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An analysis of predetermined time systems

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AN ANALYSIS OF PREDETERMINED TIME SYSTEMS

BY

RICHARD O. SCHMID

A THESIS
SUBMITTED TO THE FACULTY OF
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ABSTRACT

This paper endeavors to compare three predetermined time systems, namely; Work-Factor, Methods-Time Measurement and Basic Motion Timestudy, elemental-by-elemental, through the use of a series of detailed analyses. The following information in the form of conclusions and recommendations has been set forth from the investigation of the various comparative analyses contained herein:

1. Reasons for the variation between the elementals.
2. A chronological order of attack for further study with an eye to accomplishing the most in the shortest possible time.
3. The results of a composite analysis which utilizes the most realistic elemental definitions of the three systems. (This includes the comparison of the latter and the other three systems of predetermined time standards to the Time Study values for the operation being analyzed).
4. An indication of which systems appear to be the quickest and easiest to use, based on the operation that was analyzed.
5. Recommendations concerning the selection

of a predetermined time system for
actual use.

In addition, the introductory chapters acquaint the reader generally with the Time Study Technique and the history and operation of all of the well known systems of predetermined time standards.

APPROVAL OF THESIS

FOR

DEPARTMENT OF MANAGEMENT ENGINEERING
NEWARK COLLEGE OF ENGINEERING

BY

FACULTY COMMITTEE

APPROVED: ______________________________

NEWARK, NEW JERSEY
JUNE, 1957

PREFACE

The purpose of this paper is essentially to compare three well known predetermined time systems, elemental by elemental, in order to find out how and why they differ, if at all, and also to determine which of the systems is the easiest and quickest to use based on the operation that was analyzed. Originally it was planned to analyze a hand operation and a man-machine operation. However, it was soon realized that either one or the other was sufficient for the purposes of this paper, since the fundamental motions are designated as universal and hence found in either operation. Analysis of both would simply have amounted to duplication. Actually it did not matter which type of operation was chosen for analysis, as long as the one selected "ran the gamut" of the fundamental motions as presented by the predetermined time systems. In short, coverage of elementals was essential.

As the work progressed, it became apparent that it would be advantageous to analyze the industrial operation that was selected, not only by the three standard predetermined time systems, but also by a "composite system" which utilized the most realistic fundamental motion definitions of each of those systems. This, of course, was done with the purpose of comparing all four values to the time study value for the operation to ascertain which system(s) compared most favorably to time study. Of course, the results of this phase of the analysis cannot be as detailed nor as accurate as those described in the first paragraph. This type of analysis done properly would involve the use of many time studies of various types of operations (a representative sample) with their respective predetermined time system or "composite system" analyses in order to statistically determine whether or not a significant difference exists. Although this paper considers only one operation, it appears to be a step in the right direction and definite trends can be determined.

Chapter I acquaints the reader with the two basic techniques for determining the standard time of an operation - Time Study and the Predetermined Time Systems, through a discussion of the basic concepts and individual histories of each.

Chapter II familiarizes the reader with the principles of operation of each predetermined time system as discussed in Chapter I, so that he might proceed to the rest of the text and follow the various detailed analyses contained therein.

Chapter III sets forth the actual element analyses of a selected industrial operation through the use of each of three specific predetermined time systems. These are Work-Factor, Methods-Time Measurement and Basic Motion Timestudy. This is preceded by a detailed description of the operation.

Chapter IV has as its purpose the presentation of the various detailed breakdowns of the latter analysis in the form of the charts, tables and discussions that are necessary to fulfill the purposes of the thesis as stated.

Finally, Chapter V presents the conclusions derived from a searching analysis of the results of Chapter IV, and as well sets forth some recommendations based primarily on those conclusions.

It is strongly suggested that the reader read each chapter and especially the introduction to Chapter IV before attempting to study any of the analysis charts or discussions as presented in Chapter IV.

I would like to express sincere appreciation for the many helpful suggestions and criticisms given me by Professor Oliver J. Sizelove of Newark College of Engineering. Also, grateful acknowledgment is made to Mr. James H. Duncan, Managing Partner of the Work-Factor Company for sending me a copy of *The Detailed Work-Factor Manual*; to Messrs. Gilbert P. Blackwood and David Egan, also of the latter Company, who were kind enough to review the technical details of the Work-Factor analysis contained herein; to Harold B. Maynard, President of the Methods Engineering Council who forwarded to me much useful information concerning the application of Methods-Time Measurement; and to my typist Miss Joan M. Schmid who spent many tedious hours at the keyboard.

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TABLE OF CONTENTS

CHAPTER I: INTRODUCTION TO STOPWATCH TIME STUDY AND THE PREDETERMINED TIME SYSTEMS

CHAPTER II: THE OPERATION OF THE PREDETERMINED TIME SYSTEMS

CHAPTER III: THE ANALYSIS OF A SELECTED INDUSTRIAL OPERATION USING THE PREDETERMINED TIME SYSTEMS

CHAPTER IV: COMPARISON OF THE ELEMENTALS

Element 1: Pick Up Carton

Element 2: Open Carton and Fold Ends

CHAPTER V: CONCLUSIONS AND RECOMMENDATIONS

LIST OF FIGURES

LIST OF TABLES

CHAPTER I

INTRODUCTION TO STOPWATCH TIME STUDY AND THE PREDETERMINED TIME SYSTEMS

BACKGROUND OF STOPWATCH STUDY

Time Study - The Definition

What is Time Study? Presented below may be found the definitions of Time Study as seen by several notables in the field:

> "Time Study - A searching scientific analysis of methods and equipment used or planned in doing a piece of work, development in practical detail of the best manner of doing it, and determination of an accurate time standard."[1]

> Barnes states "Common practice today requires that motion study and time study be used together since the two supplement each other. Motion and Time Study is the analysis of the methods, of the materials, and of the tools and equipment used, or to be used, in the performance of a piece of work - an analysis carried on with the purpose of (1) finding the most economical way of doing this work; (2) standardizing the methods, materials, tools and equipment; (3) accurately determining the time required by a qualified person working at a normal pace to do the task; and (4) assisting in training the worker in the new method."[2]

> "A Stop-Watch Time Study is used to find the amount of time necessary to accomplish a unit of work, using a given method, under given

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1. Morrow, Robert Lee, M. E. Time Study and Motion Economy. New York: The Ronald Press Company, 1946. p. 104.

2. Barnes, Ralph M., M. E., Ph. D., Motion and Time Study, Third Edition. New York: John Wiley & Sons, Inc., 1949. p. 1

> conditions of work, by a worker possessing a specified amount of skill on the job and a specified attitude for the job, when working at a pace that will produce, within a unit of time, a specified physical effect upon him. The time obtained is called standard time."[3]

From the foregoing definitions, it may be seen that theory holds that Time Study is not merely the setting of a rate for a job, but also a determination of the proper method for doing that job before any Time Studies are taken. However, in actual practice this, many times, is not so. Many rates are set by the stopwatch with little or no methods analysis preceding the Time Study. This serves as one excellent explanation for the widespread use of predetermined time systems, namely; the use of such a system is in effect a "forced" methods analysis. The analyst must look at methods in order to use the system at all.

History of Time Study[4]

The first known time studies were made in 1760 in France by M. Perronet. Following this in 1830 the English economist, Charles Babbage, also made a series of time studies. Coincidentally, both men concerned themselves with studying the manufacture of pins. Everything

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3. Mundel, Marvin E., Ph. D., Systematic Motion and Time Study. New York: Prentice-Hall, Inc., 1947. p. 128.

4. Ibid. I, pp. 69-71.

indicates that the studies of these men were of the type which merely indicated a total time for the completion of a stipulated amount of production.

Frederick W. Taylor "The Father of Scientific Management" is credited with taking the first time studies in the United States.

> "So great has been Taylor's contribution to the whole problem of effective utilization of human effort in industry that we can profit from a review of his work in this field. Taylor came from a well-to-do Philadelphia family, was trained at Phillips Exeter Academy to enter Harvard, and after but a year and a half at Phillips Exeter passed the Harvard entrance examinations with honors, but at the cost of seriously impaired eyesight. Forced to give up the idea of further study, at the age of eighteen he obtained a job in a machine shop where he served the apprentices of machinist and pattern-maker. In 1878 when he was twenty-two he went to work at the Midvale Steel Works. As business conditions were bad at that time, he took a job as an ordinary laborer. He was rapidly promoted to time clerk, journeyman, lathe operator, gang boss, foreman of the machine shop, and at the age of thirty-one was made chief engineer of the works. During his early years at Midvale, Taylor studied at night and in 1883 obtained a degree in mechanical engineering from Stevens Institute."[5]

Taylor's time studies were taken at the Midvale Steel Company in 1881 and were vastly different from those taken by Perronet and Babbage. The time studies were quite

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[5] Ibid. 2, p. 9.

detailed in nature, requiring that the job be broken down into basic motion groups or elements for which individual times had to be established. In 1883, E. H. Miller was hired to help Taylor in the organization of a Time Study Department. It is interesting to note that Taylor's idea of taking time studies came to him while he was a student at Exeter. His mathematics professor made a practice of timing the students with a stop watch as they did their problems.

After 12 years experience with Time Study at Midvale, Taylor presented a speech at the Detroit Meeting of the American Society of Mechanical Engineers which related the findings of his work. This proved to be a most disappointing experience for Taylor, since many of the prominent engineers of the day completely missed his message. They wrongly concluded that Taylor was primarily discussing a piece rate system of wage payment rather than a new technique which measured the amount of time necessary to complete an operation.

It was, however, in June 1903 when Taylor presented his paper "Shop Management" to the American Society of Mechanical Engineers that a more favorable response resulted. Many progressive factory managers gave the new Time Study Technique much favorable attention, and it was quite successfully used in many plants. However, at the

Watertown Arsenal, time study was not well received by labor, and after an Interstate Commerce Commission Investigation, Congress attached a rider to the government appropriation bill in 1913 which in effect stipulated that no pay be made available for any time study personnel. The rider was eliminated on August 26, 1948 during the Proceedings and Debates of the 81st Congress, 1st Session. This was accomplished largely through the efforts of such men as John W. Nickerson and Phil Carroll, Jr.

Far from being discouraged by this, Taylor was most happy to hear that the American Society of Mechanical Engineers' Report for 1912 reviewed the Time Study Technique and concluded that when properly administered, it has contributed to the good of the human race. This conviction has been upheld from that time on by the Society and by other groups.

After retirement Taylor embarked upon one of his great dreams, namely; to begin a review of all unit times that had been recorded. This was to be done in collaboration with Dwight V. Merrick and unfortunately was interrupted by Taylor's death. The work was started again by Merrick and other of the followers of Taylor.

Merrick also wrote the first complete book on time studies in the United States which fully explained the applications and uses of Time Study. The book is entitled "Time Studies as a Basis for Rate Setting" and was published in 1920.

Since 1917 the Taylor Society, which in 1936 merged with the Society of Industrial Engineers to form the Society for the Advancement of Management, has undertaken the Time Study work. The American Society of Mechanical Engineers, the American Management Association and the American Institute of Industrial Engineers are continuing to publish papers on Time Study that are presented before them.

> One final word about Taylor, "One cannot read Taylor's experiments on the art of cutting metals, his study of rest pauses in handling pig iron, or his investigations in shoveling without at once realizing that he was a scientist of high order. With Taylor, as with the factory manager today, Time Study was a tool to be used in increasing the overall efficiency of the plant, making possible higher wages for labor, and lower prices of the finished products to the consumer."[6]

PREDETERMINED TIME SYSTEMS

The Definition and Basic Concepts

> "Predetermined Time Standards (PTS) is our term for time standards developed from basic motion study data for fundamental manual motions. Grouped into tables covering a complete set of basic manual motions, these standards provide

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6. Ibid. 2, p. 12.

a system for measuring manual work."[7]

It has been the goal of the industrial engineer since the time of Taylor to develop a system of work measurement which was broad enough to be applicable to every existing job and yet defined to a point where interpretation posed no great problem. In its initial stages this type of thinking referred to the assignment of time values to operations that were being timed and retimed throughout the country, such as pushing buttons, stepping on footpedals, etc.; and that eventually all existing operations in industry would have a time value attached to them. Then, after classification in a text or manual these values were to all but eliminate stop watch time study.

This concept has remained, with one notable exception (A. B. Segur), until quite recently somewhat more of a dream than a practical reality because industry claimed that even if such a manual were developed, it would be so bulky and complicated as to render it impractical to use.

A reconsideration of the problem, however, brought

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7. "Predetermined Time Standards", <u>Factory Management and Maintenance</u>, Vol. III, September, 1953. p. 134.

about the conclusion that the fallacy was based on the conception of an element time. The time study element such as "pick up hammer", "nail wood in place", etc., indeed would be difficult to classify in such a volume. It may readily be seen that elements such as these for the various trades would be infinite in number. Hence the "element" of Taylor and Frank B. Gilbreth's further subdivision of the element into "therbligs" had to be replaced by the modern industrial engineering concept of fundamental or basic manual motions (elementals). Gilbreth had pointed out in his concept of universal elementary motions that of all jobs, the same elementary motions were used "in various combinations and sequences". Gilbreth's concept was sound, indeed it is the basis of all modern predetermined time systems, however, it remained for later work to uncover the further subdivision and/or combination of the "therblig" into the fundamental manual motion or elemental.

The efforts made in determining the meaning and magnitude of these fundamental manual motions were expended essentially to attempt to provide a table of standard time values for body motions that are common to all jobs such as reaching, moving and grasping. These timetables as recently developed are based on many stop watch and/or motion picture time studies. Using the timetables, the standard time for an operation may be built up by determining first just exactly what the operator DOES during the operation, and then analyzing these motions and breaking them down into the elementary motions, picking the values off the timetable for each elementary motion and taking the sum of these times to determine the total "standard" (base) time for the operation.

For example, the operation "sign name" would be broken down into, "Reach 12 inches for pencil, grasp pencil, move pencil to paper 15 inches", etc. The total motion time is given by summing the times for each fundamental motion as it is selected from the motion timetable. This in essence, is the thinking upon which Predetermined Time Systems are based.

History of Predetermined Time Systems

As mentioned in the section previous to this, the work of Taylor and Gilbreth paved the way to the Predetermined Time Systems of today. Taylor by his contemplation of standard times for "every element in every trade" and Gilbreth by determining his fundamental 18 motions (therbligs) which, if used in various combinations could identify any element of any job.

After the work of these two pioneers, the first person to attempt to establish a predetermined time system through an appreciation of time as it concerned a methods analysis was A. B. Segur in the early 1920's. Even though this work was essentially confined to his clients, his technique of minute motion breakdowns of body members and the assignment of physiological values to the muscle structures which caused the movements was a great stride forward in the field of Industrial Engineering. Today, Segur's system is known as Motion-Time-Analysis (MTA). This approach, which was especially applicable to the repetitive manufacture of small parts became of great interest to General Electric in the early 1920's. General Electric's original time standard plan represented the first classification of predetermined time standards for specific hand and body motions for specific types of work.

It was the work of three industrial engineers at the Radio Corporation of America beginning in 1934, which brought forth the first system of real practical value. This system, known as the Work-Factor System was developed by Messrs. J. H. Quick, W. J. Shea and R. E. Koehler and has since received widespread acceptance in industry. In 1940, H. B. Maynard of Westinghouse conducted an intensive study of sensitive drill press work which later developed into the Methods-Time Measurement (MTM) system of predetermined time standards. Other recent systems worthy of mention are the Dimensional

Motion Times system of H. C. Geppinger, and the Basic Motion Timestudy system of Ralph Presgrave.

The Uses of Predetermined Time Systems[8]

The following uses for predetermined time standards have been set forth by industry, schools and colleges:

"Developing effective methods in advance of beginning production". The reluctance with which the worker accepts a methods change is a well known fact and is based upon a fear that he may lose his job. Nevertheless Taylor has stated that:

> "Complete standardization of all details and methods is indispensable to specifying the proper time in which each operation shall be done and to insisting that it shall be done in the time allowed."[9]

It is of prime importance to apply this principle on any new job so as to avoid worker ill feeling later on and to produce the product at the lowest possible cost. Predetermined time standards lend themselves ideally for application in this area and provide, as well, predetermined instruction cards for each job before the

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[8] Maynard, H. B., Editor-in-Chief, Industrial Engineering Handbook, First Edition. New York: McGraw Hill Book Co., Inc., 1956. pp. 4-3 to 4-13. (ALL THE HEADINGS OF THIS SECTION ARE QUOTED FROM THIS TEXT)

[9] Taylor, Frederick Winslow, Shop Management. New York: Harper and Brothers Publishers, 1912. p. 123.

method is instituted on that job. All of this could be most instrumental in eliminating many industrial relations difficulties.

"Improving existing methods". The work of the methods engineer never stops because the method of a job never ceases to change. Predetermined Time Standards are particularly applicable to this area because of the nature of the system. The analyst is, in a sense, forced to examine the operation step by step, and motion by motion. A questioning attitude is raised as to which motions are really necessary, and it is indeed most difficult to find an operation that could not be improved. A justification of the importance of this use of predetermined time systems is the following fundament of Taylor:

> "The greatest permanent prosperity for workman and employer comes from doing work with the smallest expenditure of human effort, natural resources and invested capital."[10]

"Establishing time standards". Here as has been previously discussed, method of application is quite simple after adequate training and experience has been gained in the field of predetermined time systems. Standard time for an operation is merely a summation of the times required to perform each basic motion as

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10. Ibid. 9, p. 10.

presented in a motion time table.

Use of these systems effects a great savings in the amount of time required to study a job, and at the same time imposes a motion study on that job. Though many uses exist for predetermined time systems, it is the opinion of the author that this is the use which stands well above any of the others in importance. Taylor wrote that time study is the cornerstone of Scientific Management; predetermined time systems strive to determine time in a consistent manner. Their basic principle is scientifically sound.

"Developing standard data and time formulas". Time formulas or standard data is the means by which large numbers of consistent standards may be set on a given class of work. This is generally done by the laborious time study method through compilation of standard element times from a representative group of time studies. For certain types of work predetermined time systems may be used to much advantage, since the results will be developed consistently through a knowledge of the proper method. Constant and variable elements that are not process controlled may be easily determined by a predetermined time system, and combined to form the desired time formula in a fraction of the time required by the time study technique. Curve plotting methods may aid greatly in the development of time formulas.

"<u>Estimating</u>". Estimating labor costs for large quantities of repetitive work so that an accurate cost might be quoted to a potential customer is one of the more important applications of a predetermined time system. It may readily be seen that use of this method will be far more time consuming than use of conventional "rule-of-thumb" estimating methods, but if the quantity of production is large and exact estimates are required, then use of such a system is fully justified.

"<u>Guiding product design</u>". Refinements in design may be effected if an industrial engineer analyzes the manufacture of the part through a motion-by-motion analysis with a predetermined time system. Hence, suggestions may be made before the part is designed and/or jigs and tools are built which, in turn, may reduce the work and cost of manufacture.

"<u>Developing effective tool designs</u>". A tool designer's final choice of design may be based upon such considerations as accuracy obtainable, tool life, cost and handling time necessary. The least amount of handling time may not necessarily mean lowest cost, but generally this is a desirable condition. Predetermined elemental times, through a visualization of the method of use, are a great aid to the tool designer in a predetermination of the least handling time.

"Selecting effective equipment". When one is considering the purchase of a piece of machine tool equipment for a job he would naturally want the machine which could be manipulated most quickly and easily. Through use of a predetermined time system analysis (visualizing motions) as outlined in the preceding paragraphs, the proper conclusion might be arrived at in a short period of time.

"Training supervisors to become methods-conscious". The supervisor is the man who should instruct his personnel in the proper methods of doing their work. In order to do this the supervisor should be able to analyze a job through use of the basic motions as prescribed in any predetermined time system. The analysis should then indicate to the supervisor the motions required to perform the job and the layout of the workplace. He should be able to explain and demonstrate the method to the worker.

"Settling grievances". Many workers are reluctant to accept the validity of time study standards due to the judgement involved in rating the original times. However, a foreman trained to analyze basic motions can generally settle a standards grievance at his own level by showing the worker the exact motions required to perform his job. This demonstrates satisfactorily to most workers that the job may be done in the prescribed time if the exact method is used, but if extra motions are introduced then the reason for the supposed "tightness" of the standard is evident. It must be realized, however, that the above is not wholly true, in that judgement is indeed brought to bear in the selection of the fundamental motions used in any analysis, and of course judgement in the form of rating was used in the gathering of the original data of each predetermined time system.

"Operator training". The teaching of motions in the form of reaches, grasps, etc. along with a presentation of corresponding time values has been a great aid in operator training in recent years. This is so because the operator will become motion conscious, and will be able to easily recognize and eliminate wasteful motions.

"Research". Predetermined time systems are a tool whereby knowledge about methods and time in general can be increased greatly. Examples of research projects might be a study of how methods vary as the operator learns to do a new operation, and the learning time required for same. There exist many fascinating studies of this type for one interested in research. (Also, see Recommendations For Further Study in Chapter V of this manuscript).

Advantages, Disadvantages and Limitations of Predetermined Time Systems

Advantages. "1. The judgement factor involved

> in the rating of individual operators is eliminated. (The author is not in full accord with this. Judgement used in rating is not eliminated through the use of a predetermined time system. It is merely bypassed, since such judgement was used in gathering the original data).
>
> 2. The job breakdown and analysis of individual motions necessary to assign time values from the tables encourage improvement in work methods; and provide an accurate, minute description of each job that serves as a record for future reference.
> 3. Time estimates can be made before a job starts running, even if it has never run before.
> 4. Building up work standards from tabular data is faster and more accurate, particularly for short jobs, than time study, if the engineer knows exactly what will take place on the job.
> 5. Because times are obtained from a table they are consistent."[11]

John S. Kelly of Sargent & Company, New Haven, Connecticut enthusiastically reports about predetermined time standards as follows:

> "Of even greater value than the tremendous time savings of these work sheets is the consistency of the rates. The operators know that the same application of skill and effort will always result in their same level of earnings. This does away with one of the foreman's greatest problems. There are no 'tight' or 'loose' rates that he has to watch to see that they are equally divided. He can move any job to any operator and know the operator's or group's earnings will not be affected.

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[11] "Short Cuts To Productivity", Modern Industry, Vol. 19, May 15, 1950. p. 44. (parenthesis added)

Many doubts and questions may be answered at this point by a few simple statements of resultant facts.

I. Required production per man hours was considerably raised.

II. Workers made bonuses.

III. Quality was maintained or increased where necessary.

IV. Training became remarkably efficient.

V. Grievances over rates now were reduced to, 'What did you do? What was the condition of the incoming part?'.........A change in work or quality resulted in an instant change in rate or a special allowance for a run of poor stock."[12]

<u>Disadvantages and limitations</u>.

"1. Since the various tables of motion differ, there is some question about their accuracy. They can't all be exactly right.

2. It has not been proved that a given motion will have a fixed time value, regardless of the motions which precede or follow it.

3. Stop watch studies or other techniques are still necessary for machine controlled elements of jobs, for drilling and cutting time, and the like. Furthermore, tabular systems do not solve such problems as the number of passes which must be made with a grinding wheel to secure the proper surface quality on a given type of part. ....

4. To obtain data that will be usable in the shop, it is still necessary to prepare standard data charts. This part of the work may require by far the larger part of the time, so that the timesaving, even on short jobs, is not always as great as it may seem.

5. The fact that time standards can be set without ever observing the job in the shop may lead the unwary and untrained user of these systems into two traps:

a. The 'ideal' motion pattern established by an engineer working in the office may be very different from the pattern used by operators on

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[12] Kelly, John S., "Establishing Finishing Operation Rates With Elemental Time Standards", <u>Metal Finishing</u>, Vol. 49, March, 1951. p. 74.

> the production line.
>
> b. If motions are missed in the job analysis, standards will be 'tight' (not enough time will be allowed). If motions are duplicated, standards will be 'loose'. Thus, one or two stopwatch time studies are very often necessary - not only to check standards, but also to provide a record for use in union negotiations."[13]

Summary of a Survey Which Determines What 132 Users Are Really Getting From Predetermined Time Standards[14]

The following five questions represent the results of a survey conducted by Factory Management and Maintenance in 1953:

1. "What will Predetermined Time Standards (PTS) do for you?"

A series of basic questions such as: To what extent has your system resulted in - (1) shop changes? (2) elapsed time to develop incentive or methods?, etc. were asked and the answers to them indicate a high degree of satisfaction with PTS. The amount of dissatisfaction was very small. "Nine out of ten (87%) cite better shop methods as a benefit."

2. "What's the future of PTS?"

"Nine out of ten users (92%) say they plan to increase their use of PTS." One reason for this might

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[13] Ibid. 11, p. 44.

[14] Ibid. 7, pp. 134-139. (ALL THE QUOTES IN THIS SECTION ARE TAKEN FROM THIS TEXT EXCEPT WHERE OTHERWISE NOTED)

well be that PTS acquires many more uses in a company after the company has gained experience with the system.

3. "How accurate are PTS?"

"Almost all users (97%) agree that PTS are accurate enough." In other words from a practical standpoint it is the general consensus of opinion that PTS are as accurate as can be expected where human judgement is involved.

4. "Is the stopwatch out?"

"Four out of five users continue to use the stopwatch" (to supplement PTS studies). This conclusion is in complete agreement with Harold Engstrom of Sylvania Electric Products, Inc. who speaking at a Management Conference at the University of Connecticut in 1952, stated:

> "Verification time studies should be insisted upon as an assurance that we are not digressing too far from normal. This might seem contradictory but we still have this problem of operator aptitude, managerial climate and war conditions for which we have yet to devise a measuring stick. Despite the great advances made in synthetic values, we cannot at this point consider them as substitutes for time study measurement. They are rather an aid, supplement and guide for better and improved standards determination."[15]

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[15] Engstrom, Harold, "Predetermined Time Standards", Advanced Management, Vol. 17, April, 1952. p. 17.

5. "What it takes to install PTS."

"You'd better call in a consultant". Experience must be brought to a PTS installation at the very outset. It may readily be seen that due to the complicated nature of some of the systems, training by competent personnel is necessary to eliminate many of the "bugs" and unfamiliarities with the intricacies of the system being used.

HISTORICAL BACKGROUND OF THE DEVELOPMENT OF THE INDIVIDUAL PREDETERMINED TIME SYSTEMS

History of Motion-Time-Analysis (MTA)

As was mentioned earlier, A. B. Segur, now of A. B. Segur and Company, Oak Park, Illinois was the first to establish a predetermined time system (early 1920's) through an appreciation of time as it concerned methods analysis. Originally the system was used for setting rates, but eventually came to be used primarily as a means of methods control.

> "The first key to the time equations of Motion-Time-Analysis was discovered in 1924 by analyzing micromotion films taken of expert operators in World War I. These films were originally taken with the view of discovering a means of training blind and other handicapped workers to perform useful industrial tasks. The workers studied were the best available in the industry. At the time this analysis was made, Gilbreth's motion classification was already available as an aid.

> After careful study of the work of these experts, it was discovered that, 'Within reasonable limits, the time required of all experts to perform a time fundamental motion is a constant.'
>
> In the above statement, 'reasonable limits' can be taken to mean 'industrial limits'. It was recognized that there would be a slight difference between the time required for various expert operators to perform an identical motion, but that a fairly wide limit existed within which it was possible to control industrial operations. As a result of 28 years of experience, it can be stated positively that the greatest average variation in the speed of normal individuals will be from 10 per cent below normal speed to 10 per cent above normal speed."[16]

Even though the work of Mr. Segur was essentially under wraps, being confined to his clients, his technique of minute motion breakdowns of body members and the assignment of physiological values to the muscle structures which cause the movements was a great stride forward in the field of Industrial Engineering.

History of Work-Factor[17]

Work-Factor was originated in Philadelphia, Pennsylvania in 1934. The original concept was a product of Joseph H. Quick who is now the president and general manager of the Harrington and Richardson Arms Company. He was assisted by William J. Shea, who is now vice-

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[16] Ibid. 8, p. 4-102.

[17] Ibid. 8, pp. 4-42 to 4-43.

president of the H. H. Brown Shoe Company. Also assisting was Robert E. Koehler now plant manager of the Capehart-Farnsworth Corporation. The original work of data collection was done by a staff of 12-25 engineers through the year 1937 and was made by studying a sample of about 1,100 experienced factory employees. The studies were made during working hours under normal factory conditions of experienced workers who varied in skill, ability and effort expended.

Approximately 17,000 motions were studied using a watch calibrated in thousandths of a minute and also photoelectric timers and 16 MM motion picture cameras for extremely short motions and varied complex situations. Stroboscopic photography in the laboratory was used to verify much of the shop data.

Two to five engineers worked simultaneously, but independently in rating the performance of each operation by individual motion and total operation cycle. Nothing was accepted until the sum of the leveled times for the individual motions matched the leveled time for the total cycle.

The original data was tabulated in the form of curves and later in the more convenient tabular form of the Motion-Time table.

The final time values as they appear in the motion-time table represent times required by "an average of experienced workers" as set forth by experienced engineers.

The first actual shop applications were made in Camden, New Jersey in 1938. Some 220 engineers were trained to use this system in the setting of production standards through 1945. The Camden manufacturing firm involved employed about 10,000 persons.

During this seven year period the original data was refined as problems presented themselves in the shop, and hence the time tables were revised to conform with the corrected data. In 1945, the time values and a short explanation of Work-Factor were published in the magazine, "Factory Management and Maintenance". Since that time there have been few changes in time values, but work has been expended in attempting a further standardization in the rules and procedures for using them. This development since 1945 has been under the direction of James H. Duncan, Managing Partner of the Work-Factor Company.

History of Methods-Time Measurement (MTM)[18]

The basic thinking behind the MTM predetermined time system originated in the mid-twenties with Harold B. Maynard,

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[18] "Timing a Fair Day's Work", Fortune, Vol. XL, October, 1950, pp. 129-132+.

then a recent Cornell graduate, who was engaged in time study work for Westinghouse in Pittsburgh. His supervisor was Gustav J. Stegemerten, the Superintendent of Wage Incentives. The initial work of the two men consisted of the determination of a concept of performance rating from which a definition of average performance was developed. From this, although unknowingly at the time, came the underlying definition of MTM. Average performance was that which could be expected of the conscientious worker being paid the going wage.

The definition of average performance eventually led to, through the work of Maynard and Stegemerten, a system of using numerical factors to level time study data in accordance with their performance rating system. In 1940 both men put these leveling factors together on the problem which eventually led to the development of MTM. By this time Maynard was heading up his own consulting firm - the Methods Engineering Council.

Soon, Maynard and Stegemerten using the data acquired during a methods-improvement program at Westinghouse, studied the performance times of the various job motions in this data. When their leveling factors were applied, the average times all seemed to fall along well defined curves. The work continued for another year as sensitive drill press operations were minutely studied using 16 MM motion pictures.

> "The camera used was driven by a constant speed motor. Thus, with the film exposed at a constant speed, the use of timing devices and other distracting accessories was eliminated, enabling the operator to work under normal operating conditions. The film was exposed at 16 frames per second. Exposure at a slower speed made it more difficult to analyze the film in the early research phase of MTM development because element starting and stopping points were not easily identifiable.
>
> Body, leg and foot motions were derived later by detailed time study, assisted by already developed MTM data. Simultaneous equations and statistical methods were employed to determine the published time standards."[19]

The work involved breaking down Gilbreth's basic elements or "therbligs" still further into basic motions, since their scope and coverage was too broad and was essentially indefinable.

In 1943 the drill press standards were being put to the test in various companies in Pittsburgh. At this point Jack Schwab, an extremely intelligent Westinghouse employee began to assist the men. It was Schwab who suggested an even finer breakdown of the data to cover each motion when it was found one day that the data was inapplicable to a specific type of drill press. Further

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19. Ibid. 8, p. 4-17.

film studies found the standard time values to check out perfectly.

MTM worked so well at Westinghouse that other companies fast became interested, and it was even taught by Schwab at the Bridgeport Engineering Institute. In 1946 Schwab and Stegemerten joined the Methods Engineering Council, and by 1949 there were nine MTM experts who were showing other engineers how to apply the system.

> "......in the last year, (1951) MTM has gained many champions. About 50 companies - including DuPont, Robertshaw-Fulton, and some divisions of G. E. - have put MTM to use. There is substantial evidence that the new management tool helps improve operator training, machine design and selection, etc.
>
> The Methods Engineering Council found that opportunities for the technique were becoming too big for it to handle. About a year ago, (1950) competitors of the Council were offered, and accepted training in MTM.
>
> This summer (1951), 'The MTM Association for Standards and Research' was formed......... Harold B. Maynard of MEC, is president......
>
> At its first meeting in Toronto last month, (1951) the MTM Association announced its objectives: to coordinate research, to exchange techniques, to establish standards and (ultimately) issue licenses, and to widen acceptance for the proper use of MTM.
>
> Thus the industrial consultant field has taken another step showing evidence of a desire to raise its professional sights."[20]

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[20] "Methods Time Measurement", Modern Industry, Vol. 22, August 15, 1951. p. 78. (DATES IN PARENTHESIS ADDED BY THE AUTHOR)

History of Dimensional Motion Times (DMT)

The original work for the predetermined time system known as Dimensional Motion Times was developed by Harold Engstrom and his associates at the General Electric Company in Bridgeport, Connecticut. Originally, the data was used for estimating direct labor costs, and finally for time standards. The research was eventually taken over by Mr. H. C. Geppinger, Supervisor of Time Study Training, who pursued the system to its completion and publication in book form.

> "The research project,..........., was carried on in great detail with an equitable number of samples and under closely controlled specifications and conditions. About 350,000 test runs were made, recorded and analyzed on nearly 1,000 test samples from September, 1949 to December, 1951. The project also included producing and analyzing 300 laboratory films and numerous test applications to known shop operations to reconcile and verify the data at several stages of the project."[21]

The entire DMT system, its use and application has been recently presented in a textbook by Mr. Geppinger entitled "DMT Dimensional Motion Times, Development and Application", published in 1955 by John Wiley and Sons, Inc.

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21. Geppinger, H. C., "New Motion Time Method Defined", The Iron Age, Vol. 171, January 8, 1953. p. 106.

History of Basic Motion Timestudy (BMT)[22]

Basic Motion Timestudy was developed by J. D. Woods and Gordon, Limited. Ralph Presgrave was instrumental in this development. The date of introduction was 1950, which was preceded by approximately four years of research that considered the scope, validity and timeliness of the predetermined times as an extension of the standard data technique.

The first experimentation dealt with a close analysis of actual factory operations. This experimentation followed the requirements of the "synthetic" system which are as follows:

1. Identifiable units of movement.
2. No overlapping of units of movement.
3. The sum of units of movement must yield the proper total time for the operation-in-question.

Finally, the first experimentation inferred that there exist external factors (other than distance etc.) which affect a basic motion. An example of this might be weight carried, or care exercised in performing a basic motion.

The second stage of experimentation concerned itself with introducing these variable external factors

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[22] Ibid. 12, pp. 4-91 to 4-92.

singly and/or in combination with a basic motion and measuring the results under rigid control.

These analyses were checked out against actual factory operations and confirmed or modified if the need arose. Motion picture analysis supplemented all studies.

SUMMARY

Chapter I essentially has a two-fold purpose, namely; that of acquainting the reader with the two basic techniques for determining the standard time of an industrial operation - Time Study and Predetermined Time Systems.

After reading Chapter I, the reader should have an appreciation of the meaning and history of the Time Study Movement in the United States. In addition, he will have become generally acquainted with the individual histories of each of five well known systems of predetermined time standards; and should have acquired a basic knowledge of the meaning, fundamentals, uses, advantages, and disadvantages of those systems in general.

The chapter should have given the reader enough of a background, so that he might be able to proceed to a more detailed description of the operation of each of the individual predetermined time systems.

CHAPTER II

THE OPERATION OF THE PREDETERMINED TIME SYSTEMS

INTRODUCTION

All of the Systems of Predetermined Time Standards operate in essentially the same way. Each is involved with breaking a job down into its basic fundamental motions. An example is in order at this point: Picking up a pencil from a table is not a fundamental motion. It is not universal - it is not a fine enough breakdown. Rather, the following becomes the basic elemental motion breakdown:

Move hand to pencil
Close fingers to grasp pencil
Move arm to pick up pencil

Motions such as the above are universal in nature and the predetermined time systems each set forth tables of values for those motions as well as for others. These include reaching, moving, grasping, turning, positioning, etc.

Hence, after an operation is described as above, the proper motion-time value may be taken from the motion-time table being used, and that figure will represent the base time for the motion. The summation of all base times so obtained will yield the base time for the entire element or cycle.

The next pages will endeavor to present the methods of operation of five of the most popular systems of predetermined elemental times, presented in the chronological order of their appearance on the industrial scene.

OPERATION OF MOTION-TIME-ANALYSIS (MTA)[23]

Definition and Theory of MTA

Motion-Time-Analysis is the system of predetermined time standards developed by A. B. Segur, which was originally used in a rate setting capacity, but more recently has been used more and more for methods control.

The following, in the words of Mr. Segur, best describes the basic concept of MTA:

> "The basis of Motion-Time-Analysis lies in the theory now rather widely accepted among physiologists that the mechanism of the human body is primarily a chemical engine. Each action of the body is the result of some chemical action that takes place within the body. Since this chemical reaction takes place in a constant temperature - insofar as the chemical reaction is constant - the time for the reaction will also be constant within narrow limits.
>
> The controlling time for human action may be defined as follows:
>
> Average speed of a nerve reaction in the human body is 0.000045 minute per foot of distance

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[23] Ibid. 8, pp. 4-101 to 4-118.

> traveled. Average number of messages that can be started over any one nerve path in the body is 5000 per minute. Average time for a single sarcostyle to complete a contraction in response to a nerve impulse is 0.00064 minute.
>
> In actual practice over nearly 30 years, these times have been found to hold. The units into which these reaction times are built depend entirely upon the intended use of the data. For a fixed use, they can be built into a simple set of standards, which can be memorized in 1 or 2 hours.
>
> In the use of Motion-Time-Analysis, the determination of the synthetic time for performing an operation is the simplest part of the entire procedure.
>
> The above times apply to routine thinking, as well as to muscular reaction. These reactions, which are controlled by the brain, are becoming increasingly more important in industry than those which are controlled by the muscles alone."[24]

It is extremely important in applying MTA, to observe in meticulous detail, each minute movement that is made and to set it down in longhand, so that the developed time values may be applied. These minute movements may then be grouped into one of the 17 MTA basic motions, after which each of these is examined to determine which are "useful or unuseful".

> "The times required to perform what appears to be the same motion may differ widely. In Motion-Time-Analysis practice, it was learned early that unless the motion paths could be

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[24] Ibid. 8, p. 4-102.

> closely controlled, the accuracy of the developed synthetic times was no greater (if as great) as that obtainable through ordinary stopwatch studies. Therefore, Motion-Time Analysis practice has tended more and more to be a science of motion or methods control. No good analyst will assume the responsibility for setting a time standard on any job unless he can also control the method to be used by the operator in performing that job."[25]

<u>The MTA basic motions.</u>[26] The MTA Basic Motions are essentially the same as the "therbligs" as originated by Gilbreth. These are, together with their symbols, as follows:

1. Transport Loaded (TL): Moving with a load or against a resistance.
2. Transport Empty (TE): Moving with a load.
3. Direct (D): Guiding of actions with sensory movements.
4. Grasp (G): Gaining of control over an object.
5. Hold (H): Maintaining control over an object.
6. Release Load (RL): Relinquishing control over an object.
7. Unavoidable Delay (UD): A delay beyond the operator's control.

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25. Ibid. 8, p. 4-104.

26. Ibid. 8, p. 4-105.

8. Avoidable Delay (AD): A delay within the operator's control.

9. Balance Delay (BD): A delay caused by the nervous limitations of the human body.

10. Rest (R): An operational delay permitting elimination of fatigue.

11. Pre-position (PP): A rearrangement which readies a part for the next operation.

12. Position (P): The placement of two parts to an exact relationship with one another.

13. Select (SE): Choosing between two or more parts from a specific location.

14. Search (S): The determination of location.

15. Inspect (I): Critical examination of the features of a part.

16. Plan (PL): Determination of method.

17. Use (U): Performance of a mechanical or chemical operation.

Definite laws exist concerning the wisdom of use of any of the above basic motions. As examples: Hold should never be used; Positioning is to be looked at carefully; and Grasp and Release are to be used only in limited proportions. Hence, an MTA analysis must consider which of the basic motions are useful or unuseful.

The application of MTA. An MTA analysis of an operation has as its first step a complete description of the job, in longhand, of every basic movement or motion involved in the job. This is essentially the breakdown of the above "Basic Motions" into finer submotions which must be done without the aid of symbols or convention. The term "Basic Motions" is a misnomer here, because of the fact that they are composed of various submotions which are combined in different proportions to form the MTA Basic Motion. In many cases the importance of the operation does not justify this minute description, in which case the "Direct Summary Method" is used. Use of this method indicates that there is no intention of setting a standard time for the operation, but rather the analysis is to be used for determining a method for an operation that any worker could follow with relative ease. The Direct Summary Method makes use of the MTA Basic Motions and symbols in its analysis. Use of this method generally implies that movements allowed are greater than for the detailed analysis.

As concerns the detailed analysis,

> "At the outset of a Motion-Time Analysis study, the analyst puts his attention first on getting a correct detailed description of the motions which are being performed - for this description determines the time which will be allowed for the operation. If a motion is of doubtful value

> in the job (is Loss), the figures for its time are entered in red pencil. If the motion should generally be allowed, the time is entered in black ink. The number of red figures which appear on the sheet are a very good indication of the type and extent of improvement possible on the operation. In many cases, it has been found possible to eliminate whole sections of manufacturing processes because each section of the process was composed of some form of 'forbidden' motion."[27]

This is essentially the concept of MTA which is known as Avoidable Loss Analysis. The concept is most important because it has been found that if an operation contains an excessive amount of loss, it is quite easy for the rates of that operation to get out of line. Mr. Segur states that if the Avoidable Loss is less than 25 per cent, the rates almost never get out of line.

It may readily be seen from the foregoing discussion that the Motion-Time-Analysis procedure is being used in industry today primarily to determine and establish the best methods of performing various industrial operations, after which that data is employed to train the operators in the proper method.

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27. Ibid. 8, p. 4-106.

OPERATION OF WORK-FACTOR[28; 29]

Definition and Theory of Work-Factor

> Definition. "Work-Factor is a method of determining the select time for a given motion pattern by (1) making a detailed analysis of each motion based on the identification of the four major variables of work and the use of Work-Factors as a unit of measurement and (2) applying to each motion the proper standard-time value contained in the Motion-Time Table."[30]

The four major variables. The four major variables mentioned in the above definition analyze the relations between time required and (1) distance moved (2) body member used (3) manual control involved and (4) weight carried:

1. Distance Moved

In general, the shorter the distance moved, the shorter the time will be. In general the farther the distance moved, within normal limits, the shorter the time will be per inch of movement. (Because starting acceleration and ending deceleration becomes less of the total time as the distance is increased). Distance moved is determined

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[28] Quick, J. H., Shea, W. J. and Koehler, P. E., "Motion-Time Standards", Factory Management and Maintenance, Vol. 103, May, 1955. pp. 97-108.

[29] Ibid. 8, pp. 4-40 to 4-90.

[30] Ibid. 8, p. 4-47.

simply by measuring with a scale.

2. Body Member Used

There exists a Basic Motion-Timetable for each of the following body members:

Finger - Hand
Arm
Forearm Swivel
Trunk
Foot
Leg

All of the above are exactly defined in the Work-Factor text, and this serves as their means of identification.

3. Manual Control Involved

The amount of control in making any basic motion must be considered in establishing the time standard for that basic motion. In other words, men doing crude work may move carelessly and quickly; whereas men on complex detailed jobs must exercise a varying degree of fine control over what they are doing. An example might be as follows: In painting a wall, relatively little care would be used in applying the paint; but if, on the other hand, a sign were to be painted this would require a great deal of skill, care, and dexterity with the paint brush.

Control is indeed the most difficult quality to distinguish in a motion as it cannot be measured directly in terms of physical units. However, the Work-Factor System holds that 95 per cent of all industrial motions can be classified or identified by the following factors:

> "Definite Stop Work-Factor. Manual control required to terminate a motion with a definite stop is limited to movements terminated at the will of the operator and does not include movements arrested by a physical obstruction.
>
> Directional Control Work-Factor (Steer). Manual control required to direct or steer a motion through a limited clearance or toward a small target area.
>
> Care Work Factor (Precaution). Manual control required, or precaution exercised, to prevent damage or injury, or to maintain manual control as a necessary function of the motion (other than directional).
>
> Change of Direction Work-Factor. Manual control required to change the direction of motion, such as that required in moving around an obstruction."[31]

4. Weight or Resistance

The effects of weight and resistance both are fatiguing, and definitely must be taken into consideration in determining the standard time for a basic motion. These effects vary with the body member used and the sex of the operator.

Resistance is governed by the same principle as

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[31] Ibid. 8, p. 4-49.

that which governs weight, and may be encountered in any movements which require bending, pushing, rubbing, etc.

Weight and/or resistance is measured in pounds with the exception of the forearm swivel which is measured in pound-inches of torque.

The Application of Work-Factors

> "Work-Factor is a unit used as the index of additional time required over and above the basic time when motions are performed involving the following variables:
>
> 1. Manual control
> 2. Weight or Resistance"[32]

A distinction must be made between the four major variables as discussed, and the Work-Factors which affect the basic motions. Work-Factors measure the effect of weight and control on the other two variables of distance and body member. In other words, weight and control are used to describe the motion that is made, through a determination of the amount of weight and/or the type of control involved. This essentially is the principle of Work-Factor.

The value of a Work-Factor has been determined and set down in tabular form. When reviewing a cycle of basic motions, it only becomes necessary for the analyst

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[32] Ibid. 8, p. 4-47.

to determine to what extent (how many Work-Factors) the control or weight affects the distance moved and the body member used. It might be that the motion(s) involved require no control or encounter no resistance, such being the case the motion would be classified as basic, or the simplest type of motion. If control were involved, then type of control must be determined, (Definite stop, care, etc.) and the number of Work-Factors noted. The motion would then be classified as a 1, 2, 3 or more Work-Factor motion depending upon how much the control, weight and/or resistance affect that motion. An example might be the following: Putting a peg in a hole 12 inches away from the starting point. This would involve a movement of the arm for a distance of 12 inches, and the motion would be affected by the Work-Factors of Directional Control (essentially a positioning) and Definite Stop. This is a 2 Work-Factor motion.

It may readily be seen that a basic motion such as just described may have any number of Work-Factors affecting it. Hence, the complexity of the motion is determined by the amount of control, weight, or resistance; which, in turn, determines how many Work-Factors are applicable.

It is important to note that it does not matter how a motion is affected by various factors of weight and control; the nature of the individual Work-Factors does not affect time. The important thing is to note the actual number of Work-Factors that apply so that the motion may be identified on the motion-time table. The motion described in previous example is a 2 Work-Factor motion; it would remain a 2 Work-Factor motion even if a factor of weight and a different control factor were substituted for the Work-Factors of Directional Control and Definite Stop.

The motion-time tables (see Table I on the next page) have been set forth for each of the individual body members, and their use involves only the determination of distance moved and number of Work-Factors involved. To clarify further, in order to find any motion on the motion-time table one must identify that motion in terms of:

1. Body member used

The tables have been set forth as follows:

Symbol	Body Member
F	Finger
H	Hand
FS	Forearm swivel
A	Arm
FT	Foot
L	Leg
T	Trunk
HT	Head Turn

Distance moved, inches	Basic	Work-Factors			
		1	2	3	4
(A) Arm, measured at knuckles					
1	18	26	34	40	46
2	20	29	37	44	50
3	22	32	41	50	57
4	26	38	48	58	66
5	29	43	55	65	75
6	32	47	60	72	83
7	35	51	65	78	90
8	38	54	70	84	96
9	40	58	74	89	102
10	42	61	78	93	107
11	44	63	81	98	112
12	46	65	85	102	117
13	47	67	88	105	121
14	49	69	90	109	125
15	51	71	92	113	129
16	52	73	94	115	133
17	54	75	96	118	137
18	55	76	98	120	140
19	56	78	100	122	142
20	58	80	102	124	144
22	61	83	106	128	148
24	63	86	109	131	152
26	66	90	113	135	156
28	68	93	116	139	159
30	70	96	119	142	163
35	76	103	128	151	171
40	81	109	135	159	179
Weight, pounds:					
Male...........	2	7	13	20	Up
Female.........	1	3½	6½	10	Up

TABLE I

Sample Work-Factor Motion-Time Table

(Arm Movement)

(Reproduced from The McGraw-Hill Industrial Engineering Handbook, 1956, First Edition, p. 4-51)

2. Distance moved

Distance is located on the left hand side of the table(s) and is measured in terms of inches.

3. Work-Factors

Simply count the number of Work-Factors affecting the motion being considered, and locate the proper column at the top of the table. Work-Factors are indicated in the motion analysis by the following symbols:

W - Weight or Resistance

S - Directional Control (Steer)

P - Care (Precaution)

U - Change Direction

D - Definite Stop

Hence, all variables affecting a basic motion may be recorded in one symbolic form with body member first, distance moved second, and Work-Factors third. Consider the previously mentioned example which involved putting a peg in a hole 12 inches away. In symbolic form this would be an A12SD motion (a 2 Work-Factor motion) and would be located on the "ARM" motion-time table, page 44. The time for this motion may be found under the "2 Work-Factor" column, Table I, page 44, opposite "12 inches". The time is 85 units or 0.0085 minute. The Motion-Time Tables are set forth in ten-thousandths of a minute (0.0001).

In addition to the time values already discussed, the motion-time tables make provision for the following basic motions:

1. Walking (general and restricted)
2. Head Turns
3. Visual Inspection
4. Mental Processes (Reaction Time, Decision Time and Thought Processes)

Standard Elements of Work

> "Work-Factor Standard Elements have been set up to represent the basic divisions of work. They may be composed on a single motion or series of motions. There are eight elements.
>
> 1. Transport (Reach and Move) (TRP)
> 2. Grasp (GR)
> 3. Pre-position (PP)
> 4. Assemble (ASY)
> 5. Use (Manual, Process or Machine Time) (US)
> 6. Disassemble (DSY)
> 7. Mental Process (MP)
> 8. Release (RL)
>
> During the development of the Work-Factor System, it became apparent that, for ease and simplicity of description, the eight divisions listed above are adequate and practical."[33]

The rules for the application of the Work-Factor System are set up according to the descriptions of the Standard Elements. These detailed rules are most

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[33] Ibid. 8, pp. 4-53 to 4-54.

important to proper application of Work-Factor, and should be consulted before attempting to apply the system.

Effect of Simultaneous Elements on Time

Many simple motions may be performed simultaneously by two or more body members, but certain of the more complex motions cannot be performed in that manner without an increase in elapsed time over what would normally be required to perform one of the motion independently. Such elements are called Simo Elements.

It has been found through application of the Law of Probability, that on an average basis, an increase in time of 50 per cent compensated for the extra time needed to perform two or more complex simultaneous motions.

Scope and Use of the Work-Factor System

The initial use of the Work-Factor System was to determine the standard time for an operation. Usage for methods improvement was the outgrowth of this original concept.

Varying amounts of production require different accuracies in standards. For this reason Work-Factor has been grouped into three basic sets of values as follows:

1. Detailed Work-Factor (Accurate work measurement for mass production)

2. Simplified Work-Factor (Rapid measurement for medium-quantity production)

3. Abbreviated Work-Factor (Meets the needs of small job-shop operations)

The Simplified data cuts the number of elemental descriptions by approximately 60 per cent and the Abbreviated data cuts it by approximately 90 per cent.

Making the Work-Factor Analysis

The Evaluation of the time required to perform an operation becomes a relatively simple task through the use of the Work-Factor System. The first step is to observe the job in close detail, and make a list of every motion that the operator makes (Every necessary motion). These motions are described by body member used and distance moved. Then each motion, as listed, is analyzed in terms of the Control and Weight Work-Factors that affect the motion. Next, the time value for each motion is selected from the proper motion-time table; and finally all of these individual times as recorded are summed to yield total time for performance of the operation.

OPERATION OF METHODS-TIME MEASUREMENT (MTM)[34]

Definition and Theory of MTM

> "Methods-time Measurement is a procedure which analyzes any manual operation or method into the basic motions required to perform it and assigns to each motion a predetermined time standard which is determined by the nature of the motion and the conditions under which it is made."[35]

Hence, the MTM system presents predetermined standard times in the form of basic (universal) motions, and recognizes that these basic motions will vary under different conditions. In other words, there are different classifications within any one basic motion. For example, the MTM Basic Motion "Reach" may be for a specific distance and may be of Class A, B, C, D or E. The lettered classifications are each defined as to the amount of care and control involved in the "Reach".

The MTM procedure also has determined laws about the sequences these basic motions will follow.

The MTM Basic Motions

The following represents the MTM classification of Basic Motions:

Reach (R). "Reach is the basic element

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[34] Ibid. 8, pp. 4-14 to 4-39.

[35] Maynard, Stegemerten and Schwab, "Methods-Time Measurement." New York: McGraw-Hill Book Co., Inc., 1948. p. 12.

> employed when the predominant purpose is to move the hand or finger to a destination or general location. The time for making a reach varies with the following factors:
>
> 1. The conditions under which the motion is made.
> 2. The length of the motion.
> 3. The absence of acceleration and/or deceleration in the motion."[36]

Referring to Table II ("Reach") which appears on the next page, for factor I above, note that the five classes of reach are indexed along the top of the table and described along the right hand side. For factor 2, the Length of the motion is indexed along the left margin of the table. For factor 3, the Hand in motion is indexed in the top right hand corner of the table. An inspection of the above should give an insight into how the table is actually used in an analysis for the determination of a time standard.

An example of a reach might be as follows: Reach 12 inches for a pencil lying on the tabletop. Using MTM convention this would be an "R12B" or a 12" reach during which little care is needed. The reach is to a general location for a single object. The time for this motion would be 12.9 TMU where 1TMU = .0006 minute. All tables are set up in Time Motion Units (TMU) for convenience and

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[36] Ibid, 8, p. 4-22.

REACH - R

Distance Moved Inches	Time TMU				Hand In Motion		CASE AND DESCRIPTION
	A	B	C or D	E	A	B	
¾ or less	2.0	2.0	2.0	2.0	1.6	1.6	A Reach to object in fixed location, or to object in other hand or on which other hand rests.
1	2.5	2.5	3.6	2.4	2.3	2.3	
2	4.0	4.0	5.9	3.8	3.5	2.7	
3	5.3	5.3	7.3	5.3	4.5	3.6	
4	6.1	6.4	8.4	6.8	4.9	4.3	
5	6.5	7.8	9.4	7.4	5.3	5.0	B Reach to single object in location which may vary slightly from cycle to cycle.
6	7.0	8.6	10.1	8.0	5.7	5.7	
7	7.4	9.3	10.8	8.7	6.1	6.5	
8	7.9	10.1	11.5	9.3	6.5	7.2	
9	8.3	10.8	12.2	9.9	6.9	7.9	C Reach to object jumbled with other objects in a group so that search and select occur.
10	8.7	11.5	12.9	10.5	7.3	8.6	
12	9.6	12.9	14.2	11.8	8.1	10.1	
14	10.5	14.4	15.6	13.0	8.9	11.5	
16	11.4	15.8	17.0	14.2	9.7	12.9	D Reach to a very small object or where accurate grasp is required.
18	12.3	17.2	18.4	15.5	10.5	14.4	
20	13.1	18.6	19.8	16.7	11.3	15.8	
22	14.0	20.1	21.2	18.0	12.1	17.3	E Reach to indefinite location to get hand in position for body balance or next motion or out of way.
24	14.9	21.5	22.5	19.2	12.9	18.8	
26	15.8	22.9	23.9	20.4	13.7	20.2	
28	16.7	24.4	25.3	21.7	14.5	21.7	
30	17.5	25.8	26.7	22.9	15.3	23.2	

TABLE II

Sample MTM Motion-Time Table

(Reach)

(Reproduced from the McGraw-Hill Industrial Engineering Handbook, 1956, First Edition, p. 4-19)

ease of application. The other tables are set up in similar fashion, all of the variables being indexed. A word of caution is in order at this point - one must not try to apply MTM or any other predetermined time system before thoroughly studying the subject. Many mistakes will be made if the uninitiated attempts to apply data from the time tables without being experienced in the application of the system.

The rest of the MTM basic motions will be discussed lightly in this paper. For a detailed description of those motions and their application the reader may refer to the original text by Maynard, Stegemerten and Schwab entitled "Methods-Time Measurement", New York: McGraw-Hill Book Co., Inc., 1948.

> Move (M). "Move is the basic element employed when the predominant purpose is to transport an object to a destination.
>
> Move time is varied in the same manner as Reach, by (1) the conditions present (2) the distance moved, and (3) whether the hand is in motion at the beginning and/or end of the move. In addition, the factor of weight or resistance has an effect on the move time."[37]
>
> Turn (T). "Turn is the motion employed to turn the hand either empty or loaded by a movement that rotates the hand, wrist, and forearm about the long axis of the forearm. The length of turn is measured in degrees

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[37] Ibid. 8, p. 4-23.

> turned. ...... The weight factor is handled by three classifications......."[38]

> Apply Pressure (AP). "Apply pressure is the basic element used to overcome resistance or to exert precise control. It appears as a distinct pause or hesitation and is required to overcome an amount of pressure or precision which is abnormal for the body member used to perform the action."[39]

> Grasp (G). "Grasp is defined as the basic element employed when the predominant purpose is to secure sufficient control of one or more objects with the fingers or the hand to permit the performance of the next required basic element. It begins at the end of the preceding basic element and it ends when the next basic element begins."[40]

Five classifications exist some of which have sub-classifications. Any complex grasps which do not fall in any of these classifications must be analyzed through use of other of the MTM elements.

> Position (P). "The MTM element Position is defined as 'the basic element employed to align, orient, and engage an object with another object, where the motions used are so minor that they do not justify classification as other basic elements'. A position usually follows a Case C Move. ..... There are three classes of Position. They are:
>
> 1. Class of fit
> 2. Symmetry
> 3. Ease of Handling

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38. Ibid. 8, p. 4-24.

39. Ibid. 8, p. 4-24.

40. Ibid. 8, p. 4-24.

> ......Since the time standard for the element Position is large, improper classification can result in serious errors in MTM analyses."[41]
>
> Disengage (D). "Disengage is the basic element employed to break the contact between one object and another. It is characterized by an involuntary movement caused by the sudden ending of resistance.
>
> There are three variables that have been found to affect the time for Disengage. These are:
>
> 1. Class of Fit
> 2. Ease of Handling
> 3. Care of Handling."[42]
>
> Release Load (RL). "Release Load is the basic element employed to relinquish control of an object by the fingers or the hand."[43]

In addition to the basic motions as described above, there also exist some other miscellaneous body member motions which are set forth as follows:

1. Walking (W - FT or W-P
2. Foot Motion (FM)
3. Leg Motion (LM)
4. Side Step (SS)
5. Turn Body (TB)
6. Bend (B)
7. Stoop (S)
8. Kneel On One Knee (KOK)
9. Kneel on Both Knees (KBK)

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41. Ibid. 8, pp. 4-25 and 4-26.

42. Ibid. 8, p. 4-27.

43. Ibid. 8, p. 4-28.

10. Sit and Stand From A Sitting Position (SIT and STD)

Also Eye Travel Time, Eye Focus and cranking motions have been added since the original data was gathered.

<u>Limiting Motions</u>

The MTM system has developed a law called the Principle of Limiting Motions which essentially tells the analyst which motions can be performed simultaneously and which cannot. This data is represented in two dimensional chart form on the MTM Motion-Time Table. This data is most important, because if not considered, will frequently result in an incorrect standard time for an operation.

The "Limiting Motion" is the one which takes the greatest amount of time, if two or more motions are combined, overlapped or performed simultaneously.

Combination motions are those which are performed by the same body member at the same time. An example would be moving a part to a location and regrasping at the same time.

Simultaneous motions are motions performed by different body members at the same time. The time for a right hand motion may be greater than that for the left when the two are performed simultaneously; hence the right hand motion is the limiting motion and determines the standard time.

Simplified Data

Many times the Industrial Engineer, the Estimator and the Tool Designer, among others, will want to quickly determine the time to perform an operation. The MTM data has been simplified through averaging, and the results are claimed to have a loss of accuracy not greater than 5 per cent. Also a 15 per cent factor for personal, fatigue and delay allowances has been included in the data.

The tables are extremely easy to use, and the values are so few that they may be memorized quite readily. The major advantage of this simplification procedure is the large savings in application time.

MTM Application Procedure

> "The methods-time measurement procedure may be applied in two ways:
>
> 1. By visualizing an operation not yet existent.
> 2. By Observing an already established operation.
>
> The approach to either method is similar except that the application of MTM to a visualized operation requires more attention to detail in order to avoid error. The procedure for applying MTM by either method can be divided

into certain basic steps......these are:

Visualization

Create the operation.
Visualize and organize information.
Plan the operation method.
Analyze operation details and establish time.

Observation

Observe the operation.
Broadly analyze and record existing information.
Record the operation method.
Analyze the method and establish the time."[44]

"Why is MTM Different?

MTM is the only published system that meets all four of these tests for standard data:

1. The data must be absolutely consistent at all times and under all conditions.
2. It must be possible to reproduce the data.
3. It must be possible to apply the data quickly and cheaply.
4. It must be easy for the operator to understand the data.

There are other systems which meet these tests. But, while time values have been published for other systems, basic research data have not been made available for impartial investigations and analysis. The situation could change at any time, but right now (1950) MTM stands above as the only tool of scientific management that can be proved to have met the tests."[45]

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[44] Ibid. 8, p. 4-31.

[45] "How Good is MTM?", Factory Management and Maintenance, Vol. 108, August, 1950, p. 86.

OPERATION OF DIMENSIONAL MOTION TIMES (DMT)[46]

Definition and Theory of DMT

> "DMT is a systematic procedure for analyzing elements of work in terms of motions and for measuring the work content by predetermined time values which are related to distances and other dimensional terms whenever such relationship was found to exist."[46]

The basic concept upon which the DMT system of predetermined time standards is based was expressed by Lord Kelvin in 1883 when he said:

> "I often say that when you can measure what you are speaking about, and express it in numbers, you know something about it; but when you cannot measure it, when you cannot express it in numbers, your knowledge is of a meagre and unsatisfactory kind........."

The DMT system translates the meaning of the above statement into its predetermined time standards by using dimensions to describe the basic motions wherever possible.

> "DMT is constructed on the basis of terms which are more clearly defined and specified. Common motions which recur in any operation are directly related and expressed by dimensions in inches. They refer to distance, part size, target size, and clearance. The time values designating any particular motion

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46. Geppinger, H. C., DMT Dimensional Motion Times Development and Application. New York: John Wiley & Sons, Inc., 1955, p. 1.

> are positive. Concise dimensional terms require only a small number of explanatory and defining rules, since they deal to a large extent with factual measurement."[47]

It is claimed that the factor of judgement had been eliminated in other predetermined time systems as far as effort rating was concerned, but the judgement had taken on a new aspect in the determination of the step by step basic motions to be used in analyzing an operation. In other words, it was necessary to use judgement when selecting such motions as grasping and positioning which are generally described in terms of "easy", "difficult" etc. The DMT approach leaves nothing to the imagination, as it pins down and describes these motions exactly in terms of the dimensions of the object under consideration. It makes something specific out of a generality, and truly maximizes the claim of all predetermined time systems that they eliminate the factor of judgement.

> "By eliminating word descriptions and the factor of judgement in the selection of a motion value, the newly developed system assumes a more scientific aspect."[48]

Scope of application. It is claimed that DMT can be used for measuring all kinds of manual work, but actually

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[47] Geppinger, H. C., "New Motion Time Method Defined," The Iron Age, January 8, 1953, p. 106.

[48] Ibid. 47, p. 106.

it was developed for a specific purpose, and that was to measure processes that have been divided into specific operations which have specific methods with no variation whatsoever from that method. The work place of such an operation must be fixed and permanent in its layout, and variations in material conditions must be held to a minimum. Hence it would appear that DMT is applicable in a practical manner only to the repetitive assembly operations of small parts. It must be concluded, therefore, that DMT is not universally applicable to all operations, at least not in the same sense of the word, as are the other systems of predetermined time standards.

The DMT Basic Motions

The DMT Basic Motions and Time Tables are considerably more complicated in the opinion of the author than those of any of the other systems. However, since many of the tables are indexed by dimension only, the application from those tables does become somewhat simpler because of the elimination of judgement. Nevertheless, this is more than offset by Table number one (DMT-I) whose variables are all affected by the judgement factors which the system is supposed to eliminate. Transports (Reaches and Moves) require approximately the same amount of judgement as do any of the other systems; and it is generally agreed that these two are the more important of the basic motions. Also, there is a list of no less than 41 separate miscellaneous motion times, each of which involve judgement. Motions such as this are interspersed throughout the five DMT motion-time tables.

Presented below in a short survey form are the DMT basic motions as presented in the five motion-time tables:

Data sheet DMT-I. Transport Motions (T) - Corresponds to a "reach" motion. Base Transport (B) - Corresponds to a "move" motion. Toss Transport (T) - Applicable when the hand does not come to a complete stop at the end of a transport.

Transports are affected by the factors of:

1. "Restricted" (Refers to all positioning moves not specifically covered by positioning tables)
2. "Wiping" (The rubbing of a cloth of a surface with pressure)
3. "Brushing" (The brushing of liquids on the surfaces of parts)
4. "Weight" (Also applies to grasping, positioning and release load motions)

In addition DMT-I lists a time table for turning a crank, 41 separate miscellaneous motion times, and 5 standardized elemental times.

Data sheet DMT-2 (Grasp-J). This motion-time table contains motion times for grasping block-type as well as rod-type parts (on 2 separate tables), for parts jumbled in trays. Please refer to the reproduction of one of the tables as presented on the following page (Table III). As an example of its use: Assume we were to grasp a washer out of a tray and the dimensions of the washer were 5/16" diameter and 0.041" thickness. This would be taken from the table and noted as a "J39C" motion having a time value of 101 or 0.0101 minute. (All time values are expressed in ten thousandths of a minute, 0.0001). Note that the coding is not quite as descriptive as some of the symbols of the other systems. This is understandable, however, in view of the fact that dimensions are the governing factors in the selection of a basic motion.

Data sheet DMT-3 (Grasp - S, I, TS, & GC). This motion-time table contains motion times for grasping block-type as well as rod-type parts (on 2 separate tables) for parts scattered on a bench. Also, the table includes Grasping Times for isolated parts on a surface, prepositioned tools, and parts from a combined area. A table for Release (RL) is presented. The tables are indexed in a similar manner to the table presented in the previous example (By Dimension).

GRASP-JUMBLED PARTS IN TRAYS - J

ROD TYPE PARTS

Diameter Inches	THICKNESS OR LENGTH, INCHES										
	Limit	0.007 0.015	0.035	0.080	0.187	0.375	0.750	1.5	3.0	6.0	40.0
	Code	A	B	C	D	E	F	G	H	I	J
0.015 to 0.035	35					174	156	134	122	115	106
0.080	36				154	135	121	106	95	90	82
9/64	37	181	161	136	118	106	96	87	79	72	68
7/32	38	151	137	115	100	91	84	77	71	66	63
3/8	39	127	117	101	88	80	74	68	64	61	59
3/4	40	102	92	80	71	66	61	58	55	55	56
1.5	41	78	71	63	58	53	50	47	45	46	49
3.0	42	69	63	57	52	49	46	42	41	42	44
6.0	43	66	60	55	51	48	45	42	40	41	43

TABLE III

Sample Dimensional Motion Times Motion-Time Table

(Grasp)

(Reproduced from DMT Dimensional Motion Times Development and Application by H. C. Geppinger. New York: John Wiley and Sons, Inc., 1955, p. 17)

Data sheet DMT-4 (Position-P). This motion-time table includes two positioning time tables. The first deals with positioning a Hole to a Pin or a Pin to a Hole. The second covers the positioning of square and oblong Holes and Pins. Three other tables are presented also, namely; Directional Turn (DT), Rotate, and a table of 10 miscellaneous motions. The positioning time tables are indexed again by dimension, the others are not.

Data sheet DMT-5 (Position-PF). This motion-time table presents 4 separate tables. The first deals with positioning various parts to nests. The second and third deal, respectively, with the single or simultaneous motions of positioning a nut to a screw or a screw to a nut. The last has to do with positioning in a restricted area.

The Application of DMT

In the application of the motion-time data for an analysis of an operation, one must be quite careful that the proper table is selected for a specific basic motion. After that it is not too difficult to select the proper motion by using the dimensions of the object under consideration (only where applicable) to determine the proper time value.

It would follow then that application of DMT data requires an analyst well versed in the data and having considerable experience in same. This definitely is not a system for the novice; none of the PTS systems are, but DMT even more so. Despite the claims of the author that judgement in the selection of basic motions is all but eliminated, a look at the 5 DMT tables in the DMT textbook will convince anyone that this is so only in those tables which are indexed by dimension. The others leave a lot to be desired in the elimination of the judgement factor.

OPERATION OF BASIC MOTION TIMESTUDY (BMT)[49]

Definition and Theory of BMT

Basic Motion Timestudy is the system of predetermined time standards that is dependent upon the definition of a Basic Motion which states that such a motion has taken place when and only when a body member that has been at rest moves, and then again comes to rest. This is so even though the rest be infinitesimal in duration. This concept aids the analyst in describing consecutive motions where the breakoff point between those motions might be rather vague; such as a reach followed by a grasp.

Arbitrary terminology and vague terms have been left

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[49] Ibid. 8, pp. 4-91 to 4-100.

out of Basic Motion Timestudy. Many classifications have been described by numbers wherever possible. This, of course, helps the transfer of the data from one analyst to another with no distortion.

The BMT Basic Motions

The BMT Motion-time tables have time values which are expressed in ten-thousandths of a minute (0.0001) for ease of application.

Reach and move (R and M). No distinction is made between Reach and Move - they represent a hand moving through space with no reference to purpose.

The Reach or Move essentially refers to movements of the arms and fingers. It is here that the previously mentioned definition of basic motion enters the picture. Reach includes a grasp, and Move includes placing an object. This is so only if the hand does not stop before making the grasp etc., in which case an additional reach or move time must be given to allow for the grasping time.

Referring to Table IV on the next page it may be seen that Reach or Move time is dependent upon three factors as follows:

1. Distance body member travels.
2. Degree of muscular control needed to stop the

TIMES FOR REACHES OR MOVES

Inches	½	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	22	24	26	28	30
A	27	30	36	39	42	45	47	50	52	54	56	60	64	68	72	76	80	84	88	92	96
B	32	36	42	46	49	52	55	58	60	62	64	68	72	76	80	84	88	92	96	100	104
BV	36	42	48	53	57	60	63	66	68	70	73	77	81	85	89	93	97	101	105	109	113
C	41	48	55	60	64	68	71	74	77	79	81	86	90	94	98	102	107	111	115	119	123
CV	45	54	62	67	72	76	79	82	85	87	90	95	99	104	108	112	116	120	124	128	132

TABLE IV

Sample Basic Motion Timestudy Motion-Time Table

(Reach and Move)

(Reproduced from the McGraw-Hill Industrial Engineering Handbook, 1955, First Edition, p. 4-93)

movement. There exist three classifications here namely:

A. No muscular effort required to stop the motion.

B. The motion is stopped entirely by muscular effort.

C. The motion is stopped by contacting a surface usually with a grasping or placing action. The greatest amount of control is required here.

3. The function of the eye during the motion or Visual Direction. This depends entirely upon whether or not the eyes move while the motion which needs eye attention is being performed. If the end point may be watched, and not the body member, then no time is required for Visual Direction. This factor is used in connection with Class B and C Motions and is designated by the letter V.

Thus it may be seen that this data, the most important in the BMT system has easily identifiable units that are more or less evenly spaced in time values. Referring to Table IV on page 67 which presents the BMT Reach and Move Data, an example of its use might be the following: "Reach to a pencil 10 inches away", which would be designated by an "R10C" motion, having a time value of 81 or 0.0081 minute.

In addition to the above three factors the basic motions Reach and Move are affected by two other very important factors. These are as follows:

> 1. The precision factor (P). "In effect this is an extension of the B and C motions.....It relates to the slowing down at the end of a move while the eye directs more minute or delicate grasps or placements. The degrees of precision are described numerically by way of measured tolerances. There are five tolerance groupings ranging from 1/2 to 1/32 inch. Where the tolerance is greater than 1/2 inch, no retardation because of precision is imposed."[50]

This data is presented in a table whose distances correspond to those of the Reach-Move table so that the Precision Factor may be applied when necessary.

> 2. Simultaneous motions. "A complicating element in connection with Moves and Reaches is the possible retarding effect when motions are performed simultaneously. This does not always occur, and many simultaneous motions are performed without either being retarded. For instance, in driving a car one hand can steer while the other shifts gears, signals, or the like. It is only when the end points of both motions require visual direction and one hand has to wait for the eyes to direct the other to the end of the motion that added time is required.
>
> The extent of the added time taken for this delay is governed by two obvious factors. The first is the actual distance separating the end points of the two motions, and the second is the degree of precision required to end the motions."[51]

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50. Ibid. 8, p. 4-95.

51. Ibid. 8, p. 4-96.

The symbol for this special factor is simply listed directly below the symbol for the Reach or Move to which it pertains, along with the time as taken from the Simultaneous Motion Timetable.

> Eye time. "In addition to the slowing down of motions for eye fixation, there are frequent instances of actual cessation of motion while the eyes transfer focus from one point to another and when the new point of focus is different from the ending point of the arm motion that is delayed.
>
> The allowance for this eye time is 80, to be added each time movement is stopped for eye fixation."[52]

> Force factor. "One of the more serious retarding elements in a move occurs when it becomes necessary to overcome the effect of weight, friction, and the like. For want of a better term, this is called Force.......It is measured in terms of weight plus three broad, but practicable, groupings of distance. ..
>
> The Force factor is introduced in three phases which may occur singly or combined. Arbitrary separation into these phases is introduced to simplify analysis.
>
> 1. To apply pressure when grasping an object in order to gain control of the weight. (AP)
> 2. After control is gained, to overcome inertia and start the weight in motion. (ST)
> 3. Toward the end of a motion, to apply restraining muscular effort to overcome momentum and bring the weight to a stop. (SP)
>
> Thus when a motion consists of picking up, moving and placing an object of significant

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[52] Ibid. 8, p. 4-96.

> weight, all the time phases of the Force factor are present."[53] (Parenthesis added)

> Turn (T). "......Turn represents a specialized phase of the 'Move and Reach' motions requiring higher time values for corresponding distances because of differences in the degree of control required."[54]

The Turn timetable is indexed by the number of degrees of the turn and the classifications A, B, BV, C, and CV, which apply in the same manner as for the Reach and Move Timetable.

Body motions. Body motions are those performed by the trunk or legs, and may be complementary to arm motions or may occur as completely separate and distinct motions. The latter case includes both motions which may be performed as separate units over a range of distances, as well as those which have no range of distance but are performed in the same manner each time.

The BMT Body Motions together with their symbols are as follows:

1. Foot Motion (FM)
2. Leg Motion (LM)
3. Side Step (SS)

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[53] Ibid. 8, pp. 4-96 to 4-97.

[54] Ibid. 8, p. 4-97.

4. Walking (W)
5. Turn Body (TB)
6. Bend (B)
7. Stoop (S)
8. Kneel (K)
9. Arise (A)
10. Sit (SIT)
11. Stand (STAND)

Application of BMT

Concerning the application of BMT, the author of the system puts out a few words of warning pertaining to its limitations and use:

> There do exist certain operations such as motions which require extreme care or balance etc. that are not covered by the BMT Timetables. However, it is pointed out that such motions are negligible in the total work picture.
>
> BMT is not a formula which may be applied by plugging in numbers. Those who use BMT must have training, skill, experience and imagination in its application.

SUMMARY

Chapter II was written with the intent of familiarizing the reader with the systems of predetermined time standards, so that he might have an appreciation of how they function, and how they are applied to an industrial operation.

It was also considered important to acquaint the reader with the thinking that preceded the conception of each of these predetermined time systems, so that he would acquire a basic understanding of the theory upon which each system is based.

Again, much more detailed data as well as descriptions of data, than is presented in Chapter II must be sought if the reader is contemplating the use of any of the mentioned systems. Training and experience are uppermost in importance as concerns the application of such a system. Chapter II presents but a general survey of the operation of the most notable of the predetermined time systems, so that the reader can better understand the analyses as set forth in the next chapter.

CHAPTER III

THE ANALYSIS OF A SELECTED INDUSTRIAL OPERATION USING THE PREDETERMINED TIME SYSTEMS

SELECTION OF THE PREDETERMINED TIME SYSTEMS TO BE USED IN THE ANALYSIS OF THE OPERATION, "MAKE CARTONS"

The Predetermined Time Systems that were selected for analyzing the operation "Make Cartons" are presented in this paper as follows:

1. Work-Factor
2. Methods-Time Measurement (MTM)
3. Basic Motion Timestudy

A first consideration was the relative popularity of the systems. It is here that MTM and Work-Factor are essentially keeping abreast of one another, even though Work-Factor had better than a 10 year start on MTM. Each system has received considerable representation in the form of articles in the leading industrial magazines. Segur's system of Motion-Time Analysis, though the oldest of the systems of predetermined time standards, has received little publicity due to the fact that his work was highly secretive until recently. Basic Motion Timestudy and Dimensional Motion Times have not been available long enough to rate as much publicity as the others.

Secondly, ease of understanding the application of the systems was considered, both from the standpoint of the analyst and the people whom the study would subsequently affect. MTM and Work-Factor are quite straightforward in their operation, and the convention or symbols used in the analysis are clearly indicative of their meaning. Basic Motion Timestudy, in the author's opinion, is the simplest of the systems to apply because the variables seem to be cut to an absolute minimum. Here too, the symbols used in the analysis are indicative of their meaning. Motion-Time-Analysis is relatively simple to understand, but one must write the entire operation out in longhand as no symbols exist for the basic motions.

In addition MTA, by its author's admission is being primarily used in the industrial scene today as a "Means of methods control". Dimensional Motion Times is quite complicated, as can be seen by examining the five motion-time tables as they appear in Geppinger's text, "DMT Dimensional Motion Times, Development and Application". Many miscellaneous motions exist (at least 50) which involve judgement on the part of the analyst in their usage. It must be said, however, that the grasping and positioning motion-time tables, among others, go a long way in eliminating judgement since they are indexed in the dimensions of the object only. DMT symbols, using a dimensional coding system, are in general not too indicative, as such, of the nature of the basic motion represented by the symbol.

Lastly, it would appear that Dimensional Motion Times, as previously discussed is not universally applicable to all operations, in the same sense of the word, as are the other systems of predetermined time standards. DMT is at its most practical state of usage when it is being used to analyze small, repetitive assembly operations having a fixed workplace and few variations in material conditions.

In the author's opinion, Work-Factor, MTM, and BMT are readily comprehensible, have the greatest breadth of application, and will likely continue to be the most popular systems of predetermined times. Thus, these will be used in the analyses set forth on the following pages.

THE NATURE OF THE ELEMENTAL ANALYSIS

The first step in the elemental analysis of an industrial operation was to find such an operation which "ran the gamut" of the basic or fundamental motions so that each would be covered in the elemental analysis, as well as the comparative and composite analyses which follow in the next chapter. Any operation which did not cover most of the basic motions would be of no value to this paper. The operation, "Make Cartons" meets this requirement.

In addition, the time study element descriptions of the operation "Make Cartons" are presented, along with illustrations, so that the reader might be able to familiarize himself with the operation as it exists. This, of course, is followed up by the actual elemental analysis of "Make Cartons" through use of Work-Factor, MTM and BMT. Incidentally, the MTM convention for crossing out and/or circling non-limiting motions has been used on all analysis sheets because of the ease of understanding it affords.

SHOE WELTING OPERATION - OPERATIONAL DESCRIPTION

This operation is limited to the packaging of coils of plastic shoe welting of various colors and styles into cardboard cartons. The coils of shoe welting are approximately 10" in diameter and 10" in height. An electric truck brings the shoe welting from the production unit into the packaging area, stacked 4-5 high on wooden skids. Please refer to Figure 3, page 85 for the layout of the shoe welting packaging area.

The following is a step-by-step analysis of the operations involved:

1. "Make Cartons"

This operation refers to opening the flat cartons, and stapling one end of same. Usually 8-10 cartons are made up before proceeding to the next operation.

2. "Line up Cartons on White Line"

After the cartons have been stapled they are lined up at the white line as per Figure 3, page 85. The purpose of doing this is to enable the operator to seal the open ends of the cartons with the compressed air stapler that runs overhead on a rail.

3. "Load Shoe Welting in Cartons"

It is here that the operator turns toward the skids of shoe welting, picks up one coil and places it in the carton, after which another is placed on top of it in the same manner. All boxes are filled in the same way.

4. "Staple Ends of Cartons"

Next the ends of the cartons are folded over one at a time, and sealed with the compressed air stapler which runs on an overhead rail.

5. "Label Cartons"

In this operation the pre-glued labels are run over a water-soaked brush to moisten and are placed on each individual carton top.

6. "Get Skid"

The operator pulls a skid from storage and places it in front of the sealed boxes.

7. "Load Cartons on Skid"

The operator walks toward, picks up and sets a finished carton of shoe welting on the skid. This is repeated until all boxes are loaded.

8. "Write Order Information on Carton"

This operation refers to the identification of the order and number of cartons by writing that information on one conspicuous carton with a black crayon.

9. "Store Skid"

The final operation as concerns the operator is that of procuring a hand electric platform truck and moving the finished skid of shoe welting to a storage area where it remains until shipped.

Next will be presented the detailed element descriptions and time study values of the sub-operation "Make Cartons" as presented in this section. This sub-operation is the one which has been selected for analysis by the three predetermined time systems.

ELEMENT DESCRIPTIONS OF SUB-OPERATION I. "MAKE CARTONS"

The following is a series of complete element descriptions for the operation "Make Cartons" which is to be subsequently analyzed by the three predetermined time systems as discussed earlier. Please refer to Figure 3, page 85, the layout of the stapling operation.

Also included with each element description is the base time in minutes for that element as determined by time study. Each value as set forth represents at least 50 time study observations of an experienced normal operator. Leveling of the values never dropped below 90% nor above 110%. It is the opinion of the author that said values are quite accurate.

Element 1: Pick up Carton

A. Time Study Base Time Value - .07 minutes

B. Element Description - The element begins as the operator turns away from the completed cartons to the right of the stapling machine and walks toward the unopened cartons. He grasps one carton with the left hand, and the element ends as he reaches to the carton and grasps it with his right hand.

Element 2: Open Carton and Fold Ends

A. Time Study Base Time Value - .10 minutes

B. Element Description - Element begins as operator moves edge of carton towards floor so he may regrasp and gain better control. He then proceeds to open the carton by exerting pressure on the flaps with his thumbs. After the carton is opened, the operator sets it in front of him, and folds the flaps down. The element ends as the operator regrasps the carton end while holding the flaps down.

Element 3: Place Carton on Stapler

A. Time Study Base Time Value - .06 minutes

B. Element Description - Element begins as the operator raises the carton from the floor and moves it to the stapler. He then places the carton on part "A" of the stapler as per Figure 2, page 84. The element ends as the top left hand corner of the carton is resting on part "A" of the stapler.

<u>Element 4: Staple Carton Ends</u>

A. Time Study Base Time Value - .13 minutes

B. Element Description - Element begins as the foot moves toward the foot pedal. The operator then proceeds to staple the end of the carton (16 staples) following the motion path shown in Figure 2, page 84. The machine continues to staple as long as the foot is depressed, hence the stapling time for each row of 6 staples (1 to 2 and 7 to 8) has been designated as "USE" or process machine time. This part of the element was determined by time study to be .03 minutes per row, and naturally was not analyzed by the predetermined time standards. (The values have been, however, included in the analysis to make it more realistic). The element ends as the foot completely releases the foot pedal and is placed to rear of operator on floor. (Part "A" of machine automatically returns to a 45° position).

<u>Element 5: Set Carton Aside</u>

A. Time Study Base Time Value - .06 minutes

B. Element Description - Element begins as the operator reaches to the upper left hand corner of the carton, and turns it 90 degrees on part "A" of machine to facilitate removal. Carton is then removed and turned right side up as the operator turns his body and steps toward completed cartons. Element ends as the left hand places the completed carton on the floor.

The next step in this analysis will be the application of MTM, Work-Factor and BMT to the elements as described above. Please refer to the element descriptions as presented and the illustrations, Figures 1 to 3, pages 83 to 85, for a clarification of the analyses as they follow.

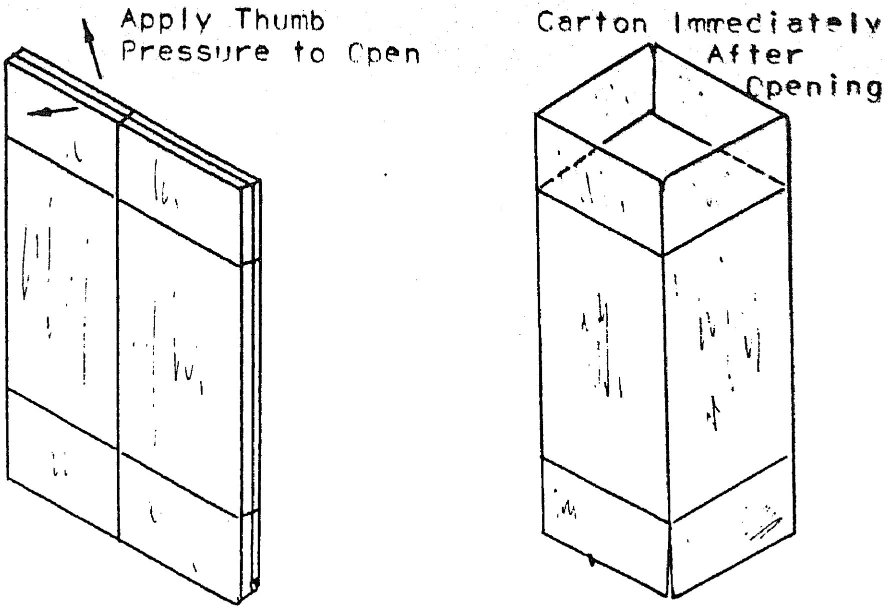
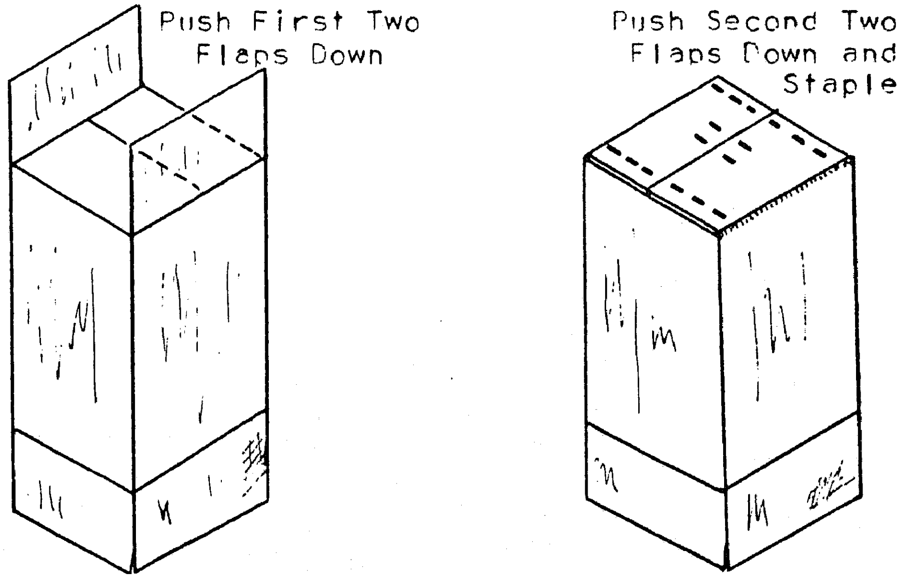


FIGURE 1

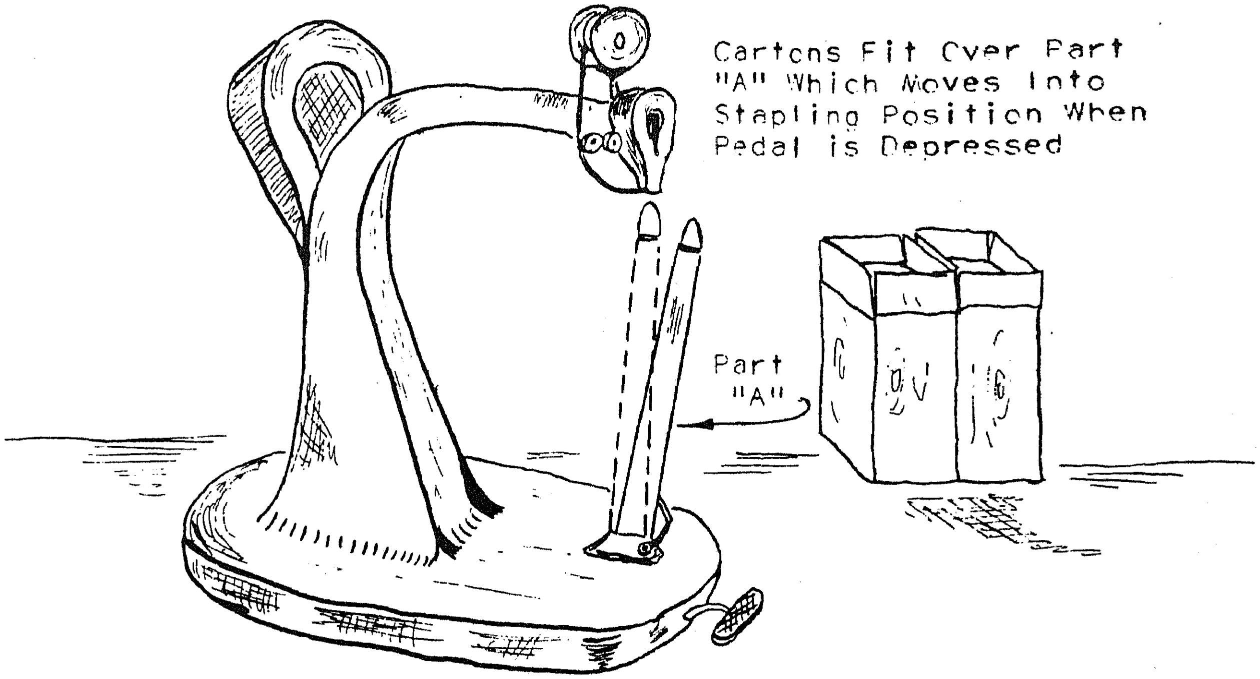
Basic Steps in the Opening and

Subsequent Stapling of the Carton



Carton Dimensions: 11" x 11" x 21"

Flap Dimensions: 5½" x 11"

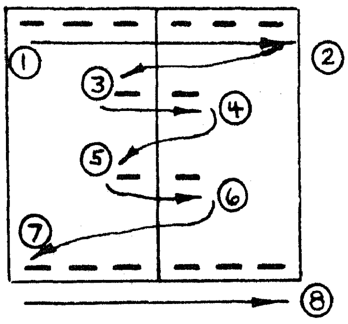


Cartons Fit Over Part "A" Which Moves Into Stapling Position When Pedal is Depressed

Acme "Silver Stitcher"

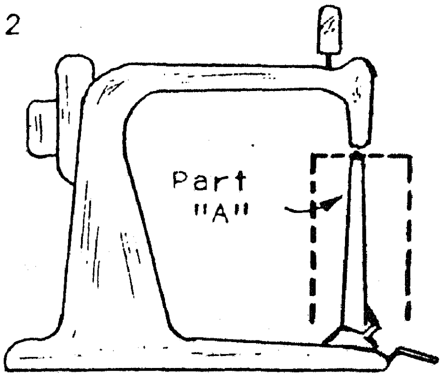
Stapling Machine

FIGURE 2



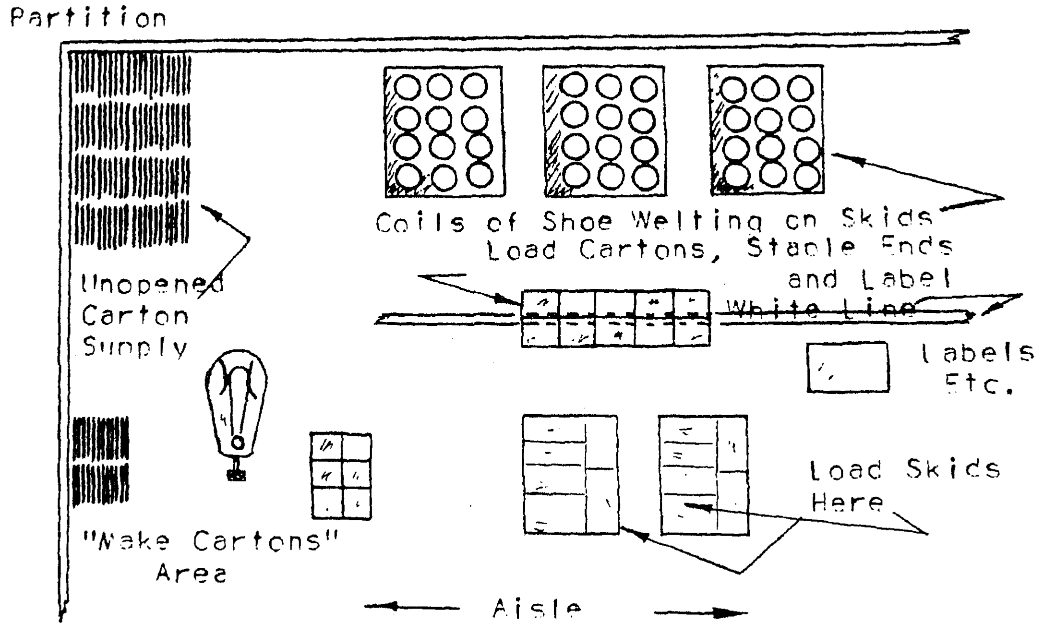
Carton: Top View

16 Staples Showing Motion Path Followed in the Operation. (Indexed as per the Element Analysis Sheets)



Carton in Stapling Position

NOTE: Stapling Machine Keeps Running As Long As Pedal is Depressed



ABOVE: Shoe Welting Operation - Complete Layout

BELOW: Stapling Operation (Make Cartons) - Layout

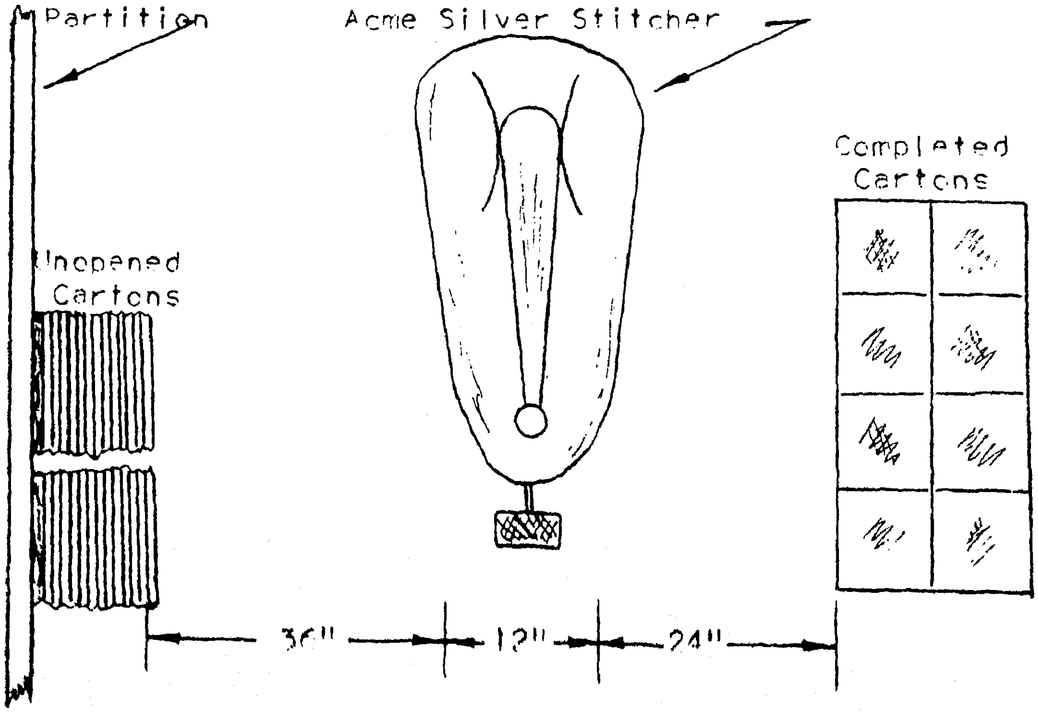


FIGURE 5

WORK-FACTOR ELEMENT ANALYSIS

ELEMENT 1: Pick Up Carton

	LEFT HAND			Cumulative Time		RIGHT HAND			
	Elemental Description	Motion Analysis	Elem Time			Elem Time	Motion Analysis	Elemental Description	
				100	100	100	From Walking Time	135° Turn Preceding Walk	1
				360	360	260	Table	Walk 2 Paces Toward Carton Storage	2
3	Reach for Unopened Carton & Contact Carton With Forefinger	A6SD CT-GR	60 0	420 420	- -	- -	- -	Wait Wait	
4	Pull Carton Against Palm of Hand	A2	20		-	-	-	Wait	
	Pinch Grasp the Carton	A1D ½ FI	26 8	474	474	114	BD	Wait	
	Move Carton to Front of Body	A1~~2~~D	6~~5~~	587 650 - -	587 650 - -	113 63 4~~7~~ ~~8~~	L18WW L18 A6D ½ FI	Move 1st Ft. } Side Step 18" Move 2nd Ft. Reach to Flap of Carton Grasp Flap of Carton	5

TOTAL TIME = .0650 MINUTES

NOTES: The Work-Factor Motion Time Tables used for this analysis may be found in The Industrial Engineering Handbook published by The McGraw-Hill Book Co., Inc., 1956. (Chapter 4, p. 51)
All elementals are indexed (right and left) by number so the discussion may be easily followed.

WORK-FACTOR ELEMENT ANALYSIS

ELEMENT 2: Open Carton and Fold Ends

	LEFT HAND			Cumulative Time		RIGHT HAND			
	Elemental Description	Motion Analysis	Elem Time			Elem Time	Motion Analysis	Elemental Description	
1	Place Edge of Carton on Floor	A3D	32	32	32	32	A3D	Place Edge of Carton on Floor	1
2	Release Flap by Opening Fingers	½ FI	8	40	–	–	–	Hold	
3	Slide Thumb 3" Grasp Flap-Separate Edges, Close Thumb and Fingers	A3D FI FI	32 16 16	72 88 104	– – 104	– – 72	– – BD	Hold Hold Hold	
	Hold	BD	32	136	136	32	2FI	Regrasp Flap	4
5	Open Carton Pick Carton off Floor	A7WW ~~A6~~	65 ~~32~~	201 –	201 –	65 ~~32~~	A7WW ~~A6~~	Open Carton Pick Carton off Floor	5
6	Move Carton Against Body	A3	22	223	223	22	A3	Move Carton Against Body	6
7	"Overfold Carton"	A8WWD	84	307	307	84	A8WWD	"Overfold Carton"	7
8	Set Carton on Floor Orient Carton in Front of Body Simo with Move	A14D	69	376	376	69	A14D	Set Carton on Floor Orient Carton in Front of Body Simo with Move	8
	Hold	–	–	–	384	8	½ FI	Release Flap	9

ELEMENT 2: (Continued)

	LEFT HAND			Cumulative Time		RIGHT HAND			
	Elemental Description	Motion Analysis	Elem Time			Elem Time	Motion Analysis	Elemental Description	
	Hold	–	–	–	431	47	A6D	Reach to Right Hand Flap	10
	Hold	BD	63	439	439	8	½ F1	Pinch Grasp Flap	
11	Push Flap Down	A8D	54	493	493	54	BD	Hold	
	Reach to Left Corner	A1D	~~26~~	–	547	54	A8D	Push Flap Down	12
	Grasp Left Corner of Carton	F2	~~26~~	–	–	–	–		
	Hold	–	–	–	579	32	A3D	Slide Hand to Right Corner	13
	Hold	BD		595	595	16	F1	Grasp Right Corner of Carton	
	Hold as Pivot	A3D	~~28~~	660	660	65	A12D	Twist Carton 90°	14
15	Reach to Left Flap	A8	38	698	–	–	–	Hold	
	Contact Grasp	CT-GR	0	698	–	–	–	Hold	
16	Push Flap Down	A8D	54	752	752	157	BD	Hold	
	Hold	–	–	–	790	38	A8	Reach to Right Flap	17
	Hold	–	–	–	790	0	CT-GR	Contact Grasp	
	Hold	BD	92	844	844	54	A8D	Push Flap Down	18
19	Regrasp Carton	A3D	32			32	A3D	Regrasp Carton	19
		F1	16	892	892	16	F1		

TOTAL TIME = .0892 MINUTES

WORK-FACTOR ELEMENT ANALYSIS

ELEMENT 3: Place Carton on Stapler

	LEFT HAND			Cumulative Time		RIGHT HAND			
	Elemental Description	Motion Analysis	Elem Time			Elem Time	Motion Analysis	Elemental Description	
				-	79	79	T8D	Straighten Trunk	1
	Move Carton to Stapler	A5~~0~~D	1~~2~~2	-	196 263 -	117 67 1~~2~~2	L20WW L20 A~~5~~0D	Move 1st Ft. } Side Move 2nd Ft. } Step 20" Move Carton to Stapler	2
3	Clear Part "A"	A6D	47	310	310	47	A6D	Clear Part "A"	3
4	Position Far Left Corner over "A"	A8SD	70	380	380	70	A8SD	Position Far Left Corner over "A"	4
5	Move Carton Down on "A"	A26D	90	470	470	90	A26D	Move Carton Down on "A"	5
6	Push Carton Till Flush on "A"	A2	20	490	490	20	BD	Hold	

TOTAL TIME = .0490 MINUTES

WORK-FACTOR ELEMENT ANALYSIS

ELEMENT 4: Staple Carton Ends

	LEFT HAND			Cumulative Time		RIGHT HAND			
	Elemental Description	Motion Analysis	Elem Time			Elem Time	Motion Analysis	Elemental Description	
				88	88	88	L18D	Move Foot to Foot Pedal	1
				143	143	55	L4PD	Step on Pedal	2
3	Assist Right*	–	300 –	443 –	443 –	300 ~~30~~	– – ~~L1D~~	Use (Process Time)* Staple End (6) by Moving Carton to Right Release Foot	3
4	Move Carton From (2) to (3)	A7SD	65	508	508	65	A7SD	Move Carton From (2) to (3)	4
			39	547	547	39	L1PD	Step on Pedal	5
6	Move Carton From (3) to (4)	A2SD	37	584 –	584 –	37 ~~30~~	A2SD ~~L1D~~	Move Carton From (3) to (4) (Staple) Release Foot Pressure Slightly	6
7	Move Carton From (4) to (5)	A5SD	55	639	639	55	A5SD	Move Carton From (4) to (5)	7

* 300 = Time Study Value
BD = Balancing Delay

ELEMENT 4: (Continued)

LEFT HAND				Cumulative Time		RIGHT HAND			
	Elemental Description	Motion Analysis	Elem Time			Elem Time	Motion Analysis	Elemental Description	
			39	678	678	39	L1PD	Step on Pedal	8
9	Move Carton From (5) to (6)	A2SD	37 -	715 -	715 -	37 ~~30~~	A2SD ~~L1D~~	Move Carton From (5) to (6) (Staple) Release Foot Pressure Slightly	9
10	Move Carton From (6) to (7)	A6	32	747	747	32	A6	Move Carton From (6) to (7)	10
				786	786	39	L1PD	Step on Pedal	11
12	Use (Staple)*	-	300	1086	1086	300	-	Use (Staple)*	12
				1174	1174	88	L18D	Replace Foot on Floor	13

* 300 = Time Study Value

TOTAL TIME = .1174 MINUTES

WORK-FACTOR ELEMENT ANALYSIS

ELEMENT 5: Set Carton Aside

	LEFT HAND			Cumulative Time		RIGHT HAND			
	Elemental Description	Motion Analysis	Elem Time			Elem Time	Motion Analysis	Elemental Description	
1	Reach to Corner of Carton Grasp Carton	A8D F1	54 16	54 70	- 70	- 70	- BD	Wait Wait	
2	Turn Carton 90° on Pin "A"	A10D	61	131	131	~~32~~	2F1	Regrasp Carton (Simo)	
3	Pull Carton off "A"	A30D	96	227	227	96	A30D	Pull Carton off "A"	3
4	Turn Carton 90° (Wrist Movement)	FS90D	~~30~~	292	292	65	A12D	Turn Carton 90° (Arm Movement)	4
	Hold Hold	- BD	- 95	- 387	368 387	76 19	A18D F3	Reach to Flap Grasp Flap (Wrap Around)	5
6	Move Arm Out From Under Carton (Controlling)	A14D	69	456	456	~~37~~	FS90WD	Wrist Turns 90° as Carton Falls Using Flap as Pivot (Simo)	6
						~~100~~ ~~126~~	~~Walk Table~~ ~~L24WW~~	135° Turn Preceding Walk Walk 1 Pace to Finished Cartons*	

* See Note Next Page

ELEMENT 5: (Continued)

LEFT HAND			Cumulative Time		RIGHT HAND			
Elemental Description	Motion Analysis	Elem Time			Elem Time	Motion Analysis	Elemental Description	
Wait	–	–	–	517	61	AICD	Set Carton on Floor	7
Wait	BD	69	525	525	8	½ FI	Release Carton	8

NOTE: Turn and Walk Limited Out By Elementals 4, 5, 6, 7.

TOTAL TIME = .0525 MINUTES

MTM ELEMENT ANALYSIS

ELEMENT 1: Pick Up Carton

	Description - Left Hand	*	Motion	TMU	Motion	*	Description - Right Hand	
				18.6	TBC1	✓	Turn Away From Finished Cartons	1
				30.0	W-2P	✓	Walk Toward Carton Storage	2
3	Reach For Unopened Carton Contact Carton With Forefinger	✓ ✓	R6D G5	10.1 0				
4	Pull Carton Against Palm of Hand Regrasp the Carton	✓ ✓	M3A G1A	5.3 2.0				
	Move Carton to Front of Body		M12A	40.7 ~~12.9~~	SS-C2 ~~R6A~~ ~~G1B~~	✓	Side Step 18", Close to Front of Stapler Reach to Flap of Carton Grasp Flap of Carton	5

TOTAL TMU = 106.7
TOTAL TIME = .0640 MINUTES

* Limiting Motion

NOTES: The MTM Motion-Time Tables used for this analysis may be found in the Industrial Engineering Handbook published by the McGraw-Hill Book Co., Inc., 1956. (Chapter 4, pp. 19-21)
All elementals are indexed (right and left) by number so the discussion may be easily followed.

MTM ELEMENT ANALYSIS

ELEMENT 2: Open Carton and Fold Ends

	Description - Left Hand	*	Motion	TMU	Motion	*	Description - Right Hand	
1	Place Edge of Carton on Floor		M3A	4.9	M3A	✓	Place Edge of Carton on Floor	1
2	Release Flap by Opening Fingers	✓	RL1	2.0				
3	Slide Thumb 3" Grasp Flap	✓ ✓	R3B G2	5.3 5.6				
				5.6	G2	✓	Regrasp Flap	4
5	Push Flaps Away from Body to Open Carton Pick Carton Up Off Floor Open Carton		AP-2 ~~M6A~~ M7A	10.6 ~~8.1~~ 8.9	AP-2 ~~M6A~~ M7A	✓ ✓	Push Flaps Away from Body to Open Carton Pick Carton Up Off Floor Open Carton	5
6	Move Carton Against Body		M3A	4.9	M3A	✓	Move Carton Against Body	6
7	"Overfold Carton"		mM8B AP-2	7.2 10.6	mM8B AP-2	✓	"Overfold Carton"	7
8	Set Carton on Floor Orient Carton in Front of Body		M14A ~~M3B~~	14.4 ~~5.7~~	M14A ~~M3B~~	✓	Set Carton on Floor Orient Box in Front of Body	8
				2.0	RL1	✓	Release Far Flap	9

ELEMENT 2: (Continued)

	Description - Left Hand	*	Motion	TMU	Motion	*	Description - Right Hand	
				8.9 2.0	R6B GIA	✓ ✓	Reach to Right Hand Flap Grasp End of Flap	10
11	Push Flap Down	✓	M8A	9.7				
	Reach to Lower Left Corner Grasp Left Corner of Carton		RIA GIA	9.7 -	M8A	✓	Push Flap Down	12
				5.3 2.0	R3A GIA	✓ ✓	Slide Hand Towards Upper Right Hand Corner Grasp Upper Right Corner of Carton	13
	Hold as Pivot		M3B	13.4	M12B	✓	Twist Carton 90°	14
15	Reach to Flap on Left Contact Grasp	✓	R8Am ~~G5~~	6.5 ~~0~~				
16	Push Flap Down	✓	M8A	9.7				
				6.5 0	R8Am G5	✓ ✓	Reach to Right Flap Contact Grasp	17
				9.7	M8A	✓	Push Flap Down	18
19	Regrasp Carton		R3A RIA	5.3 2.5	R3A RIA	✓ ✓	Regrasp Carton	19

* Limiting Motion

TOTAL TMU = 173.2
TOTAL TIME = .1039 MINUTES

MTM ELEMENT ANALYSIS

ELEMENT 3: Place Carton on Stapler

	Description - Left Hand	*	Motion	TMU	Motion	*	Description - Right Hand	
							Straighten Trunk (See Discussion)	1
	 Move Carton to Stapler		 ~~M50B~~	42.9 ~~36.4~~	SS-C2 ~~M50B~~	✓	Step to Front of Stapler 20" Move Carton to Stapler	2
3	Clear Part "A"		M6B	8.9	M6B	✓	Clear Part "A"	3
4	Position Far Left Corner Over "A"		PISSD	14.7	PISSD	✓	Position Far Left Corner Over "A"	4
5	Move Carton Down on "A"		M26B	21.8	M26B	✓	Move Carton Down on "A"	5
6	Push Carton Till Flush on "A"	✓	M2A	3.6				

* Limiting Motion

TOTAL TMU = 91.6
TOTAL TIME = .0551 MINUTES

MTM ELEMENT ANALYSIS

ELEMENT 4: Staple Carton Ends

	Description - Left Hand	*	Motion	TMU	Motion	*	Description - Right Hand	
				21.5	LM-18	✓	Move Foot to Foot Pedal	1
				7.1	LM-4	✓	Step on Pedal	2
3	Assist Right Hand[x]			50.0			Process Time[x]: Staple End (6) by Moving Carton to Right	3
4	Move Carton from (2) to (3)		M7C	11.1	M7C	✓	Move Carton from (2) to (3)	4
				7.1	LM-1	✓	Step on Pedal	5
6	Move Carton from (3) to (4)		M2C	5.2	M2C	✓	Move Carton from (3) to (4) (Staple)	6
7	Move Carton from (4) to (5)		M5C	9.2	M5C	✓	Move Carton from (4) to (5)	7
				7.1	LM-1	✓	Step on Pedal	8
9	Move Carton from (5) to (6)		M2C	5.2	M2C	✓	Move Carton from (5) to (6) (Staple)	9

[x] 50TMU = Time Study Value

ELEMENT 4: (Continued)

	Description - Left Hand	*	Motion	TMU	Motion	*	Description - Right Hand	
10	Move Carton from (6) to (7) Against "A"		M6A	8.1	M6A	✓	Move Carton from (6) to (7) Against "A"	10
				7.1	LM-1	✓	Step on Pedal	11
12	Process Stapling Time^{x}		-	50.0	-		Process Stapling Time^{x}	12
				21.5	LM-18	✓	Replace Foot on Floor	13

x 50TMU = Time Study Value

* Limiting Motion

TOTAL TMU = 210.2
TOTAL TIME = .1261 MINUTES

MTM ELEMENT ANALYSIS

ELEMENT 5: Set Carton Aside

	Description - Left Hand	*	Motion	TMU	Motion	*	Description - Right Hand	
1	Reach to Corner of Carton and Grasp	✓ ✓	R8B G1A	10.1 2.0				
2	Turn Carton 90° on Pin "A"	✓	M10B	12.2	G2		Regrasp Carton	
3	Pull Carton Off "A"		M30B	24.3	M30B	✓	Pull Carton Off "A"	3
4	Turn Carton 90° (Wrist Movement)		T90S	13.4	M12B	✓	Turn Carton 90° (Arm Movement)	4
				12.3 2.0	R18A G1A	✓ ✓	Reach to Flap Grasp Flap	5
6	Move Arm out from under Carton	✓	M14E	13.0	T90M		Wrist Turns 90° as Carton Falls Using Flap as Pivot	6
				~~18.6~~ ~~15.0~~	~~TBC1~~ ~~W-1P~~		Step to Finished Cartons	
				11.3	M10A	✓	Set Carton on Floor	7
				2.0	RL1	✓	Release Carton	8

NOTE: Step to Finished Cartons Limited Out By Elementals 4, 5, 6, 7.

* Limiting Motion

TOTAL TMU = 102.6
TOTAL TIME = .0616 MINUTES

BMT ELEMENT ANALYSIS

ELEMENT 1: Pick Up Carton

	Motion Description-Left Hand	*	Code	Motion Times	Code	*	Motion Description-Right Hand	
				110	TB	✓	Turn Away from Finished Cartons	1
				200	W-2	✓	Walk Toward Carton Storage	2
3	Reach for Unopened Carton and Contact Grasp	✓	R6CV	79				
4	Forefinger Pull Carton Against Palm and Regrasp the Carton	✓	M3A	39				
	Move Carton to Front of Body		M12B	168 ~~71~~ ~~9~~	SS2 ~~R6C~~ ~~P½~~	✓	Sidestep 18", Close to Front of Stapler Reach to Flap of Carton Grasp Flap of Carton	5

TOTAL TIME = 596 OR .0596 MINUTES

* Limiting Motion

NOTES: The BMT Motion-Time Tables used for this analysis may be found in the Industrial Engineering Handbook published by The McGraw-Hill Book Co., Inc., 1956. (Chapter 4, pp. 93-98)
All elementals are indexed (right and left) by number so that the discussion may be easily followed.

BMT ELEMENT ANALYSIS

ELEMENT 2: Open Carton and Fold Ends

	Motion Description-Left Hand	*	Code	Motion Times	Code	*	Motion Description-Right Hand	
1	Place Edge of Carton on Floor		M3C	60	M3C	✓	Place Edge of Carton on Floor	1
2	Release Flap by Opening Fingers	✓	R½B	32				
3	Slide Thumb 3" Grasp Flap	✓ ✓	R3C P½	60 6				
				41	R½C	✓	Regrasp Flap	4
5	Push Flaps Away from Body to Open Carton Pick Carton Up Off Floor		AP-10 ST-10 M7A ~~M6A~~	13 13 50 ~~47~~	AP-10 ST-10 M7A ~~M6A~~	✓ ✓ ✓	Push Flaps Away from Body to Open Carton Pick Carton Up Off Floor	5
6	Move Carton Against Body		M3A	39	M3A	✓	Move Carton Against Body	6
7	"Overfold Carton"		M8A AP-10 ST-10	52 13 13	M8A AP-10 ST-10	✓ ✓ ✓	"Overfold Carton"	7
8	Set Carton on Floor Orient Carton in Front of Body		M14C ~~M3B~~	90 ~~49~~	M14C ~~M3B~~	✓	Set Carton on Floor Orient Carton in Front of Body	8
				32	R½B	✓	Release Far Flap by Opening Fingers	9

ELEMENT 2: (Continued)

	Motion Description-Left Hand	*	Code	Motion Times	Code	*	Motion Description-Right Hand	
				71	R6C	✓	Reach to Right Hand Flap and Grasp	10
11	Push Flap Down	✓	M8A	52				
	Reach to Lower Left Corner and Grasp		R1C	52	M8A	✓	Push Flap Down	12
				60	R3C	✓	Slide Hand to Right Corner and Grasp	13
	Hold as Pivot		M3B	68	M12B	✓	Twist Carton 90°	14
15	Reach to Left Flap (Contact Grasp)	✓	R8A	52				
16	Push Flap Down	✓	M8A	52				
				52	R8A	✓	Reach to Right Flap (Contact Grasp)	17
				52	M8A	✓	Push Flap Down	18
19	Regrasp Carton		R4A	42	R4A	✓	Regrasp Carton	19

* Limiting Motion

TOTAL TIME = 1,067 OR .1067 MINUTES

BMT ELEMENT ANALYSIS

ELEMENT 3: Place Carton on Stapler

	Motion Description-Left Hand	*	Code	Motion Times	Code	*	Motion Description-Right Hand	
							Straighten Trunk (See Discussion)	1
	Move Carton to Stapler		M50B	176 144	SS2 M50B	✓	Step to Front of Stapler 20" Move Carton to Stapler	2
3	Clear Part "A"		M6B	55	M6B	✓	Clear Part "A"	3
4	Position Far Left Corner Over "A"		M8CV	85	M8CV	✓	Position Far Left Corner Over "A"	4
5	Move Carton Down On "A"		M26B	96	M26B	✓	Move Carton Down On "A"	5
6	Push Carton Till Flush On "A"	✓	M2A	36				

* Limiting Motion

TOTAL TIME = 448 OR .0448 MINUTES

BMT ELEMENT ANALYSIS

ELEMENT 4: Staple Carton Ends

	Motion Description-Left Hand	*	Code	Motion Times	Code	*	Motion Description-Right Hand	
				74	LM-18	✓	Move Foot to Foot Pedal	1
				50	LM-4	✓	Step on Pedal	2
3	Assist Right Hand^{x}		–	300	–		Process Time^{x}: Staple End (6) by Moving Carton to Right	3
4	Move Carton from (2) to (3)		M7C	74	M7C	✓	Move Carton from (2) to (3)	4
				50	LM-1	✓	Step on Pedal	5
6	Move Carton from (3) to (4)		M2C	55	M2C	✓	Move Carton from (3) to (4)	6
7	Move Carton from (4) to (5)		M5C	68	M5C	✓	Move Carton from (4) to (5)	7
				50	LM-1	✓	Step on Pedal	8
9	Move Carton from (5) to (6)		M2C	55	M2C	✓	Move Carton from (5) to (6)	9
10	Move Carton from (6) to (7) (Against "A")		M6A	47	M6A	✓	Move Carton from (6) to (7) (Against "A")	10
				50	LM-1	✓	Step on Pedal	11
12	Process Stapling Time^{x}		–	300	–		Process Stapling Time^{x}	12
				74	LM-18	✓	Replace Foot on Floor	13

^{x} 300 = Time Study Value
* Limiting Motion

TOTAL TIME = 1,247 OR .1247 MINUTES

BMT ELEMENT ANALYSIS

ELEMENT 5: Set Carton Aside

Motion Description-Left Hand		*	Code	Motion Times	Code	*	Motion Description-Right Hand	
1	Reach to Corner of Carton and Grasp	✓	R8C	77				
2	Turn Carton 90° on Pin "A"	✓	M10B	64	R2A		Regrasp Carton	
3	Pull Carton Off "A"		M30B	104	M30B	✓	Pull Carton Off "A"	3
4	Turn Carton 90° (Wrist Movement)		T90B	68	M12B	✓	Turn Carton 90° (Arm Movement)	4
				98	R18C	✓	Reach to Flap and Grasp	5
6	Move Arm Out From Under Carton	✓	M14B	72	T90B ~~SP-5~~		Wrist Turns 90° as Carton Falls Using Flap as Pivot	6
				~~110~~ ~~100~~	~~TB1~~ ~~W-1~~		Step to Finished Cartons	
				81	M10C	✓	Set Carton on Floor	7
				32	R½B	✓	Release Carton by Opening Fingers	8

NOTE: Step to Finished Cartons Limited Out By Elementals 4, 5, 6, 7.

* Limiting Motion

TOTAL TIME = 596 OR .0596 MINUTES

"MAKE CARTON" Listing Of Elements	ELEMENTAL BASE TIME VALUES (MIN), OBTAINED BY			
	TIME STUDY	WORK FACTOR	MTM	BMT
Element 1: Pick Up Carton	.07	.0650	.0640	.0596
Element 2: Open Carton & Fold Ends	.10	.0892	.1039	.1067
Element 3: Place Carton on Stapler	.06	.0490	.0551	.0448
Element 4: Staple Carton Ends	.13	.1174	.1261	.1247
Element 5: Set Carton Aside	.06	.0525	.0616	.0596
TOTAL TIME (MIN.)	.42	.3731	.4107	.3954

TIME VALUE SUMMARY SHEET

TABLE V

SUMMARY

This chapter had as its basic purpose nothing more than presenting and analyzing by predetermined time systems the industrial operation that was selected by reason of the fact that it pretty well "ran the gamut" of fundamental motions as set forth by those systems. (86% of the general fundamental motion classifications of Work-Factor, 78% of those of MTM and 71% of those of BMT were used in this analysis).

The description of the operation is accomplished first through a presentation of the background of the overall job from which the operation is taken. Next, the operation itself is fully described by five detailed element descriptions and the presentation of time study values for each.

Secondly, the actual analysis of each element by Work-Factor, MTM and BMT respectively is set forth on the appropriate analysis sheets which bring out the nature and time value of each of the fundamental motions (elementals) which make up each separate element. The predetermined time analyses as well as the element descriptions have been supplemented by a series of three illustrations.

Finally, a summary sheet of the resultant time study and predetermined time values for the elements-in-question are presented to conclude the chapter.

In any predetermined time system analysis of an operation, there are always some elementals that are controversial because of lack of exact agreement between elemental description and work description. While the author has exercised extreme care in the selection of the elementals used in the analysis, he does not represent it to be 100% accurate. He does feel, however, that were "experts" in the several systems to make parallel analyses, their results would not be sufficiently different to affect the validity of the comparisons, conclusions, and recommendations to follow.

CHAPTER IV

COMPARISON OF THE ELEMENTALS

THE NATURE OF THE ANALYSES

Chapter III set forth in very exact terms the element analyses of the operation "Make Cartons" through the use of three predetermined time systems. The next step involved the determination of just exactly what was to be compared, and how it was to be compared.

A comparison of the elements alone, or the total cycle time alone was not enough. It was necessary to go deeper into the problem. A comparison of the elementals or fundamental motions, one to another, as analyzed by Work-Factor, MTM and BMT was deemed necessary for the purposes of this paper. In short, this essentially amounts to a detailed comparison of the systems using their most recent data revisions.

The next problem was to determine how to compare the elementals. It was discovered that certain definitions were overlapping when compared to similar definitions of another system and as a result some elementals had to be grouped in order to be compared. An example of this is the BMT "reach" which is meant to include a simple grasp. Work-Factor and MTM have separate motion analyses for both "reach and "grasp". Hence, to compare the systems the motions had to be grouped.

If each elemental were compared to any other, it was found that six variations could conceivably exist as follows:

Compare:

1. Work-Factor to MTM
2. Work-Factor to BMT
3. MTM to Work-Factor
4. MTM to BMT
5. BMT to Work-Factor
6. BMT to MTM

It may readily be seen that such an analysis would result in a multitude of figures from which probably little could be derived. Therefore, it was decided to arbitrarily select one of the systems as a base and compare the other two systems to it. The latter two systems would then, in effect, be compared to each other also, since if two quantities are compared to a third quantity, they are, as a result, compared to one another. MTM was arbitrarily chosen as the base. Using this concept, each elemental was then compared to each other elemental of the same motion on a percent difference basis in chart form. This comparison is indicated on each Element Comparative Analysis chart, pages 116 to 146 under the column entitled

"% Difference from Base". Incidentally, a plus (+) sign indicates that the elemental is "looser" than the elemental to which it is being compared, and a minus (-) sign indicates that it is "tighter". Also to be included along with the per cent difference column in comparing the elementals, is a detailed Discussion and search of the data as presented, in an effort to determine WHY the time values for each individual elemental varied as the systems were compared. Following the Discussion for each element, a chart follows which summarizes the findings of the discussion for that element. To go into more detail; conceivably a definition for a basic motion as described by any one of the systems may fit the situation and yet still not compare to either of the other two definitions. In other cases, the definition might not fit the situation satisfactorily, but would have to be used because it is the only analysis available in the system being used. Other reasons for the time values being out of line with one another might be indicated by the fact that the definitions do not compare with one another even though both seem to fit the situation; or the definitions compare but the data does not - indicating a flaw in the original data analysis. Also a combination of differences in both data and definitions may be at fault. All of the foregoing is discussed FOR EACH ELEMENTAL immediately following each comparative analysis chart, and the results are summarized in table form immediately following the Discussion. See pages 117 to 150.

To take the Comparative Analysis one step further as an aid in explaining why or why not the end result (total element or cycle time) compared or did not compare, it was necessary to find out which elementals were responsible, and to what extent, for causing a per cent difference in the total element times as analyzed by the three systems. In other words, a large per cent difference between individual elementals may have a very minor effect on the total element or cycle time, because the time for that element may be a very small portion or percentage of the total time. In short a "Weighted % Difference" (column title in the Comparative Analysis) is necessary to demonstrate the effect of the individual elemental differences on the total element or cycle time. The algebraic sum of the weighted per cent differences for each elemental will result in the total per cent difference between the final element times of the three systems. (This same procedure may be followed for the cycle time, and has been done in this paper on the charts entitled "Cycle Time Weighted Per Cent Difference Analysis", pages 151 to 153). In the former chart (as well as the latter) one may readily see by inspection which of the elementals were the primary cause of the final per cent difference in total element (or cycle) time of the three systems, which, of course, should not exceed ± 5% (as per time study) if the times are to be considered comparable. It may be noted in this inspection that the weighted per cent difference is always a great deal less than the per cent difference from the base. This explains why even though the individual elementals for the most part may differ quite radically from one another, on an overall element comparison basis, they do not. The comparison also illustrates in graphic form how the various "tight" and "loose" (weighted) elementals tend to cancel one another out.

In addition the Comparative Analysis for each element includes the number of symbols per system needed to describe an elemental motion. Limiting motions are found in parentheses and limited out motions (if any) are found immediately to the right of the latter number and separated from it by a dash. This information may be found in the "Totals" row and the "Motion" columns (for each system) in the Comparative Analysis. From this data, the system of predetermined times which is easiest and quickest to use may be determined (based on the operation that is being analyzed).

The time study value for each element also appears in each comparative analysis. However the time study value and the element time value as determined by a predetermined time system cannot be directly compared, since total cycle time is represented by the addition of the latter element times which are set forth in ten-thousandths of a minute. Only total cycle times can be compared after rounding off - element times cannot be rounded off because a great loss in accuracy would result, as previously explained.

Finally, a composite analysis of the operation "Make Cartons" is included in this chapter. After acquiring a rather thorough knowledge of each system, and a corresponding knowledge of the intricacies of the definitions of the fundamental motions of each, the thought of an "ideal" system using the most realistic definitions of each entered the trend of thinking of the author. It seemed to be an avenue well worth exploring - one which might indeed provide a system whose time values compared more favorably to time study values than any of those of the other systems taken individually. These charts may be found at the end of the chapter under the title, "Composite Analysis", pages 154 to 156.

COMPARATIVE ANALYSIS

ELEMENT 1: PICK UP CARTON

#	ELEMENTAL DESCRIPTION	W-F		MTM		BMT		% DIFF. FROM BASE		WEIGHTED % DIFF.	
		MOTION*	TIME	MOTION	TIME	MOTION	TIME	W-F	BMT	W-F	BMT
1	Turn Away From Finished Cartons TOTAL	135° Turn (1)	100 100	TBC1 (1)	111.6 111.6	TB. (1)	110 110	-10.4%	- 1.4%	- 2.0%	- 0.2%
2	Walk Toward Carton Storage TOTAL	From Timetable (1)	260 260	W-2P (1)	180 180	W-2 (1)	200 200	+44.5%	+11.1%	+12.5%	+ 3.0%
3-L	Reach For Unopened Carton & Contact Grasp Same TOTAL	A6SD CT-GR (2)	60 0 60	R6D G5 (2)	60.6 0 60.6	R6CV (Grasp Included) (1)	79 — 79	- 1.0%	+30.4%	+ 0.1%	+ 2.9%
4-L	Pull Carton To Palm Of Hand & Regrasp Same TOTAL	A2 A1D ½ F1 (3)	20 26 8 54	M3A G1A (2)	29.4 12.0 41.4	M3A (1)	39 39	+30.5%	- 5.8%	+ 2.0%	- 0.4%
5	Side Step 18" Close To Front Of Stapler TOTAL	L18WW L18 (2)-3	113 63 176	SS-C2 (1)-3	244.2 244.2	SS2 (1)-3	168 168	-27.8%	-31.2%	-10.8%	-11.9%
	TOTALS	(9)-3	.0650	(7)-3	.0640	(5)-3	.0596	+ 1.6%	- 6.6%	+ 1.6%	- 6.6%
	TIME STUDY VALUE		.07 MIN.		.07 MIN		.07 MIN.				

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* No. in parenthesis = Limiting Motion Symbol(s) used in analysis.
2nd Number = Limited Out Motion Symbol(s) used in analysis.

Discussion: Element 1, Pick up Carton

Elemental Number	Reason(s) for Variation Between the Elementals
1	Work-Factor describes the Turn Body motion as a "turn" of more than 120°. MTM and BMT as compared to each other have essentially the same definition as well as the same time value. It would appear that definition in this case is the misleading factor as far as Work-Factor is concerned.
2	Walking as defined for BMT is designated as "restricted". This is designed evidently to cover the average condition of the workplace. Work-Factor breaks the definition into "restricted" or "general" walking, and MTM defines its walking time merely as average. The situation encountered in the "Make Cartons" operation is not restricted, yet in the BMT analysis we are forced to accept the one value which includes restricted walking and which strangely enough allows less time than Work-Factor "general" walking. Definitions as well

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* Refer to the Comparative Analysis Sheets. (Pages 116 to 146)

as time values do not agree for the three systems.

3 Reaching for the carton involves an accurate reach and a certain amount of vision since the unopened cartons are stacked one against the other much the same as a deck of cards. The definitions of the motions used seem to be essentially coincident except that the BMT "C" reach includes time for a grasp. Here a contact grasp is used requiring no time, but the "C" reach does not allow for merely a contact grasp since simple grasping time is included. MTM and Work-Factor times compare quite well, and BMT is out of line because of its definition.

4 Each of the moves, by definition involves moving an object against a rigid stop (using no muscular control to stop it). The BMT "A" reach again includes a simple grasp made by closing the fingers. All definitions coincide quite well. The only thing that might be questioned is the BMT grasp for which there exists no way of determining exactly what constitutes the grasp. The definition simply states that a reach motion is intended

to include a "simple grasp".

5 The BMT and MTM definitions of sidestep coincide, but their time values do not. The Work-Factor definition of sidestep (single step with both feet) is one which is synthesized from previous data; it compares in time quite favorably to the BMT time value. Essentially all the definitions point to the same thing, even though one is synthesized. It must be concluded here that there is a flaw in the original data, since the time values do not compare.

TABLE VI

SUMMARY OF THE DISCUSSION - ELEMENT I.

CONDITION	ELEMENTAL 1	2	3	4	5
Definitions that fit the situation satisfactorily	ALL	MTM W-F	MTM W-F	ALL	ALL
All definitions similar				X	X
All times similar [1]					
Two definitions similar	X		X		
Two times similar	X		X		X
No definitions similar		X			
No times similar		X		X	
Probable reason for discrepancy between time values	Def.	Def.	Def.	Data	Data

1. Times must not vary from one another by more than ± 5% to be classed as similar.

COMPARATIVE ANALYSIS

ELEMENT 2: OPEN CARTON AND FOLD ENDS

#	ELEMENTAL DESCRIPTION	W-F		MTM		BMT		% DIFF. FROM BASE		WEIGHTED % DIFF.	
		MOTION	TIME	MOTION	TIME	MOTION	TIME	W-F	BMT	W-F	BMT
1	Place Ends of Carton on Floor	A3D	32	M3A	29.4	M3C	60				
	TOTAL	(1)	32	(1)	29.4	(1)	60	+ 8.9%	+104.0%	+ 0.3%	+ 2.9%
2-L	Release Flap By Opening Fingers	½ F1	8	RL1	12.0	R½B	32				
	TOTAL	(1)	8	(1)	12.0	(1)	32	-33.0%	+167.0%	- 0.3%	+ 2.0%
3-L	Slide Thumb 3" (An Arm Movement) & Grasp Flap (Necessitates a Regrasp)	A3D F1 F1	32 16 16	R3B G2	31.8 33.6	R3C P½	60 6				
	TOTAL	(3)	64	(2)	65.4	(2)	66	- 2.1%	+ 0.9%	- 0.1%	+ 0.1%
4-R	Regrasp Flap	2F1	32	G2	33.6	R½C	41				
	TOTAL	(1)	32	(1)	33.6	(1)	41	- 3.9%	+ 22.0%	- 0.1%	+ 0.7%
5	Open Carton By Pushing Flap Out With Fingers	A7WW	65	AP-2 M-7A	63.6 53.4	AP-10 ST-10 M7A	13 13 50				
	TOTAL	(1)-1	65	(2)-1	117.0	(3)-1	76	-44.4%	- 35.0%	- 5.1%	- 4.1%
6	Move Carton Against Body	A3	22	M3A	29.4	M3A	39				
	TOTAL	(1)	22	(1)	29.4	(1)	39	-25.2%	+ 32.8%	- 0.7%	+ 0.9%
7	"Overfold" Carton By Pushing Flaps To Body	A8WWD	84	mM8B AP-2	43.2 60.6	M8A AP-10 ST-10	52 13 13				
	TOTAL	(1)	84	(2)	103.8	(3)	78	-17.2%	-23.1%	- 1.8%	- 2.4%
8	Set Carton On Floor (Orienting of Carton is Limited Out)	A14D	69	M14A	86.4	M14C	90				
	TOTAL	(1)-1	69	(1)-1	86.4	(1)-1	90	-20.5%	+ 4.2%	- 1.7%	+ .3%

COMPARATIVE ANALYSIS

LEMENT 2: OPEN CARTON AND FOLD ENDS (CONTINUED)

#	ELEMENTAL DESCRIPTION	W-F		MTM		BMT		% DIFF. FROM BASE		WEIGHTED % DIFF.	
		MOTION	TIME	MOTION	TIME	MOTION	TIME	W-F	BMT	W-F	BMT
-R	Release Flap TOTAL	½ FI (1)	8 8	RLI (1)	12.0 12.0	R½B (1)	32 32	-33.0%	+167.0%	- 0.3%	+ 2.0%
0-R	Reach to Right Hand Flap & Grasp TOTAL	A6D ½ FI (2)	47 8 55	R6B GIA (2)	53.4 12.0 65.4	R6C (1)	71 71	-15.9%	+ 9.6%	- 1.0%	+ 0.6%
I-L	Push Flap Down TOTAL	A8D (1)	54 54	M8A (1)	58.2 58.2	M8A (1)	52 52	- 7.2%	-10.7%	- 0.4%	- 0.6%
2-R	Push Flap Down TOTAL	A8D (1)-2	54 54	M8A (1)-2	58.2 58.2	M8A (1)-1	52 52	- 7.2%	-10.7%	- 0.4%	- 0.6%
3-R	Slide Hand to Upper Right Hand Corner of Carton and Grasp TOTAL	A3D FI (2)	32 16 48	R3A GIA (2)	31.8 12.0 43.8	R3C (1)	60 60	+ 9.6%	+ 37.0%	+ 0.4%	+ 1.6%
4-R	Twist Carton 90° By Moving Right Arm 12" in a Semicircular Path Towards Body, Left Hand Acts as a Pivot TOTAL	A12D (1)	65 65	M12B (1)	80.4 80.4	M12B (1)	68 68	-19.2%	- 15.4%	- 1.5%	- 1.2%
5-L	Reach to Left Flap & Contact Grasp Same TOTAL	A8 CT-GR (2)	38 0 38	R8Am G5 (2)	39.0 0 39.0	R8A (1)	52 52	- 2.6%	+ 25.0%	- 0.1%	+ 1.0%
5-L	Push Flap Down TOTAL	A8D (1)	54 54	M8A (1)	58.2 58.2	M8A (1)	52 52	- 7.2%	- 10.7%	- 0.4%	- 0.6%

COMPARATIVE ANALYSIS

ELEMENT 2: OPEN CARTON AND FOLD ENDS (CONTINUED)

#	ELEMENTAL DESCRIPTION	W-F		MTM		BMT		% DIFF. FROM BASE		WEIGHTED % DIFF.	
		MOTION	TIME	MOTION	TIME	MOTION	TIME	W-F	BMT	W-F	BMT
17-R	Reach to Right Flap & Contact Grasp Same TOTAL	A8 CT-GR (2)	38 0 38	R8Am G5 (2)	39.0 0 39.0	R8A (1)	52 52	- 2.6%	+ 25.0%	- 0.1%	+ 1.0%
18-R	Push Flap Down TOTAL	A8D (1)	54 54	M8A (1)	58.2 58.2	M8A (1)	52 52	- 7.2%	- 10.7%	- 0.4%	- 0.6%
19	Regrasp Carton By Moving Arm 3" & Fingers 1" TOTAL	A3D F1 (2)	32 16 48	R3A R1A (2)	31.8 15.0 46.8	R4A (1)	42 42	+ 2.6%	- 10.2%	+ 0.1%	- 0.5%
	TOTALS	(26)-4	892= .0892 MIN.	(27)-4	1039= .1039 MIN.	(24)-3	1067= .1067 MIN.	-14.1%	+ 2.7%	-14.1%	+ 2.7%
	TIME STUDY VALUE		.10 MIN.		.10 MIN.		.10 MIN.				

Discussion: Element 2, Open Carton and Fold Ends

Elemental Number	Reason(s) for Variation Between the Elementals
1	Here the definitions vary widely. Work-Factor states that the "Definite Stop" factor must be included for any motion that refers to placing an object. MTM "Move Case A" infers that we are moving an object against a stop (the floor) with little sight or concentration. The comparable Work-Factor motion would not include "Definite Stop" by definition and if this were used it would vary from the MTM value by 24% and the BMT value by 44%. The BMT "C Move" fits in here because as defined, it refers to the placing of an object. Hence it may be seen that two definitions (Work-Factor and BMT) coincide, but their times do not. None of the times are within the ± 5% range.
2	The MTM and Work-Factor Definitions both amount to the same thing for a release of this type, namely; a simple opening of the fingers. The times do not agree. The BMT definition of a release left much to be desired as essentially it had to be classed as a "B" finger reach since the opening of the fingers is stopped by

"muscular control" as per the definition. The BMT "reach" includes a grasp. How can a release include a grasp? The analysis is contradictory but the BMT "reach" had to be used since that was all that was available.

3 The Work-Factor and BMT "reach" motion definitions coincide perfectly. However, the BMT value includes a simple grasping time to which must be added the "Precision Factor" value to compensate for the regrasp or second grasp. The 2 Fl motions in Work-Factor represent a "regrasp" by 2 movements of the fingers (a synthesized definition). The MTM definition for the reach does not agree with the other two in so many words, and the same applies to the regrasp, but essentially they all point in the same direction. All time values coincide within the accepted range.

4 The MTM and Work-Factor definition of a regrasp both seem to include two simple movements of the finger and the respective times compare quite well. The BMT "grasp" is difficult to put together since the "C" reach must be used because it applies to touching an object at the end point of the reach. The definition

hardly compares with the other two as the BMT "Reach and Move" table definitions seem to apply primarily to the arms. The time value is far out of line.

The opening of the flaps is a difficult thing to analyze. Lack of precise measurement caused the Analyst to assume pushing against a resistance of 10 pounds for all systems while moving the arms seven inches. The Work-Factor definition included just exactly that - a movement of the arm seven inches against a pressure of 10 pounds. The BMT application of pressure is divided into first gaining control of the object and then applying a pressure to start the motion. The MTM "Apply Pressure" must be utilized in this motion along with the move. The difference in times is due mainly to the fact that the Work-Factor arm motion includes a continuing pressure through the move, whereas the other two have somewhat of an overlap between the apply pressure and the move. In the latter two cases the full move time should not be given since some of it takes place during the apply pressure, but it is not known how much. The MTM and BMT definitions are unsatisfactory for this reason and the times allowed are therefore excessive. The Work-Factor definition appears to be entirely satisfactory.

6 All of the definitions here indicate quite clearly that an object is moved against a stop (the body) without being stopped by muscular effort. They coincide perfectly. All of the time values, however, are out of line.

7 Here the comments of "Elemental 5." apply, but in reverse. There is no continuing pressure, therefore the Work-Factor definition does not apply, but must be used since it is the only one available. The MTM and BMT definitions fit much better here because the move is followed by an apply pressure. Another factor, namely; hand in motion from the previous elemental enters into the MTM definition. This is not considered in either of the other two definitions. Basically the MTM and BMT definitions are similar but the times compare quite poorly. Strangely enough the time values are much closer for the MTM and Work-Factor motions, even though the definitions do not coincide.

8 Same comments as "Elemental 1."

9 Same comments as "Elemental 2."

10 The definitions all concur quite closely (the reaching portion only). The BMT reach includes a "simple grasp", as it is called, but there really is no way of analyzing that grasp to compare it to the others.

11 Basically this movement involves moving the flap down against a stop (the rest of the carton). It was the author's opinion that a "Definite Stop" control factor should be included in the Work-Factor Definition, because the hand does come to a stop before the next motion can begin, even though no muscular control is employed to make the stop. This may be stretching the definition a little, but thus enters the element of judgement on the part of the Analyst. The MTM and BMT definitions of movement against a stop apply perfectly. The times are just out of the ± 5% range.

12 Same comments as "Elemental 11."

13 The "reach" portion of the motions have similar

definitions. However, the grasp must be further analyzed in that it involves more than a "½ FI" for Work-Factor, since the fingers move at least an inch. The MTM "G1A" grasp is the only one which applies, even though it does not fit the situation exactly. The so-called "simple grasp" is included in the BMT value, but there is no way of knowing what the time is for the grasp, nor exactly what type it is. The definitions cannot be comparable because as may be seen the Work-Factor grasp is more than the simple "pinch" grasp. The inclusion of "grasp" in the BMT definition makes it essentially non-comparable to the other two.

14 All of the definitions here fit the case in their own way. The Work-Factor and BMT definitions are the same in that a definite stop is indicated at the end of the movement. The MTM move evidently presumes a stop since the object is moved to an approximate location, but it does not come right out and state that fact. It is concluded that the definitions all are quite applicable to this type of move. The Work-Factor and BMT times are comparable; MTM is out of line which might be due to the slight

difference in definition.

15 This type of motion is one which does not involve a factor of definite stop at the end of the motion. A contact grasp is made when the hand touches the flap. The Work-Factor and MTM definitions for this type of reach fit the situation quite well since no stop is made (no control required by operator) for the Work-Factor definition, and for the MTM the hand is in motion at the end of a reach to "an object on which the other hand rests". The contact grasp is, of course, zero. BMT is again out of line because the time value includes a simple grasp.

16 Same comments as "Elemental 11."

17 Same comments as "Elemental 15."

18 Same comments as "Elemental 11."

19 This regrasp involves a movement of the arm a distance of three inches and a subsequent closing of the fingers a distance of one inch. All motions here were analyzed satisfactorily by the three systems. The definitions coincide quite well, except that there exists the problem of

the exact nature of the grasp in the BMT "reach". The grasp cannot be analyzed - it is there as a set figure and nothing can be done about it.

TABLE VII

SUMMARY OF THE DISCUSSION - ELEMENT 2.

CONDITION	ELEMENTAL 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
Def. that fit the situation satisfactorily	ALL	W-F MTM	ALL	ALL	W-F	ALL	MTM W-F	ALL	W-F MTM	ALL	ALL	ALL	MTM W-F	ALL	MTM W-F	ALL	MTM W-F	ALL	ALL
All definitions similar			X			X													
All times similar 1			X																
Two definitions similar	X	X		X	X		X	X	X	X	X	X	X	X	X	X	X	X	X
Two times similar				X				X			X	X		X	X	X	X	X	X
No definitions similar																			
No times similar	X	X			X	X	X		X	X			X						
Probable reason for discrepancy between time values	DEF. & DATA	DEF. & DATA	-----	DEF.	DEF. & DATA	DATA	DEF. & DATA	DEF. & DATA *	DEF. & DATA	DEF. & DATA	DEF. & DATA *	DEF. & DATA *	DEF. & DATA	DEF.	DEF.	DEF. & DATA *	DEF.	DEF. & DATA *	DEF. & DATA

1. Times must not vary from one another by more than ± 5% to be classed as similar.

* Times here compare for the two definitions that are not similar.

COMPARATIVE ANALYSIS

EMENT 3: PLACE CARTON ON STAPLER

ELEMENTAL DESCRIPTION	W-F		MTM		BMT		% DIFF. FROM BASE		WEIGHTED % DIFF.	
	MOTION	TIME	MOTION	TIME	MOTION	TIME	W-F	BMT	W-F	BMT
Straighten Back (Trunk Motion) TOTAL	T8D (1)	79 79	NO ANALYSIS		NO ANALYSIS		INFINITY	0.0%	+13.9%	0.0%
Step to Front of Stapler by Side-stepping 20" (Move Carton Limited Out) TOTAL	L20WW L20 (2)-1	117 67 184	SS-C2 (1)-1	257.4 257.4	SS2 (1)-1	176 176	-28.6%	-31.6%	-13.3%	-14.7%
Clear Part "A" TOTAL	A6D (1)	47 47	M6B (1)	53.4 53.4	M6B (1)	55 55	-12.0%	+ 2.9%	- 1.2%	+ 0.3%
Position Far Left Corner Over "A" TOTAL	A8SD (1)	70 70	P1SSD (1)	88.2 88.2	M8CV (1)	85 85	-20.6%	- 3.6%	- 3.2%	- 0.6%
Move Carton Down on Part "A" of Stapler TOTAL	A26D (1)	90 90	M26B (1)	130.8 130.8	M26B (1)	96 96	-29.6%	-26.6%	- 7.0%	- 6.3%
L Push Carton Flush Against Part "A" TOTAL	A2 (1)	20 20	M2A (1)	21.6 21.6	M2A (1)	36 36	- 7.4%	+66.4%	- 0.3%	+ 2.6%
TOTALS	(7)-1	490= .0490	(5)-1	551.4= .0551	(5)-1	448= .0448	-11.1%	-18.7%	-11.1%	-18.7%
IME STUDY VALUE		.06		.06		.06				

Discussion: Element 3, Place Carton on Stapler

Elemental Number	Reason(s) for Variation Between the Elementals
1	Before the sidestep can begin, the trunk of the body must be brought up (straightened). Work-Factor takes care of this very nicely. MTM and BMT have NO analysis for such a trunk movement. Perhaps it is meant to be included in a sidestep, but this is not expressly stated, so it must be assumed that the data as well as the definitions are non-existent for this type of trunk motion in the latter two systems.
2	The motion being described here is not terminated until the left leg comes to rest beside the right leg. (Next motion cannot begin) All of the definitions state this. The BMT and MTM definitions for sidestep coincide, whereas the Work-Factor definition is slightly different, having been (synthetically) built up from two leg motions. However, it does essentially say the same thing as the other two definitions, but in other words. The Work-Factor and BMT values compare quite favorably; the MTM value is far out of line.

3 This motion has to do with merely moving the carton past part "A" so that the positioning of the carton over that part can begin. All of the definitions agree here in that movement to an approximate location is implied.

4 Neither Work-Factor nor BMT has a specific definition for this positioning. The movement itself must be analyzed and built up from the general definitions of motions of the two systems. The Work-Factor arm movement was selected as the positioning movement and the factor of "Steering" was included since the motion was directed at and through the target. The BMT definition also must be built up and the only logical choice here was the class "C" move, or the most accurate move. The "Visual Direction" Factor was added since the eyes must be directed at the target in this case. The MTM "positioning" elemental seems to fit the situation very nicely. It is a case I position since no pressure is applied; semi-semetrical because it can go over part "A" in several ways; and "D" because the length of the carton makes it difficult to handle (the hands grasp the carton quite a bit from the

point of contact, and it is in general quite awkward to handle. It would appear that the latter definition of the motion is the best for the situation, as three variables are considered; whereas BMT and Work-Factor consider only two and one, respectively. The definitions do not compare, but they are applicable to the situation. This elemental is another case of taking the only definitions available to analyze the situation-in-question.

5 This motion at first glance would appear as if a movement against a stop were involved. This is not so since the carton is moved down on part "A" in such a manner that a certain amount of muscular control is used to stop the motion. The definitions then compare quite favorably. The MTM time value is the largest of the three.

6 All definitions compare almost exactly for the movement of the carton against part "A" of the stapler, which acts as a stop. The motion is stopped with no muscular effort, hence all three definitions coincide very nicely. This is one of the few instances where all definitions fit the situation as well as coinciding with one another.

TABLE VIII

SUMMARY OF THE DISCUSSION - ELEMENT 3.

CONDITION	ELEMENTAL 1	2	3	4	5	6
Definitions that fit the situation satisfactorily	W-F	ALL	ALL	ALL	ALL	ALL
All definitions similar		X	X		X	X
All times similar [1]						
Two definitions similar						
Two times similar			X	X		
No definitions similar	X			X		
No times similar	X	X			X	X
Probable reason for discrepancy between time values	DEF. & DATA	DATA	DATA	DEF. & DATA	DATA	DATA

1. Times must not vary from one another by more than ± 5% to be classed as similar.

COMPARATIVE ANALYSIS

EMENT 4: STAPLE CARTON ENDS

#	ELEMENTAL DESCRIPTION	W-F		MTM		BMT		% DIFF. FROM BASE		WEIGHTED % DIFF.	
		MOTION	TIME	MOTION	TIME	MOTION	TIME	W-F	BMT	W-F	BMT
1	Move Foot to Foot pedal 18" TOTAL	L18D (1)	88 88	LM-18 (1)	129.0 129.0	LM18 (1)	74 74	-31.8%	-41.8%	-3.2%	-4.4%
2	Step on Pedal (Foot Hinged at Ankle)(Pressure Less Than 10 lbs.) TOTAL	L4PD (1)-1	55 55	LM-4 (1)	42.6 42.6	LM-4 (1)	50 50	+29.0%	+17.3%	+1.0%	+0.6%
3	Process Stapling Time	-	300	-	300.0	-	300	-	-	-	-
4	Move Carton From (2) to (3) (Position) TOTAL	A7SD (1)	65 65	M7C (1)	66.6 66.6	M7C (1)	74 74	- 2.4%	+11.1%	-0.1%	+0.6%
5	Step on Pedal TOTAL	L1PD (1)-1	39 39	LM-1 (1)	42.6 42.6	LM-1 (1)	50 50	- 8.4%	+17.3%	-0.3%	+0.6%
6	Move Carton From (3) to (4) (2 Staples) TOTAL	A2SD (1)-1	37 37	M2C (1)	31.2 31.2	M2C (1)	55 55	+18.5%	+76.2%	+0.5%	+1.9%
7	Move Carton From (4) to (5) (Position) TOTAL	A5SD (1)	55 55	M5C (1)	55.2 55.2	M5C (1)	68 68	0.0%	+23.2%	0.0%	+1.0%
8	Step on Pedal TOTAL	L1PD (1)	39 39	LM-1 (1)	42.6 42.6	LM-1 (1)	50 50	- 8.4%	+17.3%	-0.3%	+0.6%

COMPARATIVE ANALYSIS

EMENT 4: STAPLE CARTON ENDS (CONTINUED)

ELEMENTAL DESCRIPTION	W-F		MTM		BMT		% DIFF. FROM BASE		WEIGHTED % DIFF.	
	MOTION	TIME	MOTION	TIME	MOTION	TIME	W-F	BMT	W-F	BMT
Move Carton From (5) to (6) (2 Staples)	A2SD	37	M2C	31.2	M2C	55				
TOTAL	(1)-1	37	(1)	31.2	(1)	55	+18.5%	+76.2%	+0.5%	+1.9%
Move Carton From (6) to (7)	A6	32	M6A	48.6	M6A	47				
TOTAL	(1)	32	(1)	48.6	(1)	47	-34.2%	- 3.3%	-1.3%	-0.1%
Step on Pedal	L1PD	39	LM-1	42.6	LM-1	50				
TOTAL	(1)	39	(1)	42.6	(1)	50	- 8.4%	+17.3%	-0.3%	+0.6%
Process Stapling Time	-	300	-	300.0	300	-	-	-	-	-
Replace Foot on Floor	L18D	88	LM-18	129.0	LM-18	74				
TOTAL	(1)	88	(1)	129.0	(1)	74	-31.8%	-41.8%	-3.2%	-4.4%
TOTALS	(11)-4	1174= .1174 MIN.	(11)	1261.2= .1261 MIN	(11)	1247= .1247 MIN.	- 6.8%	- 1.1%	-6.8%	-1.1%
TIME STUDY VALUE		.13		.13		.13				

Discussion: Element 4, Staple Carton Ends

Elemental Number	Reason(s) for Variation Between the Elementals
1	The MTM and BMT definitions for a leg motion coincide perfectly in that both allow for a leg motion hinged at either the hip or the knee. The Work-Factor definition, however, is much better in that it is more specific. The former two definitions are very general in nature whereas the Work-Factor leg motion in this case includes the Factor of "Definite Stop" which does take place immediately before the short leg motion that pushes the pedal down. None of the times coincide, so it would appear that the definitions as well as the data for MTM and BMT are out of line. The latter two definitions leave much to be desired because they are far too general in nature.
2	The foot pedal in this case is similar to the clutch on an automobile in its operation, but in reverse. The operator, when stapling, pushes the pedal down just a little below the point at which it will staple so that a slight release of pressure will stop the stapling action. Hence on the push downward he is exercising caution to move it just so far, and

then a definite stop follows. This is well defined by the Work-Factor leg motion with the "Precaution" and "Definite Stop" Work-Factors added in. The MTM and BMT definitions are very poor, again because they are too general. They do not consider the care and stop as does the Work-Factor definition. Also, they consider an average distance which contradicts the theory upon which the systems are based.

It might be noted that when the foot releases the pedal, that this occurs just before the last staple hits. In other words, the operator intuitively knows that the machine will follow through with one more staple after he releases the pressure on the pedal at the proper point. Therefore, the movement of the carton to the next stapling position can take place immediately after the last staple has hit. This lowers the next leg motion to a distance of one inch which cuts the time value down considerably. However, the MTM and BMT values do not change since they are designated as applying to any leg motion of up to 6". This is far too general to make the latter definitions of any real value on a scientific basis. The release of pressure by the foot is limited out by the stapling time as previously explained, (the motion is limited out near the end of the stapling) but even so there exists no MTM or BMT definition which could fit the situation unless the LM motion be used, and that would be ridiculous, since too much time would be allowed for the motion. Therefore, it is not shown on the BMT and MTM Analysis Sheets because of this, and also because the motion is limited out anyway.

3 Process Stapling time is the time required for the machine to staple the carton 6 times as the operator moves it to the right. This cannot be analyzed by any predetermined time system.

4 This motion implies movement of the carton to an exact location so the stapling process may begin. All the definitions fill this qualification quite well. They fit the situation even though they are not exactly comparable to each other. Again the BMT Move data seems to be loose compared to the other two. This type of motion fits the need not only for the positioning move prior to stapling,

but also for the stapling of two staples which is accomplished in the same manner by the movement of the carton to an exact location for the crimping of the second staple. Note that the stapling time limits out the release of foot pressure as previously explained.

5 Same comments as"Elemental 2."

6 Same comments as "Elemental 4."

7 Same comments as "Elemental 4."

8 Same comments as "Elemental 2."

9 Same comments as "Elemental 4."

10 The motion here is one of positioning prior to stapling, but the motion involves merely moving the lower left hand corner of the carton against Part "A" of the stapler, which is essentially a stop. All of the definitions of the motions used fit this situation perfectly and their definitions coincide almost exactly. It would appear then that the Work-Factor Data is out of line.

11 Same comments as "Elemental 2."

12 Same comments as "Elemental 3."

13 Same comments as "Elemental 1" with the exception that the "Definite Stop" Factor is included in the Work-Factor definition, because the foot is essentially placed on the floor, or in a sense muscular control is required to stop the motion. It should be repeated again, that the MTM and BMT definitions in this case are too general in nature. The Work-Factor definition is the most specific of the three in that there is a choice of other variables affecting the motion, in addition to the distance factor.

TABLE IX

SUMMARY OF THE DISCUSSION - ELEMENT 4.

CONDITION	ELEMENTAL												
	1	2	3	4	5	6	7	8	9	10	11	12	13
Definitions that fit the situation satisfactorily	W-F	W-F		ALL	W-F	ALL	ALL	W-F	ALL	ALL	W-F		ALL
All definitions similar				X		X	X		X	X			
All times similar[1]			Process Stapling Time									Process Stapling Time	
Two definitions similar	X	X			X			X			X		X
Two times similar				X		X	X		X	X			X
No definitions similar													
No times similar	X	X			X			X			X		
Probable reason for discrepancy between time values	DEF. & DATA	DEF.	----	DATA	DEF.	DATA	DATA	DEF.	DATA	DATA	DEF.	----	DEF.

1. Times must not vary from one another by more than ± 5% to be classed as similar.

COMPARATIVE ANALYSIS

EMENT 5: SET CARTON ASIDE

ELEMENTAL DESCRIPTION	W-F		MTM		BMT		% DIFF. FROM BASE		WEIGHTED % DIFF.	
	MOTION	TIME	MOTION	TIME	MOTION	TIME	W-F	BMT	W-F	BMT
Reach to Upper Left Hand Corner of Carton & Grasp TOTAL	A8D F1 (2)	54 16 70	R8B G1A (2)	60.6 12.0 72.6	R8C (1)	77 77	- 3.6%	+ 6.1%	-0.4%	+0.7%
L Turn Box 90° on Part "A" by Moving Edge of Carton to Body. "A" is Pivot. TOTAL	A10D (1)-1	61 61	M10B (1)-1	73.2 73.2	M10B (1)-1	64 64	-18.1%	-12.6%	-2.2%	-1.5%
Pull Carton Off "A" TOTAL	A30D (1)	96 96	M30B (1)	145.8 145.8	M30B (1)	104 104	-34.2%	-28.7%	-8.1%	-6.8%
Turn Carton 90° (Arm Movement Right Hand) TOTAL	A12D (1)-1	65 65	M12B (1)-1	80.4 80.4	M12B (1)-1	68 68	-19.2%	-15.4%	-2.4%	-2.0%
R Reach to Flap & Grasp TOTAL	A18D F3 (2)	76 19 95	R18A G1A (2)	73.8 12.0 85.8	R18C (1)	98 98	+10.7%	+14.2%	+1.5%	+2.0%
Move Arm Out From Under Carton, Allowing it to Fall While Right Hand Holds on to Flap TOTAL	A14D (1)-3	69 69	M14E (1)-3	78.0 78.0	M14B (1)-4	72 72	-11.5%	- 7.7%	-1.5%	-1.0%
NOTE: A TURN BODY & WALK ONE PACE HAS BEEN LIMITED OUT BY ELEMENTALS 4, 5, 6, & 7										
-R Set Carton on Flr. TOTAL	A10D (1)	61 61	M10A (1)	67.8 67.8	M10C (1)	81 81	-10.0%	+19.8%	-1.1%	+2.2%
-R Release Carton TOTAL	½ F1 (1)	8 8	RL1 (1)	12.0 12.0	R½B (1)	32 32	-33.3%	+166.6%	-0.6%	+3.2%
TOTALS	(10)-5	525= .0525 MIN.	(10)-5	615.6= .0616 MIN	(8)-6	596= .0596 MIN.	-14.8%	- 3.3%	-14.8%	-3.3%
TIME STUDY VALUE		.06		.06		.06				

Discussion: Element 5, Set Carton Aside

Elemental Number	Reason(s) for Variation Between the Elementals
1	Here again exists a case of what has been previously discussed many times, namely; that the BMT "reach" contains a "grasp", but that grasp cannot be analyzed. The definitions for the "reach" part of the motions are all comparable by analysis though not in so many words, but the "grasp" part of the BMT reach remains a mystery. The exact nature of the grasp contained therein is not known.
2	This motion deals simply with pulling the carton towards the body as it rests on part "A" and uses same as a pivot point. The definitions here are all straightforward, stating that the carton be moved to an approximate location and muscular control be used to stop the carton. All of the definitions fit the situation and imply the same thing, if not saying it in exactly the same manner.
3	Here the comments immediately above apply, since the motion simply involves moving the carton to an approximate location and requiring muscular control to stop the motion. The

definitions all fit the situation, but the time values are out of line as compared to one another.

4 Here the carton is turned from a vertical to a horizontal position using the left hand as a pivot. The left hand motion (turning motion) is limited out by the movement of the right hand. All of the definitions imply a move with a stop at the end and compare quite well.

5 Same comments as "Elemental I."

6 The movement of the carton cannot begin until the left hand is taken out from under the carton and moved out of the way. Then the carton can drop while the right hand holds on to the flap. The left hand motion is limiting here and is well defined by all definitions, but particularly well by MTM which states that the hand is moved out of the way. The other two definitions imply a stop at the end of the motion. They all point to the same thing.

7 In this move, the operator is to relinquish control of the carton as soon as the object touches the floor. All definitions imply the placing of an object and compare quite favorably.

8 The release in this case is represented by a simple opening of the fingers. The MTM release spells this out in exact language, whereas with the Work-Factor and BMT definitions the opening of the fingers must be analyzed. The Work-Factor simple release has been standardized as $\frac{1}{2}$ FI. The BMT "B" reach was used because the fingers essentially open up and musculer control stops the opening process when necessary. The BMT time value is ridiculously out of line simply because the definition states that any reach includes a simple grasp - how can a release include a grasp? This is obviously contradictory. The value was used because it was all that was available.

TABLE X

SUMMARY OF THE DISCUSSION - ELEMENT 5.

CONDITION	ELEMENTAL							
	1	2	3	4	5	6	7	8
Definitions that fit the situation satisfactorily	MTM W-F	ALL	ALL	ALL	MTM W-F	ALL	ALL	MTM W-F
All definitions similar		X	X	X		X	X	
All times similar 1								
Two definitions similar	X				X			X
Two times similar	X			X	X	X	X	
No definitions similar								
No times similar		X	X					X
Probable reason for discrepancy between the time values	DEF.	DATA	DATA	DATA	DEF.	DATA	DATA	DEF. & DATA

1. Times must not vary from one another by more than ± 5% to be classed as similar.

CYCLE TIME WEIGHTED % DIFFERENCE ANALYSIS

		Weighted % Diff. On Basis Of Cycle Time		
ELEMENTAL NO.	TYPE OF MOTION	W-F	BMT	
1	Body Motion (Turn Body)	- .28%	- .04%	ELEMENT 1
2	Body Motion (Walk)	+1.95%	+ .49%	
3	Reach & Grasp	- .01%	+ .45%	
4	Move	+ .30%	- .06%	
5	Body Motion (Side Step)	-1.65%	-1.86%	
	SUB TOTAL	+0.31%	-1.02%	

		Weighted % Diff. On Basis Of Cycle Time		
ELEMENTAL NO.	TYPE OF MOTION	W-F	BMT	
1	Move	+ .06%	+ .74%	ELEMENT 2
2	Release	- .10%	+ .49%	
3	Reach & Grasp	- .03%	+ .01%	
4	Grasp	- .03%	+ .18%	
5	Move	-1.27%	-1.00%	
6	Move	- .18%	+ .23%	
7	Move	- .44%	- .58%	
8	Move	- .43%	+ .09%	
9	Release	- .10%	+ .49%	
10	Reach & Grasp	- .25%	+ .15%	
11	Move	- .10%	- .15%	
12	Move	- .10%	- .15%	
13	Reach & Grasp	+ .10%	+ .40%	
14	Move	- .38%	- .30%	
15	Reach & Grasp	- .02%	+ .24%	
16	Move	- .10%	- .15%	
17	Reach & Grasp	- .02%	+ .24%	
18	Move	- .10%	- .15%	
19	Release	+ .03%	- .12%	
	SUB TOTAL	-3.36%	+ .66%	

CYCLE TIME WEIGHTED % DIFFERENCE ANALYSIS (CONTINUED)

		Weighted % Diff. On Basis Of Cycle Time		
ELEMENTAL NO.	TYPE OF MOTION	W-F	BMT	
1	Body Motion (Trunk)	+1.88%	0.0%	
2	Body Motion (Side Step)	-1.79%	-1.97%	
3	Move	- .16%	+ .04%	ELEMENT 3
4	Position	- .44%	- .08%	
5	Move	- .94%	- .85%	
6	Move	- .04%	+ .35%	
	SUB TOTAL	-1.49%	-2.51%	

		Weighted % Diff. On Basis Of Cycle Time		
ELEMENTAL NO.	TYPE OF MOTION	W-F	BMT	
1	Body Motion (Leg)	-1.00%	-1.31%	
2	Body Motion (Leg)	+ .30%	+ .18%	
3	---- PROCESS TIME ----			
4	Move	- .04%	+ .18%	
5	Body Motion (Leg)	- .09%	+ .18%	
6	Move	+ .14%	+ .58%	
7	Move	.00%	+ .30%	ELEMENT 4
8	Body Motion (Leg)	- .09%	+ .18%	
9	Move	+ .14%	+ .58%	
10	Move	- .40%	- .04%	
11	Body Motion (Leg)	- .09%	+ .18%	
12	---- PROCESS TIME ----			
13	Body Motion (Leg)	-1.00%	-1.32%	
	SUB TOTAL	-2.13%	- .31%	

CYCLE TIME WEIGHTED % DIFFERENCE ANALYSIS (CONTINUED)

		Weighted % Diff. On Basis Of Cycle Time		
ELEMENTAL NO.	TYPE OF MOTION	W-F	BMT	
1	Reach & Grasp	- .06%	+ .11%	ELEMENT 5
2	Move	- .32%	- .22%	
3	Move	-1.21%	-1.02%	
4	Move	- .37%	- .30%	
5	Reach & Grasp	+ .22%	+ .30%	
6	Move	- .22%	- .15%	
7	Move	- .16%	+ .33%	
8	Release	- .10%	+ .49%	
	SUB TOTAL	-2.07%	- .46%	

COMPOSITE ANALYSIS

ELEMENT 1

Elemental No.	COMPOSITE ANALYSIS			Number of Symbols *
	W-F	MTM	BMT	
1		111.6		(1)
2	260			(1)
3	60			(2)
4	54			(3)
5		244.2		(1)-3
ELEMENT 1:	SUMMARY TOTAL TIME=.0730 MIN.			(8)-3

ELEMENT 2

Elemental No.	COMPOSITE ANALYSIS			Number of Symbols *
	W-F	MTM	BMT	
1			60	(1)
2		12.0		(1)
3	64			(3)
4	32			(1)
5	65			(1)-1
6			39	(1)
7		103.8		(1)
8			90	(1)-1
9		12.0		(1)
10		65.4		(2)
11		58.2		(1)
12		58.2		(1)-2
13	48			(1)
14		80.4		(1)
15			52	(1)
16		58.2		(1)
17			52	(1)
18		58.2		(1)
19	48			(2)
ELEMENT 2:	SUMMARY TOTAL TIME=.1056 MIN.			(23)-4

* 1st No. = Limiting Motion Symbol(s) used in analysis
2nd No. = Limited Out Motion Symbol(s) used in analysis

COMPOSITE ANALYSIS (CONTINUED)

ELEMENT 3

Elemental No.	COMPOSITE ANALYSIS			Number of Symbols
	W-F	MTM	BMT	
1	79			(1)
2		257.4		(1)-1
3			55	(1)
4		88.2		(1)
5			96	(1)
6			36	(1)
ELEMENT 3:	SUMMARY TOTAL TIME=.0612 MIN.			(6)-1

ELEMENT 4

Elemental No.	COMPOSITE ANALYSIS			Number of Symbols
	W-F	MTM	BMT	
1	88			(1)
2	55			(1)-1
3	Process Time = 300			-
4	65			(1)
5	39			(1)-1
6	37			(1)-1
7	55			(1)
8	39			(1)
9	37			(1)-1
10		48.6		(1)
11	39			(1)
12	Process Time = 300			-
13	88			(1)
ELEMENT 4:	SUMMARY TOTAL TIME=.1191 MIN.			(11)-4

COMPOSITE ANALYSIS (CONTINUED)

ELEMENT 5				
Elemental No.	COMPOSITE ANALYSIS			Number of Symbols
	W-F	MTM	BMT	
1		72.6		(2)
2		73.2		(1)-1
3		145.8		(1)
4		80.4		(1)-1
5	95			(2)
6		78.0		(1)-3
7			81	(1)
8		12.0		(1)
ELEMENT 5:	SUMMARY	TOTAL TIME=.0638 MIN.		(10)-5

TOTAL CYCLE TIME = .4227 MIN.

SUMMARY

The purposes of Chapter IV are: First, to set forth an analysis which would compare each of the predetermined time systems, elemental by elemental, so that definite conclusions could be drawn as to why they do or do not compare; secondly to establish which of the systems was the quickest and easiest to use in the analysis of the operation considered; and thirdly to present a composite analysis of the operation "Make Cartons" through a use of the most realistic definitions of all three systems.

The conclusions drawn from the comparison charts, discussions, summary charts and composite analysis are presented in the next chapter, along with several recommendations concerning the use of the systems and suggestions for further study.

CHAPTER V

CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

Comparison of the Elementals

From the Comparative Analysis of Chapter IV, pages 116 to 146, it has been determined from an examination and search of the column entitled "% Difference from Base", that of 147 (49 x 3) elemental comparisons, roughly 60 elementals (3 within each grouping compared) or 41% of the total compared with each other within the ± 5% range as far as time values are concerned. (The ± 5% standard Time Study acceptable time difference has been used here as well as throughout the text for comparison purposes.) The other 59% of the elementals (as grouped and compared in threes) are different from one another by an amount greater than ± 5%. The question to be asked here is whether or not these per cent differences, as far as individual elementals are concerned, are really important in terms of their effect on the comparison of the final cycle times. In other words, what is the nature of the effect of individual elemental differences on total cycle time?

To answer this question it must be realized, as previously explained, that a large individual elemental per cent difference (as compared to one another) may affect the total element time very little if its time value is very small compared to total element time. In the Comparative Analysis, the column entitled "Weighted % Difference" (from base) brings this principle out very nicely. Referring to the analysis, pages 116 to 146, notice how the individual difference percentages from base are all lessened by quite an amount in the next column to the right, "Weighted % Difference", in direct proportion to the amount of total element time that the elemental takes to perform. The latter weighted percentages are additive and their algebraic sum represents the total percent difference of one total element time as compared to another. Hence, for example the algebraic sum of the BMT column under "Weighted % Difference" would represent the per cent difference between the total element time of BMT as compared to the total element time of the base, MTM. Thus, it may be concluded here that the controlling factor in determining whether or not element times will compare is not the difference in time values between individual elementals alone, but rather the weighted difference as well as the dispersion of "tight" (+) and "loose" (-) values which tend to cancel one another out.

When the preceding principles are applied to elementals as opposed to cycle time, rather than from elementals to element time, the weighted % difference becomes smaller yet and the (+) and (−) values (tight or loose values) work to more advantage in the subsequent comparison of those total cycle times, since there are more of them and a better dispersion exists. The "Cycle Time Weighted % Difference Analysis" presents this in chart form, pages 151 to 153. Again, the element % difference from base (sub-totals on chart) are additive algebraically to yield the final % difference of one cycle time as compared to another. An examination of this analysis vs. the original Comparative Analysis will demonstrate how the original (high) % differences between elementals have been reduced drastically when compared on the basis of their effect on overall <u>cycle</u> time. The tight and loose values tend to cancel one another out. In general these cancellations are not too favorable in the case of the Work-Factor system. The founders of Work-Factor have implied that the Work-Factor Select Time does not compare to the base time of any other system of predetermined times, since the select time does not include an allowance for incentive payment. They do, therefore, also imply that the base times of those other systems do include an allowance for incentive. No where in the author's study of predetermined time systems has the latter point been verified. It might appear then, that this explanation is somewhat of a "device" which very nicely explains why Work-Factor is just a little bit "tight" when compared to the other systems of predetermined times. This should not in any way, however, be taken as a criticism of Work-Factor, since to the author's way of thinking the system is second to none in analyzing WHAT IS DONE in an operation. The system of symbols, definitions and variables, is highly universal in scope. Any general condition such as tightness or looseness in any system of predetermined times can very easily be adjusted to conform to an industrial organization through use of a constant correction factor. This, of course, will maintain consistency with Time Study.

A further examination of the "Cycle Time Weighted % Difference Analysis", pages 151 to 153, will provide a good indication of which fundamental motions or elementals are out of line the most as concerns their effect on total cycle time. The first step was to take the weighted % differences by elemental group (Body motions, moves, etc.) and determine from the analysis chart the weighted average ABSOLUTE % difference within each group. This was done, for example, simply by adding all the Body Motion weighted absolute figures together (disregarding sign) and dividing by the total number of Body Motions used in the analysis. In other words, what is essentially being said here is that the elementals with larger time values (all other things being equal) will in general tend to have the greatest effect on total cycle time if the original data is out of line in any way. A summary chart as follows was prepared:

Elemental Group	Average Absolute % Difference From Base Each Time One Motion Is Used	
	Work-Factor	BMT
Body Motions	± .92%	± .70%
Reach & Grasp	± .08%	± .23%
Move	± .32%	± .36%
Position	± .44%	± .08%
Release	± .08%	± .40%

On the basis of the operation studied, an example of the use of the above chart would be as follows: If BMT were being used and eight body motions of negative character came up in an analysis then the algebraic sum (8 x -.70 = 5.60%) would indicate a difference between it and the base system of over the prescribed limit of ± 5%. What is being brought out here is that if further study were contemplated by anyone, it would be more advantageous to concentrate on and review first those fundamental motions which had the greatest effect on total cycle time and the subsequent % difference engendered between systems when they are compared. Such a chronological order as developed from the previous chart is as follows:

A. First consider those motions which are most recurrent in any analysis, in the following order:

1. Body Motions
2. Moves

        3. Reaches and Grasps
    B. Other Motions
        1. Position
        2. Release

Hence, the above represents the most advantageous order of attack (from the standpoint of doing the most good as soon as possible) for further study of the validity of those motions as they affect differences in total cycle times when one system is compared to another.

The next problem is to take each group of elementals and determine how to analyze the data for that group if further study is contemplated. In short, the question must be asked, "Should the validity of the original data of each system be analyzed first or are the definitions of elementals as presented by each system primarily to blame for the time values being out of line with one another"? For the answer to this one must refer to the Discussion Summary Sheets which follow the Comparative Analysis of each elemental, pages 120 to 150. At the bottom of each summary sheet is indicated the probable reason(s) for discrepancy between the elemental time values. These reason(s) were determined for each elemental through an examination of the Comparative Analysis and the Discussion which follows each. The summary on the following page will prove helpful.

% Difference between individual elementals due to:

	From 48 Elementals *
Data	17
Definitions	14
Data and Definitions	17
TOTAL	48

* One of the elementals was omitted here because all of the definitions as well as all of the times compared favorably for that elemental.

From the above summary, it is rather difficult to say which classification held the greatest weight as far as causing individual elementals to be out of the ± 5% limit when compared to one another. However, it is the opinion of the author that if anything, it would appear from the results that the data should be checked first. The results as presented above do tend to lean in this direction at any rate.

Hence, there has been established in the preceding paragraphs, a chronological order for further study of the elementals, and also how to treat each elemental group in that study. The entire order of study was developed from the standpoint of doing the greatest good in the shortest amount of time.

Use of the Systems

Composite analysis. The cycle time values of the three predetermined time systems as compared to one another have already been determined for the operation, "Make Cartons", to be as follows:

1. Work-Factor...........	.3731 minutes
2. MTM...................	.4107 minutes
3. BMT...................	.3954 minutes

An inspection of the differences in times as well as the experience gained in analyzing the operation indicated the following things to the author:

1. Any one of the systems might perhaps have a definition for an elemental motion which would fit a specific situation, but many times a definition from another system would fit the situation better, simply on the merit of the actual wording of the definition and/or the number of variables which it considered. In other words, very often a specific elemental definition of a specific system really did not fit the situation too well, but it had to be used since it was the only value available and was, in effect, "better than using nothing at all". (See Discussion Summary Sheets, pages 120 to 150.)

2. At times any one system might not have any elemental definition at all to fit the situation. (This

occurred once in the analysis but could conceivably occur many times in other analyses).

The above considerations led the author to believe that there might be some particular advantage to using the most realistic elemental definitions of ALL of the systems to analyze a cycle and in so doing perhaps come closer to the time study cycle time value. From this standpoint the idea seemed to have enough merit to warrant the presentation of a "composite analysis" of the operation "Make Cartons" as presented in the preceding chapter. The following "rules" were used in the Composite Analysis:

1. Considering each elemental, select and use for that elemental the definition from any one of the three systems which best fits the situation.

2. If two or more definitions fit the situation equally well, then use the one which gives the highest time value.

The final cycle time value as determined by the Composite Analysis was found to compare more favorably to the Time Study value than that of any one of the other three systems. The chart on the following page indicates the comparison of the time values of the four systems to Time Study.

Time Value From	Cycle Time For Operation, "Make Cartons"
Time Study	.42
Composite	.4227
Work-Factor	.3731
MTM	.4107
BMT	.3954

In addition, it is interesting to note that of a total of 49 elementals being analyzed in the Composite Analysis, 20 were selected from Work-Factor, 20 from MTM and 9 from BMT; or 40.8%, 40.8% and 18.4% of the total respectively. The use of BMT was somewhat restricted because of its reach which included a grasp. For most situations encountered, this was felt not to be a good analysis, as previously discussed many times, because the exact nature of the "included" grasp could not be readily determined.

Which system is quickest and easiest to use? (Based on the operation that was analyzed) The question posed above requires that the investigation to be made include the actual number of symbols used in each analysis by each predetermined time system. In this investigation, in order to give a truer picture of the actual amount of symbol writing involved in each individual analysis, it was decided to include in the total the symbols for motions which are limited out as well as for those which are limiting. (Limited out motions must be written down in the analysis as well). The results are taken from the

Comparative and Composite Analysis Sheets of Chapter IV, pages 116 to 156, and are as follows:

System	Number of Symbols Used in the Analysis
Composite	75
Work-Factor	80
MTM	73
BMT	66

The above chart states, in effect, that on the basis of the operation that was analyzed, BMT is the quickest and easiest system to use, MTM was second, and Work-Factor the most time consuming. Impressions gained from actually analyzing the operation bear this out. It must be noted that the figure for the composite analysis is not realistic because that analysis considers three elemental definitions for each definition that is written down on the final composite analysis sheet. Hence the amount of work encountered in using the composite system would be multiplied approximately threefold, if not more.

RECOMMENDATIONS

Concerning Further Study of the Predetermined Time Systems

Comparison of the systems one to another (elementals). As per the conclusion, the following chronological order of study of the basic motions or elementals is advised on the basis of the accuracy it can add to the systems in bringing their time values more in line with one another in the shortest possible period of time.

Chronological Order Of Study	Considerations Within Each Group In Order Of Importance
1. Body Motions	a. Data b. Definitions
2. Move	a. Data b. Definitions
3. Reach and Grasp	a. Data b. Definitions
4. Position	a. Data b. Definitions
5. Release	a. Data b. Definitions

Comparison of the systems to time study. This is a different picture entirely from the general theme upon which this thesis has concentrated. In order to compare any predetermined time system (PTS) to Time Study, there must first be available many time studies and their respective PTS analyses. In short, there must exist a representative sample. Each individual time study result should be compared to its respective PTS analysis and the cycle time differences noted and recorded. After the proper sample size (number of studies to be considered) has been determined statistically, the analysts must treat this data, again statistically, to determine whether or not there is a significant difference between Time Study and the Predetermined Time System being used, based on some predetermined % difference (an acceptance percentage) that is acceptable to management. (Normally this would be the ± 5% difference that is allowed in time study).

This type of analysis, however, will require a great deal of time, but it is highly advisable for an industrial organization to undertake such an investigation before turning to full use of PTS, so that first, confidence in the system is had by all, and secondly and more important, that CONSISTENCY (the backbone of Time Study) is maintained. Even if it is discovered that the time values exceed the ± 5% acceptance percentage as described, the PTS values may all be adjusted by a constant correction factor as determined from the "representative sample" analysis. This procedure will maintain consistency between those time standards already in effect and the predetermined time system to be installed. This entire course of action is, of course, only to be taken if the management of a company decides that the use of a predetermined time system is worthwhile either on a "full or a part time" basis.

Concerning Use of the Systems

Composite system. The results of the Composite Analysis, pages 154 to 156, indicate the existence of a definite trend toward the validity of the thinking that a composite type analysis which uses the "best" of all predetermined time systems is an excellent answer to the question, "Which system shall I use?".

Of course, the problem of practicality enters at this point, since the Industrial Engineers of a company would have to put forth much time and effort in familiarizing themselves with all of the established systems of predetermined time standards. It is a known, but oft neglected fact that the uninitiated should never attempt to use a predetermined time system without adequate study and experience with the system-in-question. Hence, from this standpoint, the idea of a composite system may not be given further consideration from many industrial organizations, since such an intricate knowledge of all of the systems is involved. Perhaps the idea of a composite system will receive more attention in the future when the various systems of predetermined times are better known.

Nonetheless, regardless of the practicality as discussed, the results of the Composite Study as brought forth in the Conclusions do show a definite trend towards producing a cycle time which compares much more favorably to the time study value than any one of the other three systems of predetermined time standards. This is so most probably because the Composite System takes into account the most realistic elemental definitions of each system. It is the author's opinion that properly used, a System of Composite Analysis would be quite worthwhile, and would fit quite well into the plans of any industrial organization contemplating the use of a system of predetermined times.

Standard systems. If it is desired to select any one of the three predetermined time systems (Work-Factor, MTM, BMT) for use in an industrial organization, it might be wise to study the Discussion and Summary Charts of Chapter IV as well as the description of how to use each system as presented in Chapter II. Much of this information can serve as an excellent basis for comparison between the systems, and should prove valuable as an aid in helping one decide which system best fits the needs of the company-in-question. Also the fact that one may observe each system as it is used to analyze the same operation may be classed as a distinct aid in the selection of a predetermined time system.

It might be added here that if full or part time use of any one of the predetermined systems is contemplated then a progressive management should:

1. Make sure that their Industrial Engineers have proper training in the system of their choice, such training being given by qualified personnel.

2. Undertake the statistical investigation of the

Time Study and PTS data as set forth in the Conclusions.

Consideration of these two points will greatly increase the probability of the successful use of any system of predetermined times within an industrial organization.

CHAPTER VI

CRITICAL EVALUATION

THE OKONITE COMPANY

OKONITE

MANUFACTURERS OF INSULATED WIRES, CABLES AND SPLICING TAPES

FOUNDED 1878

FACTORIES: PASSAIC, N. J.
WILKES-BARRE, PA. - PATERSON, N. J.

TELEPHONE
PRESCOTT 7-0400

PASSAIC, N. J.

May 10, 1957

Mr. Richard O. Schmid
379 Washington Avenue
Union, New Jersey

Dear Mr. Schmid:

I have reviewed your thesis entitled, "An Analysis of Predetermined Time Systems". I sincerely believe you are to be commended on the comprehensiveness of your thesis and, also, on the painstaking manner in which you have analyzed the inherent variations which characterize three (3) of the most prominent predetermined time systems.

I have appreciated this opportunity to read your thesis since a great deal of consideration has been given to the desirability of adopting a predetermined time system at Okonite to augment the present practice of time study. Your report, in part, has substantiated some of the arguments which have been presented in favor of adopting a predetermined system. Since your thesis did not concern itself, however, with a comprehensive comparison to time study on all factors, the prevailing arguments against predetermined time systems for our operations cannot be included as a part of this critique.

It should be stated, however, that work measurement -- whether time study or some system of predetermined times is used -- inherently contains features which could give rise to inaccuracies and inconsistencies in the completed standards. Assuming all other variables are held constant through competent personnel, the rating factor and allowances, in most instances, generate the controversial aspects in the daily applications of time study and its counterpart, wage incentives.

I am inclined to agree that the adoption of a predetermined system should minimize the inconsistencies and inaccuracies which are normally related to the rating factor. However, it would seem that this feature, alone, is not so superior over other considerations that it should govern one's decision to adopt a predetermined system, or to select one system over another.

In the first part of your thesis you have very capably presented the background of predetermined time systems and, also, presented most of the advantages associated with the use of them. I do not believe that these alleged advantages can be generally applied to all types of operations. I believe that predetermined time systems predominate at only one end of the spectrum -- particularly on fine assembly operations where micro-motion study could also be advantageously applied. In most other areas, I believe that some very cogent arguments could be presented in favor of conventional time study.

I cannot completely agree that the evolution of a System of Composite Analysis is the solution for reconciling the problem of which system a company should adopt. The results of each system do not compare so unrealistically that refinement, to the degree of a composite system, is required.

The essence of the selection would be to select a system of predetermined time values which would be applicable -- within the accepted degree of deviation -- to supplement a conventional time study system. Any company which has been using time study to good advantage for any period should be able to select, and support statistically, the system which gives the desired accuracy and ease of application.

One further thought should also be expressed concerning the development of a standard data system which uses information a company has developed and applied successfully. I would expect that it would be a very time consuming and unrewarding program to develop facility with any more than one system of predetermined time values. You have not particularly emphasized the development of predetermined time values based on time study information which has been converted to standard data; but I would recommend that this would prove much more beneficial to a company than adopting a system of time values which could not get their genesis within the company's operations.

All in all, I believe you have handled the subject matter quite expertly and have provided any reader with a deep insight into systems of predetermined values. My comments would not take exception in any way with the accuracy of your data, but rather with the practical relationships which should be associated with any system of work measurement.

Very truly yours,

V. A. VIGGIANO,
DIRECTOR OF INDUSTRIAL ENGINEERING,
THE OKONITE COMPANY.

VAV:ks

25 Grant Avenue,
Clifton, New Jersey
May 16, 1957

Professor O. J. Sizelove
Department of Management Engineering
Newark College of Engineering
Newark, New Jersey

Dear Professor Sizelove:

I have read the thesis submitted to you by Mr. R. O. Schmid entitled, "An Analysis of Pre-determined Time Values," and the following is my critical evaluation thereof.

Mr. Schmid has written a well-organized thesis which uses a sound approach in attempting to compare the various systems under consideration. It is my opinion, that he has made an excellent start towards weighing the factors involved and presenting a sound approach for future research in this direction. However, there are several features which require revision before the conclusions indicated are accepted on face value.

1) It is apparent from a cursory study of the analysis sheets that the writer has not had substantial experience in the application of the specific techniques. Despite this lack of experience, he arrives at reasonably accurate results but before further developments are made upon this base, these analyses should be reviewed for their accuracy.

2) The conclusions at which Mr. Schmid arrived at were, of necessity, based upon a very small sample. If this type of research were extended by experienced personnel and a statistically reliable sample were employed, the results obtained would have more weight in the profession.

3) Mr. Schmid's analysis points up one of the basic problems in evaluating pre-determined time values that is the fact that some of the elemental descriptions employed are not sufficiently discriminating to enable the user to apply them without rationalizing their meanings.

4) Comment was made in the thesis in an interpretation of the Work Factor technique that its time values are a bit on the tight side, and that its explanation was merely a device to explain this away. It should be noted that since the inception of Work Factor, the authors have maintained this same statement and have not adjusted their time values to cover this up.

5) Mr. Schmid suggests the possibility that a solution in this problem is to develop a composite system. Several attempts have been made at this, namely; General Electric Company, etc., and the resulting systems have not been much of an improvement. It is my suggestion that instead of trying to develop a composite system, that some person or group select one of the systems which they feel has merit and work out the specific problems on this system to meet the criteria which have been established.

6) Lastly, Mr. Schmid suggests a sequence for further study and indicates that the data should be revaluated first, and then the definitions clarified later. It should be noted that if the definitions are not sufficiently clarified before the data is collected, the results will be of little value since the data will be collected on one basis, while the definitions will be established on another basis. Again, it is my suggestion that firstly, we agree upon adequate definitions and then collect the data in consonance with the definitions.

In summary, I feel that my qualifications of this thesis are minor compared with the basic work which Mr. Schmid has done. However, I think that if these few modifications are made and further study is developed, we might achieve the goal that Mr. Schmid and others of us have been seeking for years.

Yours truly,

John Feltman

JF:bc

CRITICAL EVALUATION

Of Thesis:

AN ANALYSIS OF PREDETERMINED TIME SYSTEMS

Penetration:

Mr. Schmid's thesis shows evidence of considerable detailed analysis of three systems for developing predetermined time standards. His is a complete grasp of the origin, development and application of those systems.

Scope:

The scope of the study does not satisfy the title of the thesis, which leads one to believe that all extant systems for the predetermination of time standards are considered in the study.

Rather, the scope is limited to three of the five systems identified in the body of the thesis. This limitation reduces the value of the work from one of broad contribution to a selective comparative study. It would appear that only those persons interested in making a selection from among the three systems chosen by Mr. Schmid would find the thesis helpful.

Although antiquity is not necessarily a measure of value, one wonders why Motion-Time-Analysis (MTA) was given such shortshrift, in view of the fact that this particular system was originated some ten years prior to Work-Factor, the earliest of the three systems subjected to analysis.

Approach:

It is this critic's opinion that the use of a specific operation as a basis for comparison of the systems was unnecessary for the purpose of the thesis and does, in fact, make difficult the reader's acceptance of the conclusions. It would seem the same end might be reached by simply comparing times for well-known elements or elementals, such, for example, as the operation of a typewriter, or a pencil sharpener.

Conclusion:

The conclusion of the thesis is difficult to identify. On the basis of resultant time values, none of the systems appears to agree with any of the others. Nor do any of them appear to be compatible with the results of normal timestudy procedure.

The inferred conclusion that a compromise of all three systems agrees with the results of normal timestudy practice is not very scientific. As one swallow does not make a summer, one coincidence does not make a theory a fact.

Usefulness:

Perhaps the most useful feature of the thesis is the conclusion that much more study will be needed before the validity of the principle of predetermined time standards can be proved. From the point of view of the industrial manager, reliable answers to the following questions need to be developed:

1. Is there a system which is better than normal timestudy procedure for the determination of standard times for specific operations?
2. If so, how is such a system better; is it less costly in application; does such a system give more uniform results?

Composition:

Length is perhaps the most obvious characteristic of the thesis. One gets the impression that a careful editing job would improve considerably the readability of the work and would result in pruning out much of the well-known material.

The thesis would be much more readable if it were presented somewhat in reverse. That is, the conclusions first, then the detail supporting the conclusion and finally, in appendix form, the historical data concerning the various systems.

W. F. Weir
Plant Manager
The Okonite Company
Passaic, New Jersey

5/13/57

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