A FEASIBILITY STUDY FOR A FOOD SERVICE PRODUCTIVITY INDEX DERIVED FROM METHODS-TIME MEASUREMENT

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1973

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
May, 1977

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ACKNOWLEDGEMENTS

The author would like to thank her major adviser, Miss Mary E. Leidigh, for her guidance and foresight and also the other committee members, Dr. Esther A. Winterfeldt and Dr. Bernice Kopel, for their assistance in the writing of the thesis.

Thanks are also extended to Mr. F. Joe Blair, Director of Food Service, and to Mr. W. Dale Sloan, Manager of Willham Cafeteria, for allowing this study to be performed and to Mrs. Bea Wagner and the salad workers at Willham Cafeteria for their patience and aid during the study.

A note of gratitude also goes to Mr. James Stewart for his aid in setting up the engineering analysis and to Mr. John R. Fannan for his support and assistance throughout the study. Also, thanks to Mrs. Joyce Gazaway for assistance in typing, arranging and doing final tasks for the completion of this degree, to Mrs. Allene Brown for her assistance in the writing of this thesis, and to Dr. Ruth Pestle for guidance during the preliminary stages.

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CHAPTER I

INTRODUCTION

Statement of the Problem

In the present days of spiraling labor and product costs, the food service industry faces some complex questions which require immediate solutions. For instance, how can labor be utilized to the best advantage? Is the industry searching for better products, methods, and equipment; or is food service falling behind in scientific research designed to update industry?

Unfortunately, statistics indicate that the food service industry is not meeting the challenges facing it quickly enough. Service industries have the lowest productivity growth for the period of 1950 to 1972 according to the National Commission on Productivity (1). For the same time span the annual rate of productivity growth was only 2.6 percent for food service as compared with 3.5 percent for industries producing goods rather than services. One cause for the low productivity in food service is the lack of coordination among different sectors of the industry and the government programs. Often, positive gains toward increased productivity in one part of the food service industry are negated by another sector because of this lack of coordination. For instance, a food processing firm may alter the packaging of a product in order to ease the loading, transportation, and deliveries and to increase the amount of space utilized. The receiving firm may not have the facilities or equipment to handle these innovations and must expend more time and energy in the handling and storage of the new packages.

Productivity is difficult to define and measure in service industries. Because processes are not highly repetitious, tasks do not lend themselves to easy analysis of work elements. The purpose of this research was to test the feasibility of a new type of productivity tool--a productivity index for food service. Nine vegetable preparation tasks were chosen to be analyzed and to be assigned standard times for the operations performed using a specific method. The analysis system used was methods-time measurement (MTM). The standard times derived were tested on vegetable preparation personnel to check the feasibility of developing such an index more fully. Two assumptions have been made: (1) the food service industry has an urgent need for an accurate and standard measuring device for productivity; and (2) the developed index could be used in any food service establishment.

It is anticipated that, with minor adjustments, a fully developed index could be used in any food service operation. Managers and supervisors would be able to rate the productivity level of their personnel. In addition, employees would be able to find ways to change the present work systems to increase output. In essence, the index would be more than a measurement device; it would be a tool to increase productivity in the food service industry.

Objectives

The first objective of this study was to assign standard time values to the observed vegetable preparation operator's motions by using the methods-time measurement technique. The second objective was to develop a productivity index for the nine chosen vegetable preparation tasks, utilizing the MTM data. The third objective was to test the proposed index and the fourth was to evaluate it. The results are stated in terms which will help a food service manager in deciding whether to use an index or another measurement system to measure productivity.

Delimitations

1. The data was collected at Willham Cafeteria, an Oklahoma State University Food Service cafeteria.

2. The study involved fresh vegetable preparation personnel only.

3. Food quality was a constant factor.

4. All produce which did not meet the standard quality requirements of the respective food service establishment was eliminated from the study.

Definition of Terms

Productivity is a concept that expresses the relationship between the quantity of goods and services produced--output, and quantity of labor, capital, land, energy, and other resources that produced it--inputs (2).

Productivity growth means getting more output for a given level of resources used, or getting the same output for less input of resources (3).

A productivity index is a work measurement concept indicating the amount of work required to accomplish a given output (4). It is a ratio obtained for observations used as an indicator or measure of productivity.

Methods-time measurement (MTM) is:

> . . . a system of predetermined motion-time standards. It is a procedure which analyzes any operation into certain classifications of human motions required to perform it and assigns to each motion controlling only the individual performing it a predetermined time standard which is determined by the nature of the motion and the conditions under which it is made (4, p. 345).

A job component is that detailed part of a work task which, when combined with other related components, forms the entire job. It is a minute description of one of the tasks constituting a job. For example, slicing celery is a job component of the task of making potato salad.

Quality denotes a degree of excellence. Excellence is measured by the degree of acceptability of a food of specific quality by the majority of people (5).

Simulation is a process where an analysis is made using a mock workplace, blueprints, and samples of equipment and ingredients. The observer does not see the operation in actual practice, but rather visualizes and simulates with the aid of props.

CHAPTER II

REVIEW OF LITERATURE

The review of literature highlights several phases of productivity, including productivity growth, the measurement of productivity and the relationship of productivity growth to food service. It also discusses methods-time measurement, its history, objectives and the uses for MTM.

Productivity is:

> . . . a concept that expresses the relationship between the quantity of goods and services produced--output; and the quantity of labor, capital, land, energy, and other resources that produced it--inputs (2, p. 1).

Productivity Growth

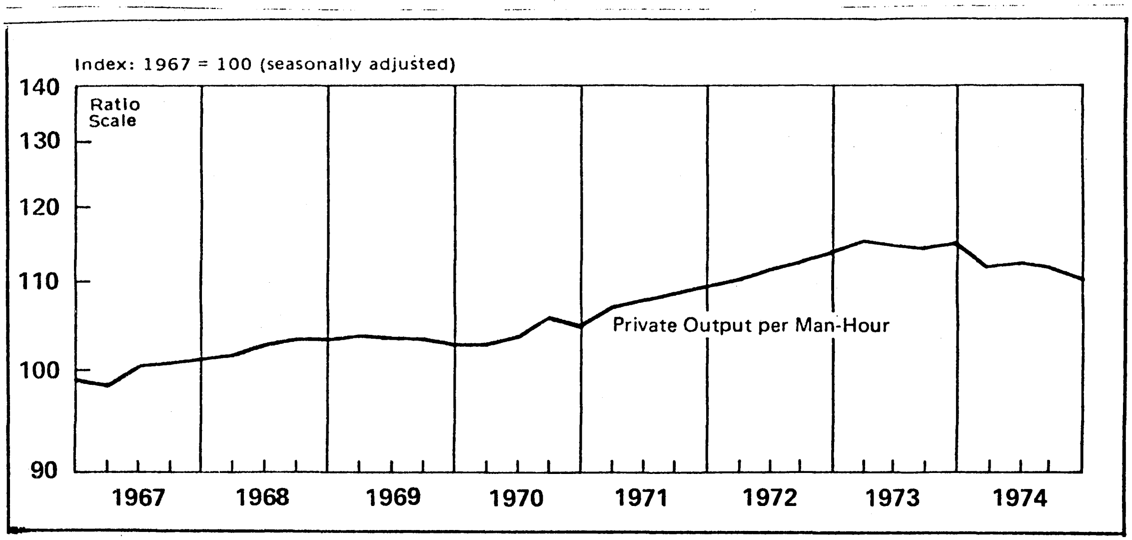
Productivity growth implies that more output can be produced by using the same amount of inputs or that the same amount of output can be produced using smaller amounts of inputs. Increased productivity results in higher wages and the increased buying power of consumers with more and better choices of products available (3).

The National Commission on Productivity (6) states six results of productivity growth. The first is a sound economy. Productivity growth also helps curb inflation as the growth directly affects the upward movement or expansion of the business cycle. Output growth is also necessary for any country to compete in an international market. Increased productivity raises wages and profits enough to direct efforts toward new areas such as a clean environment. It also allows for contributions and aid to underdeveloped nations. Finally, productivity growth allows for greater community services without an increase in taxes.

Four sources of productivity are listed by the National Commission on Productivity (6). Human resources is the first source. As the quality of the labor force rises, so does the growth of output. The rise in quality is due to a generally higher level of education of the working force and to the greater amounts of employees in highly skilled professions. Natural resources are the second source of productivity growth. These are limited and the best utilization of them is a factor contributing to output growth. A third source of growth comes from capital, which is funds, facilities, equipment, and technological tools. An economy in a state of expansion attracts capital returns to the economy with a relatively stable price. This in turn creates a stimulus for new and efficient growth. The amount of capital supporting each worker has increased, thus raising the overall output. Technological innovation, the result of research and development, is the last source of growth. For the technology to be useful, there are three prerequisites according to Nelson, Peck and Kalachek (7). The work force must have the relevant knowledge, the organization must be able to effectively control the knowledge, and the necessary material inputs must be provided. Technological advances are evident in new product designs, new process routines, and improved management techniques.

In the United States private economy the productivity fell by 2.7 percent starting in the first quarter of 1973 through 1974 (see Figure 1). For 1974, productivity fell in most industries. It increased at an average annual rate of 3.1 percent in the post-war period of 1947 to

1974. Figure 2 shows the trend line and gives evidence that the growth rate is decreasing for each decade. The average rate of growth at the beginning of the post-war period was 3.6 percent per year; it was 3.0 percent in the middle and 2.4 percent at the end (8).



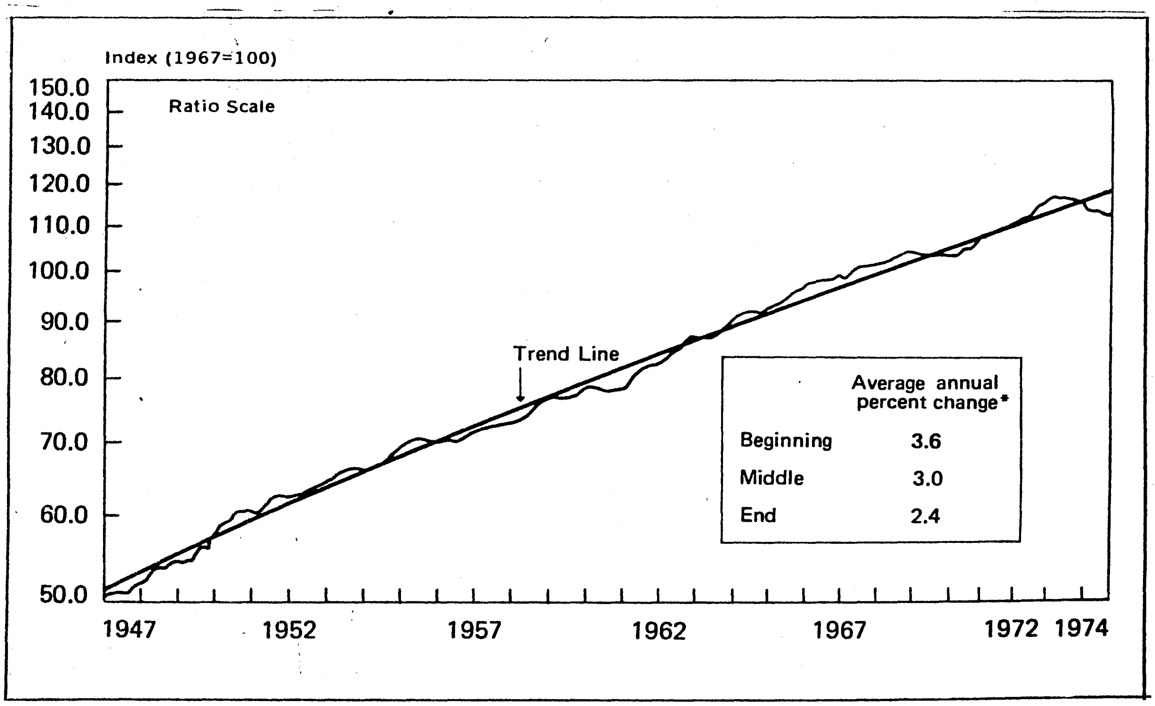
Source: National Commission on Productivity and Work Quality, Fourth Annual Report, March 1975 (1975).

Figure 1. Productivity Dropped Sharply from 1973 to 1974

The decrease in productivity in the past several years has these possible factors:

1. Some major industries are being faced with a retarded productivity growth brought about by various conditions.
2. Service industries and government are employing a larger segment of the work force. Productivity levels in these areas are historically low (see Figure 3).
3. As employment in agriculture declined, productivity increased as a result of industrialization. The employment rate has now ceased to decline.

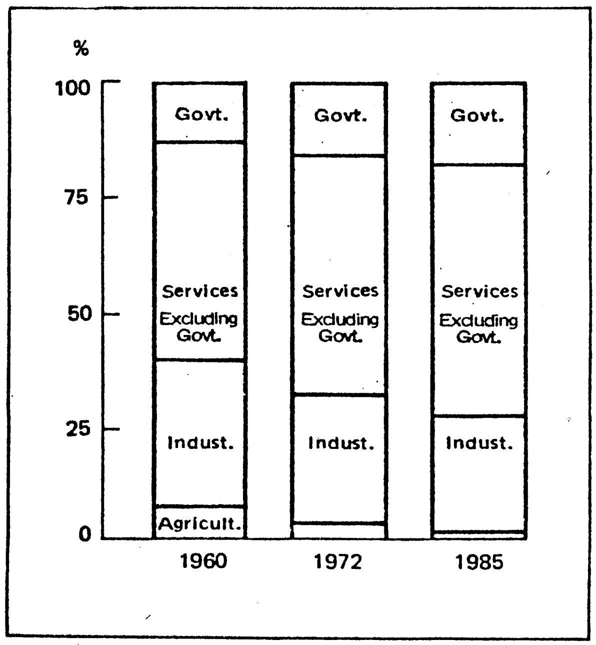
4. In the late 1960's a large number of young and inexperienced workers entered the labor force, depressing productivity.
5. On an international basis, the United States had the smallest proportion of Gross National Product in capital investment over the 1960-1973 period in comparison to the other major countries: Japan, Germany, France, United Kingdom and the USSR. Output in the United States was also low.
6. The United States is spending less money for research and development than Japan, Germany, and the USSR (8, pp. 14-15).



Source: National Commission on Productivity and Work Quality, Fourth Annual Report, March 1975 (1975).

Figure 2. Output per Man-Hour Growth Rate has Tended to Slow Down Over the Post-War Period

The American public tends to mistrust any economic moves toward productivity increases. Many employees have the idea that speedups of production mean harder work with the same wages. They feel that stockholders and the management gain from growth in output, but not the worker. In addition, the average consumer does not understand long-term gains of productivity growth. Short-term losses such as job displacement are well advertised by this group. These attitudes harm the national effort to increase output growth (9).



Source: National Commission on Productivity and Work Quality, Fourth Annual Report, March 1975 (1975).

Figure 3. Shift in Industrial Distribution of Employment is to Services

In order to ease the problems associated with increasing productivity the United States must not only develop new technological processes;

it must adjust to the changes brought about by the developments. To ease the adjustment, a higher level of education, better transportation and communication, and a greater savings reserved should be emphasized. Arrangements are also being made by the governments and private organizations to help displaced workers, such as retraining services, job relocation, and unemployment services (8).

The area of productivity growth needs more research. Better methods are needed to show what an adequate level of output actually is. Comparative data from other countries must be compiled. A uniform and consistent measurement system must be devised which will take into consideration prices, wages, and unit labor costs.

> The task of developing a long-range program to raise productivity must proceed on a wide front and involve policies relating to support of science and technology, capital investment requirements, development of management skill, manpower training and adjustment, the quality of the work environment, government operations, market structure and many other factors. National policies must take into account the specific problems of individual industries if they are to have practical results (8, p. 20).

Measuring Productivity

There are several methods of measuring productivity. One measurement system relates an output to a single input. For instance, the output of an industry could be related to an input or capital labor. Another way to measure productivity takes all inputs into account and is called a total factor measure. This method relates the output to combined inputs and the relative importance of the inputs is reflected (2).

Siegel (10) of the United States Department of Commerce, has the following comments on measurement of productivity. He states that an index is one method of measuring productivity for it can be a ratio of physical output and input measures, such as the number of units produced related to labor. The ratio in the index can also be one of dollars, or the cost of inputs and outputs rather than physical quantities. Also, an index can reflect the difference between the sum totals of output and input quantities expressed in a common unit, for instance dollars. The output or numerator of the ratio can be expressed in gross or net terms, depending on the purpose. The gross national product, for instance, is the "total final output of goods and services produced in the economy of a nation" (11, p. 80) while the net national product "measures net income or output created" (11, p. 104). Inputs can be divided into categories, such as man hours and quality of labor, or remain as a composite figure such as the total aspects of labor.

Siegel's quasi-productivity measure, therefore, infers that the denominator of the ratio is not solely, or at all, input. The ratio can be that of a finished product, or output, to the required volume of intermediate products. Intermediate products are "goods purchased and resold, with or without further processing" as defined by the Department of Commerce (12, p. 63).

Food Service and Productivity Growth

In America today over 66 percent of the work force is employed in service industries. This is due to the consumer's willingness to purchase luxuries. In 1972 sales figures for the food service industry reached $32 billion as compared to $23 billion for the automobile industry and $19 billion for the steel industry. Food service establishments employed 2.5 million people or 3 percent of the total United

States' labor force or 22.5 percent of all people employed in the retail market. The growth of employment is projected by the National Commission on Productivity at a compound annual rate of six percent through 1980. Over the past 30 years food service has experienced a productivity growth of nearly zero. Contributing to this low level of growth is the lack of adequately trained personnel at all levels and the lack of communication and common goals between the worker and management. In some areas of the food service industry the labor turnover is as high as 300 percent per year. Restaurants are often thinly capitalized and operate over a short-run period rather than a long-run (9).

The National Commission on Productivity (1) created a task force in 1972 to study the food industry because of the large proportion of employees involved and the amount of sales. It was found that the food industry is composed of separate and complex industries which are dependent on each other. Each individual industry makes attempts to raise productivity within itself. There is an obvious need to coordinate these separate industries and revamp government regulations so the improvements instituted in one arm of the industry will not adversely affect another branch. Five areas for improvement were identified by the task force. They are:

1. Eliminate poor and restricting government regulations.
2. Increase the use of rail transportation for food.
3. Identify and implement agricultural production operation changes.
4. Clarify anti-trust regulations which cause confusion and result in inhibition of trade.
5. Increase research and market development (1, p. 10).

In the spring of 1974, the National Commission on Productivity held three conferences with the Massachusetts Institute of Technology.

The project--Technology Applied to the Food Industry (TAFI)--hosted a variety of food-oriented business people and engineers who exchanged ideas. As a result of these conferences, MIT urged expansion of the project and cooperation by food industry trade associations to establish research priorities (8).

Any further actions taken require the combined efforts of the industries involved and the government. Changes must be made with the long run trends in mind and it must be understood that the single improvements will not be effective without accompanying changes. The improvements mentioned cannot be made at the expense of other national goals such as safety and environmental control (1).

The History of Methods-Time Measurement

The father of scientific management, Frederick W. Taylor, was promoted in 1885 to the position of foreman at the Midvale Steel Company in Philadelphia. In his new position Taylor was responsible for the quantity of production of the men under him. He soon came to the conclusion that the factory was operated inefficiently with the main the lack of organization. The management and the workmen seemed to be two separate entities atagonistic to each other's ideas and performance.

Taylor soon stated that "the greatest obstacle to harmonious cooperation between the workmen and the management lay in the ignorance of management as to what really constitutes a proper day's work for a work man" (13, p. 10). Taylor proceeded to work on this problem and developed what is now commonly called "time study". Using a stop watch he broke down the day's work into smaller elements. He analyzed the jobs in this way, timing them and rearranging the job elements to find the best methods. Not only was Taylor concerned with the materials, equipment and tools used by the workmen but also with the workman himself and his mental and physical condition and reactions. Taylor's "proper day's work" is taken to mean the work that can be done every day all year and not that which can be accomplished in short periods of time. He realized the greatest productivity results when the workman has a definite task, a definite time period and a definite method to use in performing the task.

Four objectives were outlined by Taylor. The first was to replace the old rule-of-thumb methods with scientific management. The second was to select the best man for each job and to train, teach, and develop him. The third was to enlist the cooperation of the management and workmen in the application of scientific manpower. The fourth principle was that of dividing the work evenly between management and the employees, giving each group those tasks for which it was best suited (13).

Not all people agreed with Taylor's new principles. Most of the objections came in the early 1920's when several groups felt that he was not concerned with the human side of the employee and that he was creating problems instead of solving them. But today Taylor is accepted as a prominent man in the management field with tremendous ideas which have come a long way.

Other pioneers in this area were Frank B. and Lillian M. Gilbreth. They made many field and laboratory studies of motions and methods. Frank Gilbreth was instrumental in analyzing and improving many methods but his greatest contribution was made with his wife when they developed the micromotion study procedure. With this procedure a job could be recorded on film and a timing device would enable the researcher to determine the time required to perform the elements of a task.

At first Taylor's time study and the Gilbreths' motion study techniques were considered to have no relationship. Through the years with continuous use and knowledge, the two methods have merged in use and application and have become inseparable.

In 1948, Harold B. Maynard, G. J. Stegemerten and John L. Schwab (14) presented a new system of analysis to the engineering world. It was called the methods-time measurement (MTM). Their data was obtained from motion picture analysis from which was developed a classification system with nine major groups and 68 subdivisions of basic body motions (see Appendix B). The data was made public so that other groups could test the new system. One school in particular, Cornell University, found the data to be sound, but indicated the need for additional research. The MTM Association for Standards and Research originated there in the late 1940's. The purpose of the association was to develop research, maintain high standards of application and provide members with information at frequent intervals.

From 1948 to 1960 the association was involved mainly with validating and expanding Maynard's, Stegemerten's and Schwab's original data. Since 1960 the MTM Association has devoted its efforts to technical assistance to expand the uses of MTM. MTM enjoys the distinction of being the only "predetermined motion-time system" to have "laid down an international standard of competence" (14, p. 8). Its use has increased greatly as ten countries have joined to form an international MTM Directorate to guide the advancement of MTM.

The Methods-Time Measurement System

Methods-time measurement, being a type of methods analysis used by industrial engineers, is closely related to other types of analysis systems.

> Methods engineering is the technique that subjects each operation of a given piece of work to close analysis . . . to eliminate every unnecessary operation . . . and to approach the quickest and best method of performing each necessary operation; it includes the standardization of equipment, methods and working conditions; it trains the operator to follow the standard method; . . . it determines by accurate measurement the number of standard hours in which an operator working with standard performance can do the job; . . . it usually . . . devises a plan for compensating labor which encourages the operator to attain or to surpass standard performance (15, p. 7).

As a broad category, methods engineering encompasses many types of measurement and analysis procedures. The method concerned with in this study is MTM (methods-time measurement).

> Specifically, MTM 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 (15, p. 12).

The requirements of methods engineering are fulfilled by MTM. Each operation receives close scrutiny. After the method is observed it is analyzed for useful and useless motions and an "ideal" method is derived. Standardization of methods and operation times follows with a training period for the operator. Standard times for specific jobs and elements of these jobs are found. An MTM study does not have to result in a plan for compensating labor, although productivity should be increased; profits should rise and employees should feel some positive benefits from their increased productivity level. Work improvement is another term used to describe an organized analysis of work problems and their solution (16).

Barnes (13, p. 4) defines motion and time study as:

> . . . the systematic study of work systems with the purposes of (1) developing the perferred system and method--usually the one with the lowest cost; (2) standardizing this system and method; (3) determining the time required by a qualified and properly trained person working at a normal pace to do a specific task, or operation; and (4) assisting in training the worker in the perferred method.

MTM falls under the motion and time study definition also. The time standard spoken of above is defined by Kazarian (4, p. 350):

> . . . the time which is determined to be necessary for a qualified workman, working at a pace which is ordinarily used under capable supervision, and experiencing normal fatigue and delays, to do a defined amount of work of specified quality when following the prescribed method.

The principles of motion economy are the backbone of MTM. No effective solutions can be formulated without knowledge of these principles. They should be followed in order to increase productivity and at the same time keep effort and fatigue at a minimum. The principles which are stated and explained in Appendix C (page 74) cannot possibly apply to every situation, but they are included as a basis for work analysis. Appendix A (page 51) explains how to set up an MTM system while Appendix B (page 55) shows the charts and detailed explanations of each chart. Barnes' (13) Motion and Time Study and Karger and Bayha's (17) Engineered Work measurement were used as the basis of Appendixes A and B.

The Objectives and Uses of Methods-Time Measurement

All methods of work analysis or improvement have the same general objectives. One is to decrease the costs of operating a business but at the same time improve service to the consumer. Another objective is to avoid those activities which are nonessential and thereby increase the effectiveness of those activities which are necessary. A work analysis program should help the employee to make his job easier and safer, eliminate any duplication of effort or waste of time, energy or materials and estimate manpower and equipment needs. The program, if conducted properly with the acceptance and support of both management and employees should introduce a climate receptive to change, make them aware of the scientific approach to work problems and in general increase productivity (16).

Each branch of work analysis also has specific objectives beyond those noted above. MTM is used either to develop effective methods of production before the operation is begun or to improve those methods already in existence. For example, MTM can establish time standards for individual jobs and also time formulas (standard data). In addition, it can be applied to the estimation of labor cost. Before a product has been produced, it can influence its design, develop effective tool designs to be used for the production method, and select the most effective equipment for the specific job. By using MTM analysis and involving management, supervisors, and employees, all those participating can be trained to be methods-conscious. When work grievances arise MTM data can often be used to help settle them, especially when time standards are involved. The use of the MTM system can result in more research, especially concerning methods, learning time and rating (15, 18).

There are factors which adversely affect any work analysis system. The first is resistance to change. This resistance can be cultivated by emotional blocks to progress, an attitude which connotes that anything new is impossible and by a general lack of understanding. Habit is another factor which contributes to resistance; it is very hard to break a long-term habit.

Job dissatisfaction and probably poor self esteem can advance the attitude of resistance to change. When management is consistent in giving late notices involving changes and does not consult with employees or properly explain the work analysis program, the employees may experience a personal loss of status (16). To overcome the resistance to change, employees should be encouraged to participate and express their own ideas and opinions. Those changes originated by employees will seldom be challenged by that group.

The second factor adversely affecting work analysis is the resentment of criticism which also arises from a lack of understanding or fear of what an unknown method or system can do to the employee's job, status, and wages. The resentment can be overcome by explaining properly and involving employees fully with the proposed changes and making them understand that no criticism of past or existing methods is intended (19).

According to Close (16) there are four ways to increase employee interest in a job and thereby decrease the resistances mentioned above. The first way is to rotate jobs, allowing for more variety and thus avoiding boredom. The second way is to provide an inspection of work, which will tell employees that supervisors and the management really are interested in their accomplishments. Being able to adjust and set up their own work areas, which shows the employees they are trusted, is a third method and the fourth one is to plan the facilities to be conducive to employee interaction.

Close (16, pp. 341-342) also feels that employees are concerned primarily about the following ten conditions (in descending order of importance):

1. Full appreciation of work being done.
2. Feeling of 'being-in' on things.
3. Sympathetic help on problems.
4. Job security.
5. Good wages.
6. Interesting work.
7. Promotion and growth in the company.
8. Personal loyalty to workers.
9. Good working conditions.
10. Tactful disciplining.

By keeping all of these factors in mind while setting up a work analysis program, it can prove quite successful.

The Pros and Cons of Methods-Time Measurement

Methods-time measurement has a long list of advantages for those who may choose to use this analysis method over another. For example, MTM

--eliminates rating of operator performance by leveling, or the evaluation of skills, efforts, conditions and consistency.

--forces the supervisor and analyst to concentrate on the method, not the time. Following the same vein, employees will be aware of observations but no timing will be evident, thereby discouraging problems with those who resent being timed. The use of a stop watch is very limited with MTM.

--forces the analyst, supervisor, and employee to see the method as it is. MTM can help improve methods if it is necessary.

--produces accurate time standards without the application of timed studies and in less time than direct time studies.

--develops a more consistent standard approach to work between departments and jobs. If the study has been conducted properly a team spirit between management and employees will ensue. Employee morale will rise as his satisfaction in his job and work increase.

--decreases rigid resistance to change and increases productivity if the employees accept the program.

--develops time standards and methods for the future.

--makes supervisors aware of internal problems and presents ways of solving them. As supervisors and employees become more proficient in this area, operating costs can be reduced and common goals can be developed with the two groups.

--can be the basis for resolving grievances, whether union-based or otherwise. Employees and managers will have actual standards (time and method) to rely upon.

As in all systems, MTM has several limitations. MTM

--can be applied only to manual operations where the performance time is not influenced by the processing time, or that time over which the employee has no control such as machine operation.

--requires prior training, a complete understanding of the system and an ability to make quick and accurate judgments. The analyst must be aware of the advantages and limitations and not abuse the system.

CHAPTER III

PROCEDURE

Ten vegetable preparation tasks were chosen by the researcher from a complete list of vegetable preparation tasks performed at Willham Cafeteria, an Oklahoma State University Food Service Residence Hall cafeteria. The tasks were analyzed and had standard times assigned so a productivity index could be derived for each of the tasks. The ten jobs selected were:

1. cleaning cabbage,
2. paring carrots,
3. cleaning celery,
4. cleaning head lettuce,
5. cleaning yellow onions,
6. cleaning green onions (this task was eliminated from the study because the produce available was of an inferior quality),
7. chopping potatoes,
8. cleaning radishes,
9. dicing tomatoes, and
10. dicing apples.

These tasks were chosen for several reasons. The jobs were fairly universal in that most food service operations would have one or more employees performing these tasks. The index could be used in any of these food service operations. The analysis of each task was relatively easy to perform for a lay person and fairly readily understood by persons not directly involved with the study. Each task could be, and was performed using hand tools. Also, each task was performed several times within a short time span to warrant convenient checks and analyses.

An operator was then chosen. The woman selected was experienced in the salad and vegetable preparation departments. She was a mature woman who was anxious to cooperate and proved to be a reliable and fairly flexible subject for observations. The operator was a salad worker at Willham Cafeteria when the study was begun. She was a better than average employee who assumed more responsibility for production and quality than did the other employees in the same department. Being experienced, the operator brought much useful information to the researcher. Also, the operator was patient with the process of many observations and seemed to work well even while under direct observation. She had also been involved in a previous study performed by the researcher and was acquainted with the techniques. Because of these qualities and attributes, this operator was chosen over all other employees in the cafeteria.

After the operator was chosen, a thorough explanation of the study was made to the worker and to her three fellow employees in the salad department. Each salad worker was urged to contribute to the study by voicing suggestions and criticisms. Each operation was studied by the women involved to get their input. Detailed explanations were made of the purpose and need for the study. Each employee knew the objectives of the project and they appeared eager to assist. The women were proud to be so closely involved in the research and hoped the results were accepted and useful universally.

The next phase was to train the operator. Lengthy discussions between the researcher and the operator were held to acquaint the employee with the methods-time measurement technique, to arrange work areas, equipment and tools used, and to put her at ease with the operations.

Preliminary motion studies were made using the operator as a subject. They were done at the proper work station with the correct tools and equipment, and a suitable layout. The preliminary work consisted of the listing and counting of similar and/or repetitious tasks. For example, the number of leaves pulled from a head of lettuce while cleaning it were counted, recorded, and averaged, as were the number of times a carrot was pared to complete the task of paring a carrot. The average number of times derived from this procedure were then used to apply standard times to the operations.

After the preliminary data was collected and the workplace was set up on paper, the MTM analysis could be made. The set-up information is recorded in Appendix D. The actual recording of motions, as described in Appendix B, was done by simulation by the author after studying the preliminary motion patterns. Methods-time measurement is a detailed and time-consuming procedure, and the time available to perform observations while on the job was very limited. Standard times were computed for each task and segment of the task. These were arranged in the form of an index (Chapter IV).

The times derived were tested at a simulated workplace by the researcher. At this time the researcher held the position of Administrative Dietitian with the University of Delaware Food Service. The results of the tests, along with conclusions and suggestions are included in Chapters IV and V.

CHAPTER IV

THE RESEARCH FINDINGS AND DISCUSSION

The Data Interpretation

The methods-time measurement data was developed for each of the nine vegetable preparation tasks on the MTM Element Analysis sheets (see Appendix D). (The technique for making an MTM analysis is presented in Appendix A.) The motions of each hand were detailed and the time unit (TMU) for the non-limiting motion recorded. One TMU is equal to 0.00001 hour or 0.0006 minutes. Also included with each MTM Element Analysis is a Methods Analysis Record. This explains the tools required for each operation, the condition of the produce, the work place layout and any additional pertinent information.

After the MTM data was converted from TMU's to seconds, the results were compiled on the MTM Analysis Summary (see Table I). For each operation the TMU's, element time allowed (TMU's converted into seconds), 15 percent fatigue allowance (in seconds), and total time allowed (element time plus fatigue allowance) were recorded. Each operation was also timed with a stop watch to determine the accuracy of the MTM productivity index times. The averages of these times were also recorded (Average Actual Time) as were the ranges of time. The last column shows a comparison of the allowed and average actual times. The negative sign signifies that the average actual performance time was

TABLE I

MTM ANALYSIS SUMMARY

Operation	Analysis Chart Page Number	Element Time (TMU)	Element Time (Seconds)	15 Percent Allowance (Seconds)	Total Time Allowed (Seconds)	Average Actual Time (Seconds)	Range of Actual Times (Seconds)	Difference Between Allowed and Actual Times*
Quarter cabbage	85	391.6	14.0976	2.1146	16.2122	22.2285	28.2 to 17.0	-6.0163
Pare carrots	89	2801.8	100.8648	15.1297	115.9945	116.0250	144.3 to 79.1	-0.0305
Clean celery	93	1357.9	48.8844	7.3327	56.2171	41.5867	53.1 to 28.7	+14.6304
Core head lettuce	96	73.5	2.6460	0.3969	3.0429	3.4467	4.4 to 2.6	-0.4038
Peel yellow onion	98	89.1	3.2076	0.4811	3.6887	10.1667	17.6 to 7.4	-6.4780
Cube potato	101	240.5	8.6580	1.2987	9.9567	16.5833	22.9 to 13.5	-6.6266
Clean radishes	104	297.0	10.6920	1.6038	12.2958	16.3882	20.0 to 14.4	-6.2775
Dice tomato	107	323.9	11.6604	1.7491	13.4095	16.8733	22.5 to 12.6	-3.4638
Dice apple	111	434.7	15.6492	2.3474	17.9966	42.3267	51.1 to 38.5	-24.3301

*A negative sign indicates that the element time (TMU) and the allowance time in seconds was less than the actual time. A positive sign indicates that the element time (TMU) and allowance time in seconds was greater than the actual time.

greater than the allowed time while the positive sign indicates that the average actual was less than the allowed time.

From the MTM Analysis Summary, the Vegetable Preparation Productivity Index derived from the Methods-time Measurement Analysis was developed (see Table II). The seconds given for each operation are allowed times including the 15 percent fatigue allowance. They are not actual recorded times. Also included in the index is specific information on the size of the produce used for the analysis. All produce was in good or very good condition when tested.

The Examination of Analysis Times for Vegetable Preparation

The actual times for the performance of each operation have been graphed, as well as the average actual times and the allowed times. These appear in Table XIII in Appendix D.

Analysis Times for Quartering Cabbage

Fourteen heads of cabbage were quartered and each operation was timed. The times ranged from 17.0 seconds to 28.2 seconds, with the average actual time being 22.2 seconds, as indicated by the dashed line in Figure 4. The time allowed for the MTM analysis was 16.2 seconds (solid line). The difference between the lowest and highest recorded times was 11.2 seconds. The difference between the average actual time and allowed time was high at 6.0 seconds indicating that either the MTM data was not accurate, the operator was slow in the performance of the task, or the differences in the condition of the cabbage were outstanding. Assuming that the data was correct and the operator performed to

TABLE II

VEGETABLE PREPARATION PRODUCTIVITY INDEX DERIVED FROM METHODS-TIME MEASUREMENT ANALYSIS

Operation	Seconds Allowed*	Specific Information
Quarter one head of cleaned cabbage	16.21	Cleaned heads range from one and one-half to two pounds in weight
Pare six carrots	115.99	Five and one-half to seven inches in length; one to one and one-fourth inches in diameter at top end
Clean one bunch of celery	56.22	About 12 inches in length; average of ten stalks per bunch
Core one head of cleaned head lettuce	3.04	Cleaned heads range from four to five inches in diameter
Peel one yellow onion	3.69	Two and one-half to three inches in diameter
Cube one peeled potato	9.96	One and three-fourths to two and one-half inches in diameter
Clean five radishes	12.30	Three-fourths to one inch in diameter
Dice one tomato	13.41	Three to three and one-fourth inches in diameter
Dice one apple	18.00	Size 113

*15 percent fatigue allowance included in times.

at least an average speed (which was assumed throughout this analysis), the condition of the produce was the limiting factor. One element which could conceivably affect the times of performance was the firmness of the head. The cabbage ranged from firm to very firm, the firmest heads requiring more pressure to cut and consequently the operation required a greater amount of time. The weights of the heads ranged from one and one-half to three pounds, which indicated not only the firmness, but the size of the cabbage as well. A large head of cabbage (diameter) took more time to cut than one with a smaller diameter. This was reflected also in the range of actual times. Another factor to be considered was the quality of the cabbage. While each head of cabbage was free of decay and excessive blemishes, there were different degrees of quality. This factor had a negligible effect on the times since blemishes were removed during the timing.

Analysis Times for Paring Carrots

Twelve groups of six carrots each were pared and the times recorded. The times ranged from 79.1 seconds to 168.6 seconds (a difference of 89.5 seconds). The average actual time and the allowed time were essentially the same at 116.0 seconds and 115.9 seconds, respectively (see Figure 5). Because of the closeness of these two figures, it would seem that this analysis had very few variables, but the large range of the actual times reveals that there were in fact many variables which caused the times to be so erratic. Firmness was one factor, although not an important one in this case. All of the carrots were firm and did not bend when pared. A second factor was the size and shape of the carrots. The carrots ranged from five and one-half to seven inches in length and from one to one and one-fourth inches in diameter at the largest part. The carrots were fairly well formed but any type of depression or extrusion on the carrot impeded the paring motion adding seconds to the analysis. Since the carrots to be pared were chosen at random, there was no way to approximately equal the sizes of the carrots between each group. The quality of all of the carrots was high but as with the cabbage some blemishes were evident which had the effect of slowing the paring process.

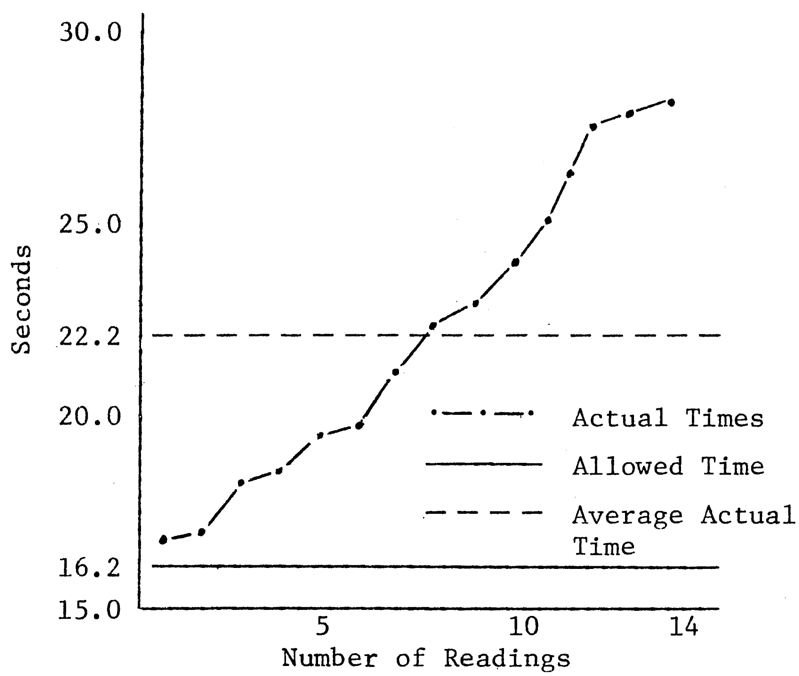


Figure 4. Analysis Times for Quartering Cabbage

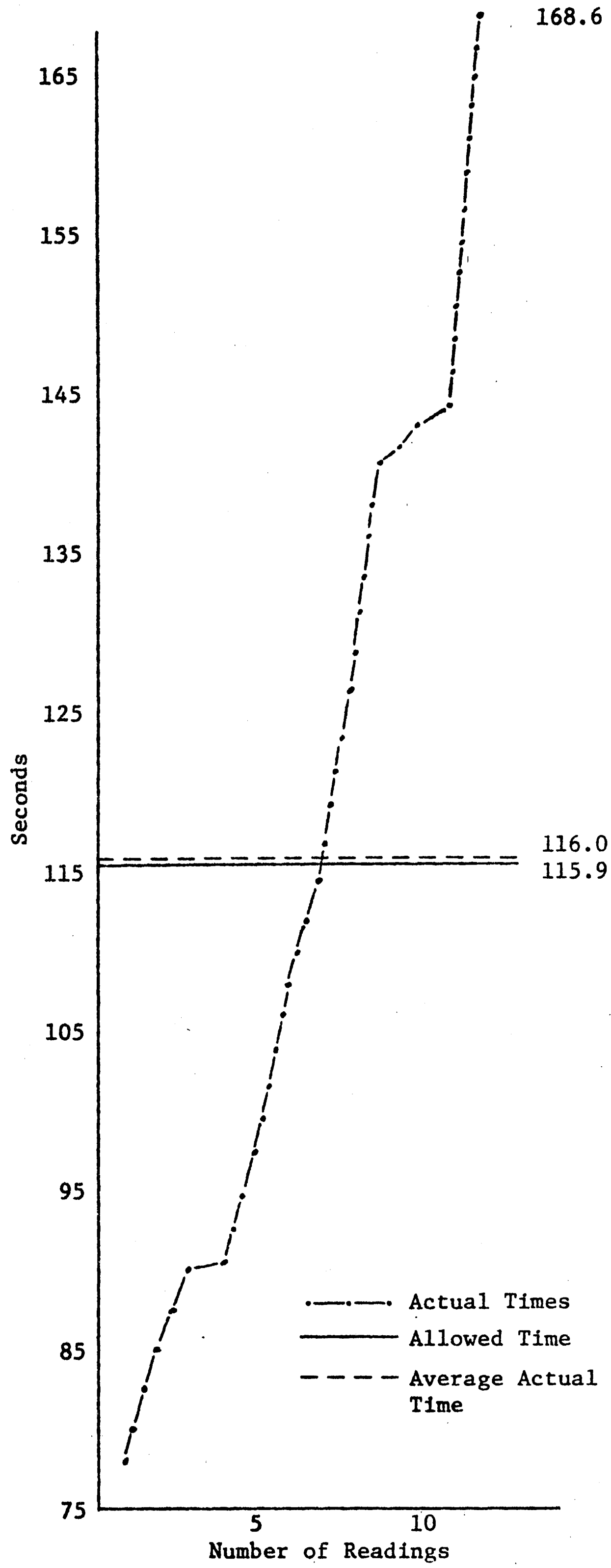


Figure 5. Analysis Times for Paring Carrots

Analysis Times for Cleaning Celery

Fifteen bunches of celery were cleaned and the times recorded. The range of the times was 28.7 seconds to 53.1 seconds, making a difference of 24.4 seconds. The allowed performance time was 56.2 seconds and the average actual time was 41.6 seconds (see Figure 6). This was the only case in the study where the actual cleaning times were less than the allowed (MTM) time. Again, assuming that the MTM analysis was accurate for the methods of vegetable preparation used, the cause for the high allowed time was to be found with the produce itself. Each bunch of celery was of excellent quality; few individual stalks had blemishes (which were not removed for the analysis). The bunches were each approximately 12 inches in length. Each bunch contained from 9 to 14 large to medium size stalks (or an average of 10) which were cleaned with the vegetable brush. This very easily accounted for most of the differences in the range of actual times, as a bunch with 14 stalks would require more time to clean than one with nine stalks. Possibly another influence on the lower average actual cleaning time was the cleanliness in general of the stalks of celery. Hard rubbing was not required to remove debris, while the average quality celery tested with MTM did require pressure, thus increasing the time required. If the celery used for timing purposes had been of a lesser quality, especially in regard to cleanliness, the actual times would have probably been closer to the allowed time.

Analysis Times for Coring Head Lettuce

Fifteen readings were made on coring head lettuce with a range of

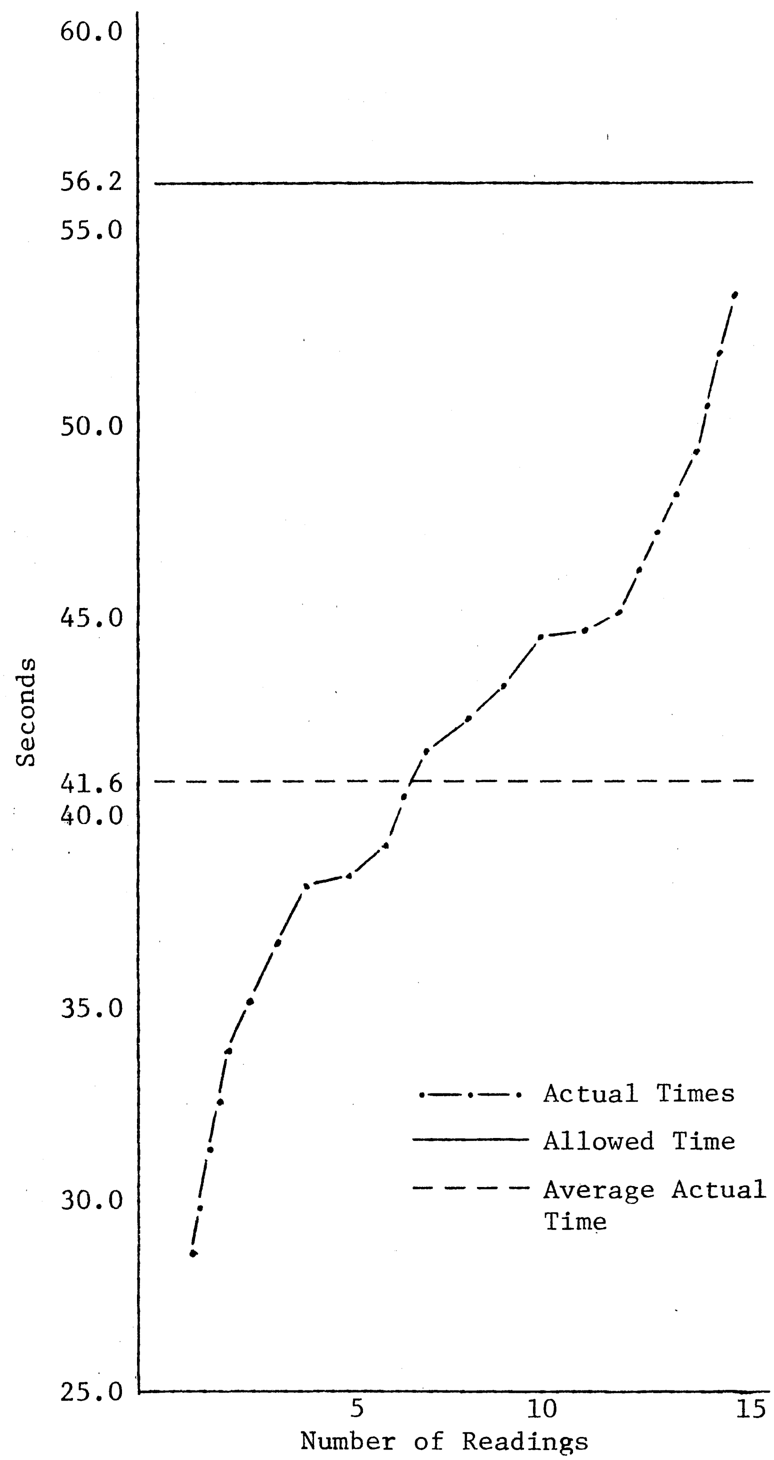


Figure 6. Analysis Times for Cleaning Celery

2.6 seconds to 5.8 seconds (a difference of 3.2 seconds). The allowed time was 3.0 seconds and the average actual time was 3.4 seconds (see Figure 7). This difference of 0.4 seconds was relatively negligible while the range difference was high at 3.2 seconds. The analysis was made during an extended period of time when the quality of lettuce was particularly low because of adverse weather conditions throughout the United States. The MTM analysis was made on a firm head of lettuce and ten heads which were used for the timing were of a comparable quality. The times derived from the ten heads were grouped around the allowed time (the solid line on Figure 7). The remaining five heads were of a lesser quality as there was a lower degree of firmness and the heads were not compact, making it harder to twist the paring knife around the core. The heads were all four to five inches in diameter but some heads were slightly misshapen with loose leaves. Most of the time difference could be placed on the poorer quality of lettuce, which was a direct result of the weather conditions.

Analysis Times for Peeling Yellow Onion

Fifteen onions were used for timing purposes. The range in the times was from 7.4 seconds to 17.6 seconds with a difference of 10.2 seconds. The average actual time for peeling an onion was 10.2 seconds and the allowed time was 3.7 seconds. As indicated by Figure 8, the range of the readings was clustered around the average actual time except for the high reading of 17.6 seconds. Therefore, the biggest discrepancy lay between the average actual time and the allowed time, which was a difference of 6.5 seconds. The onions were of fairly equal size (two and one-half to three inches in diameter), shape (slightly elliptical and well shaped), firmness (hard), and quality (very good). The difference probably developed in the actual peeling of the onions. The right hand did not make a move of average speed at all times when the peel was removed. The peel itself tended to stick to the onion because of the moisture and the round shape. Any future MTM analysis would have to account for this problem.

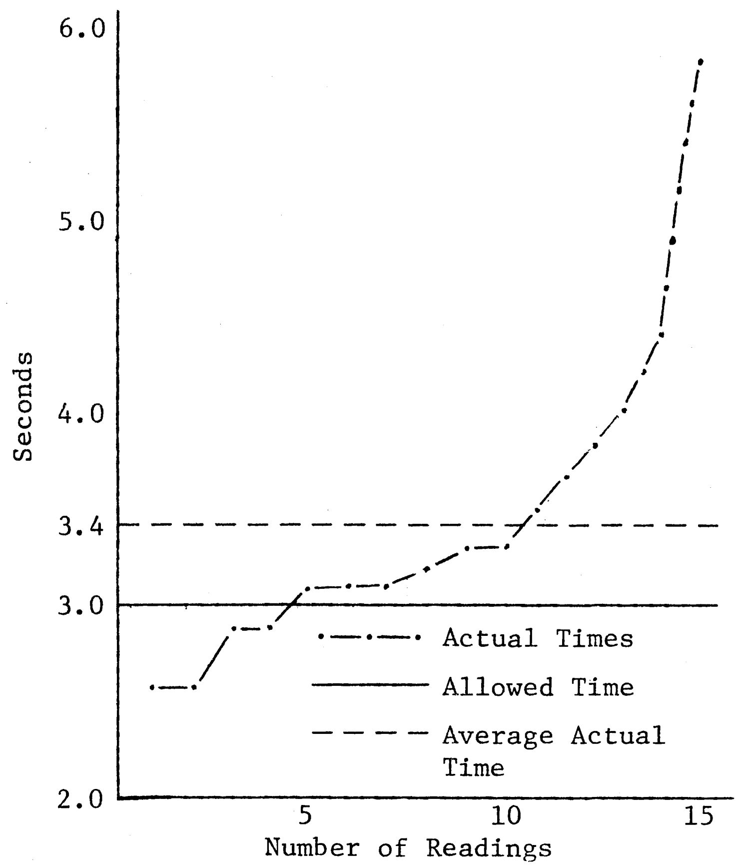


Figure 7. Analysis Times for Coring Head Lettuce

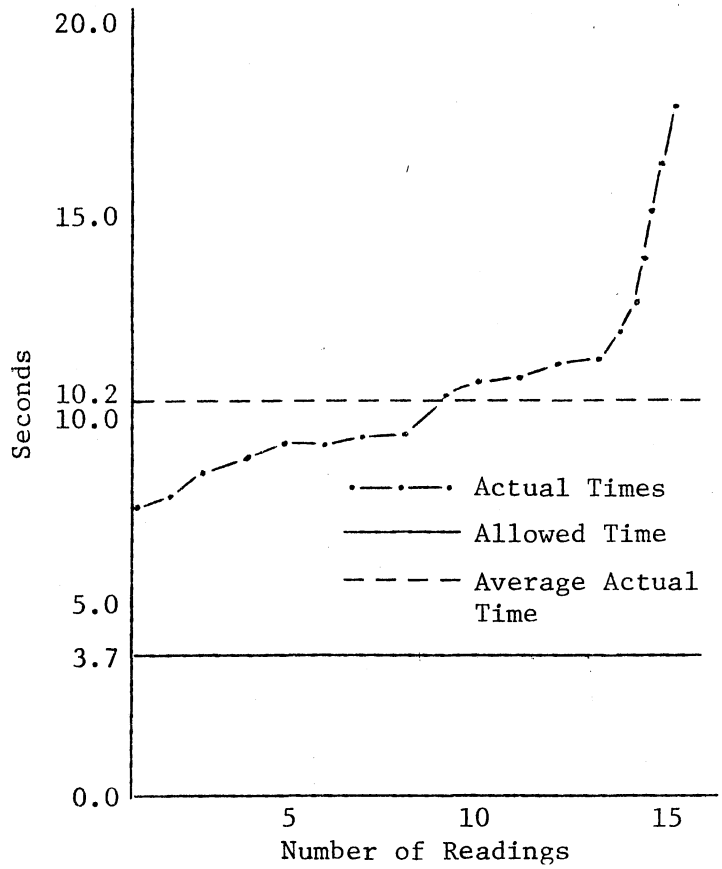


Figure 8. Analysis Times for Peeling Yellow Onion

Analysis Times for Cubing Potato

Twelve readings were completed on the potato with a range of times from 13.5 seconds to 22.9 seconds, for a difference of 9.4 seconds. The seconds allowed were 10.0 and the average actual seconds were 16.6. The range of the timings was not extreme. The sizes and shapes of the potatoes could have accounted for much of the difference. The average actual time was 6.6 seconds above the allowed time (see Figure 9). The potatoes ranged from one and three-fourths to two and one-half inches in diameter. This size difference could cause a difference in the range but not in the average actual and allowed times. The shape of the potato could have had an effect on these times. The potatoes were fairly uniformly shaped in an elliptical form. Some potatoes had indentations and small bumps, but the effect of these was miminal. All of the potatoes were very firm. Probably the biggest factor to raise the actual time was the moisture content of the potatoes. The knife could not be drawn "cleanly" through the cut potatoes without a slight suction being formed. The time and extra pull necessary to break this suction probably had the biggest effect on the time utilized to cube the potatoes.

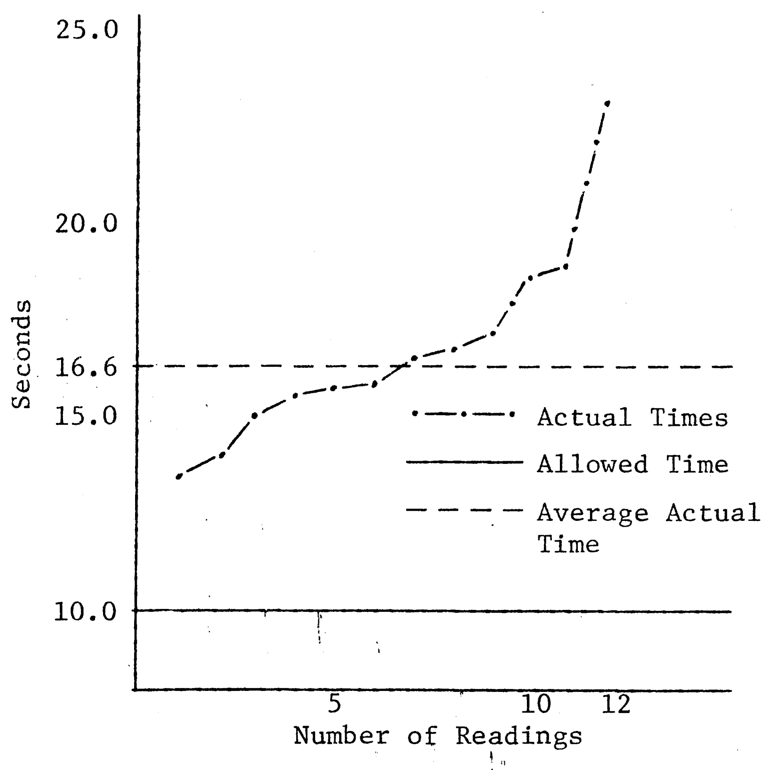


Figure 9. Analysis Times for Cubing Potato

Analysis Times for Cleaning Radishes

Seventeen groups of five radishes each were tested. The times ranged from 14.4 seconds to 20.0 seconds (a 5.6 second difference). The average actual time was 16.4 seconds and the allowed time was 12.3 seconds, a difference of 4.1 seconds (see Figure 10). The radishes ranged in size from three-fourths to one inch in diameter. Size probably had very little effect on the difference in times. The shape could have been a factor as some radishes were round and some were elliptical. The motions involved in turning the radishes in the left hand could have been hindered or additional short moves could have been necessary with changes in shape. The quality was also a factor to be considered. Some radishes were of excellent quality with a minimum amount of ends to remove while other radishes had blemishes or a larger area to remove. Time was probably lost in deciding where to place the knife for cutting purposes. The hesitation involved probably accounted for part of the difference between the average actual time and the allowed time and between the 17 trials themselves.

Analysis Times for Dicing Tomato

Fifteen readings with a range from 12.6 seconds to 22.5 seconds were made on tomatoes. There was a 9.9 second difference in the range. The allowed time was 13.4 seconds and the average actual time was 16.9 seconds (see Figure 11). The tomatoes were firm and of an even size (three to three and one-fourth inches in diameter) and shape. The time differences most likely occurred when the tomatoes were diced. Because of the high moisture content it was very difficult to hold the tomatoes

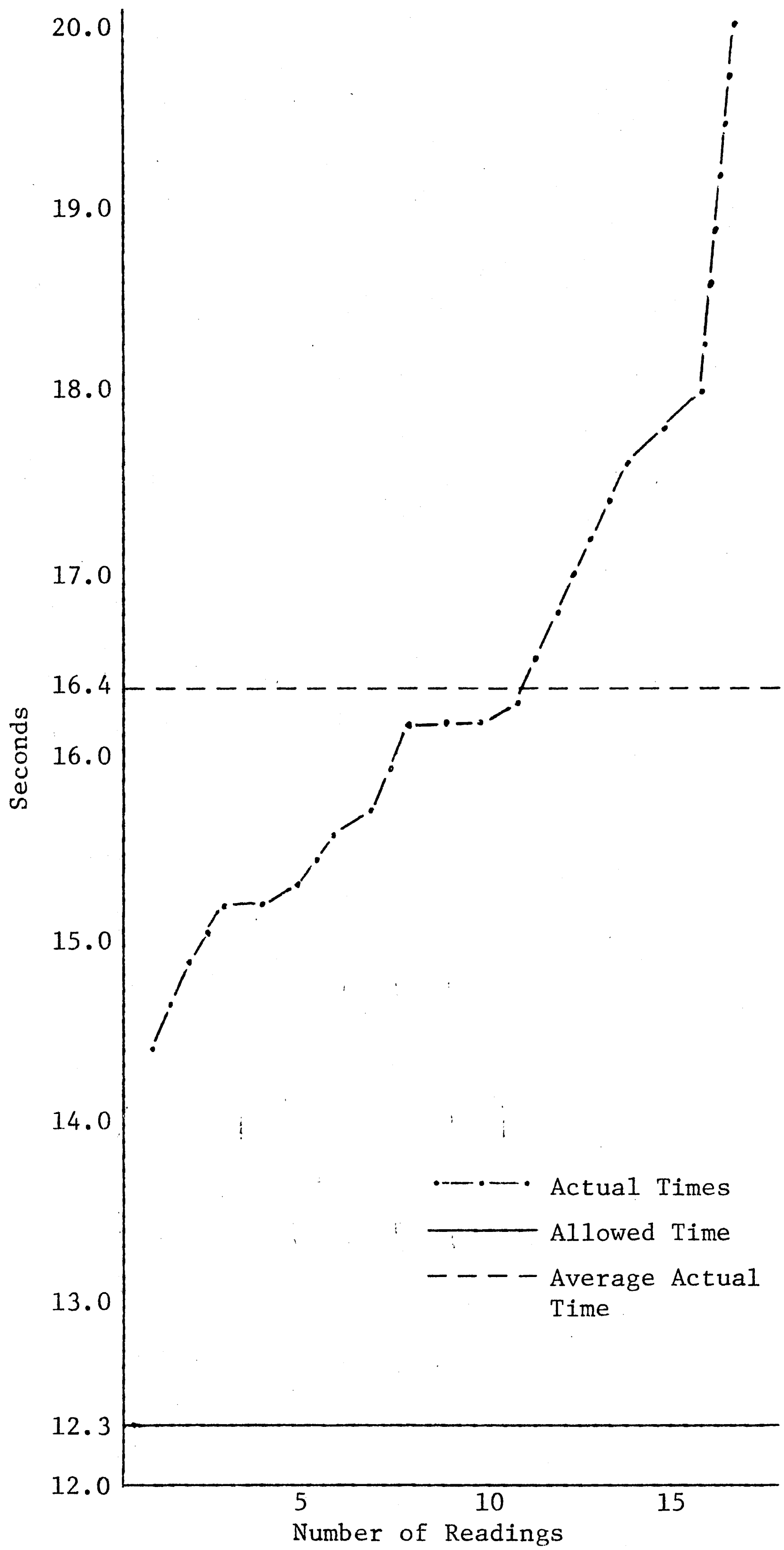


Figure 10. Analysis Times for Cleaning Radishes

in shape for cutting. Slipping occurred at times necessitating longer strokes with the knife. The texture of the skin may also have had an effect on the times. Some tomatoes had a slightly "tougher" skin to pierce which may have caused a minor loss of time.

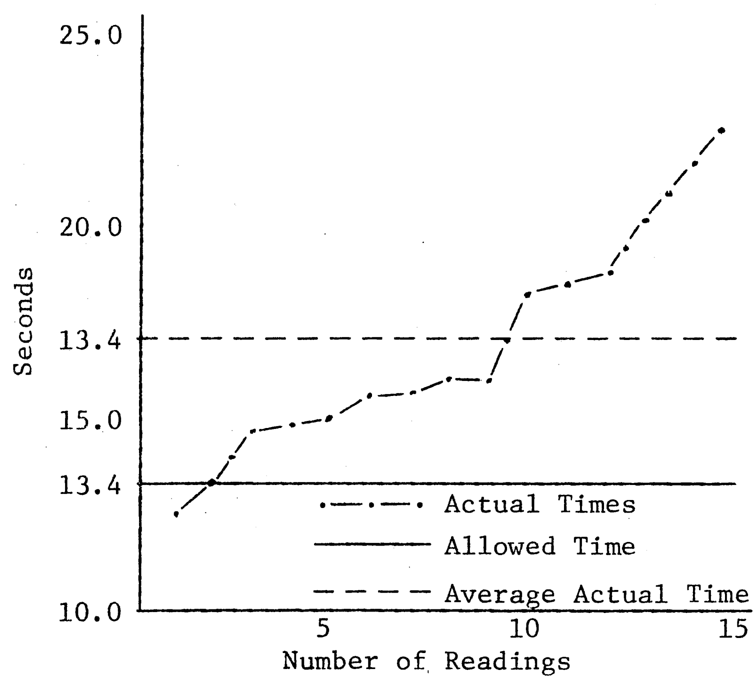


Figure 11. Analysis Times for Dicing Tomato

Analysis Times for Dicing Apple

Fifteen apples were tested and the times ranged from 38.5 seconds to 51.1 seconds (with a difference of 12.6 seconds). The average actual time was 42.3 seconds and the allowed time was 18.0 seconds. The readings did not have a large divergence (see Figure 12) from the average but the difference between the average actual and allowed times, at 24.3

seconds, was the most extreme difference encountered during the study. The apples all came from a box of size 113 apples and the diameters differed by a maximum of three-fourths inch. All of the apples were of good quality with no blemishes. The shapes were approximately the same. Some apples were slightly more firm and crisp than others, making the cutting motions easier, while some had a slightly "tougher" skin making the initial motion of cutting through the skin more difficult. Another difficulty encountered was the moisture of the apples. As with the potatoes, the moisture formed a small suction between the apple and the knife increasing the time necessary to cut the apple. The apple pieces also slipped occasionally, causing slight hesitations or longer strokes with the knife. Another factor which was variable with each apple was the core itself. Some cores were deeper than others and depending on how the apple was cut into quarters, some pieces of core were larger than others. A decision had to be made initially with each apple quarter about where the apple piece should be cut to remove the core and the knife had to be guided to the depth of the core. This caused hesitation and added time to the readings. The apple analysis was the most variable analysis performed, thus accounting for the large discrepancy between the average actual and allowed times.

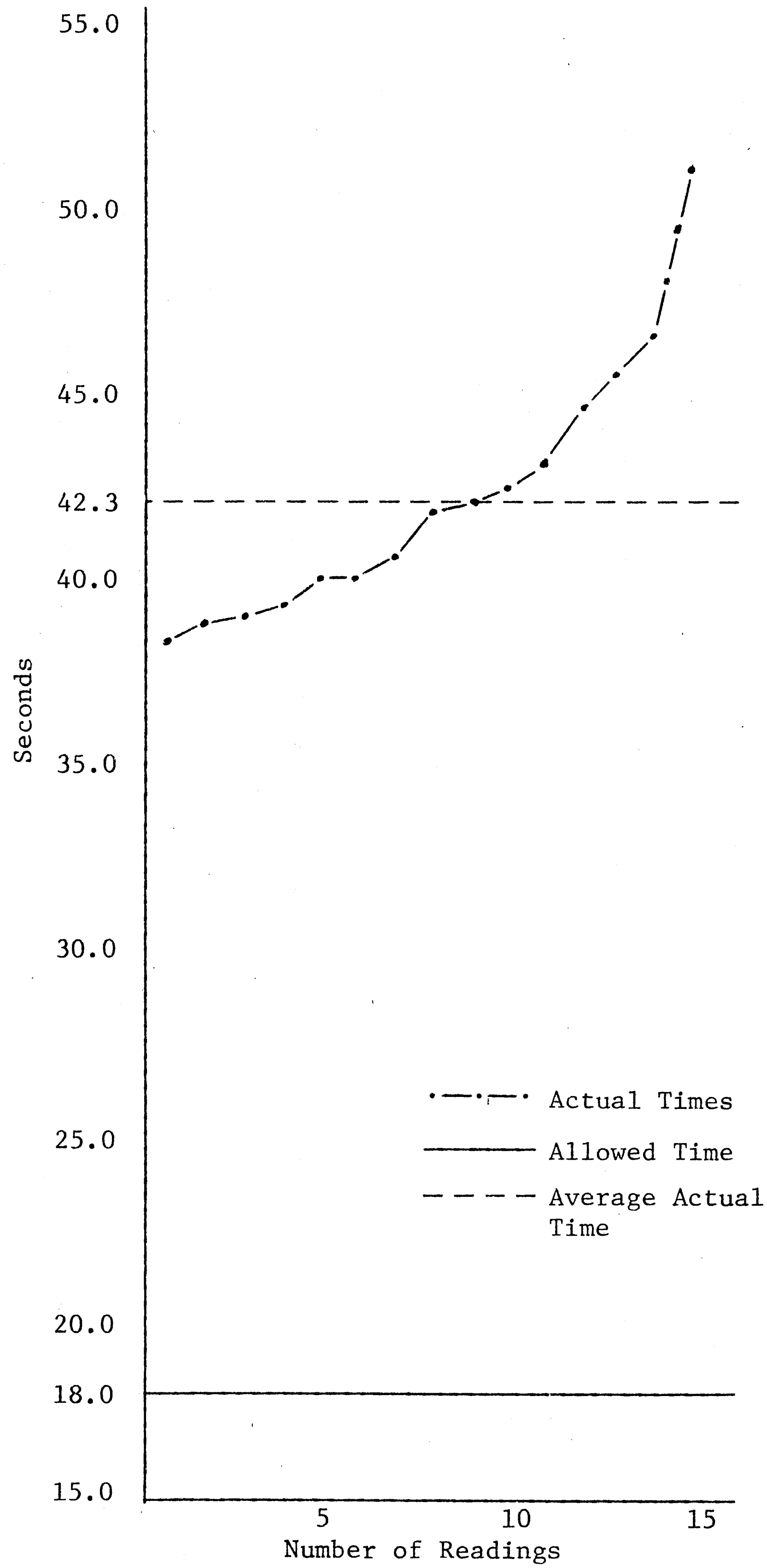


Figure 12. Analysis Times for Dicing Apple

CHAPTER V

SUMMARY AND CONCLUSIONS

Summary

The food service industry is faced with the world-wide challenge of increasing productivity. A major drawback in this effort is the absence of any convenient method to measure productivity in the industry. Because of the nature and complexity of food service, it is very difficult to define and label what constitutes a productive employee or kitchen. The premise of this thesis was that a productivity measurement device is needed by food service and specifically a simple productivity index which was derived from methods-time measurement analyses. The index times have been tested 12 to 18 times by the researcher for reliability.

The vegetable productivity index produced showed the operation which was performed, the seconds allowed to perform the task, and specific information about the size of the produce used in this study. The MTM analyses and the time studies were performed on produce in optimum condition for the season during which the testing occurred. The analysis of the data indicates that the following factors affect the production time for the preparation of any vegetable:

1. overall quality,
2. firmness and texture,
3. size and shape, and

4. blemishes.

The results of the study indicated that the MTM allowed times and the actual seconds (from time studies) for the performance of the vegetable preparation tasks in most cases did not concur. Usually the MTM allowed time was less than the average actual time. For several of the analyses performed, the actual times varied widely (for instance dicing apples and paring carrots), indicating that differences in the produce itself were a major factor in the time discrepancies.

Conclusions

Methods-time measurement was chosen as the measurement device for this study for several reasons:

1. the operator was judged by an objective method (MTM) and not by a subjective method such as leveling;
2. the method was analyzed with MTM, timing during an MTM analysis was unnecessary, methods were studied for efficiency; and
3. MTM gave time standards without lengthy timing sessions.

MTM could not be used during process time (when equipment is being utilized). Since much time in food service businesses is spent operating equipment, MTM cannot be used for every operation, although MTM data could be utilized for manual operations with process times added to make a complete analysis. MTM also requires lengthy training and a thorough understanding of the system. Because of this it is unrealistic for each food service to conduct MTM analyses. If MTM were to be used as a basis for a productivity index, the best method would be to secure the services of an engineer with expertise in this area. It would be very difficult for a novice to attempt the mammoth job of indexing all vegetable preparation tasks, or for that matter, all food preparation tasks.

The results of this study indicated that methods-time measurement is not the best method for an analysis of vegetable preparation tasks. There are many variables involved in vegetable preparation. The overall quality of the produce decides how quickly and efficiently cuts can be made. Sizes and shapes vary widely with each crate of produce, making production times differ markedly within each packaging unit. Weather can affect the quality of produce and since weather cannot be controlled, at times the quality of the produce suffers. Because of these ever-present variables in vegetable preparation, MTM, which was designed for "standard" products, is an inefficient and inaccurate measuring standard.

This study in no way discredits the development of a productivity index. Two assumptions were made at the start of the study: (1) the food service industry has an urgent need for an accurate and standard measuring device for productivity, and (2) the developed index should be one which can be used in any food service establishment. An index must be adaptable to any food service establishment with a minimum of adjustments. It should be evolved under the sponsorship of a professional organization which could be instrumental in disseminating the resultant information. A national organization also might be able to offer aid in the area of training and utilization of the index.

Another method for developing the index must be arrived at. Because of the numerous variables encountered, a standard time cannot be produced for each vegetable preparation operation by MTM. A system of timing, similar to that used for testing the MTM data, could be used. A range of performance times could be arranged with an average of these times used as an index figure. This method would take into account all of the variables (quality, firmness and texture, size and shape, and blemishes). No distinction would be made, such as size, as this would vary and be covered within the range of times. An exact method would not have to be followed, as it is with the MTM system. Slight variations could be utilized to relieve boredom. But an explanation of the method of vegetable preparation should be included (perhaps in an appendix to the index) so that users could duplicate the method. The use of a productivity index need not be limited to vegetable preparation. The preparation and production of all types of foods and the service of these foods could be the basis for standard times. Other jobs performed in food service establishments such as cleaning and the operation of certain pieces of equipment might also lend themselves to analysis for index purposes. Managers would be able to rate employee productivity by comparing the index values with performance times of employees. Managers and employees could also learn new methods and understand the need for increased productivity through training and the use of a productivity index such as has been described. In this way the indexes could be not only measurement devices but also tools to increase productivity in the food service industry.

SELECTED BIBLIOGRAPHY

1. National Commission on Productivity: Productivity in the Food Industry: Preliminary Study of Problems and Opportunities. Washington, 1973.

2. National Commission on Productivity: Productivity and the Economy, Bulletin 1779. Washington, 1973.

3. National Commission on Productivity: Ten Questions and Answers on Productivity. Washington.

4. Kazarian, Edward A.: Work Analysis and Design for Hotels, Restaurants and Institutions. 2nd ed. Westport, Conn.: Avi Publishing Co., 1974.

5. Terrell, Margaret E.: Professional Food Preparation. New York: John Wiley and Sons, 1971.

6. National Commission on Productivity: First Annual Report of the National Commission on Productivity, March 1972. Washington, 1972.

7. Nelson, Richard R., Peck, Merton J., and Kalachek, Edward D.: Technology, Economic Growth, and Public Policy. Washington: Brookings Institution, 1967.

8. National Commission on Productivity and Work Quality: Fourth Annual Report, March 1975. Washington, 1975.

9. National Commission on Productivity: Second Annual Report of the National Commission on Productivity, March 1973. Washington, 1973.

10. Siegel, Irving H.: Measurement of Productivity, Conference on an Agenda for Economic Research on Productivity, National Commission on Productivity. Washington, 1973.

11. Wykstra, Ronald A.: Introductory Economics. New York: Harper and Row, 1971.

12. Dernburg, Thomas F. and McDougall, D. M.: Macroeconomics: The Measurement, Analysis, and Control of Aggregate Economic Activity. New York: McGraw-Hill, 1972.

13. Barnes, Ralph M.: Motion and Time Study: Design and Measurement of Work. 6th ed. New York: John Wiley and Sons, 1968.

14. Neale, Fred J.: Primary Standard Data. London: McGraw-Hill, 1967.

15. Maynard, Harold B., Stegemerten, G. J., and Schwab, John L.: Methods-time Measurement. New York: McGraw-Hill, 1948.

16. Close, Guy C., Jr.: Work Improvement. New York: John Wiley and Sons, 1960.

17. Karger, Delmar W. and Bayha, Franklin H.: Engineered Work Measurement. New York: The Industrial Press, 1957.

18. Honeycutt, John M., Jr.: The Basic Motions of MTM. Pittsburgh: Maynard Foundation, 1965.

19. Lehrer, Robert N.: Work Simplification: Creative Thinking About Work Problems. New Jersey: Prentice Hall, 1957.

20. Kotschevar, Lendal H.: Standards, Principles, and Techniques in Quantity Food Preparation. 2nd ed. Berkeley: McCutchan, 1966.

APPENDIXES

APPENDIX A

HOW TO USE METHODS-TIME MEASUREMENT

HOW TO USE METHODS-TIME MEASUREMENT

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 (13, p. 496).

MTM can be applied in two ways. The first is by direct observation and the second is by visualization and simulation. The second type is used before a job is put into effect. The analyst must be familiar with the type of work to be simulated and have had some experience with this work. After the job has been analyzed and the "best" work method derived, it is put into effect. The employee who will use this method will not have to be observed.

The two methods are similar except that the analyst does not see the actual production in the second method while in the first he observes the operator performing his duty. In the second method the analyst can set up a mock work place, use blueprints and have samples of equipment and ingredients to be assembled, thus simulating the job area and performance. Since this paper deals with production in effect now, the second method will not be further discussed. The description which follows is for the first method or the use of MTM by direct observation.

Preliminaries

The choice of the best operator available can be the most important element of the study. The operator must be cooperative, know the job well, understand why she is being observed, understand how this will help her and be able to perform well while under observation. She does not necessarily have to have the best methods, in fact the person with the best methods may make the final standard times too biased above the normal. In the same way the operator who works slowly and inefficiently might bias the results below the normal. The search then is for an operator who works at a normal level. The study cannot be started until the operator understands every phase of the study. She must be informed well ahead that she will be observed and why. The operator must also understand that she will not be timed and that this in no way is a rating of her work to be used for advancements, pay changes or any other reason for which ratings may be used. She must realize the need for this type of study and be able to help the analyst with any problems there may be in the method. She must be receptive to any new ideas which would result from the study including a change in methods, location, equipment, operators, etc.

After the operator has been chosen and instructed, certain information must be secured. The operation must be identified and described. The location of the operation, materials, parts, equipment, tools, work place layout (blueprints help here), working conditions and quality requirements of the product to be produced are types of information to be ascertained. There are three reasons for the accurate collection of data. The first is to understand the general method better which contributes to accuracy and "minimizes errors or doubts about proper motion classifications when the operator is later observed in detail (18, p. 15-4). The second reason is that:

> . . . conditions and methods in use when the time value is established are made available for reference if . . . a question as to the validity of the time value is raised. The construction of MTM standard data in the future is simplified,

> and their accuracy is increased, because every condition affecting the method is known (18, p. 15-4).

After the information is gathered a preliminary motion study should be made. The analyst must learn or review the methods of MTM and learn or review the charts. The operator must also be acquainted with the method, especially if she has never been observed before. In the preliminary motion study the analyst also records all results and thus has more experience when it comes to the actual study.

The next step is to record the motions. The job or task should be divided into elements in their proper sequence and the elements should be described in detail. Each job element is then observed, classified and recorded according to the tables in Appendix B. To ease the task of recording motions, special forms should be drawn up and used.

The last step is to compute the standard times and summarize the data. First, each motion must be checked and times assigned to each element. When both hands or several body members perform a job at the same time, one of the motions is limiting and one is non-limiting. The limiting motion has the greatest performance while the non-limiting motion time is less and is deleted from the record. Allowances must be made for personal time, fatigue and unavoidable delays. These allowances are usually expressed as a percentage. The most popular percentage used in industry is 15 percent. After all the computations are made the entire method should be reviewed for accuracy and validity. If any one item does not appear to be accurate it would be best to go back and observe the complete operation again.

APPENDIX B

EXPLANATION OF METHODS-TIME

MEASUREMENT TABLES

EXPLANATION OF METHODS-TIME MEASUREMENT TABLES

Reach (R)

"Reach is the basic element used when the predominant purpose is to move the hand or fingers to a destination" (13, p. 496). There are three variables affecting reach. The first is the level of control or case. Case A reach is a reach to an object at a fixed location, to an object in the other hand, or to an object on which the other hand rests. The case A reach has low control. It is performed without visual control or mental concentration. A case B reach is a reach to an object whose general location is known. This location can be varied slightly from cycle to cycle. The case B reach is the most common type encountered. It is necessary to use either vision or concentration to locate the object. A case C reach is a reach performed with high control to an object that is jumbled with other objects in a group. Both vision and concentration are needed to locate the object. Only fairly small objects are covered by the C reach. Larger objects do not require a C reach. A case D reach is one performed with high control to a single object, which is usually very small or one where accurate grasp is required. Both vision and concentration are needed. When danger is involved in a reach, such as sharp or hot objects, this is case D. A reach to a fragile object is also included in case D. A case E reach requires low control and is made to an indefinite location. It is usually performed to get the hand into position for body balance, for the next move, or out of the way. No visual control or mental concentration is necessary.

TABLE III

REACH--R

Distance Moved Inches	Time TMU				Hand in Motion		Case and Description
	A	B	C or D	E	A	B	
1/4 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	6.9	3.8	3.7	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	7.1	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	
24	14.9	21.5	22.5	19.2	12.9	18.8	E--Reach to indefinite location to get hand in position for body balance or next motion or out of way.
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	

Source: Ralph M. Barnes, Motion and Time Study: Design and Measurement of Work (1954).

The second variable is the type of motion, of which there are three. In Type I the hand is at rest at the beginning and the end of the movement. This is the most frequently encountered type. Type I has the lowest average velocity of the three types. In Type II the hand is in motion at either the beginning or end of the reach. This type is encountered less often and has a higher average velocity. The hand is in motion at both the beginning and the end of the reach in Type III. This is an extremely rare case and has the highest average velocity of the three types.

Distance of the reach is measured from the tip of the fingers, if only the fingers are involved, or from the knuckles if the whole hand is involved. The most common reaches are performed using both the hands and fingers.

Move (M)

"Move is the basic element used when the predominant purpose is to transport an object to a destination" (13, p. 497). If the hand is empty but used as a tool, this can be classified as a move. At all times the object must be under the control of the operator. Move has four variables. The first is level of control or case. Case A is a move to the other hand or against a stop. This requires low or medium control. Case B is a move to an approximate or indefinite location and requires low or medium control also. Case B is the most frequently encountered type of move. Case C is a move to an exact location and requires high control and both visual and mental concentration.

Type of motion is the second variable. Type I means that the hand is at rest at both the beginning and the end of the move. This type

TABLE IV

MOVE--M

Distance Moved Inches	Time TMU A	B	C	Hand in Motion B	Wt. Allowance Wt. (lb.) Up to	Fac- tor	Con- stant TMU	Case and Description
1/4 or less	2.0	2.0	2.0	1.7	2.5	0.00	0.0	A--Move object to other hand or against stop.
1	2.5	2.9	3.4	2.3				
2	3.6	4.6	5.2	2.9	7.5	1.06	2.2	
3	4.9	6.7	6.7	3.6				
4	6.1	6.9	8.0	4.3	12.5	1.11	3.9	B--Move object to approximate or in-definite location.
5	7.3	8.0	9.2	5.0				
6	8.1	8.9	10.3	5.7	17.5	1.17	5.6	
7	8.9	9.7	11.1	6.5				
8	9.7	10.6	11.8	7.2	22.5	1.22	7.4	C--Move object to exact location.
9	10.5	11.5	12.7	7.9				
10	11.3	12.2	13.5	8.6	27.5	1.28	9.1	
12	12.9	13.4	15.2	10.0				
14	14.4	14.6	16.9	11.4	32.5	1.33	10.8	
16	16.0	15.8	18.7	12.8				
18	17.6	17.0	20.4	14.2	37.5	1.39	12.5	
20	19.2	18.2	22.1	15.6				
22	20.8	19.4	23.8	17.0	42.5	1.44	14.3	
24	22.4	20.6	25.5	18.4				
26	24.0	21.8	27.3	19.8	47.5	1.50	16.0	
28	25.5	23.1	29.0	21.2				
30	27.1	24.3	30.7	22.7				

Source: Barnes, Motion and Time Study: Design and Measurement of Work (1954).

occurs most frequently and has the lowest average velocity. In a Type II move the hand is in motion at either the beginning or the end of the move. This type of move is occasionally found and has a higher average velocity than a Type I move. A Type III move, when the hand is in motion at both the beginning and the end of the motion, is extremely rare. This type of move has the highest average velocity.

The third variable is distance. The distance measured in a move is the same as that in a reach.

Weight or resistance is the last factor involved. If there is an increase of weight or resistance in a move, there will also be an increase in the time of the performance. Effective Net Weight (ENW) is the resistance encountered by a hand when a move is being performed. The static component (SC) is "the time required for muscular tension to be built up to a level that results in motion of the object to be moved" (18, p. 4-13). The static component takes place before the object is moved and is variable only with resistance. Distance does not affect it. The static component does not occur if the object is already under the control of the operator. The formula for SC is TMU = 0.475 + 0.345 ENW. The dynamic component (DC) is the time the object is in motion. The formula for DC is TMU = x(1 + 0.011 ENW) where x is the TMU for the unweighted DC. The static and dynamic component times are added together to get the time for the whole move.

Turn (T)

Turn "is the . . . basic motion performed when rotating the empty or loaded hand by the long axis of the forearm" (18, p. 5-5). A reach-turn is a turn performed with an empty hand while a move turn is one performed with a loaded hand. Turn has two variables. The first is distance, which is the number of degrees turned about the long axis of the forearm. The second variable is resistance. Resistance has four categories: (1) hand is empty (no resistance), (2) small object encountered, (3) medium object encountered, and (4) large object encountered.

TABLE V

TURN AND APPLY PRESSURE--T AND AP

Weight	Time TMU for Degrees Turned										
	30°	45°	60°	75°	90°	105°	120°	135°	150°	165°	180°
Small--0 to 2 lbs.	2.8	3.5	4.1	4.8	5.4	6.1	6.8	7.4	8.1	8.7	9.4
Medium--2.1 to 10 lbs.	4.4	5.5	6.5	7.5	8.5	9.6	10.6	11.0	12.7	13.7	14.8
Large--10.1 to 35 lbs.	8.4	10.5	12.3	14.4	16.2	18.3	20.4	22.2	24.3	26.1	28.2

Source: Barnes, Motion and Time Study: Design and Measurement of Work (1954).

Apply Pressure (AP)

Apply pressure is "an application of muscular force to overcome object resistance, accompanied by little or no motion" (18, p. 6-3).

Slight hesitation, tensed muscles and pushing, squeezing or pulling by the hand characterizes apply pressure. A movement is analyzed as apply pressure only when it is not a part of some other basic motion. Apply pressure has two cases. Case 1 requires adjustment of the body member to prevent discomfort or injury or preliminary setting of the muscles to squeeze or constrain the object. The second case is the same as the first except that reorienting or adjustment of the body member or setting of muscles is not required.

Grasp (G)

> Grasp is the basic element employed when the predominant purpose is to secure sufficient control of one or more objects with the fingers or hand to permit the performance of the next required basic element (13, p. 498).

There are seven types of grasp motions. They are described as follows:

- 1A--The simple grasp of a single object.
- 1B--The action of pinching a small object or an object lying against a flat surface.
- 1C--Type of grasp where interference is present on the bottom side of the object.
- 2---A regrasp during the shifting of the position of the fingers.
- 3---Transferring the grasp of an object from one hand to the other.
- 4---Grasping an object from a group of objects so search and select are required.
- 5---The action of touching an object without picking it up (4, p. 300).

Release Load (RL)

> Release load is the basic element to relinquish control of an object by the fingers or the hand. The two classifications of release load are (1) normal release . . . (RL1) which is performed by simply opening the fingers and . . . (2) contact release, . . . (RL2) where . . . the release begins and is completed at the instant the following reach begins (no time allowed (13, p. 498).

TABLE VI

GRASP--G

Case	Time TMU	Description
1A	2.0	Pick up grasp--Small, medium, or large object by itself, easily grasped.
1B	3.5	Very small object or object lying close against a flat surface.
1C1	7.3	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter larger than 1/2".
1C2	8.7	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter 1/4" to 1/2".
1C3	10.8	Interference with grasp on bottom and one side of nearly cylindrical object. Diameter less than 1/4".
2	5.6	Regrasp.
3	5.6	Transfer grasp.
4A	7.3	Object jumbled with other objects so search and select occur. Larger than 1" x 1" x 1".
4B	9.1	Object jumbled with other objects so search and select occur. 1/4" x 1/4" x 1/4" to 1" x 1" x 1".
4C	12.9	Object jumbled with other objects so search and select occur. Smaller than 1/4" x 1/4" x 1/4".
5	0.0	Contact, sliding or hook grasp.

Source: Barnes, Motion and Time Study: Design and Measurement of Work (1954).

Position (P)

"The position motion is used to align, orient, or engage one object with another" (4, p. 300). Positioning time is affected by three

TABLE VII

RELEASE--RL

Case	Time TMU	Description
1	2.0	Normal release performed by opening fingers as independent motion.
2	0.0	Contact release.

Source: Barnes, Motion and Time Study: Design and Measurement of Work (1954).

TABLE VIII

POSITION--P*

Class of Fit		Symmetry	Easy to Handle	Difficult to Handle
1--Loose	No pressure required	S	5.6	11.2
		SS	9.1	14.7
		NS	10.4	16.0
2--Close	Light pressure required	S	16.2	21.8
		SS	19.7	25.3
		NS	21.0	26.6
3--Exact	Heavy pressure required	S	43.0	48.6
		SS	46.5	52.1
		NS	47.8	53.4

*Distance moved to engage--1" or less.

Source: Barnes, Motion and Time Study: Design and Measurement of Work (1954).

variables. The first is class of fit. A loose class of fit requires no pressure. A close class of fit requires light pressure while an exact class of fit requires heavy pressure.

Symmetry is the second variable. This refers to the shapes of the objects to be engaged. Symmetrical (S) means that the part can be turned in any direction about the orientation axis. Non-symmetrical (NS) refers to parts which can be located in only one direction about the orientation axis. Semi-symmetrical (SS) includes all cases which are neither symmetrical or non-symmetrical.

Ease of handling is the third variable. There are two classes here: easy (E) and difficult (D). Difficult is used for large sizes, flexible objects, heavy objects or those held at a distance.

Disengage (D)

"Disengage is performed to separate objects, characterized by an involuntary movement occasioned by the sudden ending of resistance" (18, p. 9-4). Disengage is the opposite of position, the difference being the sudden ending of resistance. Disengage has three variables. The first is class of fit which is determined by the tightness of the parts being separated. D1 (loose) takes very slight effort to separate. D2 (close) takes normal effort to separate and D3 (tight) requires considerable effort to separate objects and the hand recoils markedly.

The second variable is ease of handling. Easy to handle (E) is a disengage where the grasp does not need to be changed. Difficult to handle (D) is a disengage where the grasp must be changed during the movement.

TABLE IX

DISENGAGE--D

Class of Fit	Easy to Handle	Difficult to Handle
1--Loose--Very slight effort, blends with subsequent move.	4.0	5.7
2--Close--Normal effort, slight recoil.	7.5	11.8
3--Tight--Considerable effort, hand recoils markedly.	22.9	34.7

Source: Barnes, Motion and Time Study: Design and Measurement of Work (1954).

Care in handling is the third variable, involving care required to prevent damage to either the object or the hand. If it occurs in D1, use D2; if in D2, use D3; if in D3 the method should be changed. The disengage times in Table IX are based on situations where no binding occurs. If binding does occur other motions should be added to the disengage time.

Eye Travel (ET) and Eye Focus (EF)

> Eye travel is the visual motion performed to shift the axis of vision from one location to another. Eye focus is the visual and mental basic element of looking at an object long enough to determine a readily distinguishable characteristic (18, p. 11-6).

Eye travel is seldom a limiting motion. Eye focus involves time needed to focus the eyes and make a simple decision based on what the eye sees. Reading is a series of eye travels and eye focuses.

TABLE X

EYE TRAVEL TIME AND EYE FOCUS--ET AND EF

Eye Travel Time = $15.2 \times \frac{T}{D}$ TMU, with a maximum value of 20 TMU,

where T = the distance between points from and to which the eye travels,
D = the perpendicular distance from the eye to the line of travel T.

Eye Focus Time = 7.3 TMU.

Source: Barnes, Motion and Time Study: Design and Measurement of Work (1954).

Walk (W)

"Walk is a forward or backward movement of the body performed by alternate steps" (18, p. 12-6). Walk can be unobstructed (walking on a good surface free from obstructions) or obstructed (walking in a congested work area or where length of pace is restricted). An increase in weight of a load tends to decrease the length of a pace. Loads over 50 pounds increase the time per pace from 15.0 TMU to 17.0 TMU. Pace is the most commonly used unit of measure, the standard length being 34 inches. The foot is occasionally used as a unit of measure but primarily for long walks.

Sidestep (SS)

"Sidestep is a lateral movement of the body, without rotation, performed by one or two steps" (18, p. 12-7). If the sidestep is less than 12 inches, the movement is rarely limiting. Sidestep Case 1

TABLE XI

BODY, LEG, AND FOOT MOTIONS

Description	Symbol	Distance	Time TMU
Feet Motion--Hinged at ankle	FM	Up to 4"	8.5
With heavy pressure	FMP		19.1
Leg or Foreleg Motion	LM	Up to 6"	7.1
		Each additional inch	1.2
Sidestep--Case 1--Complete when leading leg contacts floor	SS-C1	Less than 12"	Use REACH or MOVE time
		12"	17.0
		Each additional inch	0.6
Case 2--Lagging leg must contact floor before next motion can be made	SS-C2	12"	34.1
		Each additional inch	1.1
Bend, Stoop, or Kneel on One Knee	B, S, KOK		29.0
Arise	AB, AS, AKOK		31.9
Kneel on Floor--Both Knees	KBK		69.4
Arise	AKBK		76.7
Sit	SIT		34.7
Stand from Sitting Position	STD		43.4
Turn Body 45 to 90 Degrees--			
Case 1--Complete when leading leg contacts floor	TBC1		18.6
Case 2--Lagging leg must contact floor before next motion can be made	TBC2		37.2

TABLE XI (Continued)

Description	Symbol	Distance	Time TMU
Walk	W-FT	Per foot	5.3
Walk	W-P	Per pace	15.0

Source: Barnes, Motion and Time Study: Design and Measurement of Work (1954).

(SS-C1) consists of one step while SS-C2 consists of two steps. The distance the foot moves measured at the ankle, is the length of the sidestep.

Turn Body (TB)

"Turn body is a rotational movement of the body performed by one or two steps" (18, p. 12-7). Most turn body motions are between 45 and 90 degrees. Turn body is rarely limiting when the turn is less than 45 degrees. To make a 90 degree turn two turn body motions are usually required. TB-C1 (case 1) consists of one step and TB-C2 consists of two steps.

Foot Motions (FM) and Leg Motions (LM)

> Foot motion is the movement of the ball of the foot up or down with the heel or the instep serving as a fulcrum . . . Leg motion is the movement of the leg in any direction with the knee or the hip as the pivot, where the predominant purpose is to move the foot, rather than the body (18, p. 13-1).

The motion of the foot in a foot motion hinges at the ankle. The distance of the leg motion is measured at the ankle. If a leg motion is performed while standing, the hip is the pivot point. If it is performed while sitting, the knee is the pivot point.

Bend (B) and Arise from Bend (AB)

> Bend is the lowering of the upper part of the body by bending at the hips so that the hands can reach to or below the level of the knees . . . Arise from bend (AB) . . . is the returning of the body from a bend to an erect standing position (18, p. 13-4).

Stoop (S) and Arise from Stoop (AS)

> Stoop is the lowering of the upper part of the body by bending at the hips and knees so that the hands can reach to or near the floor . . . Arise from stoop (AS) . . . is the returning of the body from a stoop to an erect standing position (18, p. 13-5).

Kneel on One Knee (KOK), Arise from Kneel on One Knee (AKOK), Kneel on Both Knees (KBK), and Arise from Kneel on Both Knees (AKBK)

> Kneel on one knee is the lowering of the body by shifting one foot forward or backward and lowering one knee to the floor . . . Arise from kneel on one knee is . . . the returning of the body from a kneel on one knee to an erect standing position . . . Kneel on both knees is the lowering of the body by performing kneel on one knee followed by a shifting of the other knee to the floor . . . Arise from kneel on both knees is the returning of the body from a kneel on both knees to an erect standing position (18, p. 13-5).

Sit (SIT) and Stand (STD)

"Sit is the lowering of the body to a seat . . . Stand is the returning of the body from a sit to an erect standing position" (18, p. 13-5).

Simultaneous Motions

A simultaneous motion is one where two or more motions are performed simultaneously by two different body members. Combined motions are where two or more motions are performed by the same body member. The principle of the limiting motions states that "if an operator performs one or more motions at a time, all of the motions can be performed in the time required by the one demanding the greatest amount of time" (18, p. 14-1). The simultaneous motion table (Table XII) shows the motions which are easy to perform simultaneously, those which can be performed simultaneously with practice and those which are difficult to perform simultaneously, even after long practice. Variables included in the table are movements made within the area of normal vision, those mad made outside the area of normal vision, movements which are easy handle and those which are hard to handle.

Motions which are not included in Table XII are as follows:

1. Turn--normally easy with all motions except when turn is controlled or with disengage.

2. Apply pressure--may be easy, practice, or difficult. Each case must be analyzed.

3. Position--Class 3--always difficult.

4. Disengage--Class 3--normally difficult.

5. Release--always easy.

6. Disengage--any class may be difficult if care must be exercised to avoid injury or damage to object.

TABLE XII

SIMULTANEOUS MOTIONS

Reach				Move						Grasp					Position						Disengage				
A,E	B	C,D		A,Bm		B		C		G1A G2 G5	G1B G1C		G4		P1S		P1SS P2S		P1NS P2SS P2NS		D1E D1D	D2			
		W*	O	W*	O	W*	O	W*	O		W*	O	W*	O	E**	D	E**	D	E**	D		E**	D	Case	Motion
□	□	□	□	□	□	□	□	☒	☒	□	□	□	□	□	□	□	□	☒	☒	☒	□	□	□	A,E	
	□	□	☒	□	□	□	☒	☒	■	□	□	☒	☒	■	☒	☒	☒	■	■	■	□	□	☒	B	Reach
		□	☒	☒	■	☒	■	■	■	□	☒	■	■	■	■	■	■	■	■	■	☒	■	■	C,D	
				□	□	□	□	□	□	□	□	□	□	□	□	□	□	☒	☒	☒	□	□	□	A,Bm	
						□	□	□	□	□	□	☒	☒	■	☒	☒	☒	■	■	■	□	□	☒	B	Move
								☒	■	□	☒	■	■	■	■	■	■	■	■	■	☒	■	■	C	
										□	□	□	□	□	□	□	□	■	■	■	□	■	■	G1A, G2, G5	
											■	■	☒	■	■	■	■	■	■	■	■	■	■	G1B, G1C	Grasp
													■	■	■	■	■	■	■	■	■	■	■	G4	
															☒	■	■	■	■	■	■	■	■	P1S	
																	■	■	■	■	■	■	■	P1SS, P2S	Position
																			■	■	■	■	■	P1NS, P2SS, P1NS	
																					□	□	□	D1E, D1D	Disengage
																						□	□	D2	

*W = within the area of normal vision, O = outside the area of normal vision.

**E = easy to handle, D = difficult to handle.

□ = Easy to perform simultaneously, ☒ = can be performed simulteously with practice, ■ = difficult to perform simultaneously even after long practice (allow both times).

Source: Barnes, Motion and Time Study: Design and Measurement of Work (1954).

APPENDIX C

THE PRINCIPLES OF MOTION ECONOMY

THE PRINCIPLES OF MOTION ECONOMY

The principles of motion economy have been classified by Close (16, p. 237) as:

Motion Economy of the Human Body,
Motion Economy of the Workplace,
Motion Economy of Tools and Equipment,
Motion Economy of Materials Handling,
Motion Economy for Conservation of Time.

Motion Economy of the Human Body

Barnes (13) and Kazarian (4) list the following principles of motion economy of the human body.

1. The two hands should begin as well as complete their motions at the same time. Both hands should reach for items at the same time, as reaching with one hand for a paddle to stir and with the other hand to a dial to open the steam on a kettle; both hands should work together and be finished with the tasks at the same time.

2. The two hands should not be idle at the same time except during rest periods. This will bring about the most productive work arrangement.

3. Motions of the arms should be made in opposite and symmetrical directions, and should be made simultaneously. These types of movements will balance the body and allow the operator to work with less physical and mental effort.

4. Hand and body motions should be confined to the lowest classification with which it is possible to perform the work satisfactorily. The five classifications are:

a. finger movements,

b. finger and wrist movements,

c. finger, wrist, forearm movements,

d. finger, wrist, forearm and upper arm movements, and

e. finger, wrist, forearm, upper arm and shoulder movements.

The finger movements involve the least amount of time and effort but are the weakest type of movement. The last classification can exert considerable force, but the movement itself is inefficient. The movements most commonly used with the greatest efficiency are b, c and d. Another factor involved here is extra body movements. These are costly in terms of time loss and fatigue.

5. Momentum should be employed to assist the worker wherever possible, and it should be reduced to a minimum if it must be overcome by muscular effort. Momentum develops as body members are put into motion. Instead of using stop-start movements, the momentum should be used to the best advantage.

6. Smooth continuous curved motions of the hands are preferable to straight line motions involving sudden and sharp changes in direction. Studies indicate that circular movements are most accurate, easier and quicker to perform than straight line movements.

7. Ballistic movements are faster, easier and more accurate than restricted (fixation) or controlled movements. Fixation movements are those which use two contracted muscles which oppose each other to perform a task. An example is holding a pen and writing. Ballistic motions are fast, easy and accurate. The muscles which put the body member into motion relax once the motion is begun. The ballistic movement is less fatiguing, less likely to cramp muscles and smoother than controlled movements.

8. Work should be arranged to permit an easy and natural rhythm wherever possible. Rhythm refers to the regular repetition of a certain cycle of motions by an individual. When the work area is arranged properly, allowing for easy repetition, rhythm is developed and the task becomes automatic. It has been noted that fatigue will throw the rhythm and timing off balance.

9. Eye fixations should be as few and as close together as possible. If the work involves extensive and concentrated use of the eyes, the work area should be arranged to give the eyes a shorter traveling distance. If the eyes must move a great distance and search, the hands must wait, thereby increasing the performance time.

10. The number of motions and the length of time of these motions necessary to complete a task should be minimized. The arrangement of the work area is the biggest influence on the motions. A properly arranged area will necessitate fewer and shorter movements. Employee training of the principles being discussed is also a factor here.

11. Intermittent use of the different classifications of movements should be provided to combat fatigue. Tasks performed with short movements invite fatigue. Some of this fatigue may be alleviated by inserting longer movements into the pattern occasionally.

Motion Economy of the Workplace

Koteschevar (20) and Barnes (13) enumerate the principles of motion economy of the workplace.

1. There should be a definite and fixed place for all tools and materials. By storing and placing materials in the same spot workers will form habits and the production will become automatic.

2. Tools, materials and controls should be located close to the point of use. The point of use should be within the normal working area. The normal working area for a female is an arc approximately 14 inches from the shoulder and the maximum work area is an arc about 23.5 inches from the shoulder. The male distances for normal and maximum working areas are approximately 15.5 inches and 26.5 inches, respectively. When the maximum work area arcs of both arms meet, they form an area outside which work cannot be performed without causing strain and fatigue. When tools, equipment and materials are properly located, the proper sequence should follow with the least possible movements.

3. Gravity feed bins and containers should be used to deliver material close to the point of use.

4. Drop deliveries should be used wherever possible. A time and motion saving comes when a finished product can be released and dropped, allowing gravity to deliver it.

5. Materials and tools should be located to permit the best sequence of motions. Proper arrangement of tools and ingredients will make a task flow easily. By ending a cycle in a position near the beginning of the next cycle, motions can be saved.

6. Provisions should be made for adequate conditions for seeing. Good illumination is the first requirement for satisfactory visual perception. Adequate illumination involves three factors: sufficient intensity, proper color without glare and direction of light source. Objects with a low reflection factor or very fine work require light intensity higher than normal or a lighter background.

7. The height of the workplace and the chair should preferably be arranged so that alternate sitting and standing at work are easily

possible. Alternate sitting and standing helps to rest the muscles and improve circulation. More fatigue results from long periods in one position. When determining the height of a work surface, the height of the elbow is the factor involved. The height of the average female's elbow is 40 inches. The hand can work comfortably one to four inches below the elbow, so the height of the working surface for females should be 36 to 39 inches high. A chair should be 25 to 31 inches high.

8. A chair of the type and height to permit good posture should be provided for every worker.

9. The work area should be limited so that energy will not be wasted in walking.

10. The environment and working conditions of the work area should be conducive to productive motions.

Motion Economy of Tools and Equipment

Barnes (13) and Kotschevar (20) state the principles of motion economy of tools and equipment.

1. The hands should be relieved of all work that can be done more advantageously by a jig, fixture, or a foot-operated device. The use of these devices keeps the hands free for productive work.

2. Two or more tools should be combined wherever possible. The combination-tools reduce the time needed to lay down, select and pick up a second tool. A spatula used to spread sandwiches with filling would be more efficient if it had a serrated edge to cut the sandwich.

3. Tools and materials should be prepositioned whenever possible. An object is prepositioned when it is placed, at the end of a cycle, in the correct position to be used for the next cycle. If a holder is

necessary to keep the material or tool in place, it should be provided.

4. Where each finger performs some specific movement, such as in typewriting, the load should be distributed in accordance with the inherent capacities of the fingers. For most people the right hand is slightly more efficient than the left. The first and second fingers of both hands are more capable of performing than the third and fourth fingers.

5. Levers, crossbars, and hand wheels should be located in such positions that the operator can manipulate them with the least change in body position and with the greatest mechanical advantage. The controls should have a maximum contact spot with the body member to ease the operation. Machine production will likely be greatest when the controls are easy to operate. In operating a machine, the employee should not have to leave his working position to operate the controls.

6. Tools, hand equipment, handles and controls to be grasped for any length of time or that require force should be fit to the palm surface. The palm and fingers should be able to hold tightly without discomfort.

7. If a machine can perform an operation, consider the use of it.

Motion Economy of Materials Handling

Kazarian (20) lists the following principles of motion economy of materials handling.

1. Movements and storage should be minimized. The storage should be as close as possible to the point of first use. A proper storage area should be arranged in some logical order and be accessible in terms of sight and easy grasp. A good arrangement will eliminate searching.

2. Materials should be moved by employees only when absolutely necessary. When heavy or bulky items are moved a mechanical device should be utilized. When a fixed route is used a conveyer should be considered.

3. The movement of materials should take place over the shortest and straightest route possible. Prepositioning items eliminates some handling. If possible, materials to be moved should be kept in motion until the destination is reached.

4. During transport inspectors should be present to avoid back-tracking. When large quantities of materials are involved it might be more economical to move men and machines to the materials.

5. Gravity-fed equipment can be utilized to deliver materials to the point of usage. Drop delivery can be used to release finished products.

6. Scrap and trash should be disposed of at the point of creation.

7. Machines and equipment which are frequently moved should have wheels. If a product cannot conform to the above principles of materials handling, the design may need reevaluation.

Motion Economy for Conservation of Time

Close (16) states the principles of motion economy for conservation of time.

1. Each hesitation or ceasing of action by man or machine should be questioned. The procedure may be causing fatigue and the break is necessary to overcome it.

2. If possible, two or more parts should be processed at the same time. Slicing through a stack of sandwiches is more efficient than

slicing each sandwich separately.

3. While a machine is running the operator should be working. The material being processed should be taken from the machine and immediately to its next step if the operator has been preparing while the machine is in use.

4. Rest periods should be staggered throughout the work period. Breaks from work allow the employee to regain physical and nervous strength and thereby continue to produce at a steady pace.

APPENDIX D

METHODS-TIME MEASUREMENT ANALYSES

METHODS ANALYSIS RECORD

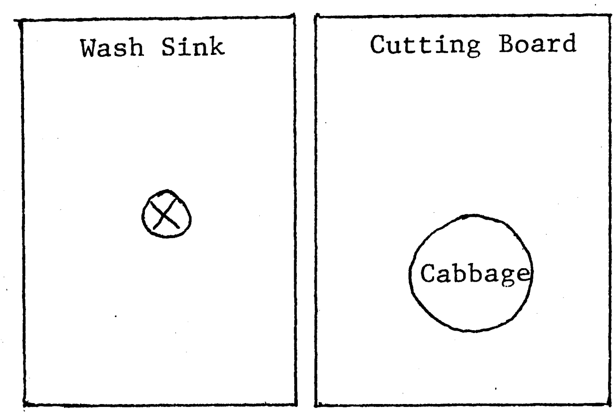
Operation: Quarter Cabbage Date: November 2, 1976

Analyst: A. Fannan

Tools: Cutting board
French knife

Produce Condition: Cabbage heads well rounded, ranges in weight from one and one-half to three pounds. Firmness of heads range from firm to very firm. No decay or rot.

Workplace Layout:



Scale: 1" = 10"

Additional Information: The knife used was sharp. The cabbage was trimmed (outside leaves removed) before the analysis began. The MTM element analysis was begun with the knife on the base of the cabbage. The analysis ended as the last quarter of cabbage had the core cut out.

MTM ELEMENT ANALYSIS

Sheet 1 of 3

Operation: Quarter Cabbage

Date: November 2, 1976

Analyst: A. Fannan

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Hold cabbage				~~M4A~~		Cut off core end
			10.6	AP2		
Turn cabbage onto core end			6.9	M4B		Move knife aside
Reach to top of cabbage		R6B	12.2	M10B		Move knife to cabbage
Grasp cabbage		G5	0.0			
			10.6	~~M2B~~		Cut cabbage
				AP2		
				~~M4B~~	5	Cut cabbage
			53.0	AP2	5	
				~~M5A~~		Cut cabbage in half
			10.6	AP2		
			12.2	M10B		Move knife away from cabbage
Regrasp cabbage to hold left side		G2	10.6	M8B		Move knife against cabbage on right
Move cut side down on board		M5B	8.0			
Release cabbage		RL1	2.0			
Reach for other piece		R5B	7.8			

Operation: Quarter Cabbage

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Grasp cabbage		G1A	6.9	M4B		Move knife aside
Move cut side down on board		M4B	6.9			
Release cabbage		RL1	2.0			
Reach to end of knife		R4A	10.6	M8B		Move knife to cabbage
Grasp knife		G5	0.0			
Assist in cutting cabbage	2 2	~~M2B~~ AP2	21.2	~~M2B~~ AP2	2 2	Cut cabbage
Assist in cutting cabbage	2 2	M2A AP2	21.2	~~M2A~~ AP2	2 2	Cut cabbage
Reach with knife		R8B	10.6	M8B		Move knife to other piece
Release knife		RL2	2.0			
Reach to cabbage piece at left		R4B	6.4			
Grasp cabbage		G1A	2.0			
Move cabbage to left		M2B	10.6	M8B		Move knife to cabbage
			42.4	~~M2A~~ AP2	4 4	Cut out core
Move cabbage to water	3	M10B	36.6	R4B G2	2 2	Reach to next cabbage piece Regrasp knife

Operation: Quarter Cabbage

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Release cabbage over water	3	RL1	6.0			
			4.0	G1A	2	Grasp cabbage
Reach to next cabbage piece	2	R10B	23.0	M5B	2	Turn cabbage over
Grasp cabbage	2	G1A		~~G2~~	2	Regrasp knife
			11.4	M3B	2	Move knife to cabbage
Reach to third cabbage piece		R14B	14.4	M6B		Move knife away
Grasp cabbage		G1A	2.0			
Move cabbage to left		M2B	6.9	M4B		Move knife to cabbage

*Frequency of occurrence.

METHODS ANALYSIS RECORD

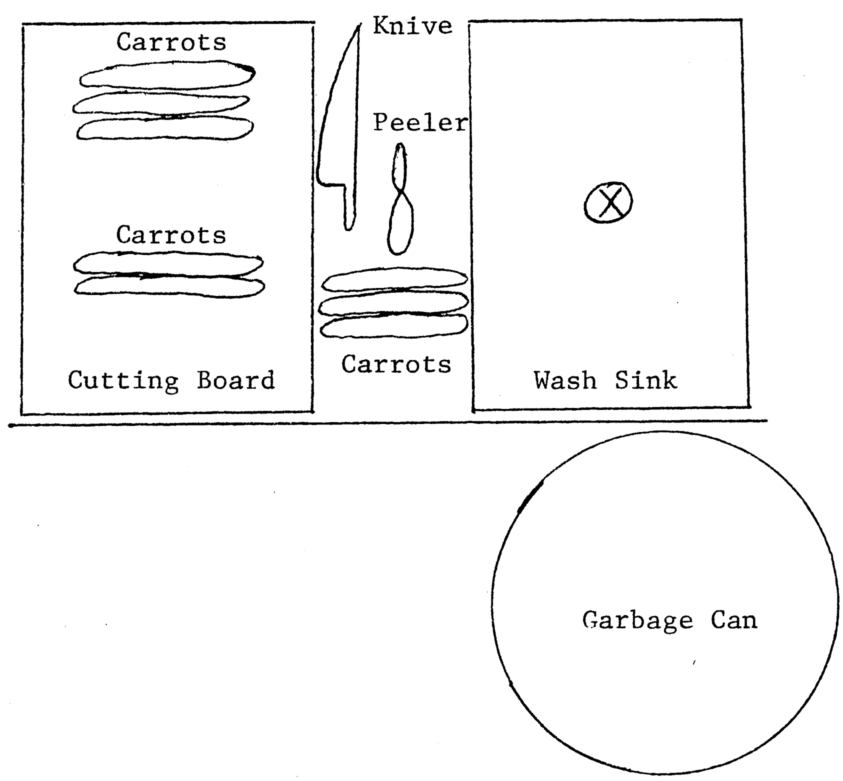
Operation: Pare Six Carrots   Date: October 20, 1976

Analyst: A. Fannan

Tools: Cutting board
French knife
Vegetable peeler

Produce Condition: Carrots ranged from five and one-half to seven inches in length and one to one and one-fourth inch in diameter at the top end. No decay or rot. Carrots tapered at the end, fairly well formed, firm.

Workplace Layout:



Scale: 1" = 10"

Additional Information: The knife and peeler used were sharp. The MTM element analysis was begun with the knife on the top ends of the carrots. The analysis ended as the sixth carrot was released over the water.

MTM ELEMENT ANALYSIS

Operation: Pare Six Carrots

Sheet 1 of 3

Analyst: A. Fannan

Date: October 20, 1976

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Hold carrots				(~~M2A~~	3	Slice off ends of carrots
			31.8	(AP2	3	
Move carrots to turn	3	M2B	17.1	M3B	3	Move knife
Release carrots	3	RL2	0.0			
Reach to carrots	3	R5B	23.4			
Grasp carrots	3	G1A	6.0			
Move carrots to turn	3	M2B	13.8			
Push carrots against knife	3	M1B	17.1	M3B	3	Push knife against carrots
			13.8	M2B	3	Move knife to end of carrots
				(~~M1A~~	3	Slice off ends of carrots
			31.8	(AP2	3	
Release carrots	2	RL1	4.0			
Reach for two more carrots				(G2	2	Regrasp knife
	2	R9C	24.4	(R4B	2	Reach for carrots
Grasp two carrots	2	G4A	14.6	G1A	2	Grasp carrots

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Move carrots to board	2	M9B	24.4	M10B	2	Move carrots aside
			4.0	RL1	2	Release carrots
Push carrots against knife	2	M1A	19.4	M7B	2	Move knife to end of carrots
				~~G2~~	2	Regrasp knife
			11.4	M3B	2	Move knife to end of carrots
Move carrots aside		M10B	12.2	M6B		Move knife away
Regrasp carrots (release one)		G2	5.6	RL1		Release knife
			5.3	R3B		Reach for peeler
			2.0	G1A		Pick up peeler
Turn body toward trash can		TBC2	37.2			
Move carrot toward body		~~M3A~~		M3A		Move peeler toward carrot
			538.2	M4B	78	Pare carrot
Regrasp carrot (to turn)	36	G2	496.8	M4B	72	Move peeler up to carrot
				~~R1A~~	6	Reach to carrot
			33.6	G2	6	Regrasp peeler
			12.0	G1A	6	Grasp carrot
Release carrot	6	RL1	67.8	M10A	6	Turn carrot (end to end)
Grasp carrot	6	G1A	12.0	RL1	6	Release carrot
			41.4	M4B	6	Move peeler toward carrot
				~~G2~~	6	Regrasp peeler

Operation: Pare Six Carrots

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
			538.2	M4B	78	Pare carrot
Regrasp carrot (to turn)	36	G2	496.8	M4B	72	Move peeler up to carrot
Move carrot to water	6	M15B	91.2			
Release carrot	6	RL1	12.0			
Reach for another carrot	5	R8B	50.5			
Grasp carrot	5	G1A	10.0			
Move carrot toward peeler	5	M17B	82.0	M2B	5	Move peeler toward carrot

*Frequency of occurrence.

METHODS ANALYSIS RECORD

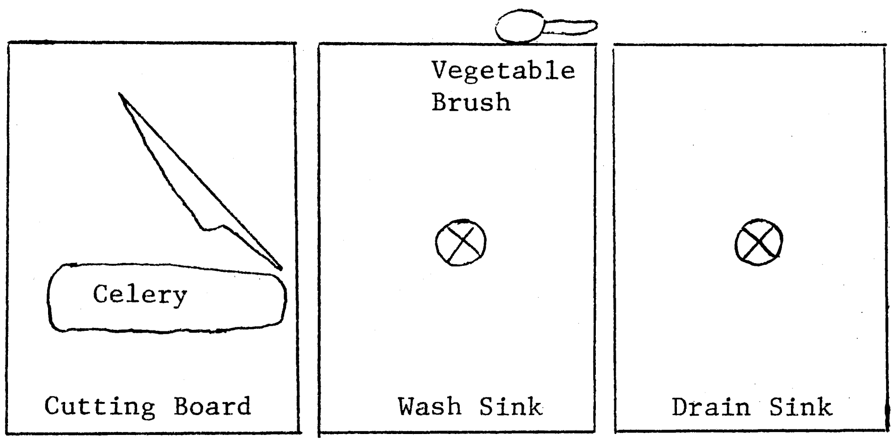
Operation: Clean Celery Date: October 20, 1976

Analyst: A. Fannan

Tools: Cutting board
French knife
Vegetable brush

Produce Condition: Celery stalks firm and fairly straight. No rot or decay.

Workplace Layout:



Scale: 1" = 10"

Additional Information: The knife used was sharp. The MTM element analysis was begun with the knife on the root end of the celery. The analysis ended as the last stalk of celery was released over the drain sink. There was an average of ten stalks to each bunch of celery.

MTM ELEMENT ANALYSIS

Operation: Clean Celery Sheet 1 of 2

Analyst: A. Fannan Date: October 20, 1976

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Hold celery bunch			10.6	~~M2B~~ AP2		Cut off one and one-half inches from bottom of celery
			10.6	~~M3A~~ AP2		Cut bottom off celery
			8.0	M5B ~~G2~~		Move knife from celery Regrasp knife
			2.0	G1A		Grasp bottom of celery
			13.4	M12B		Move knife and bottom aside
			2.0	RL1		Release knife and bottom
Move celery bunch into water Sidestep to sink		~~M12B~~ SSC2	34.1	R12B		Reach for vegetable brush
Release celery bunch		RL1	2.0	G1A		Grasp vegetable brush
Reach for one stalk celery		R14C	15.6	M8A		Move brush toward celery
Grasp one stalk celery		G4A	7.3			

Operation: Clean Celery

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Regrasp celery stalk Move celery stalk to brush		~~G2~~ M14A	14.4	M2A		Move brush to celery
			388.0	M7B	40	Rub stalk with brush
Turn celery over (regrasp)	10	G2	56.0			
			388.0	M7B	40	Rub stalk with brush
Transfer stalk to right hand	10	G3	56.0	G2	10	Regrasp brush
Reach for new celery stalk	9	R14C	140.4	M10B	9	Move celery to drain sink
Grasp celery stalk	9	G4A	65.7	RL1	9	Release celery stalk
Move celery to brush Regrasp celery stalk	9 9	M14A ~~G2~~	129.6	M10A ~~G2~~	9 9	Move brush to celery Regrasp brush
			12.2	M10B		Move last celery to drain sink
			2.0	RL1		Release celery stalk

*Frequency of occurrence.

METHODS ANALYSIS RECORD

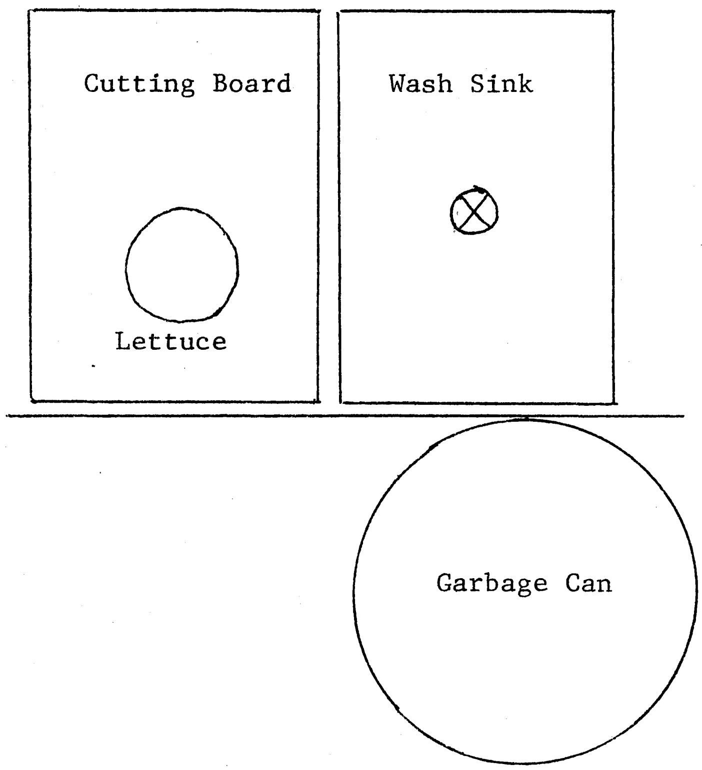
Operation: Core Head Lettuce Date: October 20, 1976

Analyst: A. Fannan

Tools: Cutting board
Paring knife

Produce Condition: Iceberg lettuce, four to five inches in diameter. Moderately firm heads, no rot or decay.

Workplace Layout:



Scale: 1" = 10"

Additional Information: The knife used was sharp. The MTM element analysis was begun with the knife on the core end of the lettuce. The analysis ended as the head of lettuce was released into the water. The lettuce was trimmed (outside leaves removed) before the analysis began.

MTM ELEMENT ANALYSIS

Operation: Core Head Lettuce — Sheet 1 of 1

Analyst: A. Fannan — Date: October 20, 1976

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Hold head of lettuce			10.6	~~M2B~~ AP2		Push knife into head of lettuce
Turn head to aid cutting	2	T90S	17.8	M6B	2	Move knife around core
Release head of lettuce		RL2	0.0			
Reach to top of head		R5B	7.8			
Grasp head of lettuce		G5	0.0			
			6.9	M4B ~~G2~~		Move knife from head Regrasp knife
			6.4	R4B		Reach for core
Regrasp head of lettuce		G2	5.6	G1A		Grasp core
Move head to water		M17B	16.4	M17B		Move core to trash can
Release head into water		RL1	2.0	RL1		Release core

*Frequency of occurrence.

METHODS ANALYSIS RECORD

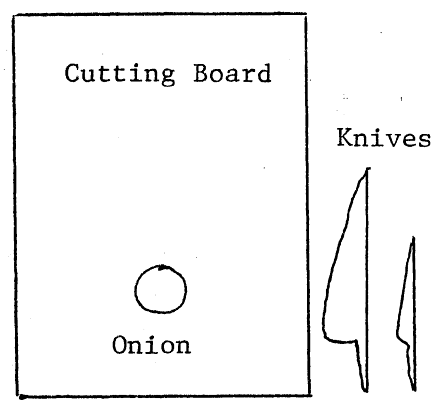
Operation: Peel Yellow Onion   Date: October 20, 1976

Analyst: A. Fannan

Tools: Cutting board
French knife
Paring knife

Produce Condition: Yellow onion, two and one-half to three inches in diameter. No rot or decay. Well-rounded and hard.

Workplace Layout:



Scale: 1" = 10"

Additional Information: The knives used were sharp. The MTM element analysis was begun with the French knife on the tip of the onion. The analysis ended as the onion peel pulled away from the onion.

MTM ELEMENT ANALYSIS

Operation: Peel Yellow Onion | Sheet 1 of 2

Analyst: A. Fannan | Date: October 20, 1976

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Hold onion			10.6	(~~M2A~~ AP2		Cut off end of onion
			2.9	M1B		Move knife aside
Move onion to turn	4	MfB	8.0	M3B		Move knife to end of onion
			10.6	(~~M2A~~ AP2		Cut off end of onion
			8.0	M5B		Move knife aside
			2.0	RL1		Release French knife
Move onion to turn	3	MfB	6.0	R2B		Reach for paring knife
			2.0	G1A		Pick up paring knife
Move (rock) onion forward		M1B	10.6	M8B		Move knife to onion
Move (rock) onion backward		M1B	2.9	M1B		Cut skin of onion
Regrasp onion		G2	5.6	G2		Regrasp knife

Operation: Peel Yellow Onion

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Lift onion upward		M3A	6.4	R4B		Reach to corner of peel
			3.5	G1B		Grasp corner of peel
Move onion to turn	5	MfB	10.0	M5B		Pull peel off of onion

*Frequency of occurrence.

METHODS ANALYSIS RECORD

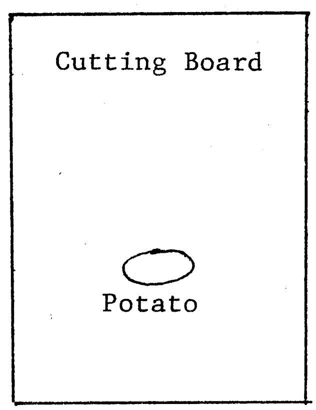
Operation: Cube Potato   Date: October 26, 1976

Analyst: A. Fannan

Tools: Cutting board
French knife

Produce Condition: Large, round-type potatoes (one and three-fourths to two and one-half inches in diameter). No interior or exterior defects, very firm. No decay or rot.

Workplace Layout:



Scale: 1" = 10"

Additional Information: The knife used was sharp. The potatoes used were peeled prior to the analysis. The MTM element analysis was begun with the knife on the potato. The analysis ended as the last cut was made to cube the potato.

MTM ELEMENT ANALYSIS

Operation: Cube Potato   Sheet 1 of 2

Analyst: A. Fannan   Date: October 26, 1976

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Hold potato			21.2	~~M3A~~ AP2	2 2	Cut potato
			17.8	M6B	2	Move knife from potato
			8.9	M6B		Place knife on potato
Regrasp potato		G2	11.5	~~G2~~ R10B		Regrasp knife Reach for potato piece
Slide two pieces of potato away		M2B	4.6	G1A		Grasp potato piece
Turn hand to set pieces down		T90S	5.4	T90S		Turn hand to set pieces down
Release potato pieces		RL1	2.0	RL1		Release potato piece
Reach to end of knife		R4B	8.0	~~G2~~ M5B		Regrasp knife Move knife to potato
Place hand on end of knife		G5	0.0			
Assist in cutting potato	6 6	~~M1A~~ AP2	63.6	~~M1A~~ AP2	6 6	Cut potato

Operation: Cube Potato

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Reach with knife	5	R1B	14.5	M1B	5	Move knife from potato
Reach with knife	5	R3B	28.5	M3B	5	Place knife on potato
Reach with knife		R1B	2.9	M1B		Move knife from potato
Reach with knife		R1B	10.6	M8B		Move knife to make parallel cuts
Cut potato	3 3	~~M1A~~ AP2	31.8	~~M1A~~ AP2	3 3	Cut potato
Place knife on potato	2	R2B	9.2	M2B	2	Place knife on potato

*Frequency of occurrence.

METHODS ANALYSIS RECORD

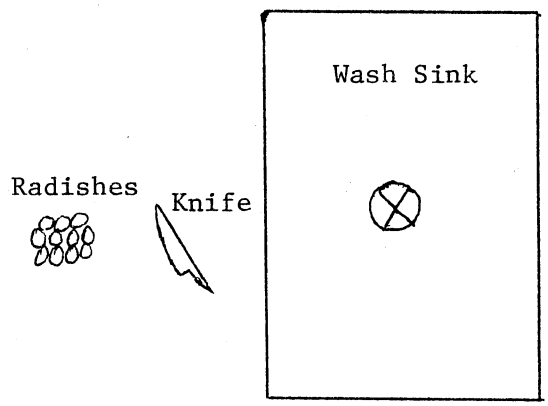
Operation: Clean Five Radishes   Date: October 26, 1976

Analyst: A. Fannan

Tools: Paring knife

Produce Condition: Size medium (three-fourths to one inch in diameter). Well-rounded, smooth, firm. No badly marked radishes. No decay or rot.

Workplace Layout:



Scale: 1" = 10"

Additional Information: The knife used was sharp. The MTM element analysis was begun with a radish in the left hand and the knife in the right hand. The analysis ended when the fifth radish was released over the water.

MTM ELEMENT ANALYSIS

Operation: Clean Five Radishes — Sheet 1 of 2

Analyst: A. Fannan — Date: October 26, 1976

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Move radish toward knife		M7A	9.7	M8A		Move knife toward radish
Regrasp knife		~~G2~~		~~G2~~		Regrasp knife
Hold radish				~~M1A~~	5	Slice off end of radish
			53.0	AP2	5	
Turn radish in fingers	15	MfA	30.0	M1A	5	Move knife away from thumb
				~~M1A~~	5	Slice off end of radish
			53.0	AP2	5	
Transfer radish to right hand	5	G3	28.0	G2	5	Regrasp knife
Reach for another radish	4	R6C	40.4	M6B	4	Move radish to water
Grasp radish	4	G4B	36.4	RL1	4	Release radish
Move radish toward knife	4	M7A	35.6	M6A	4	Move knife toward radish
Regrasp radish	4	~~G2~~		~~G2~~	4	Regrasp knife
			8.9	M6B		Move last radish to water

Operation: Cube Potato

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
			2.0	RL1		Release radish

*Frequency of occurrence.

METHODS ANALYSIS RECORD

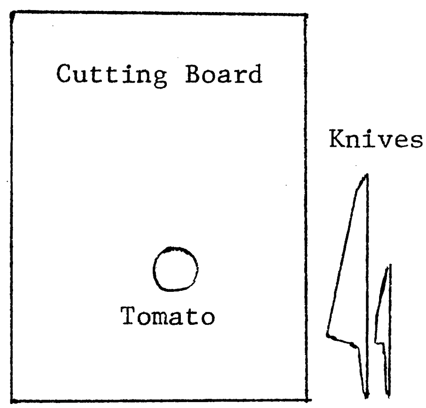
Operation: Dice Tomato Date: October 26, 1976

Analyst: A. Fannan

Tools: Cutting board
Paring knife
Eight-inch serrated knife

Produce Condition: Packed 5 x 6. Diameter--three to three and one-fourth inches. Firm tomatoes, red, vine-ripened. No soft spots on tomatoes. No decay or rot.

Workplace Layout:



Scale: 1" = 10"

Additional Information: The knives used were sharp. The paring knife was held to the blossom end of the tomato when the MTM element analysis was begun. The analysis ended as the last cut to dice the tomato was made.

MTM ELEMENT ANALYSIS

Operation: Dice Tomato | Sheet 1 of 3

Analyst: A. Fannan | Date: October 26, 1976

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Hold tomato				~~M1B~~	5	Push knife into tomato
			53.0	AP2	5	
Turn tomato to aid cutting		T180S		~~M6B~~	5	Pull knife around to cut out blossom
			53.0	AP2	5	
Regrasp tomato		G2				
Set tomato on side		M2B	9.7	M7B		Move knife aside
			2.0	RL1		Release paring knife
			5.3	R3B		Reach for serrated knife
			2.0	G1A		Grasp serrated knife
			10.6	M8B		Move knife to tomato
				~~M3A~~	2	Cut tomato
			21.2	AP2	2	
Regrasp tomato	2	G2	13.8	M4B	2	Move knife away
			6.9	M4B		Place knife on tomato

Operation: Dice Tomato

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Turn tomato on end		M3B	5.7			
Regrasp tomato		G2	8.0	M5B		Move knife to tomato
				(~~M4B~~	2	Cut tomato
			21.2	(AP2	2	
				(~~M4A~~	2	Cut tomato
			21.2	(AP2	2	
Regrasp tomato	2	G2	13.8	M4B	2	Move knife away
			6.9	M4B		Place knife on tomato
Turn tomato		T90S	5.4			
Release tomato		RL2	0.0			
Turn hand to hold tomato		T90S	8.0	M5B		Move knife to tomato
Grasp tomato		G5	0.0			
				(~~M3B~~	2	Cut tomato
			21.2	(AP2	2	
				(~~M4A~~	2	Cut tomato
			21.2	(AP2	2	
Regrasp tomato		G2	6.9	M4B		Move knife away

Operation: Dice Tomato

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
			6.9	M4B		Place knife on tomato

*Frequency of occurrence.

METHODS ANALYSIS RECORD

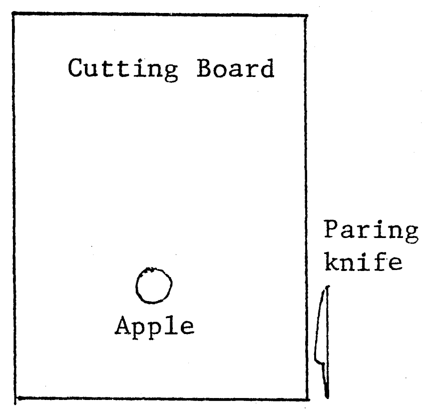
Operation: Dice Apple   Date: October 26, 1976

Analyst: A. Fannan

Tools: Cutting board
French knife
Paring knife

Produce Condition: Jonathan apples--size 113. Condition--unbruised, firm fruit, no bad spots.

Workplace Layout:



Scale: 1" = 10"

Additional Information: The knives used were sharp. The French knife was held on the apple when the MTM element analysis was begun. The analysis ended as the last cut was made to dice the apple.

MTM ELEMENT ANALYSIS

Operation: Dice Apple — Sheet 1 of 4

Analyst: A. Fannan — Date: October 19, 1976

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Aid in cutting apple		~~M2A~~ AP2	10.6	~~M2A~~ AP2		Cut apple in half
Release knife		RL2	5.7	M3B		Lift knife away
Reach to apple piece		R3B	5.3			
Grasp apple piece		G1A	2.0			
Turn apple piece onto cut side Regrasp apple piece to turn		~~M3A~~ G2	5.6			
Release apple piece		RL2	0.0			
Reach to other apple piece		R5B	7.8			
Grasp apple piece		G1A	2.0			
Turn piece onto cut side Regrasp apple piece to turn		~~M3A~~ G2	5.6			
Release apple piece		RL2	0.0			

<u>Operation</u>: Dice Apple

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Reach for top of knife		R5B	7.8	M3B		Move knife to apple piece
Grasp knife		G5	0.0			
Aid in cutting apple piece		~~M2A~~ AP2	10.6	~~M2A~~ AP2		Cut apple piece in half
Move knife to other apple piece		M3B	5.7	M3B		Move knife to other apple piece
Aid in cutting piece in half		~~M2A~~ AP2	10.6	~~M2A~~ AP2		Cut apple piece in half
Release knife		RL2	10.6	M8B		Move knife to set down
			2.0	RL1		Reiease French knife
Reach to first apple piece		R3B	5.3	R2B		Reach to paring knife
Grasp apple piece		G1A	2.0	G1A		Grasp knife
Move apple piece toward knife Regrasp apple piece		M4A ~~G2~~	11.3	M10A ~~G2~~		Move knife toward apple Regrasp knife
Move apple to aid cutting	4	MfA	42.4	~~M2B~~ AP2	4 4	Cut core out
Move apple piece toward board	3	M4B	20.7			
Regrasp apple piece	3	G2	16.8			

Operation: Dice Apple

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Release apple piece	3	RL2	0.0			
Reach to next apple piece	3	R1B	7.5			
Grasp apple piece	3	G1A	6.0			
Move apple toward knife Regrasp apple piece	3	M4A ~~G2~~	18.3	M2A	3	Move knife toward apple
Move apple to board		M4B	12.2	M10B		Move knife to board
Regrasp apple piece		G2	5.6	RL1		Release paring knife
Release apple piece		RL2	4.0	R2B		Reach to French knife
			2.0	G1A		Grasp French knife
			5.6	G2		Regrasp knife
Reach to top of knife		R5B	7.8	M4B		Move knife to apple
Grasp knife		G5	0.0			
Aid in cutting apple piece	8 8	~~M1A~~ AP2	84.8	~~M1A~~ AP2	8 8	Cut apple
Move knife to next apple piece	7	M1B	20.3	M1B	7	Move knife to next apple piece
Release knife		RL2	0.0			

Operation: Dice Apple

Description--Left Hand	F*	Motion	TMU	Motion	F*	Description--Right Hand
Reach to apple pieces		R5B	8.9	M6B		Move knife to side of apple pieces
Grasp apple pieces		G5	0.0			
Turn body to help . . . Move apple pieces		TBC1 ~~M3B~~	18.6	M6B		Move apple pieces with knife
Release apple pieces Turn body to original position Reach to top of knife		~~RL2~~ TBC1 ~~R12B~~	18.6	M13B		Move to position to cut
Grasp knife		G5	0.0			
Aid in cutting apples	2 2	~~M2A~~ AP2	21.2	~~M2A~~ AP2	2 2	Cut apples
Move knife to cut		M1B	2.9	M1B		Move knife to cut

*Frequency of occurrence.

TABLE XIII

TEST TIMES IN SECONDS AND TENTHS OF SECONDS

Cabbage	Carrots	Celery	Lettuce	Onion	Potato	Radishes	Tomato	Apple
17.0	79.1	28.7	2.6	7.4	13.5	14.4	12.6	38.5
17.1	85.9	33.8	2.6	7.7	13.9	14.9	13.3	39.0
18.4	91.0	36.1	2.9	8.4	15.0	15.2	14.8	39.1
18.8	91.3	38.0	3.1	8.6	15.5	15.2	14.9	39.3
19.7	98.3	38.3	3.1	9.0	15.6	15.3	15.0	40.1
19.9	108.4	39.0	3.1	9.0	15.7	15.6	15.6	40.1
21.5	114.9	41.4	3.2	9.2	16.4	15.7	15.7	40.8
22.5	126.6	42.2	3.3	9.2	16.5	16.2	16.0	41.9
23.0	140.9	43.1	3.3	10.2	16.9	16.2	16.0	42.3
24.1	143.0	44.3	3.6	10.6	18.5	16.2	18.2	42.5
25.5	144.3	44.5	3.8	10.7	18.6	16.3	18.5	43.2
27.6	168.6	45.0	4.0	11.1	22.9	16.8	18.8	44.7
27.9		47.2	4.4	11.1		17.2	20.1	45.6
28.2		49.1	5.8	12.7		17.6	21.1	46.7
		53.1		17.6		17.8	22.5	51.1
						18.0		
						20.0		

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