Time Study of Bolt Making Process at LPS Ltd. using Maynard Operation Sequence Technique

A Major Project thesis

submitted in partial fulfillment

for the requirement of the degree of

Masters of Engineering

in

Production and Industrial Engineering

by

Vikas Kukreja

01/ME (P)/2003

Univ. Roll No. 2452

Under the guidance of

Sh. Rajiv Chaudhary

Sh. R.C.Singh

DEPARTMENT OF MECHANICAL ENGINEERING
DELHI COLLEGE OF ENGINEERING
DELHI UNIVERSITY, DELHI-42

Measure of work brings Knowledge. Through this Knowledge, factual decisions and improvements can be made and control exercised.

When you can measure what you are speaking of and express it in numbers, you know that on which you are discoursing. But if you cannot measure and express it in numbers, your knowledge is of a very meager and unsatisfactory kind.

Lord Kelvin

CANDIDATE'S DECLARATION

I hereby certify that the work which is being presented in the dissertation entitled "Time Study of Bolt Making Process at LPS Ltd. using Maynard Operation Sequence Technique", in partial fulfillment of the requirements for the award of the Degree of Master of Engineering in Production and Industrial Engineering, submitted in the Department of Mechanical Engineering, Delhi College of Engineering, Delhi is an authentic record of my own work carried out for a period of one year under the supervision of Sh. Rajiv Chaudhary & Sh. R.C.Singh of Mechanical Engineering Department, Delhi College of Engineering, Delhi.

I have not submitted the matter embodied in this dissertation for the award of any other degree.

Vikas Kukreja

This is to certify that the above statement made by the candidate is true to the best of my knowledge.

Rajiv Chaudhary
Lecturer
Department of Mech. & Prod. Engineering
Delhi College of Engineering,
Delhi-110042 (India)

R.C. Singh
Lecturer
Department of Mech. & Prod. Engineering
Delhi College of Engineering,
Delhi-110042 (India)

ACKNOWLEDGMENT

Yes, a start leads to an end; initially I never thought that life would be as easy as now. That was in old days where everything was strange but thanks to the God and the institute community for their will and cooperation to feel the comfort I am feeling now. Here, I wish to express my heartily and sincere gratitude and indebtedness to Sh. Rajiv Chaudhary & Sh. R.C.Singh Lecturer's of Mechanical Engineering Department, Delhi College of Engineering, Delhi for their valuable guidance and wholehearted cooperation. They have a special place in my heart for many reasons but to be limited, they are the one who generated confidence in my inner being and helped my hidden energies to come out in full. I like to thank my friends Mr. Tushar Chaudhary and Mr. Vipin Rohilla who helped me a lot during my project completion.

My heartily thanks to all my professors for their expertise and all rounded personality they have imparted me.

My credit also goes to all my pals for their humor, innocence, too much sincerity and cooperation, openness and the like which flourishes my stay here.

Finally, I have shortage of words to express my love and thanks to my beloved parents to whom I owe my knowledge.

Vikas Kukreja

EXECUTIVE SUMMARY

Many companies today realise the importance of good work systems and organised management that leads to better management, decision-making and quality improvement. At the same time, productivity is becoming more and more difficult to achieve and manage. The demands of the engineers and analysts are continuously rising in view of the rapidly changing market places and competition world-wide. This has made it imperative for organizations to upgrade and keep pace with progress.

However, what has not changed much is the ability of the engineers and analyst to respond well to these rising demands and how they would cope with greater decision-making requirements. Many engineers and analysts are technically competent but have been slow in responding to the needs for better organised work processes involving people, machine and workflow. This is because many organizations have not use the right intelligent decision-making tool to engineer work and processes. With MOST training, the engineers and analysts will become more productive. They will spend less on data collection and will be able to transform the work processes for improvements in a much shorter time. In this way, cost improvements can be made at an early stage rather than allowing costly processes to run without making efforts for improvements.

MOST (Maynard Operation Sequence Technique) is a breakthrough work measurement technique that allows a greater variety of work (both repetitive and non-repetitive) for manufacturing, engineering to administrative service activities to be measured quickly with ease and accuracy. This enables today's engineers and analysts to expose wastes and unproductive methods of work quickly and rectify problems at the workplace as they arise at the design stage. A brief description of what MOST can do for an organization includes: accurate work standard, capacity analysis and manpower planning, workplace design and job activity analysis for re-organization and, allocation for work balancing, cost estimating for existing and new processes etc.

This dissertation attempts to show the application of the Maynard Operation Sequence Technique for time study of bolt making processes at Laxmi Precision Screws Ltd., Rohtak and shows the comparison with the time standard established using stopwatch method. Statistical t-test is used to show the significance level between stopwatch and MOST results. Test shows a 95% level of confidence in the result obtained using MOST.

Since the company is under an expansion drive. It becomes relevant for the company to standardize the time required to carry out certain jobs. Also, it will help them to identify suitable layout for their company.

CONTENTS

LIST OF FIGURES

LIST OF TABLES

CHAPTER – I WORK STUDY

1.1 Introduction

Work study, as defined by British Standard Institution, is a generic term for those techniques particularly 'Method Study' and 'Work Measurement' which are used in the examination of human work in all its contexts and which lead systematically to investigation of all the factors which effect the efficiency of the situation being reviewed, in order to seek improvements.

Actually work study investigates the work done in an organization and it aims at finding the best and most efficient way of using available resources, i.e., men, material, money and machinery. Every organization tries to achieve best quality production in the minimum possible time. One phase of work study known as Method Study aims at finding the best possible manufacturing procedure which involves, least time and does not cause fatigue to workers.

Once the method study has developed an improved procedure for doing a job, the work measurement or time study will find the time allowed to complete the job by that procedure. Work Measurement may be defined as the application of different techniques to measure and establish the time required to complete the job by a qualified worker at a defined level of performance.

1.2 Definitions:

1. A Time and Motion study (or time-motion study) is a business efficiency technique combining the Time Study work of Frederick Winslow Taylor with the Motion Study work of Frank and Lillian Gilbreth (best known through the biographical 1950 film and book Cheaper by the Dozen). It is a major part of Scientific management (Taylorism).

A time and motion study would be used to reduce the number of motions in performing a task in order to increase productivity. The best known experiment involved bricklaying. Through carefully scrutinising a bricklayer's job, Frank Gilberth reduced the number of motions in laying a brick from 18 to about 5. Hence the bricklayer both increased productivity and decreased fatigue.

The Gilbreths developed what they called therbligs ("therblig" being "Gilbreth" spelled backwards, with a slight variation), a classification scheme comprising 17 basic hand motions.

2. An analysis of the efficiency with which an industrial operation is performed. Also called motion study, time study.

3. Measuring the time and motions necessary for the completion of specific job tasks. Time and Motion studies were first advocated by Frederick W. Taylor in his book Scientific Management in order to create a management standard for evaluating individual employee productivity.

4. Systematic study of the time and human motions used to perform an operation. The purpose is to eliminate unnecessary motions and to identify the best sequence of motions for maximum efficiency. Therefore, time and motion study can be an important source of productivity improvements. For example, a time and motion study analyzing the functioning of tellers in a bank might be conducted in an effort to effect savings in costs and processing time.

5. Time and motion study, analysis of the operations required to produce a manufactured article in a factory, with the aim of increasing efficiency. Each operation is studied minutely and analyzed in order to eliminate unnecessary motions and thus reduce production time and raise output, which increases productivity. The first effort at time study was made by F. W. Taylor in the 1880s. Early in the 20th cent., Frank and Lillian Gilbreth developed a more systematic

and sophisticated method of time and motion study for industry, taking into account the limits of human physical and mental capacity and the importance of a good physical environment.

6. Process of analysis applied to a job or number of jobs to check the efficiency of the work method, equipment used, and the worker. Its findings are used to improve performance. Time and Motion studies were introduced in the USA by Frederick Taylor at the beginning of the 20th century. Since then, the practice has spread throughout the industrialized world.

1.3 Need for Work Study

Work study finds application in

- Industries (Production operations, research and development)
- Marketing, sales and warehouse
- Offices, stores, and warehouses
- Material Handling
- Design
- Building and other constructions
- Transport
- Hospital
- Army
- Agriculture etc.

1.4 Advantages of Work Study

- Uniform and improved production flow
- Higher productive efficiency
- Reduced manufacturing costs
- Fast and accurate delivery dates
- Better employee-employer relations

- Better service to customers
- Job security and job satisfaction to workers
- Better working and other conditions
- Higher wages to workers.

1.5 Objectives of Method Study

- Improved working processes and standardized procedures
- Better work place layout; neat and clean environment and working condition
- Less fatigue to operators
- Better product quality
- Effective utilization of men, material and machinery
- Efficient and fast material handling
- Reduced health hazards
- Efficient planning of the sections
- Streamlined working conditions

1.6 Objectives of Work Measurement

- Work measurement:
- Determines the time required for a job; thus it compares alternative methods and establishes the fastest method.
- Decide men power required for a job; it helps in man power economy
- Decide equipment requirements
- Provide information for effective production planning and maintenance procedures
- Aids in calculating exact delivery dates
- Provide a basis for fair and sound incentive schemes
- Results in effective labour control

1.7 Method Study Procedure:

The procedure consists of the following steps:

1. Select work to be studied
2. Record present method.
3. Critically analyze present method.
4. Develop improved method
5. Install improved method.
6. Maintain improved method.

1.8 Time Study Methods / Work measurement

Time study methods were originally proposed by Frederick Taylor and were later modified to include a rating factor (RF) adjustment. They have now become one of the most widely used method so work measurement. Basically by using time study, an analyst is taking a small sample of one worker's activity and using it to derive a standard for the entire organization. The only equipment needed is a stopwatch plus paper and pencil. In brief the procedure is as follows:

1. Select the job, inform the worker, and define the best method.
2. Time an appropriate number of cycles (such as 25-50)
3. Compare the average cycle time:

   $$CT = \sum \text{times} \ / \ n \text{ cycles}$$

4. Compute normal time:

   $$NT = CT(RF)$$

5. Compute Standard Time:

   $$ST = NT(100) \ / \ (100 - \% \text{ allowance})$$

The final computation of standard time (ST) makes allowances for personal tim, fatigue and unavoidable delays.

1.9 Predetermined Motion Time System (PMTS)

A predetermined motion time system (PMTS) is frequently used to set labor rates in industry by quantifying the amount of time required to perform specific tasks. The first such system is known as Methods Time Measurement, released in 1948 and today existing in three variations, commonly known as MTM-1, MTM-2, and MTM-3. Another popular PMTS is the Maynard Operation Sequence Technique, which was first released in 1972. That method also has several variations, with the most commonly used being Basic MOST, and others being Mini MOST, Maxi MOST, and Admin MOST. The variations of both systems differ from each other based on their level of focus. MTM-1 and Mini MOST are optimal for short processes with only small hand motions, while MTM-3 and Maxi MOST are more properly used for longer processes that are less repetitive. Unlike time studies, in which an analyst uses a stopwatch and subjectively rates the operator's effort to calculate a standard time, a PMTS requires that the analyst break apart the process into its component actions, assign time values to each action, and sum the times to calculate the total standard time.

Most predetermined motion time systems use time measurement units (TMU) instead of seconds for measuring time. One TMU is defined to be 0.00001 hours, or 0.036 seconds. These smaller units allow for more accurate calculations without the use of decimals. In the most in-depth PMT systems, motions observed will be on the level of individual TMUs, like toss (3 TMUs in Mini MOST) and simple pick-up (2 TMUs in MTM-1). More general systems simplify things by grouping individual elements, and thus have larger time values – for example, a bend and arise (61 TMUs in MTM-2) and one or two steps (30 TMUs in Basic MOST). Systems with even less detail work with TMU values in the hundreds, like climbing 10 rungs on a ladder (300 TMUs in Maxi MOST) or passing through a door (100 TMUs in Maxi MOST).

The choice of which variation of a certain PMTS to use is dependent on the need for accuracy in contrast to the need for quick analysis, as well as the length of the operation, the distances involved in the operation, and the repetitiveness of the operation. Longer operations often take place on a larger spatial scale, and tend to be less repetitive, so these issues are often treated as one. For longer, less repetitive operations, statistical analysis demonstrates that the accuracy of less detailed systems will generally approach the accuracy of more detailed systems. Thus, in order to reduce the time required for analysis, less detailed systems (like MTM-3 and Maxi MOST) are usually used when possible. Conversely, very short, repetitive processes are commonly analyzed with more exact methods like MTM-1 and Mini MOST because of the need for accuracy.

Application of PMTS:

PMTS is usefully employed for the following types of jobs:

1. Machining work
2. Maintenance work
3. Assembly jobs
4. Servicing and
5. Office work

CHAPTER-II LITERATURE REVIEW

There are many reasons for wanting to know the amount of time a particular task should take to accomplish. It may simply be the reason of curiosity. But realistically, it is for any three reasons: to accomplish planning, determine performance, and establish costs. Using an economical predetermined motion time system the planning and budgeting process could be accomplished. Knowing the time to manufacture and assemble various parts and/or components, a manager could:

- Determine the total labour cost of the product.
- Determine the number of production workers needed.
- Determine the number of machines needed.
- Determine the amount of and delivery times for material.
- Determine the overall production schedule.
- Determine the feasibility of entering into production of the product.
- Set production goals.
- Follow up on production: have goals been achieved?
- Check individual or departmental efficiency.
- Know the actual cost of production.
- Pay by results.

As a consequence, a manager can achieve an even and sufficiently high utilization of personnel, material, and equipment to result in an overall efficiency that will allow an organization to survive and grow.

A true innovator, Frederick Taylor, looked at work as something that could be controlled or engineered. It did not have to be haphazard repetition of what had gone on before; in fact, workers could be instructed as to the best way to perform certain tasks. The result was that tasks were broken down into elements or short tasks that could be arranged and managed to produce more efficient and productive and less fatiguing work. Each element was studied to determine which was productive and which was useless. Keeping only productive elements, a stopwatch was used to determine the time for each. The time recorded was the actual time taken by a particular individual to perform a certain task under specific conditions. To make such times transferable to other workers and other situations, time for the average worker working under average working conditions had to be determined. This was and is now accomplished by performance rating. The performance rating is a determination by the analyst of the pace of the individual observed as compared to the ideal, imaginary average worker working at a level of 100% effort and skill. If the worker observed is not putting forth the effort imagined to be 100%, a rating of less than 100% would be applied to the time recorded by the stopwatch and the time would be leveled to 100% performance. Likewise, if the worker observed was working with more skill and effort than the imagined average worker, a rating of over 100% would be applied to the time on the stopwatch and the time leveled to 100% performance.

It was observed by Frank and Lillian Gilberth that all manual operations were combinations of basic elements. The Gilberths isolated and identified these elements primarily so that methods could be more accurately explained and improved. They reasoned that to produce the motion content of a task was to reduce the effort and time to perform the task. The result is higher production.

Understandably, followers of Taylor practiced time study, but followers of the Gilberths practiced motion study. As frequently occurs, a third party entered and joined together the best of both techniques. A marriage of the time study technique and motion study philosophy was arranged. From this union of time and motion studies was born the predetermined motion time system (PMTS). These systems utilized the time study and micromotion techniques of the earliest techniques to determine and assign times to specified basic motions.

Of all the predetermined motion time systems, the most well known is Methods – Time Measurement (MTM), as developed by Harold B. Maynard, G.J. Stegemerten, and J.L.Schwab and published in 1948. Because it is a very detailed system and in the public domain, MTM has been recognized as the most accurate and widely accepted predetermined motion time system in use today.

The MTM has a detailed data card of basic motions (reach, move, grasp, position, release, body, leg, and foot motions and so on), each concerned with particular variables. Basic motions are identified, and with the variables considered the appropriate times are chosen from the data card. Because of its detail, MTM can be a very exact system and also very slow to apply. Also, basic motion distances must be accurately measured and correctly classified. Because of the detail, applicator errors can be a problem. The times that results from performing an MTM analysis reflects a 100% performance level, and times can be established for operations prior to production.

Synthesized versions of MTM were developed to reduce applicator errors and the time of analysis. Two such versions are MTM-2 and MTM-3. These systems grouped or averaged together certain basic motions and / or variables to reduce the applicator effort required to apply the technique.

2.1 Frederick Taylor and Scientific Management:

In 1911, Frederick Winslow Taylor published his work, The Principles of Scientific Management, in which he described how the application of the scientific method to the management of workers greatly could improve productivity. Scientific management methods called for optimizing the way that tasks were performed and simplifying the jobs enough so that workers could be trained to perform their specialized sequence of motions in the one "best" way.

Prior to scientific management, work was performed by skilled craftsmen who had learned their jobs in lengthy apprenticeships. They made their own decisions about how their job was to be performed. Scientific management took away much of this autonomy and converted skilled crafts into a series of simplified jobs that could be performed by unskilled workers who easily could be trained for the tasks.

Taylor became interested in improving worker productivity early in his career when he observed gross inefficiencies during his contact with steel workers.

Soldiering

Working in the steel industry, Taylor had observed the phenomenon of workers' purposely operating well below their capacity, that is, soldiering. He attributed soldiering to three causes:

1. The almost universally held belief among workers that if they became more productive, fewer of them would be needed and jobs would be eliminated.
2. Non-incentive wage systems encourage low productivity if the employee will receive the same pay regardless of how much is produced, assuming the employee can convince the employer that the slow pace really is a good pace for the job. Employees take great care never to work at a good pace for fear that this faster pace would become the new standard. If employees are paid by the quantity they produce, they fear that management will decrease their per-unit pay if the quantity increases.
3. Workers waste much of their effort by relying on rule-of-thumb methods rather than on optimal work methods that can be determined by scientific study of the task.

To counter soldiering and to improve efficiency, Taylor began to conduct experiments to determine the best level of performance for certain jobs, and what was necessary to achieve this performance.

Time Studies

Taylor argued that even the most basic, mindless tasks could be planned in a way that dramatically would increase productivity, and that scientific management of the work was more effective than the "initiative and incentive" method of motivating workers The initiative and incentive method offered an incentive to increase productivity but The initiative and incentive method offered an incentive to increase productivity but placed the responsibility on the worker to figure out how to do it.

To scientifically determine the optimal way to perform a job, Taylor performed experiments that he called time studies, (also known as time and motion studies). These studies were characterized by the use of a stopwatch to time a worker's sequence of motions, with the goal of determining the one best way to perform a job.

The following are examples of some of the time-and-motion studies that were performed by Taylor and others in the era of scientific management.

Pig Iron:

If workers were moving 12 1/2 tons of pig iron per day and they could be incentivized to try to move 47 1/2 tons per day, left to their own wits they probably would become exhausted after a few hours and fail to reach their goal. However, by first conducting experiments to determine the amount of resting that was necessary, the worker's manager could determine the optimal timing of lifting and resting so that the worker could move the 47 1/2 tons per day without tiring.

Not all workers were physically capable of moving 47 1/2 tons per day; perhaps only 1/8 of the pig iron handlers were capable of doing so. While these 1/8 were not extraordinary people who were highly prized by society, their physical capabilities were well-suited to moving pig iron. This example suggests that workers should be selected according to how well they are suited for a particular job.

The Science of Shoveling :

In another study of the "science of shoveling", Taylor ran time studies to determine that the optimal weight that a worker should lift in a shovel was 21 pounds. Since there is a wide range of densities of materials, the shovel should be sized so that it would hold 21 pounds of the substance being shoveled. The firm provided the workers with optimal shovels. The result was a three to four fold increase in productivity and workers were rewarded with pay increases. Prior to scientific management, workers used their own shovels and rarely had the optimal one for the job.

Bricklaying:

Others performed experiments that focused on specific motions, such as Gilbreth's bricklaying experiments that resulted in a dramatic decrease in the number of motions required to lay bricks. The husband and wife Gilbreth team used motion picture technology to study the motions of the workers in some of their experiments.

Taylor's 4 Principles of Scientific Management

After years of various experiments to determine optimal work methods, Taylor proposed the following four principles of scientific management:

1. Replace rule-of-thumb work methods with methods based on a scientific study of the tasks.
2. Scientifically select, train, and develop each worker rather than passively leaving them to train themselves.
3. Cooperate with the workers to ensure that the scientifically developed methods are being followed.
4. Divide work nearly equally between managers and workers, so that the managers apply scientific management principles to planning the work and the workers actually perform the tasks.

These principles were implemented in many factories, often increasing productivity by a factor of three or more. Henry Ford applied Taylor's principles in his automobile factories, and families even began to perform their household tasks based on the results of time and motion studies.

Drawbacks of Scientific Management

While scientific management principles improved productivity and had a substantial impact on industry, they also increased the monotony of work. The core job dimensions of skill variety, task identity, task significance, autonomy, and feedback all were missing from the picture of scientific management.

While in many cases the new ways of working were accepted by the workers, in some cases they were not. The use of stopwatches often was a protested issue and led to a strike at one factory where "Taylorism" was being tested. Complaints that Taylorism was dehumanizing led to an investigation by the United States Congress. Despite its controversy, scientific management changed the way that work was done, and forms of it continue to be used today.

2.2 Historical Background :

Genaidy, A.M., Agrawal, A., Mital, A. (1) presented an article on “Computerized predetermined motion-time systems in manufacturing industries”. In recent years, a number of computerized work measurement systems have been developed. In particular, attempts have been made to computerize the manual versions of existing predetermined motion-time systems (PMTS). The main objective of the paper was to survey the various computerized PMTS. In particular, the study examined the computerized systems of Methods-Time Measurement (MTM), Modular Arrangement of Predetermined Time Standards (MODAPTS), and Maynard Operation Sequence Technique (MOST) due to their popular and worldwide support.

Raouf, A. (2) presented an article on “Computer-aided workplace design: applications in predetermined motion time systems”. Predetermined Motion Time Systems (PMTS) are based on the assumption that an entire operation can be decomposed into a series of basic motions which have predetermined time values. To obtain the total time to perform the operation, the times needed for the basic motions involved are summed up. There are currently several PMTS available. Each offers a package of procedures basically serving the same function.

Dossett, R. (3) presented an article on “Computer application of a natural-language predetermined motion time system”. A number of PMTS were studied, including MTM-1, MTM-2, MTM-UAS, MSD, MOST, and MODAPTS. Though similar in the way human motions were classified, each uses a different coding system for the motions. A new PMTS, called MST (Motion Standard Times), was developed using more descriptive, natural language coding.

Brown, S. (4) presented an article on “TQM and work study”. This article argues that total quality management is not a quick-fix solution aimed at driving down costs in the short term; it is rather an ongoing pursuit of excellence with the aim of satisfying both internal and external customers. The role of work study is explored in this context. It is suggested that, while work study is not in itself an absolute assurance of quality, some of the tools and techniques offered by work study methods can serve the organization in measuring progress in terms of reduced lead times, lower cost and faster responses to delivery, all of which are important factors in providing customer satisfaction.

Al-Dahaim, Y.A., Naqvi, S.A.A. (5) presented an article investigating the use of work design techniques at an aluminium factory specialising in the design and production of prefabricated houses. The particular process examined was the cutting and bending of metal sheets into a specific dimension to form the edges of the walls pressed by a hydraulic press. The current process was described, together with the setup and operation, the operator, specifications and existing layout. Layout and jig improvements resulting from time and motion study techniques were discussed. Predetermined time of the improved system was carried out using MOST.

Koelling, C.P., Ramsey, T.D. (6) presented an article on “Multimedia in Work Measurement and Methods engineering” in 1996. The use of computer-based multimedia systems for industrial engineering education and training is increasing rapidly. This article outlines the development and application of multimedia in a work measurement and methods engineering course.

Kanthi M.N. Muthiah, Samuel H. Huang (7) presented an article on manufacturing systems productivity measurement and improvement. Globalization is posing several challenges to the manufacturing sector. Design and operation of manufacturing systems are of great economic importance. Factory performance remains unpredictable, in spite of the considerable literature on manufacturing productivity improvement and the long history of manufacturing, as there is no widespread agreement on how it can best be performed (Gershwin, 2000). Productivity measurement and improvement goes hand in hand, because one cannot improve what one cannot measure. The review of literature on manufacturing systems productivity measurement and improvement had been summarized under four categories; they are Operations Research- (OR-) based methods, system analysis-based methods, continuous improvement methods and performance metrics-based methods. A survey of commercial tools available to measure manufacturing system performance was also performed. The review indicates that quantitative metrics for measuring factory level productivity and for performing factory level diagnostics (bottleneck detection, hidden capacity identification) were lacking. To address this gap, a factory level effectiveness metrics-based productivity measurement and diagnostic methodology was proposed.

Richard A. Reid (8) presented a paper on Productivity and Quality Improvement. Most managers realize that their success is directly related to effective and continual implementation of process improvements in their organizations. A major managerial problem has been the inability to successfully implement change in many firms. Research shows that the effective application of team-oriented and data-focused total quality (TQ) improvement tools is not sufficient to assure the efficacious implementation of change. Nor were teams that utilized solely the logic tools of the theory of constraints (TOC) totally successful in implementing change in their organizations. Firms were more likely to achieve their improvement goals when they used a structured and repeatable method, rather than an ad hoc approach, for continuous improvement (CI). Viewing the situation from an operations management perspective, this paper presents a logical and well-structured framework for implementing the CI managerial philosophy to improve the productivity and quality of the organization as a whole, as well as its work-performing processes.

Brown, S. (9) presented an article in 1994 showing the role of work study in TQM. This article links the role of work study to total quality management and argues that work study methods can play an integral role in TQM. It suggests that many TQM programmes fail because they do not have measurement techniques in place which TQM requires on an on-going basis, and which work study methods can supply.

Oakland, J.S., Wynne, R.M. (10) presented an article on “Efficiency of UK engineering production management systems, part 1 -- the research”. In this first of a two-part series, the methodology for the research is described. This took the form of a postal questionnaire carried out in conjunction with the Institute of Industrial Managers to establish the current situation. The results were compared with a similar study carried out in 1980. Work on the questionnaire was supplemented by a series of interviews and in-company work. This included measurement of the movement of materials through the system and machine utilization.

Kroll, E. (11) presented a paper on “Application of work measurement analysis to product disassembly for recycling” in 1996. This paper introduces a method for evaluating the ease of disassembly of products. Its primary use is in designing products for recycling and making environmentally related decisions, but it is also relevant to servicing and maintenance. The evaluation procedure is centered around a spreadsheet-like chart and uses a catalogue of task difficulty scores. The scores were derived from work measurement analyses of standard disassembly tasks and provide a means of identifying weaknesses in the design and comparing alternatives quantitatively. The procedure of applying work measurement analysis to disassembly tasks is described and demonstrated in detail.

Cohen, Y., Bidanda, B., Billo, R.E. (12) presented a paper that presents the steps and factors to consider for successful integration of automatic speech recognition (ASR) systems into industrial environments. In particular, it shows the successful application of ASR within the context of the generation of work measurement time standards. By using ASR, the work analyst can develop more efficient, more reliable, detailed time estimates in real-time, without the need for a keyboard or paper.

Hall, M. (13) article on “Computer work Measurement Systems” considers four main categories - conventional (stop watch) time study; standard data systems; Predetermined Motion Time Systems (PMTS); and MRA - statistically based data. The application of computers to these categories, and the quality of data collected, is discussed, and outlines of present and future scenarios presented.

Parker, C. (14) paper on “Performance measurement” identifies the reasons for performance measurement and the failings of many traditional measurement systems which rely principally on financial indicators. It describes the factors underlying an effective measurement regime and comments briefly on some of the more modern approaches to performance measurement, such as the balanced scorecard and activity-based costing.

Westerkamp, T.A. (15) article on “Measuring Maintenance” suggests that nowhere is the application of work measurement likely to generate more productivity improvement than in maintenance. It outlines the basic principles which should be followed for lasting results. It then looks at the nature of maintenance work, organizing the data collected, and planning and implementing a maintenance work measurement programme.

Lehto, M.R., Sharit, J., Salvendy, G. (16) presented an article on “The application of cognitive simulation techniques to work measurement and methods analysis of production control tasks” in 1991. The implementation of flexible control in production and manufacturing operations has resulted in jobs largely consisting of cognitive tasks. This paper presents cognitive simulation as a promising tool for work measurement and methods analysis of the cognitive tasks found within such jobs. Levels of performance, taxonomies of tasks, and the sequencing of elemental tasks are discussed from this perspective.

CHAPTER – III MAYNARD OPERATION SEQUENCE TECHNIQUE

3.1 Introduction:

Maynard Operation Sequence Technique (MOST) is a predetermined motion time system that is used primarily in industrial settings to set the standard time in which a worker should perform a task. To calculate this, a task is broken down into individual motion elements, and each is assigned a numerical time value in units known as time measurement units, or TMUs, where 100,000 TMUs is equivalent to 1 hour. All the motion element times are then added together and any allowances are added, and the result is the standard time. It is an easier to use form of the older and now less common Methods Time Measurement technique, better known as MTM.

The most commonly used form of MOST is Basic MOST, which was released in Sweden in 1972 and in the United States in 1974. Two other variations were released in 1980, called Mini MOST and Maxi MOST. The difference between the three is their level of focus—the motions recorded in Basic MOST are on the level of tens of TMUs, while Mini MOST uses individual TMUs and Maxi MOST uses hundreds of TMUs. This allows for a variety of applications—Mini MOST is commonly used for short (less than about a minute), repetitive cycles, and Maxi MOST for longer (more than several minutes), non-repetitive operations. Basic MOST is in the position between them, and can be used accurately for operations ranging from less than a minute to about ten minutes.

Another variation of MOST is known as Admin MOST. Originally developed and released under the name Clerical MOST in the 1970s, it was recently updated to include modern administrative tasks and renamed. It is on the same level of focus as Basic MOST.

Basic MOST

The Maynard Operation Sequence Technique (MOST) including Basic, Mini and Maxi versions, makes the measurement of work a practical, efficient, and inexpensive task for the industrial engineer.

A powerful analytical tool that helps increase productivity, improve methods, facilitate planning, establish work loads, estimate labor costs, improve safety, and maximize resources. MOST can be applied to any type of work for which a method can be defined and described. MOST has become the standard for thousands of companies in a broad range of industries.

Fast, economical, accurate, consistent, and easy to learn, MOST eliminates the need for inefficient stopwatch studies in the development of realistic and reliable work/time standards. Via the MOST for Windows software, keyword descriptions of the work area and methods automatically generate standards without any further input of symbols or time values. In turn, these standards provide an accurate and consistent database for costing, planning, processing, scheduling, line balancing, incentive wage payment, and performance evaluation systems.

- Applicable for all short and long cycle
- Suitable for Assembly and Automatic Assembly
- All Machinery Work
- Excluding for Resource Planning and Organising

Mini MOST

- Highly repetitive, short-cycle operations
- Identical motion patterns
- 2-10 second operations

Maxi MOST

- Non-repetitive, long-cycle operations
- Applied 1½ times faster than Basic MOST
- Low unit production rate operations

Benefits

- Improves Industrial Engineering productivity
- Quickly identifies inefficient methods
- Provides accuracy to within + 5% with a 95% confidence level
- Can be applied to any method-defined manual work
- Reduces the time required for data development and standard setting
- Is easy to learn and use

3.2 Concept of MOST Work Measurement Technique:

Because industrial engineers are taught that with sufficient study any method can be improved, many efforts have been made to simplify the work measurement analyst task. This has, for instance, led to a variety of higher level MTM data system now in use. This attitude also led to examine the whole concept of work measurement to find a better way for analysis to accomplish the mission. The result was the formation of the concept known as MOST, Maynard operation Sequence Technique.

Work to most of us means exerting energy to accomplish some task or to perform some useful activity.

Work W = f x d i.e. work is the displacement of a mass or object.

Though process or thinking time is an exemption to this concept, as no objects are being displaced. For the overwhelming majority of work, however, there is a common denominator from which work can be studied, the displacement of objects. All basic units of work are organized for the purpose of accomplishing some useful results by simply moving objects. That is what work is. MOST is a system to measure work; therefore, MOST concentrates on the movement of objects.

Efficient, smooth, productive work is performed when basic motion patterns are tactically arranged and smoothly choreographed (methods engineering). It was noticed that the movement of objects follow certain consistently repeating patterns, such as reach, grasp, move, and position of object. These patterns are identified and arranged as a sequence of events (or sub activities) followed in moving an object. A model of the sequence is made and acts as a standard guide in analyzing the movement of an object.

Object can be moved in only one of the two ways: either they are picked up and moved freely through space, or they are moved and maintain contact with another surface. For example, a box can be picked up and carried from one end of a workbench to the other or it can be pushed across the top the workbench. For each type of move, a different sequence of events occurs; therefore, a separate MOST activity sequence model applies. The use of tools is analyzed through the use of a separate activity sequence model that allow the analyst the opportunity to follow the movement of a hand tool through a standard sequence of events, which, in fact, is a combination of the two basic sequence models.

Consequently, only three Basic MOST activity sequences are needed for describing the manual work, plus a fourth for measuring the movements of the objects with manual cranes:

The General Move Sequence (for the spatial movement of an object freely through the air)

The Controlled Move Sequence (for movements of object when it remain in contact with a surface or is attached to another object during the movement)

The Tool Use Sequence (for the use of common hand tools).

Basic MOST Sequence Models:

General Move Sequence Model:

General move is defined as moving objects manually from one location to another freely through the air. The activity sequence is made up of four subactivities:

A Action distance (mainly horizontal)

B Body Motion (mainly vertical)

G Gain Control

P Placement

The General Move Sequence Model, which is the most commonly used sequence model, is defined as follows:

A	B	G	A	B	P	A
Action Distance	Body Motion	Gain Control	Action Distance	Body Motion	Placement	Action Distance

These subactivities, or sequence model parameters, are then assigned time related index numbers based on the motion content of the subactivity. A fully indexed General Move Sequence for example, might appear as follows:

$A_6 \quad B_6 \quad G_1 \quad A_1 \quad B_0 \quad P_3 \quad A_0$

Where:	A_6	=	Walk Three To Four Steps To Object Location
	B_6	=	Bend and arise
	G_1	=	Gain control of one light object
	A_1	=	move object a distance within reach
	B_0	=	no body motion
	P_3	=	Place and adjust object
	A_0	=	No return

General move is by far the most frequently used of the three sequence models. Roughly 50% of all manual work occurs as a general move, with the percentage running higher for assembly and material handling and lower for machine shop operations.

Controlled Move Sequence Model:

The second type of move is described by the Controlled Move Sequence. This sequence is used to cover such activities as operating a lever or crank, activating a button or switch, or sliding an object over a surface. In addition to the A,B, and g parameters from the general move Sequence, the sequence model for a controlled move contains the following subactivities:

M	X	I
Move	Process	Align
Controlled	Time	

As many as one third of the activities occurring in machine shop operations may involve controlled move. The sequence model for this activity might be indexed as follows:

$A_1 \quad B_0 \quad G_1 \quad M_1 \quad X_{10} \quad I_0 \quad A_0$

Where:	A_1	=	Reach to the lever a distance within reach
	B_0	=	No body motion
	G_1	=	Get hold of the lever
	M_1	=	Move lever up to 12 inches to engage feed
	X_{10}	=	process time of approximately 3.5 seconds
	I_0	=	No alignment
	A_0	=	No return

Tool Use Sequence Model:

The third sequence model included in the Basic MOST work measurement technique in the tool use sequence model. This sequence model covers the use of hand tools for such activities as fastening or loosening, cutting, cleaning, gauging, and recording. Also certain activities requiring use of the brain for mental processes can be classified as Tool use, e.g. reading and thinking.

The use of a Wrench, for example, might be described by the following sequence:

$$A_1 \quad B_0 \quad G_1 \quad A_1 \quad B_0 \quad P_3 \quad F_{10} \quad A_1 \quad B_0 \quad P_1 \quad A_0$$

Where:	A_1	=	Reach to the wrench
	B_0	=	No body Motion
	G_1	=	Get hold of wrench
	A_1	=	Move wrench to fastener a distance within reach
	B_0	=	No body motion
	P_3	=	place wrench on fastener
	F_{10}	=	Tighten fastener with wrench
	A_1	=	Move wrench a distance within reach
	B_0	=	No body motion
	P_1	=	Lay wrench aside
	A_0	=	No return

3.3 Time Units:

Time units used in MOST are identical to those used in the basic MTM system and are based on hours and parts of hours called Time Measurement Units (TMU). One TMU is equivalent to .00001 hour. The following conversion is provided for calculating standard times:

1 TMU	=	.00001 hr.
1 TMU	=	.0006 hr.
1 TMU	=	.036 second

Time value in TMU for each sequence model is calculated by adding the index numbers and multiplying the sum by 10 in Basic MOST sequence Model.

All time values established by MOST reflect the activity of an average skilled operator working at an average performance level on normal pace. This is often referred to as the 100% performance level that in time study is achieved by using "leveling factors" to adjust times to defined levels of skill and effort. Therefore, when using MOST, it is not necessary to adjust times unless they must confirm with particular high or low task plans used by some companies. This also means that a properly established time standard, using MOST, MTM, or stopwatch time study, will give nearly identical results in TMU.

3.4 Advantages of MOST:

Activity Timing: MOST reflect the activity of an average skilled operator working at an average performance level on normal pace. Therefore, when using MOST, it is not necessary to adjust times

Parameter Indexing: Time calculation in MOST is accomplished by applying time-related index numbers to each sequence model parameter, based on the motion content of the subactivity. Index number will be assigned automatically by the computer program based on the input of a limited number of key words representing the parameter variants.

Application Speed: MOST does not require that operations be broken down into details. Instead, MOST group together the basic motions that frequently occur into a predefined sequence.

Work Measurement Technique	Total TMU's Produced per Analyst Hour
MTM-1	300
MTM-2	1000
MTM-3	3000
Mini MOST	4000
Basic MOST	12000
Maxi MOST	25000

Table 1: Comparison of application speeds

Accuracy: The accuracy principles that apply to MOST are the same as those used in statistical tolerance control. MOST provides the means for covering a high volume of annual work with accuracy comparable to existing predetermined motion time systems.

Documentation: MOST requires as few as 5 pages of documentation. The substantially reduced amount of paperwork enables the analysts to complete studies faster and to update standards more easily.

Work Measurement Technique	Number of Documentation Pages Used (3-minute operation)
MTM-1	16
MTM-2	10
MTM-3	8
Mini MOST	2
Basic MOST	1
Maxi MOST	1/2

Table 2: Comparison of Documentation Required

Method Sensitivity: MOST is a method-sensitive technique; i.e. it is sensitive to the variations in time required by different methods. This feature is very effective in evaluating alternative methods of performing operations with regard to time and cost. MOST systems method sensitivity greatly increases its worth as a work measurement tool.

Keyword Concept: The use of keywords seemed to be the logical approach to solve the data input problem. The keywords served a dual purpose: 1.) to make the computer select proper index values and (2) to bring quality and uniformity into the method descriptions. Not only is the keyword concept an appealing and efficient practice for the MOST computer user, but for the manual MOST user as well. Because of the extensive use of keywords, with MOST computer systems, it can be considered a language-based system. It will also be possible to further utilize AI (artificial intelligence) principles to enhance the performance of MOST computer systems.

3.5 Levels of Work Measurement:

MOST is used to economically measure work ranging from building of ships and railroad cars to minute electronic assembly and rapid pace yarn-handling operations. Basic MOST is routinely used to analyze the very wide range of manual operations most common to industry. Mini MOST provides detailed analysis of highly repetitive operations, such as small assembly and the packaging of small items. Clerical MOST, an extension of Basic MOST, is used for analyzing office activities. Maxi MOST is used for longer cycle operations, such as setups, maintenance, material handling, heavy assembly, and job shop work.

MOST SYSTEMS

MOST WORK MEASUREMENT SYSTEMS

- Basic MOST-General Operation
- Mini MOST-Repetitive Operations
- Maxi MOST- Non Repetitive Operations
- Clerical MOST-Clerical operations

MOST APPLICATION SYSTEMS

- Assembly
- Metal Working
- Electronics
- Aerospace
- Material Handling
- Textile
- Shipbuilding
- Maintenance
- Utilities
- Administration
- Hospitals
- Etc.

MOST COMPUTER SYSTEMS

BASIC PROGRAM
- Work Measurement (Basic, Mini, Maxi MOST)
- Database Management
- Time Standards Calculation
- Mass Update
- Data Transfer
- Where Used / Data History
- Work Management Manual Documentation

SUPPLEMENTARY MODULES
- Machine Data
- Welding Data
- Line Balancing
- Multi Man-Machine Analysis
- Mega MOST
- Auto MOST

APLICATION PROGRAMS
- Systems Integration Module
- Manpower Planning
- Process Planning
- Tool / Fixture Tracking
- Cost Estimation
- Performance Reporting

Fig. 1 Overview of MOST Systems

3.6 Work Measurement System Selection:

Maxi MOST: at the highest level, Maxi MOST is used to analyze the operation that are likely to be performed fewer than 150 times per week. An operation in this category may be less than 2 minutes to more than several hours in length. Maxi MOST index ranges accommodate the wide cycle-to-cycle variations tht are typical in such work as setups or heavy assembly.

Basic MOST: at an intermediate level, operation that are likely to be performed more than 150 but fewer than 1500 times per week should be analyzed with Basic MOST. An operation in this category may range from a few seconds to 10 minutes in length. The majority of operations in most of the industries fall into this category. Basic MOST index ranges readily accommodate the cycle-to-cycle variations typical at this level.

Mini MOST: at the lowest level, Mini MOST provides the most detailed and precise methods analysis. In general, this level of detail and precision is required to analyze any operation likely to be repeated more than 1500 times per week. Operation having an occurrence frequency this high have cycle times of less than 1.6 minutes. Such operations usually have little variation from cycle-to-cycle owing to operator's high level of practice and to management efforts to improve the design, layout, and method. Opportunities for small but significant improvements in these areas often highlighted by a Mini MOST analysis. Regardless of the cycle length, Mini MOST should also be used to analyze any operation in which nearly all reach and move distances for an operation are less than 10 inches (25 cm).

Decision Diagram:

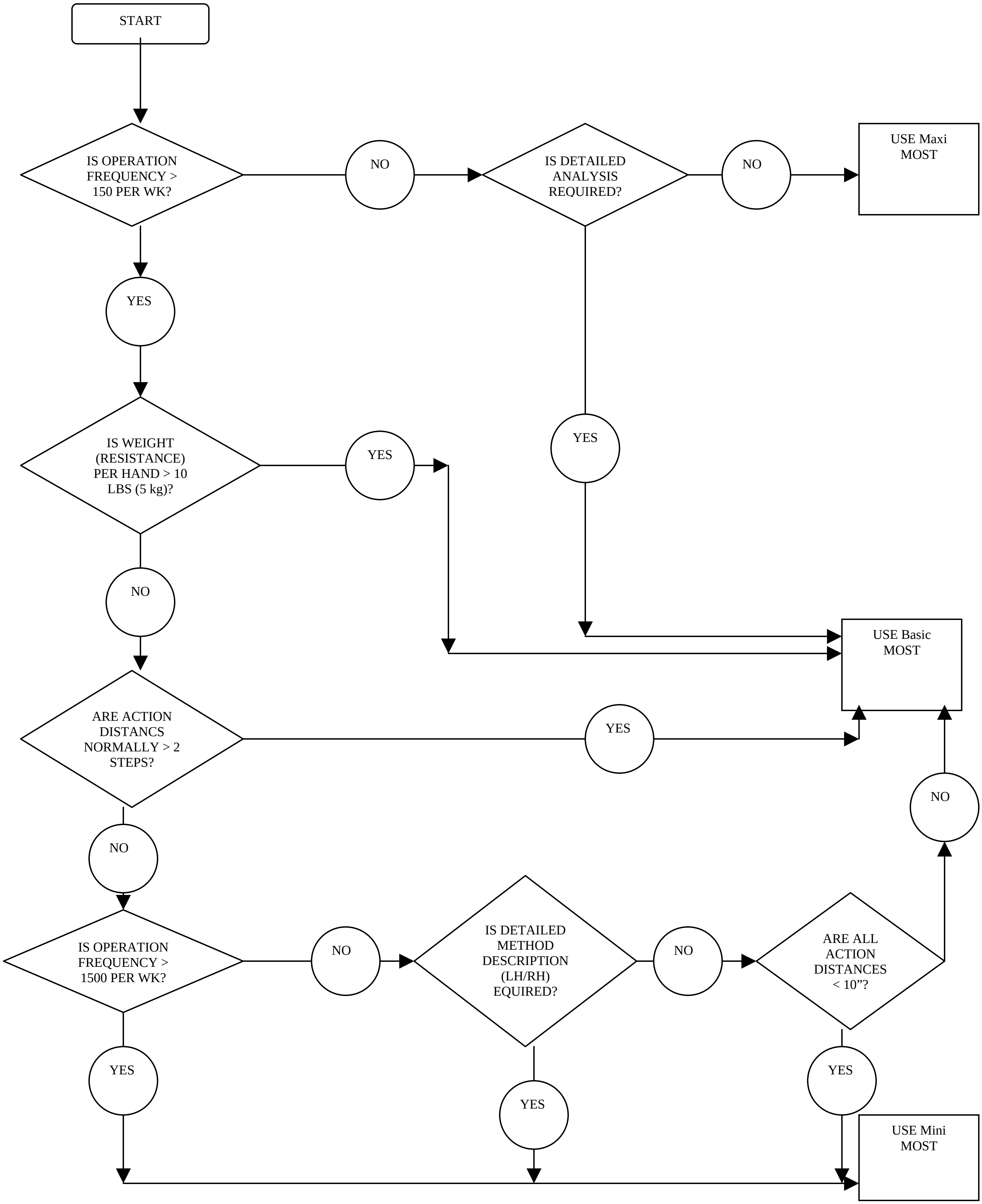


Fig. 1: Procedure for selecting the appropriate MOST Work Measurement System

3.7 Basic MOST System :

Every company very likely has some operations for which Basic MOST is the logical and most practical work measurement tool. The sequence models of Basic MOST represent the only two basic activities necessary to measure manual work: General Move and Controlled Move. The two remaining sequence models included in Basic MOST are Hand Tool sequence model and Manual Crane sequence model.

General Move Sequence: deals with spatial displacement of an object. Under manual control, the object follows an unrestricted path through air. Characteristically, General Move follows a fixed sequence of sub activities identified by the following steps:

1. Reach with one or two hands a distance of object(s), either directly or in conjunction with body motions or steps.
2. Gain manual control of the object
3. Move the object a distance to the point of placement, either directly or in conjunction with body motion or steps.
4. Place the object in a temporary or final position.
5. Return to workplace.

The existence of the sequence model provides increased analyst consistency and reduces subactivity omission.

The Sequence Model & Phases:

Get			Put			Return
A	B	G	A	B	P	A

Where:	A	=	Action Distance
	B	=	Body Motion
	G	=	Gain Control
	P	=	Placement

e.g

A man walks four steps to pick up a small suitcase from a low conveyor belt and, without moving further, places it on a table within reach.

A_6 B_6 G_1 B_0 P_1 A_0

(6+6+1+1+1) X 10 = 150 TMU

Basic MOST System		**A B G A B P A**				**GENERAL MOVE**		
Index X 10	**A** Action distance		**B** Body Motion		**G** Gain Control		**P** Placement	
	Parameter Variant	Keyword	Parameter Variant	Keyword	Parameter Variant	Keyword	Parameter Variant	Keyword
0	=< 2 in. =< 5 cm	CLOSE					Hold	THROW TOSS CARRY PICKUP
1	Within reach				Light object Light objects simo	GRASP (optional)	Lay aside Loose fit	MOVE PUT
3	1-2 steps	1 STEP 2 STEP	Bend and arise 50% occ.	PBEND	Non Simo Obstructed Heavy / Bulky Interlocked Blind Collect Disengage	GET DISENGAGE FREE COLLECT	Adjustement Light Pressure Double Placement	PLACE REPLACE
6	3-4 steps	3 STEPS 4 STEPS	Bend and arise	BEND			Care Precision Blind Obstructed Heavy Pressure Intermediate moves	POSITION REPOSITION
10	5-7 steps	5 STEPS 6 STEPS 7 STEPS	Sit or Stand	SIT STAND				
16	8-10 steps	8 STEPS 9 STEPS 10 STEPS	Through door Climb on or off Stand and bend Bend and sit	DOOR CLIMB / DESCEND STAND AND BEND BEND AND SIT				

Table 3: General Move Data Card

Controlled Move Sequence: The controlled Move Sequence describes the manual displacement of an object over a “controlled” path. That is, movement of the object is restricted in at least one direction by contact with or an attachment to another object or object moved deliberately along a specific or controlled path. Controlled Move follows a fixed sequence of subactivities identified by the following steps:

1. Reach with one or two hands a distance to the object, either directly or in conjunction with body motions or steps.
2. Gain manual control of the object.
3. Move the object over a controlled path (within reach or with steps).
4. Allow time for a process to occur.
5. Align the object following the controlled move or at the conclusion of the process time.
6. Return to workplace.

The Sequence Model & Phases

Get			Move or Actuate			Return
A	B	G	M	X	I	A

Where:	A	=	Action Distance
	B	=	Body Motion
	G	=	Gain Control
	M	=	Move Controlled
	X	=	Process Time
	I	=	Alignment

e.g.

From a position in front of a lathe, the operator takes two steps to the side, turns the handwheel two revolutions, and sets the machining tool against a scale mark.

CRANK HANDWHEEL AT LATHE 2 REVOLUTIONS WITH GUIDE + ADJUST

A_3 B_0 G_1 M_6 X_0 I_6 A_0

(3+1+6+6) X 10 = 160 TMU

Basic MOST System			A B G M X I A				CONTROLLED MOVE	
Index X 10	**M** Move Controlled			**X** Process Time			**I** Alignment	
	Push / Pull / Pivot	Keyword	CRANK (REVS)	SECONDS	MINUTES	HOURS	OBJECT	Keyword
1	=< 12 in. (30 cm) Button / Switch / Knob	PUSH PULL ROTATE		.5	.01	.001	To 1 Point	ALIGN-POINTS
3	>12in. (30cm) Resistance High Control 2 stages=<12in.(30cm.)	SLIDE SEAT TURN UNSEAT OPEN SHIFT SHUT PRESS PUSH + PULL (INCHES, CM OR STAGES)	1	1.5	.02	.0004	To 2 Points =< 4 nches(10cm)	ALIGN-POINTS CLOSE
6	2 stages>12in.(30cm.) with 1-2 steps	OPEN + SHUT OPERATE PUSH OR PULL WITH 1 OR 2 PACES	3	2.5	.04	.0007	To 2 Points > 4 inches(10cm)	ALIGN-POINTS
10	3-4 stages with 3-5 steps	MANIPULATE MANEUVER PUSH OR PULL WITH 3,4 OR 5 PACES	6	4.5	.07	.0012		
16	With 6-9 Steps	PUSH OR PULL WITH 6,7,8 OR 9 PACES	11	7.0	.11	.0019	Precision	ALIGN - PRECISION

Table 4: **Controlled Move Data Card**

Tool use Sequence Model : Any activity involving a hand tool can be analyzed by a third type of sequence model called Tool use Sequence Model. It follows a fixed sequence of subactivities, which occur in five phases:

1. Get tool (object)
   a) Reach (with) hand(s) distance to tool (or object), either directly or in conjunction with body motions or steps.
   b) Gain manual control of the tool (or object)
2. Put tool (object) in place
   a) Move the tool (or object) a distance to where t will be used, either directly or in conjunction with body motions or steps.
   b) Place tool (or object) in position for use.
3. Use tool: Apply some number or extent of tool actions(s).
4. Put tool (object) aside: retain the tool (or object) for further use (hands and fingers are always retained), toss or lay the tool aside, return the tool to its original location, or move it to a new location for disposition, either directly or in conjunction with body motions or steps.
5. Return: step or walk to the original (or other) workplace.

The Sequence Model and Phases:

Get Tool or Object			Put tool or Object in Place			Use tool	Put tool or Object Aside			Return Operator
A	B	G	A	B	P	---	A	B	P	A

Where:	A	=	Action Distance
	B	=	Body Motion
	G	=	Gain Control
	P	=	Placement

Blank space is provided for the insertion of one of the following Tool Use parameters.

Where	F	=	Fasten
	L	=	Loosen
	C	=	Cut
	S	=	Surface treat
	M	=	Measure
	R	=	Record
	T	=	Think

e.g.

Before welding two steel plates, a welder obtains a square and checks the angle between the plates to see that it is correct. The square (a profile gauge) is located three steps away on a workbench.

MEASURE PLATE ANGLE USING PROFILE-GAUGE FROM WORKBENCH AND RETURN

A_6 B_0 G_1 A_6 B_0 P_1 M_{10} A_6 B_0 P_1 A_0

(6+1+6+1+10+6+1) X 10 = 310 TMU

Basic MOST System					Cut(C), Surface Treat(S), Measure (M), Record(R), Think(T)							TOOL USE		
INDEX X 10	**C Cut**				**S Surface Treat**			**M Measure**	**R Record**			**T Think**		
	TWIST BEND	CUTOFF	CUT	SLICE	AIR-CLEAN	BRUSH-CLEAN	WIPE	MEASURE	WRITE		MARK	INSPECT	READ	
	Piers		Scissors	Knife	Nozzle	Brush	Cloth	Measuring Device	Pencil		Marker	Eyes, Fingers	Eyes	
		WIRE	CUT(S)	SLICE(S)	SQ.FT. (.1 M^2)	SQ.FT. (.1 M^2)	SQ.FT. (.1 M^2)	IN.(CM) FT.(M)	DIGITS	WORDS	DIGITS	POINTS	DIGITS, SINGLE WORDS	TEXT OF WORDS
1	GRIP		1	-	-	-	-		1	-	CHECK MARK	1	1	3
3		SOFT	2	1	-	-	½		2	-	1 SCRIBE LINE	3	3	8
6	TWIST BEND-LOOP	MEDIUM	4		1 SPOT POINT CAVITY	1 SMALL OBJECT			4	1	2	5 TOUCH FOR HEAT	6 SCALE VALUE DATE/TIME	15
10		HARD	7	3	-	-	1	PROFILE-GAUGE	6	-	3	9 FEEL FOR DEFECT	12 VERNIER-SCALE	24
16	BEND-COTTER PIN		11	4	3	2	2	FIXED SCALE CALIPER 12 IN.(30CM)	9	2 SIGNATURE, DATE	5			38
24			15	6	4	3	-	FEELER GAUGE	13	3	7			54
32			20	9	7	5	5	STEEL TAPE6FT.(2M) DEPTH MICROMETER	18	4	10			72
42			27	11	10	7	7	OD-MICROMETER 4IN.(10CM.)	23	5	13			94
54			33					ID-MICROMETER 4IN.(10CM)	29	7	16			119

Table 5: <u>Tool Use Data Card for Cutting, Cleaning, Gauging, Reading, Writing, and Other activities</u>

3.8 Mini MOST System:

Mini MOST was developed to satisfy the more rigorous accuracy requirements associated with short cycle and highly repetitive operations. Most often such operations are performed following an identical or almost identical motion pattern from cycle to cycle. Mini MOST is more detailed and takes more time to use than Basic MOST and should therefore be applied only to operations and activities that have been determined to be short cycled and identically repeated,

The sequence Model:

Mini MOST was designed to replace the more "detailed" systems, such as MTM-1 and work factors. It consists of two sequence models, the General Move

A B G A B P A

and the Controlled Move

A B G M X I A

Phases of Sequence Model:

For General Move Sequence Model:

	Get			Put		Return
A	B	G	A	B	P	A

Parameter Indexing is done using the data card shown in Table 6.

Mini MOST System				**A B G A B P A**		**GENERAL MOVE**
INDEX X 1	**A** ACTION DISTANCE			**B** BODY MOTION	**G** GAIN CONTROL	**P** PLACEMENT
	HAND		LEG			
	Inches (cm)	Degree	Inches (cm)			
0	1 (2.5)	30			SWEEP	DROP, PICK UP, KEEP
1	2 (5)	60				
3	4 (10)	120			CONTACT (Hand or Foot)	TOSS SET AND RETAIN
6	8 (20)	180	8 (20)		GRASP REGRASP	SET ASIDE; SET AND SLIDE; PLACE
10	14 (35)		12 (30)	EYE-MOTION	TRANSFER SELECT	POSITION
16	24 (60)		18 (45) 1 STEP		DISENGAGE SELECT – SMALL	ORIENT
24	>24 (60)		26 (55)			
32			>26 (65) 2 STEPS	BEND ARISE		

Table 6: **<u>Mini MOST General Move Sequence Model Data Card</u>**

For Controlled Move Sequence Model:

A B G M X I A

Where:	A	=	Action Distance
	B	=	Body Motion
	G	=	Gain Control
	M	=	Move Controlled
	X	=	Process Time
	I	=	Alignment

Phases:

Get			Move or Actuate			Return
A	B	G	M	X	I	A

Parameter Indexing:

Parameters in the controlled Move Sequence Model are indexed by referring to index value data card Table 7.

Mini MOST System				A B G M X I A			CONTROLLED MOVE	
INDEX X 1	M MOVE CONTROLLED					X PROCESS TIME	I ALIGNMENT	
	PUSH, PULL, SLIDE, ROTATE			SMALL CRANK, CRANK				
	HAND		FOOT OR LEG	SMALL-CRANK, =< 5 INCHES (13 cm)	CRANK =< 20 INCHES (50 cm)	TMU	TO POINT OR LINE	
	INCHES(cm)	DEGREEES	INCHES (cm)	REVOLUTIONS			WITHIN AREA OF NORMAL VISION	OUTSIDE AREA OF NORMAL VISION
0								
1						1.7		
3	1 (2.5) BUTTON					4.2		
6	4 (10)	90				7.7	ALIGN, CHECK INSPECT	
10	10 (25)	180	10 (25)			12.6	ALIGN-ACCURATE ALIGN-POINTS	
16	18 (45) SEAT, UNSEAT		16 (40) FOOT-PRESS	1		19.6		ALIGN-OUT, CHECK-OUT INSPECT-OUT
24	30 (75)		22 (55)		1	27.7		ALIGN-ACCURATE-OUT ALIGN-POINTS-OUT
32			30 (75)	2		36.6		ALIGN-POINTS-ACCURATE-OUT
42				3	2	47.6		
54				4	3	60.1		

Table 7: **Mini MOST Controlled Move Sequence Model Data Card.**

3.9 Maxi MOST System

In long cycles, non repetitive, non identical assembly, machining or maintenance operations, the use of the Basic MOST sequence models will likely produce a method description with unnecessary detail. Long cycle jobs could have a higher level analysis system applied to them and still produce a meaningful and descriptive method description as well as an accurate analysis established in less time. To meet this need, MOST work measurement system was expanded to include sequence models designed expressly for measurement of long cycle operations. Maxi MOST sequence Model produce accurate results, fast to apply and easy to learn and understand, and provide a meaningful method description.

The Sequence Model

The five Maxi MOST sequence Models, including parameter descriptions, are:

ACTIVITY	SEQUENCE MODEL	SUB-ACTIVITY
PART HANDLING TOOL USE MACHINE HANDLING	A B P A B T A B M	A-ACTION WALKING DISTANCE B-BODY MOTION P- GET AND PLACE PARTS T- TOOL USE M- OPERATE MACHINE OR FIXED EQUIPMENT
POWERED CRANE TRANSPORT	A T K T P T A	A- ACTION WALKING DISTANCE T- TRANSPORT K- HOOKUP AND UNHOOK P- PLACE OBJECT
WHEELED TRUCK TRANSPORT	A S T L T L T A	A- ACTION WALKING DISTANCE S- START AND STOP T- TRANSPORT L- LOAD OR UNLOAD

Table 8: Maxi MOST sequence Models

Indexing the Sequence Models:

Proper index values are assigned from the data cards. When the entire model has been indexed, the time in TMU is calculated by adding the index values for each sequence model, applying a frequency if appropriate, and multiplying the total by 100.

Time measured with MOST systems including Maxi MOST represent a performance level of 100%.

Powered Crane Sequence Model:

The powered crane sequence model is appropriate for cranes that move the load laterally and longitudinally under power and that may resemble an overhead, pendant-operated bridge crane.

The Powered Crane Sequence consists of the following activities:

1. The operator walks to the control panel. (Action Distance).
2. The Operator grasps the controls, elevates the crane hook, moves the crane so the hook reaches the position for coupling, and then releases the controls (Transport).
3. The object is fastened either directly with the crane hook or with a sling or chain, for example. The operator grasps the controls and elevates the crane hook to the correct position for hooking and then adjusts the controls so that the chain or other holding device is tight and secure (Hook-up, Unhook). The holding device is subsequently removed from the object.
4. The crane hook with the object is freed from its surroundings and elevated so the object can be moved. The object is then moved horizontally to the desired location (Transport).
5. The object is lowered and placed in the desired location (Placement).
6. The empty crane is moved aside (Transport).

7. The operator returns to the starting point after moving the crane aside (Action Distance).

The Powered Crane Sequence Model:

A T K T P T A

Where:	A	=	Action Distance
	T	=	Transport
	K	=	Hook up and Unhook
	P	=	Placement

If the local conditions call for a permanent bridge crane operator, only the K, T, and P parameters are needed for analysis purposes.

Maxi MOST System		**A T K T P T A**		**POWERED CRANE TRANSPORT**
INDEX X 100	**A** ACTION DISTANCE	**T** TRANSPORT	**K** HOOK UP AND UNHOOK	**P** PLACEMENT
	FEET (M)	FEET (M)	HOLDING DEVICE	DIFFICULTY
1	24 (7)			
3	61 (19)			Without or with Single Change of Direction
6	127 (39)		Single Hook or Electromagnet	
10	220 (67)	2 (5)		
16	360 (110)	25 (8)		With Double Change of Direction
24	505 (154)	50 (16)	1 Hook Plus Slings or Chains	With Several Changes of Direction
32	673 (205)	80 (25)	2 Hooks Plus Slings or Chains	

Table 9: **Maxi MOST-Powered Crane Transport Data Card**

CHAPTER – IV COMPANY PROFILE

4.1 Brief history of the organization:

LAKSHMI PRECISION SCREWS LTD., one of the prominent engineering units in India, is a leading manufacturer & exporter of High Tensile Automotive & Industrial Fasteners. The company has well-established state-of-the-art manufacturing facilities and has an excellent reputation for its products in the domestic as well as International Markets.

The company's manufacturing facilities and Registered offices are located at Hissar Road, Rohtak (Haryana), which is adjacent to the National Highway NO.10 (DELHI-HISSAR ROAD). The Regional Sales Offices of the company are located at Delhi (North), Mumbai (West), Calcutta (East) and Banglore (South). In addition, the company has an extensive sales network of dealers throughout India.

The LPS Group of Companies was promoted by (Late) Shri BIMAL PRASAD JAIN in 1952, with a small unit NAVBHARAT INDUSTRIES. LAKSHMI PRECISION SCREWS was incorporated as a Private Limited Company on 27th December 1972 and subsequently went public in August 1983. The company expanded its business with the manufacturing of High Tensile Fasteners and steadily increased its product range for different industrial sectors including Automobiles, Machine Tools, Refrigeration, Textile Machinery, etc. both for domestic and export markets.

The LPS Group comprises of the following companies:

1. Nav Bharat Industries.
2. Lakshmi Precision Screws Limited.
3. LPS Fasteners & Wires Pvt Ltd.
4. Universal Enterprises.
5. Lakshmi Precision Screws Ltd, Plant -II.
6. Indian Fasteners Limited.

7. Lakshmi Precision Screws Ltd, Plant-III.
8. United Engineers.
9. Amit Screws Pvt. Limited.
10. LPS Bossard Pvt. Limited.
11. Lakshmi Precision Screws Ltd, Plant-IV.

At the time of installation, the company had only one bolt-making machine (3/8" Bolt maker). Today, the company has more than one hundred different types of machines producing a wide range of products. The company has a capacity to produce more than 9000 types of industrial & automotive fasteners meeting and exceeding the expectation of domestic as well as international customers.

The installed capacity of the company (LPS I & II) is over 12,000 tonnes per annum however, the installed capacity of LPS P II is 7200 tonnes per annum. The last annual turnover of the company was little over Rs.83 crores. The LPS group employs a committed work force of nearly 1500 employees.

4.2 Milestones:

1959	Established Nav Bharat Industries as small parts manufacturer.
1972	Established Lakshmi Precision Screws Pvt Ltd as Socket Head Screws Manufacturer
1973	Technical tie-up with the German firm M/s Richard Bergner.
1977	Acknowledged quality source of fastener.
1978	Technical tie-up with M/s Richard Bergner expires.
1983	Secured self-certification status from FORD.

1984	Declared Public Limited Company.
1986	Secured self-certification status from M/s Lakshmi Machine Works.
1988	Established as manufacturer-exporter.
1991	Received Regional Export Award from Engineering Export Promotion Council, (EEPC) India.
1992	Received Regional Export Award from EEPC for the second Consecutive year.
1993	Received Regional Export Award from EEPC for the third consecutive year.
1993	Established Plant - II.
1994	Received Employment Generation Award from Director of Industries, Haryana State.
1995	Accredited in Mechanical & Chemical Testing by A2LA, USA to meet Fastener Quality Act of US.
1995	Accredited in Mechanical Measurement, Mechanical & Chemical Testing by National Accreditation Board for Calibration & Testing Laboratories (NABL), Government of India.
1996	Certified to ISO-9002.
1998	Installed Bolt Maker (AF 2525) to add production capacity to 12200 MT.

- Self-Certification status from TELCO.
- Technical Tie-up with Sunil Machinery Corporation, Korea.
- Joint Venture with Bossard AG-Switzerland.

1999 Licenced Manufacturers of TORX Screw from Camcar Co. –USA.

2000 QS 9000 Certification.

2001 ISO/TS-16949 Certification.
ISO-14001 Certification.

2002 Implemented ERP–SAP R/3.

2001 Golden Peacock Award.

2006 Established Plant - IV.

4.3 Product profile:

The company manufactures more than 9000 types high tensile industrial & Automotive Fasteners that conforms to the national as well as international (ANSI, BSI, DIN, ISO, JIS, etc.) standards. The product range includes:

- Socket head cap screws
- Socket set screws
- Hex head bolts
- Wheel bolts/ hub bolts
- Cylinder studs
- Flanges
- Special products on customers demand.
- Hexagonal nuts
- Dowel pins
- Shoulder bolts
- Con-rod bolts
- Axles
- Allen keys

The company's special fasteners are made in accordance to the customer specifications with respect to size, grade and finish to the point of precision and internationally acclaimed Quality Standards.

4.4 Main Markets:

Domestic (user industries):

- Automotive
- Aviation
- Heavy & Light Machinery
- Hydraulic/Pneumatic Pumps
- Machine Tools, Jigs & Fixtures
- Railways
- Refrigeration & Air Conditioning

International (countries):

- Australia
- Germany
- Holland
- Hong Kong
- Japan
- Singapore
- South Africa
- South Korea
- Sweden
- Switzerland
- United Kingdom
- United States of America

4.5 Esteemed Customers:

Heavy Commercial Vehicles

VOLVO | TATA | HM | EICHER | Mahindra

Light Commercial Vehicles

TATA | MARUTI SUZUKI | SWARAJ MAZDA

Tractors

ESCORTS | EICHER | HMT | Mahindra | L&T JOHN DEERE LIMITED

Cars

MARUTI SUZUKI | HM AMBASSADOR | REVA | TATA

Two Wheelers

KINETIC | LML | HERO HONDA | YAMAHA | TVS | bajaj auto ltd

Earthmoving Equipment

HM | beml | TVS

Textile Machinery

Machine Tools

Hydraulic Equipment

Heavy Electrical Equipment

Refrigeration / Air Cond.

Others

4.6 Certificates:

- A2LA
- NABL
- ISO 9002
- QS 9000
- ISO / TS 16949
- ISO 14001

4.7 Quality Management System:

The Quality Management Systems of the company has been accredited jointly by AMERICAN ASSOCIATION FOR LABORATORY ACCREDITATION (A2LA), USA and NATIONAL ACCREDITATION BOARD FOR LABORATORIES (NABL), INDIA as conforming to ISO/IEC GUIDE 25.

The company is committed to manufacture quality products and has the policy of ‘Quality without Compromise’. The company is focusing on continuous quality improvement through minimization of waste & rejection and optimum utilization of all available resources.

4.8 Various Functions:

The company has different departments to ensure smooth functioning of the plant and to meet customer's expectations. The major functions of each department are as follows:

1. MARKETING
2. D & D
3. PPC
4. TOOL ROOM
5. MATERIALS
6. PRODUCTION(FORGING)
7. HEAT TREATMENT
8. FINISHING
9. QUALITY ASSURANCE
10. LABORATORY
11. PRODUCTION (SEC.)
12. MAINTENANCE
13. FINANCE
14. HRD
15. SIG

<u>Marketing:</u>

Marketing is done through a dealer network spanning all over the country and directly through the company's Branch offices and representatives. We market high tensile fasteners, both standard and special products as per customer specifications. We are providing direct service to around 200 clients including Original Equipment Manufacturers (OEM). Our annual sales turn over is approximately 85 crores, 40% of which is from Exports. We have three full-fledged branch offices in New Delhi, Calcutta and Mumbai, which also contain a stocking point. In addition to this we are having offices at Banglore & Pune and representatives in Madras and over 20 other locations. Post delivery service and immediate follow-up of customer complaints are also the main focus area of this department.

<u>D & D (Design & Development):</u>

This function undertakes the research work for the development and improvement of the company's product profile to fulfill the expectations of the customers. The deptt. strives for the overall development in all functional areas within the plant.

The function also undertakes industrial engineering studies & design of products. Establishment of new machines and constant up gradation in the manufacturing technology are their core activities. The department designs process & tools for new products as per customer specifications, prepares the drawings, get them approved by the customer and furnish it to the shop floor for production.

PPC (Production Planning & Control):

The main function of PPC is to plan the Production / Manufacturing Schedule and follow up the same till the finished product is ready. The PPC has to co-ordinate with the RM & FG stores and marketing continuously for effective production activity control. They also co-ordinate with the D & D, Tool Room and Production functions to ensure that the production targets are met as per the schedule.

F G Stores:

The function of the F.G.Stores is to receive the finished goods from the production department and packing of the goods according to the customer requirement w.r.t. weight, package size and packaging material. They also store the finished goods inventory in the F.G. Stores warehouses using a location system. This department is also responsible for the timely dispatch of the products based on the customer delivery schedules.

R.M.Stores:

The function of the Raw Material store is to receive the Raw Material for manufacturing fasteners i.e. Steel Coils of various specifications. After the inspection of received Raw materials and found O. K, they are kept in separate locations from where the production department receives the required input raw materials. They also have a location system implemented in all the warehouses.

Tool Room:

The prime job of the function is to provide the requisite tools required for the manufacturing process. The department has to co-ordinate with the Production and D

& D departments in the designing of the tools. Tool Room department has various precision machines including the highly advanced CNC - Wire cut & CNC - Lathe Machine producing dependable and precision tools to manufacture products with zero defect.

To maintain and ensure the required quality and hardness of Tools, the indigenous Tool Heat Treatment Plant has been established. The facilities in this department include three Salt Bath Furnaces. The indigenous Tool Heat Treatment Process plant also ensures the timely availability of tools to augment the regular and timely production.

Materials:

The main material functions are:

- Arranging for raw material, semi finished goods and other input materials by interacting with LPS - I, Ancillaries & Suppliers.
- Raising purchase orders or requisitions orders based on the plant requirements.
- Storing and accounting for consumable items.

Overall responsibility of materials department is to arrange the right material at the right time and also to account for the same.

Production (Forging):

The Production function is to undertake the following responsibilities:

- To produce the scheduled quantity of products consistently.
- To produce products with zero defect.
- To co-ordinate with planning department for effective utilization of all resources.
- To strictly enforce quality standards.
- To avoid waste and maintain shop floor cleanliness.

Heat Treatment:

This function undertakes the Heat Treatment of the products, which provides the required Tensile Strength and Hardness to the products. Heat Treatment department has 3 Shaker Hearth Furnaces and 2 Vertical Flow Circulation Furnaces.

Finishing:

The product is provided with the necessary finishing as demanded by the customers by electroplating & phosphating processes. The department has fully automated Electroplating & Phosphating plants of Grow and Weil make. Zinc plating in Golden and Silver colours are done on the products.

Quality Assurance:

This functions undertakes the following functions:

- Devise and follow systems as per ISO/QS-9000 requirements.
- Support production to achieve zero rejections all along the production process.
- Endeavor to achieve total customer satisfaction.
- Strive for continuous improvements to reduce rejection and rework

Laboratory:

Laboratory is equipped with the facilities for testing of Raw materials & the product at various stages of the production consisting of latest material testing equipment including Automatic emission spectrometer, Rockwell Hardness tester, Micro hardness tester, Salt spray chamber & Coating thickness tester.

Maintenance:

This function undertakes the following activities:

- Maintaining the equipment efficiently to reduce machine down time.
- Planning & scheduling for procurement of spares required for replacement.
- Planning & execution of preventive maintenance of all the equipment.
- Maintaining of minimum inventory of spares and consumables.

Finance:

This function has central role to play in managing the economics of the company and directing and facilitating the smooth flow of the required funds. It undertakes the following functions:

- Making fund requirement decisions and providing the required funds at the proper time.
- To ensure supply of funds as and when required.
- Evaluating different investment proposals and selecting the best among them.
- Developing systems for the systematic & scientific arrangement of every process and work resulting in exact cost calculation for all the cost centres.

SIG (System Integration Group):

This function undertakes the computerization of the entire systems of the plant. The major function of this department is to implement the SAP package and maintain the same for effective functioning of the plant. The department also takes care of the proper information flow to all the functions and the development of new systems.

Production (Secondary):

The Production (Secondary) function is to undertake the activities like Grinding, Drilling, and Threading etc. including the following responsibilities:

- To produce the scheduled quantity of products consistently.
- To produce products with zero defect.
- To co-ordinate with planning department for effective utilization of all resources.
- To strictly enforce quality standards.
- To avoid waste and maintain shop floor cleanliness.

CHAPTER V – TIME STUDY AT LPS

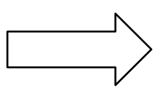
5.1 Introduction:

Bolt making processes for M 6x1x22 size Bolt has been chosen for time study. Maynard Operation Sequence Technique has been used for measuring the time for various operations used in the Bolt making at the shop floor. Process flow chart for the M x1x22 size bolt is shown in fig. 3.

Computer programme of Maynard Operation Sequence Technique has been used for time study, which gives the time for various operations in TMU's. Basic human motions, distances and equipment used by the operators are required to be noted at the shop floor. These serves as input for the programme.

5.2 Process Flow Diagram:

Part Description: M6X1.0X22.0 SHCS, 8.8 (22-32 HRC), Zn-BLUE

Direction :  Used as Movement Symbol can be in either direction as appropriate.

Process : Forging, Tread, Rolling, Heat Treatment, Finishing

Part Description : SOCKET HEAD CAP SCREW

Process Flow Diagram					
S.No.	Operation	Move	Store	Inspect	Description
					RECEIVING WIRE / WIRE ROD FROM RAW MATERIAL VENDOR
1			1		
2				1	RECEIVING INSPECTION (WIRE / WIRE ROD)
3			1		STORAGE OF WIRE ROD
4		1			MOVE TO VENDOR FOR DRAWING OF WIRE ROD
5			1		STORAGE OF WIRE ROD AT VENDOR'S PLACE
6			1		RECEIVE DRAWN WIRE FROM VENDOR
7				2	RECEIVING INSPECTION (DRAWN WIRE)
8			2		STORAGE OF DRAWN WIRE
9		2			MOVE DRAWN WIRE TO FORGING SHOP
10	3			3	FORGING (PATROL INSPECTION)
11		3			MOVED TO ROLLING MACHINE
12	4			4	TREAD ROLLING (PATROL ROLLING)
13		4			MOVED TO HEAT TREATMENT SHOP
14	5			5	HEAT TREATMENT (PATROL INSPECTION) (HAREDNING AND TEMPERING)
15		5			MOVED TO FINISHING SHOP
16	6			6	SURFACE TREATMENT (PATROL INSPECTION) (Zn-BLUE)
17		6			MOVED FOR FINAL INSPECTION
18				7	FINAL INSPECTION
19		7			MOVED FOR PACKAGING SECTION
20	8				PACKAGING
21		8			MOVED TO WARE HOUSE
22		8			DESPATCH

Area of Interest

Fig. 4: Process Flow Chart

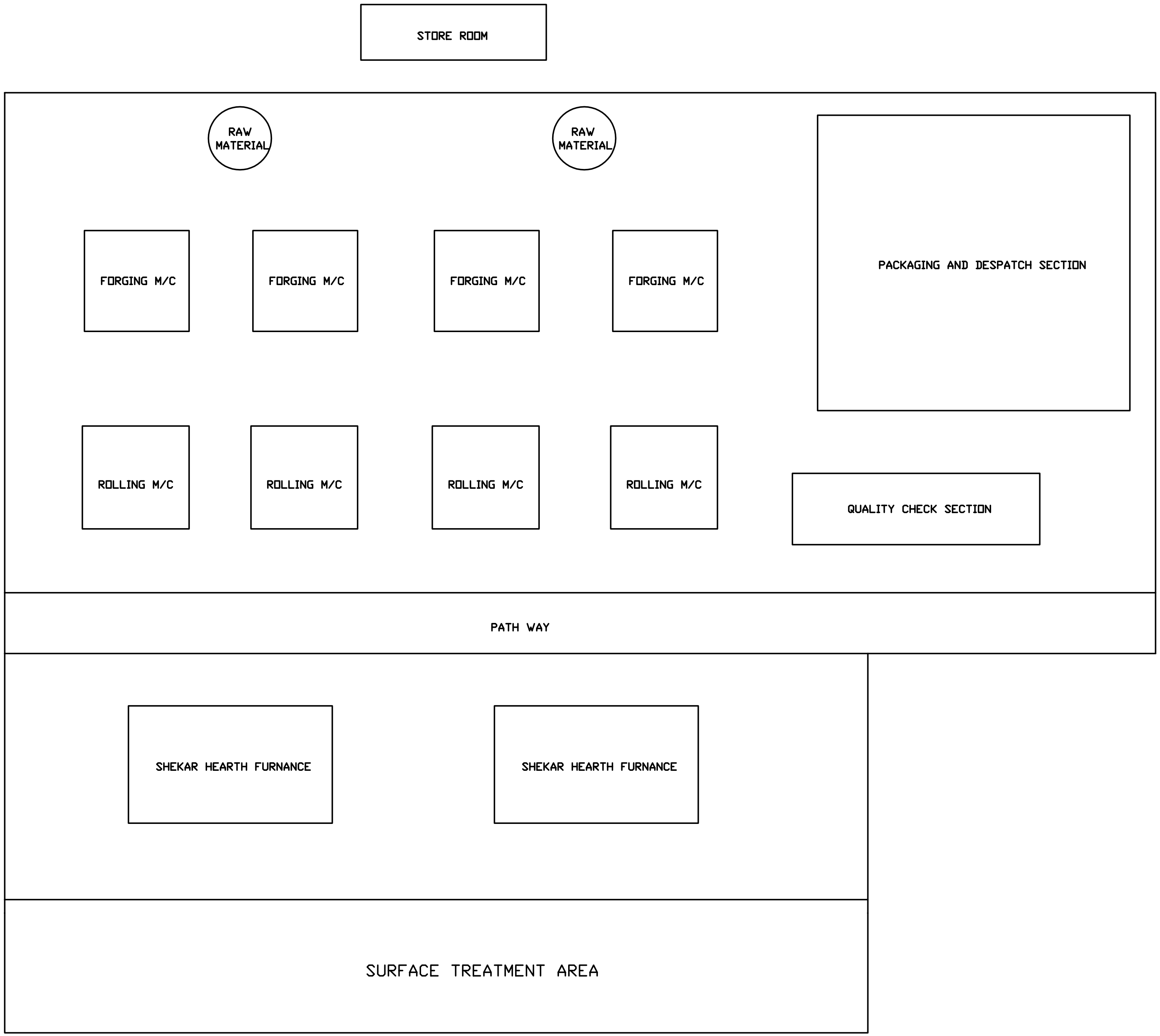


FIG. 4 SHOP FLOOR LAYOUT

MOST ELEMENTS

PARTNO M6x1x22 Socket Head Cap Screw

OPNNO 1

TITLE BOLT MAKING PROCESSES FOR M 6x1x22 BOLT SIZE

SRNO	EL_DESC
1	OPERATOR GOES TO THE FORKLIFT, RIDES IT AND BRINGS IT TO THE WIRE ROD STORE.
2	CRANE PUTS THE MATERIAL IN FORGING MACHINE STAND.
3	FORGING OPERATION: WORKER FIXES THE END OF THE WIRE IN THE GRIPPER OF FORGING MACHINE.DISTANCE BETWEEN GRIPPER AND STAND IS 4 FEET.
4	FORGING MACHINE STARTS AND FIRST BOLTS COMES OUT IN 6 MINUTES.THE OPERATIONS INVOLVES STRAIGHTENING, CUTTING & HEADING.
5	THE OVERHEAD CRANE MOVES THE FORGED BOLTS' BUCKET TO ROLLING MACHINE
6	THE CRANE POURS THE BUCKET INTO THE VIBRATING FUNNEL AT THE ROLLING MACHINE.
7	TIME FOR THREADING IN ROLLING MACHINE FOR SINGLE PICE
8	BUCKET IS TRANSPORTED FROM ROLLING MACHINE TO SHEKAR HEART FURNACE WITH THE HELP OF CRANE.
9	WORKER LOAD THE BOLTS IN THE TRAY OF SHEKAR HEARTH FURNACE. CONSIDERING 25 PIECES ON AN AVERAGE IN ONE TURN, EACH EMPLOYEE REPEATS THE LOADING PROCESS AROUND 50 TIMES.
10	HEAT TREATMENT PROCESS IN SHEKAR HEARTH FURNACE TAKES AROUND 6 HRS. WORKER REMAINS BUSY IN OTHER OPERATIONS AT THE SAME TIME.
11	BUCKET FULL OF BOLTS IS TRANSFERRED FROM HEAT TREATMENT AREA TO THE ELECTROPLATING SECTION WITH THE HELP OF CRANE.
12	BOLTS ARE LOADED ONTO THE HANGERS BY THE WORKERS MANUALLY. EACH HANGER CAN HOLD UPTO 50 PIECES.
13	HANGERS ARE LOADED ONTO THE CRANE MANUALLY BY TWO WORKERS..
14	LOADED HANGERS PASS THROUGH THE VARIOUS CHEMICAL TANKS FOR ELECTROPLATING.
15	LOADED BOLTS ARE REMOVED FROM THE HANGERS AFTER COMPLETION OF ELECTROPLATING.
16	BUCKET OF ELECTROPLATED BOLTS IS TRANSPORTED TO THE DESPATCH SECTION FOR STOTAGE AND DESPATCH.

MOST ESTIMATION SHEET INDUSTRIAL ENGINEERING DEPARTMENT	PARTNO M6x1x22 PARTNAME SOCKET HEAD CAP SCREW	PROCESS TYPE FABRICATION M/C NO DATE 10/18/2006 WORKCENTER 1	ADDITIONAL INFORMATION
OPERATION NO. 1	BOLT MAKING PROCESSES FOR M 6x1x22 BOLT SIZE		

SR NO	ELEMENT DESCRIPTION		SEQUENCE MODEL	FRQ	CYCLE TIME IN TMU	CYCLE TIME IN SEC	NO. OF MEN	WORK-CONTENT IN SEC
1	Operator goes to the forklift, rides it and brings it to the wire rod store.	MAXI FREQ. SIMO TO	A 3 S 6 T 3 L 6 T 6 L 6 T 6 A 3	1	3900	140.40	1	140.40
2	Crane puts the material in forging machine stand.	MAXI FREQ. SIMO TO	A 1 T 16 K 6 T 16 P 3 T 16 A 1	1	10500	378.00	1	378.00
3	Forging Operation: Worker fixes the end of the wire in the gripper of forging machine.Distance between gripper and stand is 4 feet.	BASIC FREQ. SIMO TO	A 10 B 0 G 3 M 6 X 32 I 16 A 10	1	770	27.72	1	27.72
4	Forging machine starts and first bolts comes out in 6 minutes.The operations involves straightening, cutting & heading.	BASIC FREQ. SIMO TO	PTIME= 360	1	10008	360.00	1	360.00
5	The overhead crane moves the forged bolts' bucket to rolling machine	MAXI FREQ. SIMO TO	A 1 T 16 K 24 T 10 P 3 T 16 A 1	1	7100	255.60	1	255.60
6	The crane pours the bucket into the vibrating funnel at the rolling machine.	MAXI FREQ. SIMO TO	A 0 T 16 K 24 T 16 P 3 T 16 A 0	1	7500	270.00	1	270.00
7	Time for Threading in Rolling machine for single pice	BASIC FREQ. SIMO TO	PTIME= 300	1	8340	300.00	1	300.00
8	Bucket is transported from Rolling Machine to Shekar Heart Furnace with the help of Crane.	MAXI FREQ. SIMO TO	A 1 T 16 K 24 T 10 P 3 T 16 A 1	1	7100	255.60	1	255.60
9	Worker load the bolts in the tray of Shekar Hearth Furnace. Considering 25 pieces on an average in one turn, each employee repeats the loading process around 50 times.	BASIC FREQ. SIMO TO	A 1 B 6 G 3 A 1 B 6 P 3 A 1	50	10500	378.00	2	756.00
10	Heat Treatment process in Shekar Hearth Furnace takes around 6 hrs. Worker remains busy in other operations at the same time.	BASIC FREQ. SIMO TO	PTIME= 21600	1	600480	!1600.0(	1	21600.00
11	Bucket full of bolts is transferred from Heat Treatment area to the Electroplating Section with the help of Fork Lift Truck.	MAXI FREQ. SIMO TO	A 3 S 6 T 3 L 6 T 6 L 6 T 6 A 3	1	3900	140.40	1	140.40
12	Bolts are loaded onto the Hangers by the workers manually. Each hanger can hold upto 50 pieces.	BASIC FREQ. SIMO TO	A 1 B 0 G 1 A 1 B 0 P 3 A 1 50	25	38500	1386.00	2	2772.00

 CHECKED BY ESTIMATED BY VIKAS

SR NO	ELEMENT DESCRIPTION		SEQUENCE MODEL	FRQ	CYCLE TIME IN TMU	CYCLE TIME IN SEC	NO. OF MEN	WORK-CONTENT IN SEC
13	Hangers are loaded onto the crane manually by two workers..	**BASIC** FREQ. SIMO TO	A 3 T 10 K 24 F 3 V 6 L 0 V 0 P 3 T 0 A 3	25	13000	468.00	2	936.00
14	Loaded hangers pass through the various chemical tanks for electroplating.	**BASIC** FREQ. SIMO TO	PTIME= 1500 4	1	54920	1975.92	1	1975.92
15	Loaded bolts are removed from the hangers after completion of electroplating.	**BASIC** FREQ. SIMO TO	A 1 B 0 G 1 A 1 B 0 P 0 A 1	50	2000	72.00	1	72.00
16	Bucket of electroplated bolts is transported to the Despatch section for Stotage and Despatch.	**MAXI** FREQ. SIMO TO	A 3 S 6 T 3 L 6 T 6 L 6 T 6 A 3	1	3900	140.40	1	140.40
SUMMARY:			Total		**782418**	**8148.0**		**30380.04**

Revision Details

Letter *Reason* *Date* *Initials*

5.4 Significance Testing

TESTING THE SIGNIFICANCE OF TIME CALCULATED USING MOST AGAINST STOP WATCH METHOD

S.NO.	OPERATION	TIME(IN MIN.) USING MOST	TIME (IN MIN.) FROM STOP WATCH METHOD	DIFFERENCE	DEVIATION FROM MEAN	SQUARE OF DEVIATION
i	DESCRIPTION	x_i	y_i	$d_i = y_i - x_i$	$d_i - d$	$(d_i - d)^2$
1	Operator goes to the forklift, rides it and brings it to the wire rod store	2.33	2.35	0.02	-0.05	0.00
2	Crane puts the material in forging machine stand.	6.3	6	-0.3	-0.37	0.14
3	Forging Operation: Worker fixes the end of the wire in the gripper of forging machine.Distance between gripper and stand is 4 feet.	0.46	1	0.54	0.47	0.22
4	Forging machine starts and first bolts comes out in 6 minutes.The operation involves straightening, cutting and heading.	6	6	0	-0.07	0.01
5	The overhead crane moves the forged bolts' bucket to rolling machine.	4.26	4	-0.26	-0.33	0.11
6	The crane pours the bucket into the vibrating funnel at the rolling machine	4.5	5	0.5	0.43	0.18
7	Time for Threading in Rolling machine for single piece.	5	5	0	-0.07	0.01
8	Bucket is transported from Rolling Machine to Shekar Heart Furnace with the help of crane.	4.26	4	-0.26	-0.33	0.11
9	Worker load the bolts in the tray of Shekar Hearth Furnace. Considering 25 pieces on an average in one turn, each employee repeats the loading process around 50 times.	12.6	14	1.4	1.33	1.77

S.NO.	OPERATION	TIME(IN MIN.) USING MOST	TIME (IN MIN.) FROM STOP WATCH METHOD	DIFFERENCE	DEVIATION FROM MEAN	SQUARE OF DEVIATION
i	**DESCRIPTION**	x_i	y_i	$d_i = y_i - x_i$	$d_i - d$	$(d_i - d)^2$
10	Heat Treatment process in Shekar Hearth Furnace takes around 6 hrs. Worker remains busy in other operations at the same time.	360	360	0	-0.07	0.01
11	Bucket full of bolts is transferred from Heat Treatment area to the Electroplating Section with the help of Crane.	4.26	4	-0.26	-0.33	0.11
12	Bolts are loaded onto the Hangers by the workers manually. Each hanger can hold upto 50 pieces.	46.2	45	-1.2	-1.27	1.62
13	Hangers are loaded onto the crane manually by two workers.	15.6	15	-0.6	-0.67	0.45
14	Loaded hangers pass through the various chemical tanks for electroplating.	32.9	33	0.1	0.03	0.00
15	Loaded bolts are removed from the hangers after completion of electroplating.	1.2	2	0.8	0.73	0.53
16	Bucket of electroplated bolts is transported to the Despatch Section for Stotage and Despatch.	2.34	3	0.66	0.59	0.35
			$\sum d_i =$ 1.14		$\sum(d_i - d)^2 =$ 5.60	

MEAN (d) = $\sum d_i$ / n = 0.07125

Using Test of Significance Based on t-distribution for testing the significance of difference between two sample means.

STATISTICS t = (d - 0) /(S/√n)

VARIANCE $S^2 = \sum(d_i - d)^2 /(n-1)$ = 0.373278333

STANDARD DEVIATION S = 0.610965084

t = 0.466475103

Testing for 5 % level of significance or 95 % level of confidence.

For (n-1) i.e. 15 d.f.

$t_{0.05}$ = 2.13 (Refer Table 10)

Since $t < t_{0.05}$

i.e. .4665 < 2.13

Difference between the sample mean is not significant.

Hence the two independent samples come from the same normal population.

T – Table

v = number of degrees of freedom

v \ P	0.5	0.1	0.05	0.02	0.01
1	1.0	6.34	12.7	31.82	63.66
2	.816	2.92	4.3	6.96	9.92
3	.765	2.35	3.18	4.54	5.84
4	.741	2.13	2.78	3.75	4.60
5	.727	2.02	2.57	3.36	4.03
6	.718	1.94	2.45	3.14	3.71
7	.711	1.90	2.36	3.00	3.50
8	.706	1.86	2.31	2.90	3.36
9	.703	1.83	2.26	2.82	3.25
10	.700	1.81	2.23	2.76	3.17
11	.697	1.80	2.20	2.72	3.11
12	.695	1.78	2.18	2.68	3.06
13	.694	1.77	2.16	2.65	3.01
14	.692	1.76	2.14	2.62	2.98
15	.691	1.75	**2.13**	2.60	2.95
16	.690	1.75	2.12	2.58	2.92
17	.689	1.74	2.11	2.57	2.90
18	.688	1.73	2.10	2.56	2.88
19	.688	1.73	2.09	2.24	2.86
20	.687	1.72	2.09	2.53	2.84
21	.686	1.72	2.08	2.52	2.83
22	.686	1.72	2.07	2.51	2.82
23	.685	1.71	2.07	2.50	2.81
24	.685	1.71	2.06	2.49	2.80
25	.684	1.71	2.06	2.48	2.79
26	.684	1.71	2.06	2.48	2.78
27	.684	1.70	2.05	2.47	2.77
28	.683	1.70	2.05	2.47	2.76
29	.683	1.70	2.04	2.46	2.76
30	.683	1.70	2.04	2.46	2.75
35	.682	1.69	2.03	2.44	2.72
40	.681	1.68	2.02	2.42	2.71
45	.680	1.68	2.02	2.41	2.69
50	.679	1.68	2.01	2.40	2.68
60	.678	1.67	2.00	2.39	2.66
∞	.674	1.64	1.96	2.33	2.58

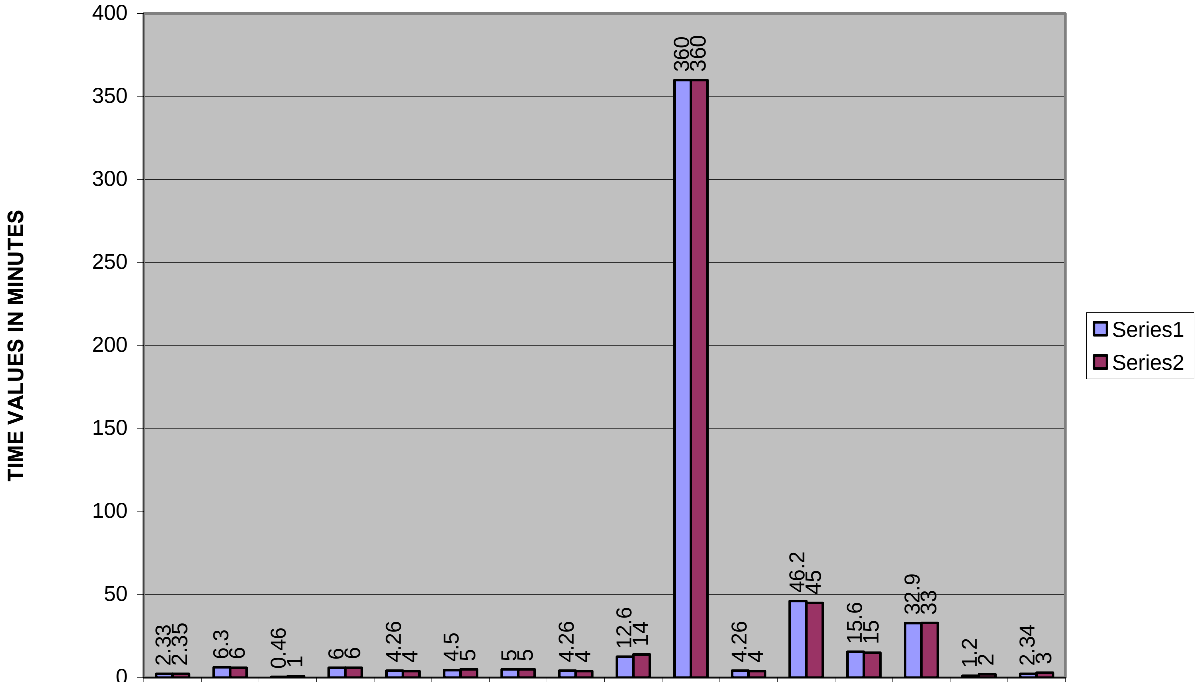
Table 10: T-Table

Comparison Between MOST and Stopwatch time values:

S.NO.	OPERATION	TIME(IN MIN.) USING MOST	TIME (IN MIN.) FROM STOP WATCH METHOD	Unit relative Deviation (in %)
i	DESCRIPTION	x_i	y_i	
1	Operator goes to the forklift, rides it and brings it to the wire rod store	2.33	2.35	-0.85
2	Crane puts the material in forging machine stand.	6.3	6	5
3	Forging Operation: Worker fixes the end of the wire in the gripper of forging machine.Distance between gripper and stand is 4 feet.	0.46	1	-54
4	Forging machine starts and first bolts comes out in 6 minutes.The operation involves straightening, cutting and heading.	6	6	0
5	The overhead crane moves the forged bolts' bucket to rolling machine.	4.26	4	6.5
6	The crane pours the bucket into the vibrating funnel at the rolling machine	4.5	5	-10
7	Time for Threading in Rolling machine for single piece.	5	5	0
8	Bucket is transported from Rolling Machine to Shekar Heart Furnace with the help of crane.	4.26	4	6.5
9	Worker load the bolts in the tray of Shekar Hearth Furnace. Considering 25 pieces on an average in one turn, each employee repeats the loading process around 50 times.	12.6	14	-10
10	Heat Treatment process in Shekar Hearth Furnace takes around 6 hrs. Worker remains busy in other operations at the same time.	360	360	0
11	Bucket full of bolts is transferred from Heat Treatment area to the Electroplating Section with the help of Crane.	4.26	4	6.5
12	Bolts are loaded onto the Hangers by the workers manually. Each hanger can hold upto 50 pieces.	46.2	45	2.66
13	Hangers are loaded onto the crane manually by two workers.	15.6	15	4
14	Loaded hangers pass through the various chemical tanks for electroplating.	32.9	33	0.30
15	Loaded bolts are removed from the hangers after completion of electroplating.	1.2	2	-40
16	Bucket of electroplated bolts is transported to the Despatch Section for Storage and Despatch.	2.34	3	-22
		508.21	509.35	

Total Relative Deviation in % = 0.223814666

Fig. 5 COMPARISON CHART BETWEEN MOST AND STOPWATCH VALUES



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Series1	2.33	6.3	0.46	6	4.26	4.5	5	4.26	12.6	360	4.26	46.2	15.6	32.9	1.2	2.34
Series2	2.35	6	1	6	4	5	5	4	14	360	4	45	15	33	2	3

OPERATION NO.

RESULTS & CONCLUSION

Calculated Time for Various operation Using MOST:

S.NO.	OPERATION	TIME(IN MIN.)
1	Operator goes to the forklift, rides it and brings it to the wire rod store	2.33
2	Crane puts the material in forging machine stand.	6.3
3	Forging Operation: Worker fixes the end of the wire in the gripper of forging machine. Distance between gripper and stand is 4 feet.	0.46
4	Forging machine starts and first bolts comes out in 6 minutes. The operation involves straightening, cutting and heading.	6
5	The overhead crane moves the forged bolts' bucket to rolling machine.	4.26
6	The crane pours the bucket into the vibrating funnel at the rolling machine	4.5
7	Time for Threading in Rolling machine for single piece.	5
8	Bucket is transported from Rolling Machine to Shekar Heart Furnace with the help of crane.	4.26
9	Worker load the bolts in the tray of Shekar Hearth Furnace. Considering 25 pieces on an average in one turn, each employee repeats the loading process around 50 times.	12.6
10	Heat Treatment process in Shekar Hearth Furnace takes around 6 hrs. Worker remains busy in other operations at the same time.	360
11	Bucket full of bolts is transferred from Heat Treatment area to the Electroplating Section with the help of Crane.	4.26
12	Bolts are loaded onto the Hangers by the workers manually. Each hanger can hold upto 50 pieces.	46.2
13	Hangers are loaded onto the crane manually by two workers.	15.6
14	Loaded hangers pass through the various chemical tanks for electroplating.	32.9
15	Loaded bolts are removed from the hangers after completion of electroplating.	1.2
16	Bucket of electroplated bolts is transported to the Despatch Section for Storage and Despatch.	2.34

Table 11: Operation times from MOST

Time values calculated using MOST gives a confidence level of 95% when compared with the time established using stop watch method. Also the time and effort required in establishing the time values for various operation is very less when compared with the stop watch method. This proves the effectiveness of the MOST in work measurement area.

Intangible Benefits that resulted from the time study of operation using MOST are:

1. It directly gives the time that is required to do a job by an average worker while working on an average pace rating. But time study using stop watch requires the analyst to rate the worker which is based on perception and so not always accurate.

2. Stopwatch method is not the best way to time the worker while they are working as it affects the performance of the worker because they feel insecure by being timed out.

3. It is a faster technique. While stopwatch study requires at least 20-25 cycles to be repeated to get certain level of accuracy with some confidence level, MOST requires only basic movements and motion patterns to be observed so as to calculate the same time.

SCOPE OF FURTHER WORK

The work done can be further extended in the selection of best plant layout for bolt making process as we can time the activities for various alternative layout at a very fast rate without actually implementing it in reality. Though the work of this dissertation is limited to establishing the time for various operations used in the production of M6x1x22 size bolt, it can be extended for other standard size bolts. Time value calculated can be used in establishing the time standards, which can form the basis of selecting the best wage incentive plan. As the company is under an expansion drive, it becomes relevant for the company to standardize the time required to carry out certain jobs.

REFERENCES

1. Genaidy, A.M., Agrawal, A., Mital, A., Aug 1990,Computerized predetermined motion-time systems in manufacturing industries, Computers & Industrial Engineering Journal, Vol. 18, No. 4, PP 571-584.

2. Raouf, A.,Jul 1991,Computer-aided workplace design: applications in predetermined motion time systems, Work Study, Vol. 40, No. 4, PP 16-19.

3. Dossett, R., Nov 1992,Computer application of a natural-language predetermined motion time system, Computers & Industrial Engineering Journal, Vol. 23, No. 1-4, PP 319-322.

4. Brown, S., March 1994, TQM and work study: partners in excellence, Production & Inventory Management Journal , Vol. 35, No. 3, PP 34-39.

5. Al-Dahaim, Y.A., Naqvi, S.A.A., Jul 1993, Using work design techniques and method engineering to enhance productivity, Industrial Engineering Journal, Vol. 25, No. 7, PP 58-60.

6. Koelling, C.P., Ramsey, T.D., 1996, Multimedia in work measurement and methods engineering, Computers & Industrial Engineering Journal, Vol. 31, Vol. 1/2, PP 49-52.

7. Kanthi M.N. Muthiah, Samuel H. Huang, 2006, A review of literature on manufacturing systems productivity measurement and improvement, Int. J. of Industrial and Systems Engineering, Vol. 1, No.4, PP 461 – 484.

8. Richard A. Reid, 2006, Productivity and quality improvement: an implementation framework, Int. J. of Productivity and Quality Management, Vol. 1, No.1/2, PP 26 – 36.

9. Brown, S., Jul 1994, The role of work study in TQM, TQM Magazine, Vol. 6, No. 3, PP 9-15.

10. Oakland, J.S., Wynne, R.M., Feb 1991, Efficiency of UK engineering production management systems, part 1 -- the research, Int. J. on Operations & Production Management, Vol. 11, No. 1, PP 14-31.

11. Kroll, E., Feb. 1996, Application of work measurement analysis to product disassembly for recycling, Concurrent Engineering: Research & Applications, Vol. 4, No. 2, PP 149-158.

12. Cohen, Y., Bidanda, B., Billo, R.E., Oct. 1998, Accelerating the generation of work measurement standards through automatic speech recognition: a laboratory study, Int. J. on Production Research, Vol. 36, No. 10, PP 2701-2715.

13. Hall, M., Nov 1990, Computer work measurement systems, Work Study, Vol. 39, No. 6, PP 10-14.

14. Parker, C., Nov 2000, Performance measurement, Work Study, Vol. 49, No. 2, PP 63-66.

15. Westerkamp, T.A., Oct 1999, Measuring maintenance, IIE Solutions, Vol. 31, No. 10, PP 32-35.

16. Lehto, M.R., Sharit, J., Salvendy, G., Aug 1991, The application of cognitive simulation techniques to work measurement and methods analysis of production control tasks, Int. J. on Production Research, Vol. 29, No. 8, PP 1565-1586.

17. Kapur, J.N. & Saxena, H.C., Mathematical Statistics, S.Chand & Company Ltd.,.

18. Khanna, O.P., Industrial Engineering & Management, Dhanpat Rai Publication (P) Ltd.

19. Monks, Joseph G., Operation Management Theory & Problems, McGraw Hill Publication.

20. Buffa, Elwood S. & Sarin, Rakesh K., Modern Production / Operation Management, 8^{th} Edition, John Wiley & Sons.

21. Zandin, Kjell B, MOST Work Measurement Systems, 2nd Edition

22. http://www.netmba.com/mgmt/scientific/

23. http://aprc.com/mostwork.htm

24. http://en.wikipedia.org/wiki/Predetermined_motion_time_system

25. Robbins, S.P., Bergman, R., Stagg, L, & Coulter, M., Management (3rd Edition), (2003) . Sydney, Australia: Prentice Hall

26. http://www.britannica.com/eb/article-9072509/time-and-motion-study