VARIABLES
      C CORRESPOND TO WORK MEASUREMENT TECHNIQUE-TYPES IN THE FOLLOWING ORDER:
      C (1) = NO STANDARD, (2) = MTM(A), (3) = ASD(A), (4) = ASD(B), (5) = ASD(2),
      C (6) = STOP WATCH(A), (7) = STOP WATCH(B), (8) = STOP WATCH(2), (9) = WORK
      C SAMPLING(A), (10) = WORK SAMPLING(B), (11) = WORK SAMPLING(2),
      C (12) = ENGINEERED ESTIMATE(2), (13) = COORDINATED ESTIMATE(3).
      C 'SYPE' IS A DUMMY VARIABLE FOR ALPHAMERIC DATA MANIPULATION.
4           DATA
         C      TYPE(1,1),TYPE(1,2),TYPE(1,3),TYPE(1,4),TYPE(1,5),TYPE(1,6),
         C      TYPE(2,1),TYPE(2,2),TYPE(2,3),TYPE(2,4),TYPE(2,5),TYPE(2,6),
         C      TYPE(3,1),TYPE(3,2),TYPE(3,3),TYPE(3,4),TYPE(3,5),TYPE(3,6)/
         C 'NO S','TAND','ARD ','    ','    ','    ','MTM(','A)  ','    ',
         C '    ','    ','    ','ASD(','A)  ','    ','    ','    ','    '/
5           DATA
         C      TYPE(4,1),TYPE(4,2),TYPE(4,3),TYPE(4,4),TYPE(4,5),TYPE(4,6),
         C      TYPE(5,1),TYPE(5,2),TYPE(5,3),TYPE(5,4),TYPE(5,5),TYPE(5,6),
         C      TYPE(6,1),TYPE(6,2),TYPE(6,3),TYPE(6,4),TYPE(6,5),TYPE(6,6)/
         C 'ASD(','B)  ','    ','    ','    ','    ','ASD(','2)  ','    ',
         C '    ','    ','    ','STOP',' WAT','CH(A',')   ','    ','    '/
6           DATA
         C      TYPE(7,1),TYPE(7,2),TYPE(7,3),TYPE(7,4),TYPE(7,5),TYPE(7,6),
         C      TYPE(8,1),TYPE(8,2),TYPE(8,3),TYPE(8,4),TYPE(8,5),TYPE(8,6),
         C      TYPE(9,1),TYPE(9,2),TYPE(9,3),TYPE(9,4),TYPE(9,5),TYPE(9,6)/
         C 'STOP',' WAT','CH(B',')   ','    ','    ','STOP',' WAT','CH(2',
         C ')   ','    ','    ','WORK',' SAM','PLIN','G(A)','    ','    '/
7           DATA
         CTYPE(10,1),TYPE(10,2),TYPE(10,3),TYPE(10,4),TYPE(10,5),TYPE(10,6),
         CTYPE(11,1),TYPE(11,2),TYPE(11,3),TYPE(11,4),TYPE(11,5),TYPE(11,6),
         CTYPE(12,1),TYPE(12,2),TYPE(12,3),TYPE(12,4),TYPE(12,5),TYPE(12,6),
         CTYPE(13,1),TYPE(13,2),TYPE(13,3),TYPE(13,4),TYPE(13,5),TYPE(13,6)/
         C 'WORK',' SAM','PLIN','G(B)','    ','    ','WORK',' SAM','PLIN',
         C 'G(2)','    ','    ','ENGI','NEER','ED E','STIM','ATE(','2)  ',
         C 'COOR','DINA','TED ','ESTI','MATE','(3) '/
8           DATA
         C    SYPE(1,1),SYPE(1,2),SYPE(1,3),SYPE(1,4),SYPE(1,5),SYPE(1,6),
         C    SYPE(2,1),SYPE(2,2),SYPE(2,3),SYPE(2,4),SYPE(2,5),SYPE(2,6),
         C    SYPE(3,1),SYPE(3,2),SYPE(3,3),SYPE(3,4),SYPE(3,5),SYPE(3,6),
         C    SYPE(4,1),SYPE(4,2),SYPE(4,3),SYPE(4,4),SYPE(4,5),SYPE(4,6),
         C    SYPE(5,1),SYPE(5,2),SYPE(5,3),SYPE(5,4),SYPE(5,5),SYPE(5,6),
         C    SYPE(6,1),SYPE(6,2),SYPE(6,3),SYPE(6,4),SYPE(6,5),SYPE(6,6)/
         C    36*'    '/
9           DATA
         C    SYPE(7,1),SYPE(7,2),SYPE(7,3),SYPE(7,4),SYPE(7,5),SYPE(7,6),
         C    SYPE(8,1),SYPE(8,2),SYPE(8,3),SYPE(8,4),SYPE(8,5),SYPE(8,6),
         C    SYPE(9,1),SYPE(9,2),SYPE(9,3),SYPE(9,4),SYPE(9,5),SYPE(9,6),
         CSYPE(10,1),SYPE(10,2),SYPE(10,3),SYPE(10,4),SYPE(10,5),SYPE(10,6),
         CSYPE(11,1),SYPE(11,2),SYPE(11,3),SYPE(11,4),SYPE(11,5),SYPE(11,6),
         CSYPE(12,1),SYPE(12,2),SYPE(12,3),SYPE(12,4),SYPE(12,5),SYPE(12,6),
         CSYPE(13,1),SYPE(13,2),SYPE(13,3),SYPE(13,4),SYPE(13,5),SYPE(13,6)/
         C    42*'    '/
10          DATA
         C    MUIIE(1),MUIIE(2),MUIIE(3),MUIIE(4),MUIIE(5),MUIIE(6),MUIIE(7),
         C    MUIIE(8),MUIIE(9),MUIIE(10),MUIIE(11),MUIIE(12),MUIIE(13),
         C    VIIE(1),VIIE(2),VIIE(3),VIIE(4),VIIE(5),VIIE(6),VIIE(7),
         C    VIIE(8),VIIE(9),VIIE(10),VIIE(11),VIIE(12),VIIE(13)/
         C    0.,534.552,78.967,54.449,41.513,107.890,80.126,20.964,311.662,
         C    157.617,90.895,11.441,7.993,0.,10239.89,111.588,61.302,32.156,
         C    314.220,180.357,6.133,6790.773,1228.228,280.061,5.439,1.124/
      C MUIIE(J) = MEAN INITIAL IE DEVELOPMENT COST, $/STANDARD-HOUR.
      C VIIE(J) = VARIANCE OF THE INITIAL IE DEVELOPMENT COST.
11          DATA
         C    MUIEM(1),MUIEM(2),MUIEM(3),MUIEM(4),MUIEM(5),MUIEM(6),MUIEM(7),
         C    MUIEM(8),MUIEM(9),MUIEM(10),MUIEM(11),MUIEM(12),MUIEM(13),
         C    VIEM(1),VIEM(2),VIEM(3),VIEM(4),VIEM(5),VIEM(6),VIEM(7),
         C    VIEM(8),VIEM(9),VIEM(10),VIEM(11),VIEM(12),VIEM(13)/
         C    0.,25.084,5.296,3.510,3.784,4.173,3.112,2.042,9.116,6.392,
         C    3.315,2.387,0.839,0.,206.060,16.396,2.336,2.436,18.184,8.707,
         C    4.070,42.387,33.507,5.877,0.610,0.054/
      C MUIEM(J) = MEAN IE MAINTENANCE COST, ($/STANDARD-HOUR)/TIME-PERIOD.
      C VIEM(J) = VARIANCE OF THE IE MAINTENANCE COST.
12          DATA
         C    MUIEDP(1),MUIEDP(2),MUIEDP(3),MUIEDP(4),MUIEDP(5),MUIEDP(6),
         C    MUIEDP(7),MUIEDP(8),MUIEDP(9),MUIEDP(10),MUIEDP(11),MUIEDP(12),
         C    MUIEDP(13),VIEDP(1),VIEDP(2),VIEDP(3),VIEDP(4),VIEDP(5),
         C    VIEDP(6),VIEDP(7),VIEDP(8),VIEDP(9),VIEDP(10),VIEDP(11),
         C    VIEDP(12),VIEDP(13)/
         C    0.,154.,27.,16.286,6.750,27.,16.286,6.750,2.,2.,2.,6.750,2.,0.,
         C    30.316,1.316,0.871,0.082,1.316,0.871,0.082,0.013,0.013,0.013,
         C    0.082,0.013/
      C MUIEDP(J) = MEAN INITIAL EDP ESTABLISHMENT COST, $/STANDARD-HOUR.
      C VIEDP(J) = VARIANCE OF THE INITIAL EDP ESTABLISHMENT COST.
13          DATA
         C    MUEDPM(1),MUEDPM(2),MUEDPM(3),MUEDPM(4),MUEDPM(5),MUEDPM(6),
         C    MUEDPM(7),MUEDPM(8),MUEDPM(9),MUEDPM(10),MUEDPM(11),MUEDPM(12),
         C    MUEDPM(13),VEDPM(1),VEDPM(2),VEDPM(3),VEDPM(4),VEDPM(5),
         C    VEDPM(6),VEDPM(7),VEDPM(8),VEDPM(9),VEDPM(10),VEDPM(11),
         C    VEDPM(12),VEDPM(13)/
         C    0.,103.786,20.250,12.,5.063,20.25,12.,5.063,1.5,1.5,1.5,5.063,
         C    1.5,0.,52.680,5.921,0.947,0.370,5.921,0.947,0.370,0.059,0.059,
         C    0.059,0.370,0.059/
      C MUEDPM(J) = MEAN EDP MAINTENANCE COST, ($/STANDARD-HOUR)/TIME-PERIOD.
      C VEDPM(J) = VARIANCE OF THE EDP MAINTENANCE COST.
14          DATA
         C    MUTWP(1),MUTWP(2),MUTWP(3),MUTWP(4),MUTWP(5),MUTWP(6),MUTWP(7),
         C    MUTWP(8),MUTWP(9),MUTWP(10),MUTWP(11),MUTWP(12),MUTWP(13),
         C    VTWP(1),VTWP(2),VTWP(3),VTWP(4),VTWP(5),VTWP(6),VTWP(7),
         C    VTWP(8),VTWP(9),VTWP(10),VTWP(11),VTWP(12),VTWP(13)/
         C    4.58,0.470,0.507,0.711,1.172,0.544,0.729,1.226,0.554,0.821,
         C    1.301,1.440,1.680,0.,0.341,0.256,3.583,4.437,0.426,1.194,6.570,
         C    0.341,2.560,17.748,5.632,7.339/
      C MUTWP(J) = MEAN COST OF UNPRODUCTIVE LABOR, $/STANDARD-HOUR.
```

TABLE XIX (Continued)

```
C VTWP(J) = VARIANCE OF THE COST OF UNPRODUCTIVE LABOR.
C NOTE: MUTWP FOR 'NO STANDARD' IS SET TO TWICE ITS ACTUAL VALUE AND VTWP FOR
C 'NC STANDARD' IS SET TO ZERO FOR LOGIC AND SIMPLICITY PURPOSES IN THE MAIN
C PROGRAM.
      DATA
     C   MUNWP,VNWP,INT/2.290,41.384,0.0241/
C MUNWP = MEAN COST OF UNPRODUCTIVE LABOR WITH NO STANDARD, $/DIRECT-LABOR-HOUR.
C VNWP = VARIANCE OF THE COST OF UNPRODUCTIVE LABOR WITH NO STANDARD.
C INT = INTEREST RATE PER TIME PERIOD, COMPOUNDED PER TIME PERIOD.
      READ(5,1) NJOB
C NJOB = NUMBER OF JOBS FOR WHICH ECONOMIC ANALYSIS IS DESIRED.
      DO 60 NANAL = 1,NJOB
      READ(5,1) N,M
C N = NUMBER OF TIME PERIODS THAT THE STANDARD WILL BE USED.
C M = NUMBER OF TIMES THAT THE JOB (FOR WHICH THE STANDARD IS TO BE SET) WILL BE
C PERFORMED EACH TIME PERIOD.
      N1 = M
      WRITE(6,2) N,N1
      WRITE(6,3)
      PR = (((1.+INT)**N)-1.)/(INT*((1.+INT)**N))
      PS = PS2N(N,INT)
      DO 10 J = 1,13
      ENPV(J) = -MUIIE(J) - MUIEDP(J) + (((MUNWP-MUTWP(J))*M)-MUIEM(J)
     C   -MUEDPM(J))*PR
      VNPV(J) = VIIE(J) + VIEDP(J) + (((VNWP+VTWP(J))*M)+VIEM(J)
     C   +VEDPM(J))*PS
      DO 10 K = 1,6
      SYPE(J,K) = TYPE(J,K)
   10 CONTINUE
      CALL SORT(TYPE,ENPV,VNPV)
      DO 20 J = 1,13
      Z = -ENPV(J)/SQRT(VNPV(J))
      PLOSS = F(Z)
      IF (PLOSS.LT.1.E-70) PLOSS = 1.E-70
      U = -Z
      Y = (U**2)/50.
      NN = 25
      IF (Y.GT.174.) GO TO 19
   18 ELOSS = (SQRT(VNPV(J))/PLOSS)*(((.4)*((1./EXP(Y))**NN))
     C   -(U*(1. - F(U))))
      WRITE(6,4) (TYPE(J,L),L=1,6),ENPV(J),VNPV(J),PLOSS,ELOSS
      GO TO 20
   19 Y = (Z**2)/2000.
      NN = 1000
      GO TO 18
   20 CONTINUE
      WRITE(6,5)
      DO 40 J = 1,12
      I = J + 1
      DO 30 K = I,13
      ENPVD = ENPV(J) - ENPV(K)
      VNPVD = VNPV(J) + VNPV(K)
      Z = -ENPVD/SQRT(VNPVD)
      PREVSL = F(Z)
      IF (PREVSL.LT.1.E-70) PREVSL = 1.E-70
      U = -Z
      Y = (U**2)/50.
      NN = 25
      IF (Y.GT.174.) GO TO 29
   28 EREVSL = (SQRT(VNPVD)/PREVSL)*(((.4)*((1./EXP(Y))**NN))
     C   -(U*(1. - F(U))))
      WRITE(6,6) (TYPE(J,L),L=1,6),(TYPE(K,L),L=1,6),PREVSL,EREVSL
      GO TO 30
   29 Y = (Z**2)/2000.
      NN = 1000
      GO TO 28
   30 CONTINUE
   40 CONTINUE
      DO 50 J = 1,13
      DO 50 K = 1,6
      TYPE(J,K) = SYPE(J,K)
   50 CONTINUE
   60 CONTINUE
    6 FORMAT(1H0,6A4/1X,'VERSUS'/1X,6A4,9X,E15.8,12X,E15.8)
    5 FORMAT(1H1/1H ,'PAIRED COMPARISONS OF TECHNIQUE-TYPES'/1H-,61X,'EX
     CPECTED LOSS'/1X,57X,'GIVEN REVERSAL OCCURS'/1X,30X,'PROBABILITY(RE
     CVERSAL)',8X,'($/STANDARD-HOUR)')
    4 FORMAT(1H0,6A4,7X,E15.8,9X,E15.8,10X,E15.8,8X,E15.8)
    3 FORMAT(1H-,32X,'EXPECTED NET',11X,'VARIANCE OF THE',34X,'EXPECTED
     CLOSS'/1X,32X,'PRESENT VALUE',9X,'NET PRESENT VALUE',31X,'GIVEN LOS
     CS OCCURS'/1X,'TECHNIQUE-TYPE',16X,'($/STANDARD-HOUR)',6X,'($/STAND
     CARD-HOUR)**2',6X,'PROBABILITY(LOSS)',6X,'($/STANDARD-HOUR)'/1H0)
    2 FORMAT(1H1,I4,' TIME PERIODS',5X,I6,' REPETITIONS PER TIME PERIOD'
     C)
    1 FORMAT(I4,F6.0)
      STOP
      END
```

```
      FUNCTION PS2N(N,XI)
C
C
C THIS FUNCTION SUBPROGRAM CALCULATES THE SUM, FROM L = 1 TO N, OF THE SQUARES
C OF THE DISCOUNT FACTORS FOR THE VARIANCES OF THE NET PRESENT VALUES OF EACH
C WORK MEASUREMENT TECHNIQUE-TYPE.
C
C
      SUMPS = 0.
      DO 101 L = 1,N
      SUMPS = SUMPS + (1./((1.+XI)**(2*L)))
  101 CONTINUE
      PS2N = SUMPS
      RETURN
      END
```

TABLE XIX (Continued)

```
      SUBROUTINE SORT(TYPE,ENPV,VNPV)
C
C
C THIS SUBROUTINE SORTS THE WORK MEASUREMENT TECHNIQUE-TYPE OPTICNS INTO
C DECENDING ORDER ACCORDING TO THEIR EXPECTED NET PRESENT VALUES.
C
C
      DIMENSIGN TYPE(13,6),ENPV(13),VNPV(13)
      DATA RYPE/'    '/
      DC 204 J = 1,12
      I = J + 1
      DO 203 K = I,13
      IF (ENPV(K).GT.ENPV(J)) GO TO 201
      GO TO 203
  201 B = ENPV(K)
      ENPV(K) = ENPV(J)
      ENPV(J) = B
      O = VNPV(K)
      VNPV(K) = VNPV(J)
      VNPV(J) = O
      DC 202 L = 1,6
      RYPE = TYPE(K,L)
      TYPE(K,L) = TYPE(J,L)
      TYPE(J,L) = RYPE
  202 CONTINUE
  203 CCNTINUE
  204 CONTINUE
      RETURN
      END
```

```
      FUNCTION F(Z)
C
C
C THIS FUNCTION SUBPROGRAM CALCULATES THE VALUE OF THE NORMAL INTEGRAL FROM
C MINUS INFINITY TO Z, WHERE Z = STANDARD NORMAL RANDOM VARIABLE.
C
C
      YY = (Z**2)/50.
      IF (YY.GT.174.) GO TO 303
      ZZ = (0.4)*((1./EXP(YY))**25)
  301 IF (Z.LT.0.) GO TO 302
      T = 1./(1.+(.33267*Z))
      F = 1. - (ZZ*((.4361836*T)-(.1201676*(T**2))+(.9372980*(T**3))))
      RETURN
  302 T = 1./(1.-(.33267*Z))
      F = ZZ*((.4361836*T)-(.1201676*(T**2))+(.9372980*(T**3)))
      RETURN
  303 YY = (Z**2)/2000.
      ZZ = (0.4)*((1./EXP(YY))**1000)
      GO TO 301
      END

$ENTRY
```

Program 4

Program 4 computes the factorial of any number greater than -1, limited only by the computer's word size. The equations used to determine these factorials are taken from Mastran and Boykin (48, pp. H-3 - H-4).

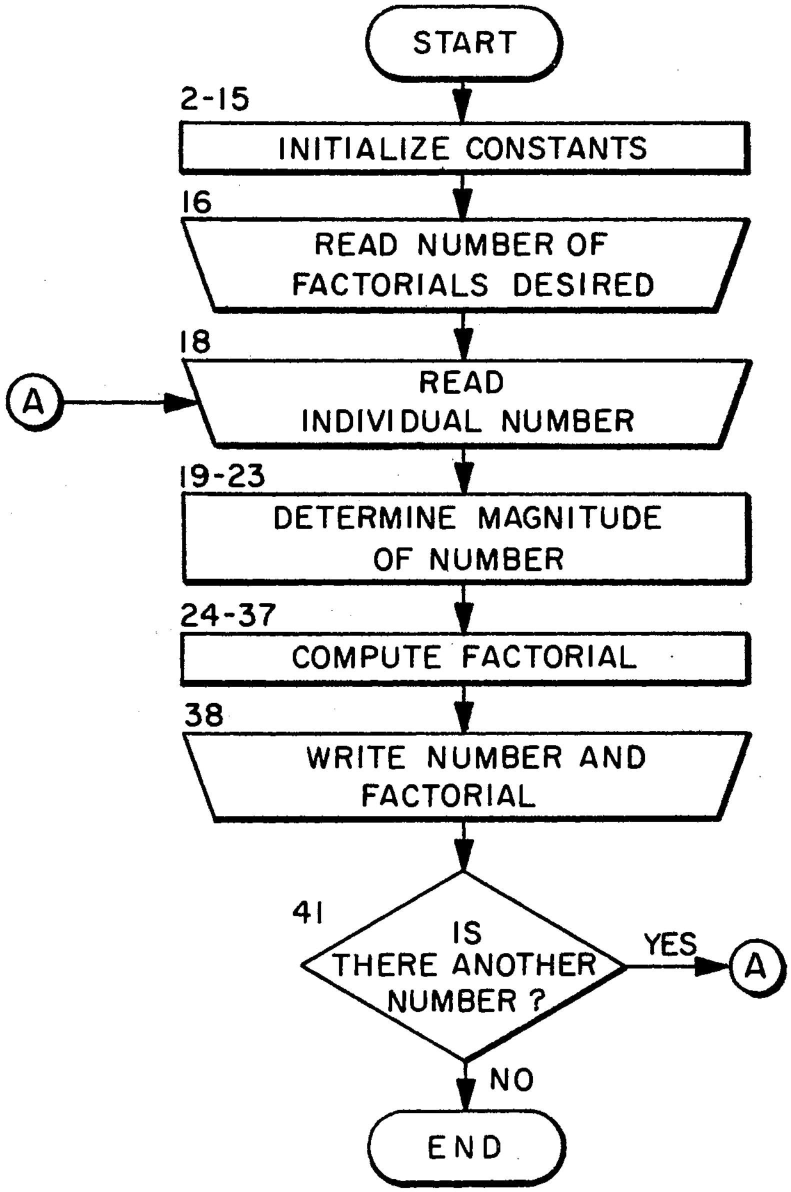


Figure 10. Flow Chart for Program 4

TABLE XX

PROGRAM 4

```
$JOB
C PROGRAM 4
C
C
C THIS PROGRAM COMPUTES THE FACTORIAL OF ANY NUMBER, A, WHERE -1<A,
C LIMITED ONLY BY THE COMPUTER'S WORD SIZE.
C
C
      DOUBLE PRECISION B1,B2,B3,B4,B5,B6,C1,C2,C3,C4,C5,C6,C7,C8,A,AA,
     C   F,AF,DLOG,DEXP
      B1 = 9.18938534D-01
      B2 = 0.83333333D-01
      B3 = 0.27777778D-02
      B4 = 0.79365079D-03
      B5 = 0.59523809D-03
      B6 = 0.84175084D-03
      C1 = 5.77191652D-01
      C2 = 9.88205891D-01
      C3 = 8.97056937D-01
      C4 = 9.18206857D-01
      C5 = 7.56704078D-01
      C6 = 4.82199394D-01
      C7 = 1.93527818D-01
      C8 = 0.03586834D-00
      READ(5,1) N
C N = THE NUMBER OF NUMBERS TC CCMPUTE FACTORIALS FOR.
      DO 40 I=1,N
      READ(5,2) A
      IF(A.GT.2.0) GO TO 10
      IF(A.GT.1.0) GO TO 15
      IF(A.GE.0.0) GO TO 20
      IF(A.GT.-1.) GO TO 25
      GO TO 30
C THIS SECTION COMPUTES A FACTORIAL FOR ANY A>2.00.
   10 AA = 1.0/(A**2)
      F = (A+.5)*DLOG(A)-A+B1+(B2-AA*(B3-AA*(B4-AA*(B5-AA*(B6)))))/A
      AF = DEXP(F)
      GO TO 35
C THIS SECTION COMPUTES A FACTORIAL FOR 1.00<A<=2.00.
   15 AA = A - 1.0
      F = 1.0-(C1*AA)+(C2*(AA**2))-(C3*(AA**3))+(C4*(AA**4))
     C    -(C5*(AA**5))+(C6*(AA**6))-(C7*(AA**7))+(C8*(AA**8))
      AF = A*F
      GO TO 35
C THIS SECTICN COMPUTES A FACTCRIAL FOR 0.00<=A<=1.00.
   20 F = 1.0-(C1*A)+(C2*(A**2))-(C3*(A**3))+(C4*(A**4))-(C5*(A**5))
     C    +(C6*(A**6))-(C7*(A**7))+(C8*(A**8))
      AF = F
      GO TO 35
C THIS SECTICN COMPUTES A FACTCRIAL FOR -1.00<A<0.00.
   25 AA = A*(-1.00)
      F = 1.0-(C1*AA)+(C2*(AA**2))-(C3*(AA**3))+(C4*(AA**4))
     C    -(C5*(AA**5))+(C6*(AA**6))-(C7*(AA**7))+(C8*(AA**8))
      AF = F/AA
   35 WRITE(6,3) A,AF
      GO TO 40
   30 WRITE(6,4) A
   40 CONTINUE
    4 FORMAT(1H0,42H ERROR: A LESS THAN OR EQUAL TO -1      A =,F8.3)
    3 FORMAT(1H0,4H A =,F8.3,19H,      A FACTORIAL =,D24.17)
    2 FORMAT(F8.3)
    1 FORMAT(I3)
      STOP
      END

$ENTRY
```

VITA 3

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