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Application of Pre-Determined Motion Time System to Develop a Standard Data System for Measuring Work Content of Garments Finishing Operations

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ABSTRACT

Over the years, Pre-determined Motion Time System (PMTS) has proved to be a powerful standardization tool in general electrical, automobile, machine shops, needle trades and even health care industries in accurately predicting the standard time for a given task. In needle trades, apart from GCD, all PMTS solutions established, commonly referred as Standard Data Systems (SDS), (GSD, Pro-SMV, SSD, SewEasy, SPD, MODSew etc.), have so far focused on the sewing department only. However, the repetitive nature of finishing operations itself introduces an enormous possibility of using PMTS in the section while it still uses the conventional time study method for labor content measurement. During this research project, by micro-motion study and using MTM database, one SDS was created for the garments finishing department for 7 types of operations- 1. Rivet Attaching 2. Button Attaching 3. Tag Attaching 4. Belt loop Trimming 5. Topper Pressing/ Denim Blowing 6. Scraping 7. Whiskering. After establishing the SDS, 12 operations of those seven types were randomly taken as samples from different countries, and based upon their method, the time values were calculated using the established SDS. Thereafter, we compared these pre-determined time values to the time values taken by those operations in real condition. Interestingly, in 83% instances, the variations were less than 5% and never went beyond 7.5%. This signifies that the time values predicted by the established SDS have been in the area of the scatter plot of the normal distribution of time study and hence, can successfully replace the conventional time study method in the department.

Keywords: PMTS, SDS, Micro-Motion Study, Work Measurement, SAM, SMV, Garments Finishing Operations, timeSSD®

1. Introduction

Renowned Engineer William Thomson, 1st Barron Kelvin said, *"to measure is to know. If you cannot measure it, you cannot improve it."* (Kelvin, 1891) In the present scenario, as time has become a critical resource even for the measurement itself; when it comes to measuring the standard times of various operations in the needle trade- PMTS can be a powerful tool as it establishes the work standard following an international benchmark. To the surprise, whilst many professional organizations are more than willing to commit to the accurate and frequent measurement of the activities in the sewing room, benchmarking SAM values, OB Preparation; few are as willing to do so where inalienable production processes like finishing are concerned.

In the garments industry, mostly the sewing operations have been the prime focus of interest of all the commercial PMTS solutions created so far. As we have seen that, there are nearly 80 job descriptions in a garments industry where around 15 happens in pre-production and nearly the same number of operation in the post-production stage (Jana P. , 2014) - very often these are found to be ignored though when it comes to setting the time standard for the operations. Industrial Engineers in Garments Industry still leave these operations out to guesses, making them susceptible to inefficiency, low productivity and poor motivation. Therefore, to sustain in the longer run of the business and realize the expectation of continuous annual improvement in productivity and efficiency, it is the need of the hour to introduce and practice scientific work measurement techniques in the finishing department as well. GSD once came up with a PMTS solution for the Cutting department (GCD) but could not become popular, attributed to longer cycle times and less repetitive nature of the operations. If we look at the finishing department, most of the operations are manual; motion sequences are less than 30 seconds and performed for more than 50% of work shift time- all directing to operations' repetitive nature (Jana, 2008). Though finishing is an integral part of the production system, it continues to be the area where the traditional time study system is followed for work measurement and planning. Therefore, there is an enormous possibility of success in establishing a database of PMTS elements for this section that could help in standardizing the manual operations of the finishing floor according to an international benchmark.

2. Review of Literature

2.1. What is PMTS?

Pre-determined Motion Time Systems (PMTS), also referred to as Pre-determined Time Standards (PTS) or Synthetic Time Standards, are the terms often used interchangeably for the same work measurement technique. PMTS is the work measurement technique that uses times established for basic human motions to build up the time for a job at a defined level of performance. (Kanawaty, 1992). According to A. B. Segur, *"within practical limits the time required for all experts to perform true fundamental motions is a constant"*. (Segur, 1927). The BS 3138 defines PMTS as tables of time data at defined rates of working for classified human movement where times for an operation or task are derived using precise conventions (Anon, 1969). As the name implies, the times required for motions are already determined and with this system, it is possible to define the standard time for a given operation even before the production begins on the shop floor by deriving the time values from the standard time-tables (Kanawaty, 1992).

During establishing the work-content or Standard Allowed Minute (SAM) value or Standard Minute Value (SMV) of the job, it is important to adjust the time for basic motions with other factors taken into account. The reason is variables like distance moved, difficulty level, the closeness of fit or precision during assembling, the weight of the object individually or collectively can influence the total time required for accomplishing job (Jana & Tiwary, 2018).

2.2. Why PMTS? : Advantages-

PMTS systems offer numerous advantages over conventional time study as below-

1. PMTS is free of added subjectivity introduced in Time Study Method as it avoids direct observation and rating followed in the same and therefore, can

lead to more consistency in setting standard times.

2. PMTS indeed comes with a certain cost of installation and application. Besides, its success often depends on factors like the system's present performance level, consistency of standard work in the present work environment and the repetitive nature of operations. Still, it boasts being a more expedient tool as Work measurement using Time Study requires more labor and time. Time Study may prove to be costlier in the long term.
3. It is possible to define the standard time for a given operation with PMTS, even before the production begins and often while the process is still at the design stage; as to derive the times for the various operations, we have to depend on the standard time tables only.
4. Based on the PMTS analysis made before, a work-study person can change the layout and design of the workplace in the pre-production stage, which paves the way for method improvement.
5. It enables the manufacturing unit to estimate the cost of production and budgeting at the pre-production stage, which may lead to greater profitability.
6. PMTS offers an internationally accepted benchmark for setting the production time. This paves the way for standardization, increase in productivity and efficiency along with continuous improvement.
7. PMTS further provides the most scientific, reliable, and the safest base of rating the performance of operators by eliminating controversies associated with the Time Study based rating where the rating is actually a matter of judgment on the part of Time Study Analyst (Barnes, 2002), making the process very subjective (Jana P. , 2002)

2.3. Different types of PMTS

The pioneer of motion classification was Frank B. Gilbreth who first published the principle of analyzing works into basic actions in 1920; as his 'Therbligs'- subdivisions of hand or hand & eye motions were the key concepts in the development of motion study (Kanawaty, 1992). A.B. Segur was the first person to attempt to establish a pre-determined system, known as Motion Time Analysis (MTA), through an appreciation of time in 1920 (Schmid, 1957).

The next important development was the work of J.H. Quick and his associates- W.J. Shea and R.E. Koehle who originated the Work Factor system in 1934 and published in 1945 (Quick, Shea, & Koehler, 1945). According to this system, four major variables decide the time to perform the motions- body members used, distance moved, manual control required and the weight or resistance involved (Barnes, Motion and Time Study Design and Measurement of Work, 1968) Although it is widely used in general industries like General Electric, it is not used in apparel manufacturing (Jana & Tiwary, 2018).

A considerable number and variety of PTS systems came to existence during and following the Second World War. Among these, the system that has become very widely used throughout the world is Methods-Time Measurement (MTM). Three men working then at the Westinghouse Electric Corporation in the United States- H. B. Maynard, G. J. Stegemerten and J. L. Schwab- first developed MTM in 1948 (Barnes, 1968). They had published their findings and thus, for the first time, full details of any PMTS system for the first time were freely available to everyone. John L. Schwab has defined that, *"Methods Time Measurement is a procedure which analyses any manual operation or method into the basic motions required to perform them and assigns to each motion a predetermined time standard which is determined by the nature* *of the motion and the conditions under which it was made* (Maynard, Stegemerten, & Schwab, 1948)." There are three official international MTM systems: **MTM-1**, **MTM-2** and **MTM-3**. **MTM-2** is the most popular and commercially used PMTS system of all. The unit of measurement in this system is TMU wherein 1 Hour = 100,000 TMU's. (General Sewing Data, 1996).

MODAPTS that stands for Modular Arrangement of Pre-Determined Time Standard, introduced in 1966, a registered trademark of International Modapts Association Inc. (IMA), received immediate acceptance and today ranks among the most popular systems in the world; though less used in the garments industry. It differs from the other systems as it focuses on the body parts doing the movement, rather than the distance covered by the body part for the object handled. An empirical study conducted by Chris Heyede's in late 1960-70, with hundreds of people in different work situations covering many different aspects of work, was the base for this PMTS system. MTM database includes 417 motion elements while MODAPT has only 21 elements useful to make Value Added Analysis and ergonomic review. The unit for time measurement in this system is MOD where 1 MOD = 0.00215 min= 0.129 sec (Jana & Tiwary, 2017) .

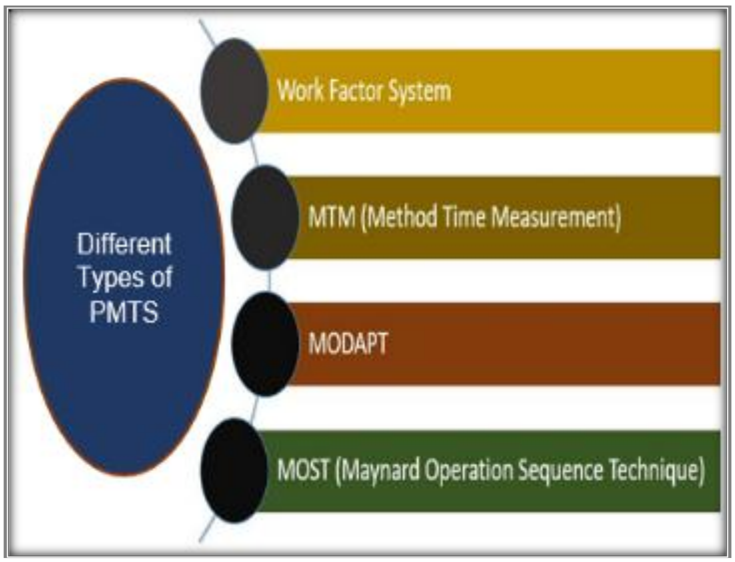

Figure 1. Different Popular PMTS Systems

H.B. Maynard created and released in 1972 one another popular PMTS system- known as Maynard Operation Sequence Technique. Accenture then acquired the solution in 2007. It has three basics levels such as- 1. **Mini MOST**: for short cycle, repetitive work; 2. **Basic Most**: for medium cycle, both repetitive & non-repetitive work (the majority of operations in most industries including sewing fall in this category); 3. **Maxi Most**: for long cycle, non-repetitive work. The time measurement unit here is TMU, the same as followed in MTM.

Until now, as per record, manufacturing industries in different domains are successfully exploiting 9 different types of commercial PMTS systems. Work Factor System and MTM are the two of all, which have garnered the most popularity and large-scale usage in industries worldwide (Jana & Tiwary, 2018).

2.4. Commercialization of PMTS: Using PMTS to establish an SDS (Standard Data System)

Many operations in a given plant have several common elements that follow a common pattern or sequence and are repetitive in nature. Timing all common elements repeatedly, therefore, can make the process of establishing the time-content for any job tedious and time-consuming. The job of a work-study person could, therefore, be much easier if a set of data of macro-elements were to be available to derive the standard times readily from these common work elements; without necessarily going into the process of timing each element in microscopic level. This is how the idea of Standard Data System or SDS came into conceptualization.

Marvin E. Mundel in his Book 'Motion and Time Study: Improving Productivity'(1978) said *"Rather than determine the standard time for each job on the basis of an individual study, standard times from a number of related jobs may be organized into a database from which the standard times for related jobs may be constructed or synthesized.''*

H.B. Maynard, one of the originators of MTM once said in the proceedings of IX Congress International DeL'Organization Scientifique, 1951, that, *"When you have a series of motions, inaccuracies in the predetermined times seem to cancel out''* (Bruckart, 1952). This bolsters the idea that SDS not only eases the process of setting up the work standard but also provides better reliability with more accuracy of the data developed (Kanawaty, 1992).

Below is the model that illustrates how to develop an SDS using PMTS:

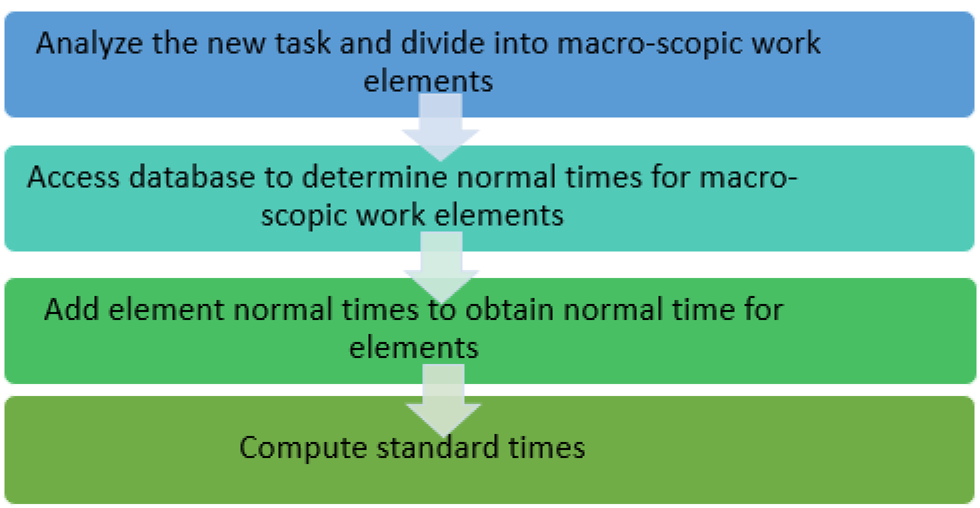

Figure 2. Model of developing SDS using PMTS

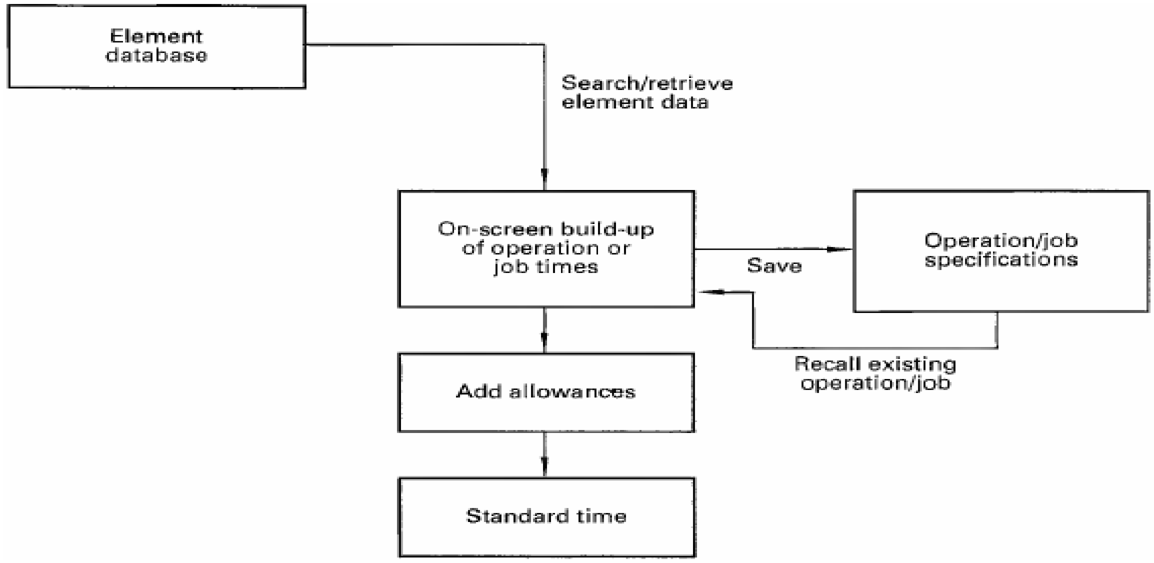

Figure 3. Model of Standard time Evaluation using Computerized SDS. Source- ILO's 'Introduction to Work Study', 4th Edition, P-428

There are a number of SDSs based on PMTS data. E.g. - Standard Sewing Data (SSD), General Sewing Data (GSD), and Clerical Work Data (CWD) etc. Such data systems are usually proprietary. Although most of all the SDS's were prepared and documented in the papers as a manual system, with the time they are now converted into Computerized Standard Data Systems for the ease of use and computation.

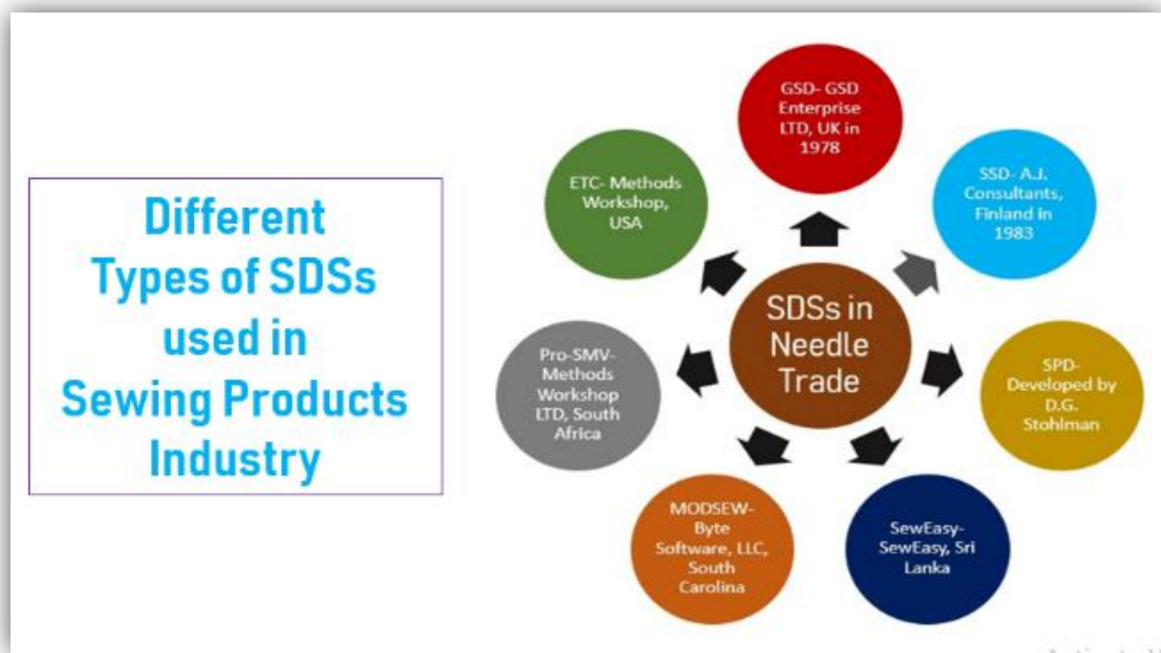

Figure 4. Different types of SDS used in Garments Sewing Department

2.5. PMTS based SDSs in Needle Trade

Over the years, a large number of standard data systems developed have eventually earned the universal acceptance for woodworking, electronic & mechanical assembly and the needle trades activities (Brown, 1994). Shortly after the development of MTM-1, industrial engineers applying the system recognized its constraints and endeavored to find an easier solution. The concept was to recognize and segregate motion patterns specific to needle trade and to make bigger building blocks (macros) using the MTM-I values for an easier and quicker application. (Jana P. , The mystical GSD: Baring it all, 2004). This initiative resulted in introducing the garments industry as well with quite a few PMTS solutions. However, almost all of these systems developed are proprietary of respective companies except one- named SPD (Sewing Performance Data) -which is available as a book in the public domain. Some popular PMTS solutions for apparel industries are as follows:

Table 1. Details about SDSs used in Garments Industry

SDSs Used in Garments Industry						
Name	Key Features	Form of the Database	Underlying PMTS Base	Department the solution established for	Product Name	Developed by
GSD	Developed from MTM in 1978. Most popular and globally accepted. Consists of 25 codes at the First Level (General), supplemented by 11 codes at the Second Level (Get & Put) and selected MTM codes are utilized to give complete coverage. Specializes in time-cost benchmarking, productivity improvement and work measurement	Soft Form(using software)	MTM	Sewing	GSD Enterprise and GSD Quest	GSD Limited, UK

Table 1. Details about SDSs used in Garments Industry

SDSs Used in Garments Industry						
Name	Key Features	Form of the Database	Underlying PMTS Base	Department the solution established for	Product Name	Developed by
SewEasy	Developed from MTM and specializes in Lean manufacturing, MTM based quick garment sewing data for transparent labor costing	Soft Form(using software)	MTM	Sewing	SewEasy	SewEasy, Sri Lanka
MODSEW	Focuses on the body parts doing the moving rather than the distance covered by the body part of the object being handled	Soft Form(using software)	MODAPTS	Sewing	MODSEW	Byte Software, LLC, South Carolina
Pro-SMV	Developed from MTM-2 and has 36 codes, 7 categories	Soft Form(using software)	MTM	Sewing	Pro-SMV	Methods Workshop Ltd., South Africa
SPD	A total of 144 motion sequences are spread over 13 easy to apply tables, covering sewing elements and time values in TMU	Book Form	MTM	Sewing	SPD (Book-Sewing Performance and Method Analysis)	D.G. Stohlman
SSD	Developed from MTM and gives a solution for benchmarking sewing operation.	Soft Form(using software)	MTM	Sewing	SSD	AJ- Consultants, Finland

Table 1. Details about SDSs used in Garments Industry

SDSs Used in Garments Industry						
Name	Key Features	Form of the Database	Underlying PMTS Base	Department the solution established for	Product Name	Developed by
	Consists of 84 macro-elements for manual motions and one different section for putting sewing related parameters for sewing time calculation. The unit of time measurement is min that is converted from the TMU values from MTM database.					
ETC	Developed from fourth generation MTM statistical database		MTM	Sewing	Engineered TruCost (ETC)	Methods Workshop, USA

2.6. Research GAP: Scope of Opportunity for PMTS in Garments finishing

While Pre-Determined Motion Time System (PMTS) has been recognizably consistent, accurate and dynamic in a changing environment in manufacturing industries for decades, its area of interest for application in the garments industry has mostly been the sewing department. Apart from GCD (General Cutting Data), all PMTS solutions in the garments industry have been established and customized for the sewing operations only (Jana P. , Are you measuring work content right?, 2010).

Dr. Prabir Jana Says, “There are about 80 job descriptions which can be plotted in a facility, in which around 15 are in the pre-production and about the same in production stage.’’ (Jana P. , Skill is Not Only about Sewing Operator, 2014). PMTS databases such as MTM or Work Factor offer a universal application with its ability to cover all work anywhere (Kanawaty, 1992). This indicates that, apart from sewing, there are many stages where successful implementation of method study and setting up time dimension can open up the door for overall productivity and efficiency improvement.

GSD Limited, UK once created one module of PMTS solution called GCD (General Cutting Data) for spreading, cutting, bundling, ticketing and other activities of the cutting room. The product could not become a success. Its failure could be attributed to the below reasons-

1. The very large work content of cutting room operations was one of the major reasons for GCD’s failure. Because, it is comparatively easier to measure the short cycle works in the sewing room with PMTS, whilst the activities in the cutting room are long and complex.
2. The longer cycle could often result in inaccurate evaluation; as the longer the task is, the greater the probability of error is while measuring, compiling and computing the “Standard Time” for that given activity.
3. The activities involve very less “frequency of occurrence” which are non-repetitive, and
4. The difficulties associated with an accurate assessment of an operator’s “performance” might also raise questions as to the accuracy of the final results.

The number of variables within the cutting room often does render the results of any earlier measurements inaccurate for that altered state (Stitch World, 2004).

PMTS is very useful when operations are repetitive in nature and have a higher frequency of occurrences (Jana & Tiwary, 2018). A task is considered repetitive if the cycle time is less than 30 seconds and the task is performed for more than 50% of the work shift (Jana, 2008). If we look at the finishing department, the operations for example- rivet attaching, snap button attaching, tagging, belt loop trimming etc. fall in this category. There are operations with longer cycle times such as – scraping or whiskering, which might take more time than 30 sec for one complete cycle; but on the other hand, they do include a very high no of the occurrence frequency of some particular tasks. For example, both scraping and whiskering involve rubbing with sandpaper and this particular task alone occupies more than 50% of the entire shift time. Therefore, although by nature, a lot of finishing operations are an integral part of the production process and satisfy all necessary conditions required to implement PMTS in a particular department; this is still an area where the traditional time-study is followed for determining the SAM, capacity planning and efficiency measurement. This fact, therefore, opens up a very exciting opportunity of research for establishing an SDS using PMTS for work measurement according to an internationally accepted benchmarking system.

Now the question may arise about whether the time-standard set by the PMTS for finishing is achievable by an operator in real condition.

The answer is- PMTS relies on predetermined times for known activities at known performance levels, and can therefore accurately predict best the optimum time for a given task. They provide a known benchmark and in so doing, provide an accurate measure of performance, efficiency and output. (Stitch World, 2004).

Dr. Prabir Jana says, *“How you do what you do is going to decide how long you will take to do it.”* Time is a by-product of the method followed. Once you define the method, PMTS can tell you the time required for the same. (Jana P. , The mystical GSD: Baring it all, 2004) PMTS is a tool for standardization irrespective of the operator and focuses on the right way of doing any operation. Thus, time values derived from PMTS are fair to all operators (Jana & Tiwary, 2018).

PMTS system measures an operator’s performance using the Synthetic Rating

System. R.L. Morrow was the first person to have introduced this system in 1946. Synthetic Rating compares the observed time (using time study) taken by the operator to perform any work against the pre-determined value of time for that operation, and expresses the ratio in percentage. This percentage value implies the performance index or rating of the operator (Barnes, Motion and Time Study: Design and Measurement of Work, 2002). However, the performance level of MTM 100, calculated using this rating system, is somewhat less than a rating of 100 on BSI scale. A public statement on this by the United Kingdom Institute of Management Services and the MTM Association suggests that MTM 100 equals BSI 83 (Work Study and Management Services, 1969). On the other hand, BSI states that an average operator with training and interest can perform fast and precise motion and achieve the 100% rating, meeting the requested standards for quality and accuracy without hesitation. This BSI 100 of performance level is actually MTM 120.48. This shows that 100% rate of performance of any operator in an MTM based PMTS scale is practically achievable in real condition.

2.7. Which PMTS database should we use to establish SDS for finishing and Why?

Apart from MODSEW, all PMTS solutions for the garments industry have MTM as their underlying basis. It is universal and can cover all work anywhere (Kanawaty, 1992) as MTM times fall within the area of the scatter plot of the normal times found by time study (Bruckart, 1952). Besides, amongst all MTM, MTM-2 is the most accepted and commercially used PMTS system. Moreover, its fewer codes and simplified structure make it both easy to understand and implement. (Jana & Tiwary, 2018). Therefore, it makes MTM-2 an ultimate choice because of both universal acceptance and success records in different industries. Therefore, here for our research, we have decided to work with MTM-2 as the underlying PMTS basis to establish the macro-elements for the finishing operations.

MTM-2 consists of nine motion categories with one weight factor category for measuring work content. These elements are as follows (Kanawaty, 1992):

Table 2. MTM-2 Motion Categories

MTM-2 Motion Categories

Category	Code	Purpose	Scope	
GET	GA	Reaching out with the hand or fingers to an object, grasping the object and subsequently releasing it	Starts	Reaching out to the object
	GB		Includes	Reaching out to, gaining control and subsequently releasing control of the object
	GC		Ends	When the object is released
PUT	PA	Moving an object to a destination with the hand or fingers	Starts	With an object grasped and under control
	PB		Includes	All transporting and correcting motions necessary to place the object
	PC		Ends	With object still under control at the intended place
REGRASP	R	Changing the grasp on an object	Starts	With the object in the hand
			Includes	Digital and hand muscular readjustment on the object
			Ends	With the object in a new location in the hand

Table 2. MTM-2 Motion Categories

MTM-2 Motion Categories

Category	Code	Purpose	Scope	
APPLY PRESSURE	A	Exerting muscular force on an object	Starts	With the body member in contact with the object
			Includes	The application of controlled increasing muscular force, a minimum reaction time to permit the reversal of force and the subsequent releasing of the muscular force
			Ends	With the body member in contact with the object, but with muscular force released
EYE ACTION	E	Recognizing a readily distinguishable characteristic of an object; or: shifting the aim of the axis of vision to a new area	Starts	When other actions must cease because a characteristic of an object must be recognized
			Includes	Muscular readjustment of the lens of the eyes and the mental processes required to recognize a distinguishable characteristic of an object; or: the eye motion performed to shift the aim of the axis of vision to a new viewing area
			Ends	When other actions can start again
FOOT MOTION	F	A short foot or leg motion when the purpose is not to move the body	Starts	With the foot or leg at rest
			Includes	A motion not exceeding 30 cm that is pivoted at the hip, knee or instep
			Ends	With the foot in a new location
STEP	S	A leg motion with the purpose of moving the body; or: a leg motion longer than 30 cm	Starts	With the leg at rest
			Includes	A motion of the leg where the purpose is to achieve a displacement of the trunk; or: a leg motion longer than 30 cm
			Ends	With the leg at a new location
BEND AND ARISE	B	A lowering of the trunk followed by a rise	Starts	With motion of the trunk forward from an upright posture
			Includes	Movement of the trunk and other body members to achieve a vertical change of body position to permit the hands to reach down to or below the knees and the subsequent arise from this position
			Ends	With the body in an upright posture
WEIGHT FACTORS	GW	The action required for the muscles of the hand and arm to take up the weight of the object (> 2 kg / hand)	Starts	With the grasp on the object completed
			Includes	Muscular force necessary to gain full control of the weight of the object
			Ends	When the object is sufficiently under control to permit movement of the object

Table 2. MTM-2 Motion Categories

MTM-2 Motion Categories				
Category	**Code**	**Purpose**	**Scope**	
	PW	An addition to a PUT motion depending on the weight of the object moved (> 2 kg / hand)	Starts	When the move begins
			Includes	The additional time, over and above the move time in PUT, to compensate for the differences in time required in moving heavy and light objects over the same distance
			Ends	When the move ends
CRANK	C	Moving an object in a circular path on more than half a revolution with the hand or finger	Starts	With the hand on the object
			Includes	All transporting motions necessary to move an object in a circular path
			Ends	With the hand on the object when one revolution is completed

The decision model for determining sub-categories of GET and PUT motion is as below (Kanawaty, 1992):

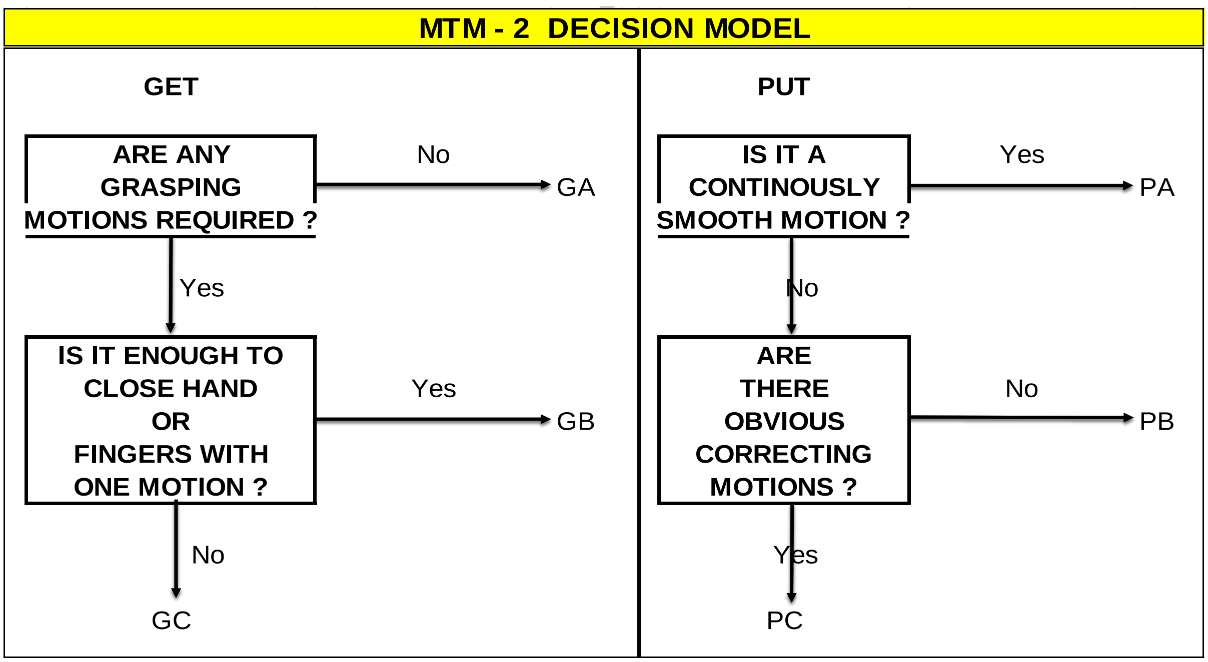

Figure 5. MTM-2 Decision model for GET & PUT motions. Source- timeSSD® Workshop Booklet

The possibilities of performing GET and PUT motions simultaneously by both hands are determined following the below model (Szabo, 2016):

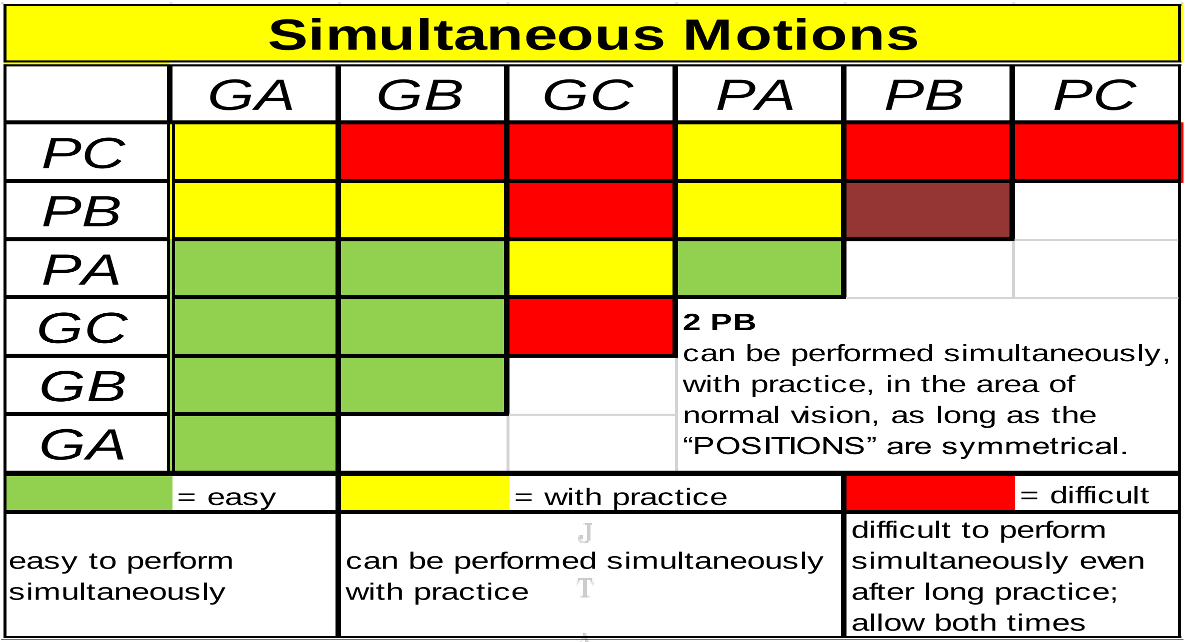

Figure 6. Simultaneous Motion Possibility as per MTM-2. Source- timeSSD® Workshop Booklet

Below is the data-card of MTM-2 showing the predetermined time value assigned to each motion in TMU unit (Szabo, 2016)-

Table 3. MTM-2 Data Card in TMU Value. Source- timeSSD® Workshop Booklet

G - Get	**MTM - 2 Data Card**					**P** - Put
	Time in **tmu**			1 Hour=	1,00,000	tmu
Code	*GA*	*GB*	*GC*	*PA*	*PB*	*PC*
Distance (cm)	No grasping motion	One grasping motion	More than one grasping motion	No correction	One correction	More than one correction
- 5	3	7	14	3	10	21
- 15	6	10	19	6	15	26
- 30	9	14	23	11	19	30
- 45	13	18	27	15	24	36
- 80	17	23	32	20	30	41
GW:	1 tmu per 1 kg / daN			*PW:*	1 tmu per 5 kg / daN	
Weight / Force	for weights/forces ≥ 2 kg/daN per hand			Weight / Force	for weights/forces ≥ 5 kg/daN per hand	

A	R	E	C	S	F	B
Apply pressure	Regrasp	Eye motion	Crank	Step	Foot motion	Bend and arise
						
14	6	7	15	18	9	61

For our project, we have used timeSSD® software which is a registered trademark of DataS, Romania (Astailor Shine Srl.). timeSSD® provides the software package for SSD- Standard Sewing Data (developed by A.J. Consultant, Finland) supplemented with MTM-2 database for evaluating SAM values of sewing operations in minute value (corresponding TMU values are converted into minute value). For establishing the higher building blocks/macro-elements for the finishing department, the time values of MTM-2 motions used in the Project, in minute value, are as below:

Table 4. MTM-2 Elements Data Card in Minute Value. Source- timeSSD® Workshop Booklet

G - Get	**MTM - 2 Data Card**			**P** - Put		
	Time in **min**			1 tmu=	0.0006	min
Code	*GA*	*GB*	*GC*	*PA*	*PB*	*PC*
Distance (cm)	No grasping motion	One grasping motion	More than one grasping motion	No correction	One correction	More than one correction
- 5	0.002	0.004	0.008	0.002	0.006	0.013
- 15	0.004	0.006	0.011	0.004	0.009	0.016
- 30	0.005	0.008	0.014	0.007	0.011	0.018
- 45	0.008	0.011	0.016	0.009	0.014	0.022
- 80	0.010	0.014	0.019	0.012	0.018	0.025
GW:	0.001 min per 1 kg / daN			*PW:*	0.001 min per 5 kg / daN	
Weight / Force	for weights/forces ≥ 2 kg/daN per hand			Weight / Force	for weights/forces ≥ 5 kg/daN per hand	

A	*R*	*E*	*C*	*S*	*F*	*B*
Apply pressure	Regrasp	Eye motion	Crank	Step	Foot motion	Bend and arise
						
0.008	0.004	0.004	0.009	0.011	0.005	0.037

3. Objectives of the research work

To establish a Standard Database System (SDS) for work measurement of operations in garments finishing unit.

4. Sub-objectives

1. One main sub-objective is to develop a compiled and detailed MTM-2 description for each code/macro-element demonstrating the logic behind the respective code's development.
2. To provide detailed descriptions of how the macro-elements can be recognized to make it self-explanatory so that even a work-study person without the knowledge of MTM-2 can use the database for evaluation of the work content of any operation.
3. Making video references and descriptions for complicated and simultaneous activities to help in training people and making them understand the standard procedure of doing method study and work measurement. It will help work-study practitioners to recognize non-value-added unnecessary motions and improve the overall efficiency, productivity.

5. Possible Outcome of the Project: Contribution to the Industry

The industry will get a PMTS solution dedicated to the finishing department, which would help to-

1. Set up time standard for a job according to internationally accepted benchmark
2. Get a reliable reference for rating the skill of the operator and overall performance, efficiency of the entire department.
3. Lead the method improvement.
4. Achieve the optimum production time when the actual production begins; as based upon the analysis done before, the work-study person can change the layout and design of the workplace at the pre-production stage.
5. Simulate the operations even before the actual production begins and hence calculate the cost, budget as the time based on PMTS is consistently accurate.

6. Research Methodology

For this research project, the methodology followed is as below:

1. First, we identified the operations with the possibility of PMTS application.
2. Then we carried out standardization of operations for Method study and

workplace engineering to eliminate unnecessary motions.

3. Afterward, we recognized the sequence of motions for each particular operation for developing macro-elements. Since MTM-2 employs exclusively behavioral concepts, we segregated the sets of elements necessarily based upon their purpose (Kanawaty, 1992) taking both distance and case into consideration as these two are considered as major variables with each Principal Motion (Methods Workshop Ltd., South Africa, 2007).
4. After that, we performed the Micro-motion study of the set of sequences of motions to recognize the associated MTM-2 elements. For doing the study, here we have analyzed the videos of operation on Tracker software, a free video analysis and modeling tool built on the Open Source Physics (OSP) Java framework, designed to be used in physics education and astronomy, but has gained popularity in Ergonomics and Motion studies for its physical marker less motion analyzing features.
5. Once the Set of Sequences are defined in MTM-2, the time-values have been assigned timeSSD® software using as per MTM-2 Data Card to those to establish the normal time/basic time for the elements for different distance categories. We have also given abbreviated code names to the macro-elements for different distances, cases.
6. After the codes/macro-elements are established, we have verified the codes comprising complicated simultaneous motions against the real-time observations.

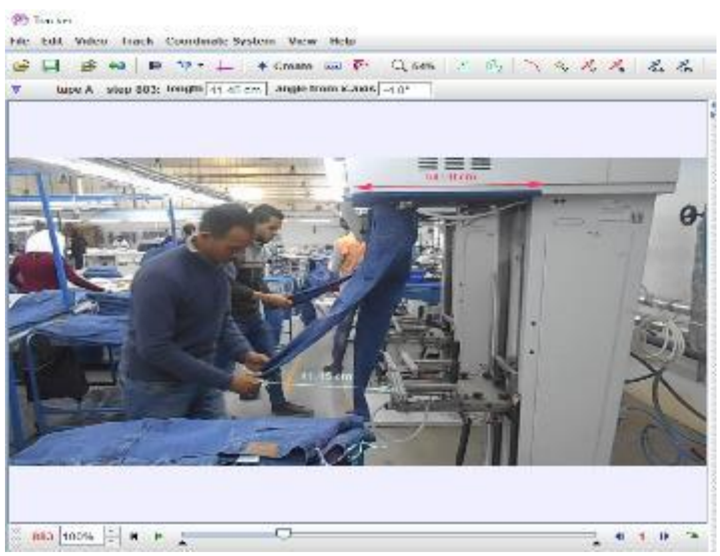

Figure 7. Use of Tracker Software for Micro-motion Study

Considerations for data validation:

a. Sample Size- For this, the no of observations for each study has been taken according to the below-suggested sample size determination table by Dr. Prabir Jana in his book 'Industrial Engineering in Apparel Manufacturing, Practitioner's Handbook (2017)'-

Table 5. Sample Size for Time Study

Cycle times in minutes	No of cycles to be observed
to 0.10	200
to 0.25	100
to 0.50	60
to 0.75	40
to 1.00	30
to 2.00	20
to 5.00	15
to 10.00	10
to 20.00	8
to 40.00	5
above 40.00	3

b. Unit- The originator themselves developed MTM by analyzing the motion picture films taken on a wide variety of industrial operations and exposed at a constant speed of 16 frames per second. This made it easy to identify the starting and stopping points of each motion and enabled the engineers to establish times for every individual motion.

   Here we have filmed all the videos and analyzed the observations at a speed of 30 frames per second and then converted into respective minute value.

   As 1 frame in 16 frames/second implies 0.0625 min, that of 30 frames/second implies 0.0333 min resulting in the possibility of greater accuracy.

c. Selection of Sample- As we know time is the by-product of the method being followed and PMTS give the time for a defined method (Jana P. , The mystical GSD: Baring it all, 2004), here only those cycles have been taken which follows the right method and sequence of motions.

   As PMTS time values itself are actually average values (Kanawaty, 1992), here no statistical tool used to select the samples from the total no of observations. Rather, here we have considered the observations following the right method for our study. Firstly, we have chosen the skilled operators perceived at 100% performance level for the study and selected the cycles with no or least unwanted variables. Then we have taken the average values of the observations to compare those to the time values determined by PMTS.

7. Then we have compiled all the established macro-elements, with data-cards of time values and detailed MTM-2 descriptions.

8. In addition to all the above-mentioned steps, we have also developed descriptions and video reference database for easy recognition of the right codes for work-study practitioners.

9. Finally, we have conducted an experiment as well to measure time for real-time operations using developed SDS. Then, we have calculated the variations from the original times taken by Time Study to study the accuracy/ closeness to determine its applicability and reliability.

7. Research Work and its Findings

7.1. Identification of the Operations in finishing operations for PMTS Study

Below are the different finishing operations, usually found in any trousers finishing department. Here all the identified operations are listed with proper reasons if PMTS can be applied to those for measuring standard time values (SMV) or not.

Table 6. Analysis on the possibility of PMTS application to Finishing Operations

Operation	Possibility of PMTS Application	Reason
Rivet Attaching	Yes	PMTS Application is Possible as it is repetitive in nature and involves manual motions
Button Attaching	Yes	PMTS Application is Possible as it is repetitive in nature and involves manual motions
Tag Attaching	Yes	PMTS Application is Possible as it is repetitive in nature and involves manual motions
Belt loop Trimming	Yes	PMTS Application is Possible as it is repetitive in nature and involves manual motions
Topper Pressing/ Denim Blowing	Yes	In these operations, the piece is subjected to air and steam blowing in the machine, for a certain period of the cycle time Apart from this machine operating time, it requires manual involvements during the rest part and the motions follow always a typical sequence repetitive in nature. Therefore, it has the possibility of PMTS Application.
Thread Trimming	Yes, but not useful	PMTS can be applicable but evaluated SAM value for any operation might be misleading. Trimming only needs to perform where extra threads are present after sewing. It is never likely to happen that all garments would have threads in the same area. The garments will have threads in different areas and the amount of trimming will always vary resulting in higher variation in cycle times for different pieces. This inconsistency makes it impossible to have one definite SAM Value for this operation.
Scraping	Yes	This Operation has a very large cycle time and involves complete manual involvement to make it happen. Motions follow a sequence and sequences are repetitive in nature. Therefore, it is possible to apply PMTS to the set time-standard of this operation.
Whiskering	Yes	Having been an operation of the same nature as Scraping this also has the possibility of PMTS application.
PP Spraying	No	Though this operation involves manual motions, it is very hard to apply PMTS to PP Spraying. The reasons are as following- 1. Unlike Sewing or other above-mentioned operations, here hands move to cover an area, do not move along a length. But, we know that PMTS is applied based upon the distance traveled by the body parts or the objects being handled. 2. There is no specific distance

Operation	Possibility of PMTS Application	Reason
		followed or practically possible to standardize in the industry practice- between standing position and the piece to spray on. This distance also varies from person to person based on their heights this distance. With the distance, the amount of sprayed PP over a certain area also changes, resulting in a change in the frequency of sprays as well with all these. 3. Spraying is a work that is by nature, more qualitative than quantitative. As a result, rather than no of sprays, worker here pays more attention to obtain the desired look no matter how many or less frequency of sprays is required. 4. To cover an area by spraying, hand movements make a complicated pattern (for different persons the pattern is also very different) to study to measure the distance traveled by hands what is the basis of measuring the time using PMTS. All these together make it hard to apply PMTS to PP Spraying Operation (*PP- Potassium permanganate)
Hand Pressing/Ironing	No	1. Like Spraying also, here the hands move to cover an area and thus make a very complicated pattern to study the distance traveled by body parts or object handled. 2. Here to get the desired aesthetic look or functionality, pressing depends more on the heat and steam from the machine. As, this is also an operation where quality is of prime concern, to get the desired look and dimensional property, the operator presses/irons until that desired level is not obtained, no matter how much time is taken for the pressing. 3. It is hard to make people follow a certain way of moving hands (method) to press the piece and there is no guarantee that with the same method followed, the same desired properties (aesthetic or dimensional) would appear in all pieces. These all-together make pressing/ironing also a hard operation to apply the PMTS to.
Pearl Attaching	Yes	This is a repetitive operation where PMTS application for the human motions involved is possible
Heat Strass/Reinforcement Sticker Attaching by Fusing	Yes	Once the strass containing heat transfer paper/reinforcement sticker is placed on the desired position, all it needs is to fuse the paper on it by applying pressure for a certain time. Therefore, it has the possibility of PMTS application to the human motions involved during the rest of the time.

7.1.1. List of identified operations in the department on which research has been conducted

7.1.2. List of operations finally selected for the research project

From the above table, we can see that, there are 9 operations to which we can apply PMTS for developing an SDS to measure the labor content. Out of these 9, because of the unavailability and considering time constraint given for the project, we have selected 7 operations for our study. These operations are:

1. Rivet Attaching
2. Button Attaching
3. Tag Attaching
4. Belt loop Trimming
5. Topper Pressing/ Denim Blowing
6. Scraping
7. Whiskering

Figure 8. Operations Selected for Research Project

7.2. Findings of the research work

After studying the patterns of motion sequences of the above operations, a database of 50 distinct macro-elements/ codes was established. As claimed as the sub-objectives of the research work before, after the creation of the codes all related information like a detailed code description, MTM-2 Breakdown of all the codes have been documented and a video clip has been recorded for each code as a reference. Below image shows a typical example of all the information documented about each of established macro-element/code.

Example of Established Elements

Pick up the Piece (0-15, 16-30, 31-45, 46-80 cm):

Code Description- It starts with left, right or both hands coming back from disposing of a part. The hand(s) move to reach the piece and grasps with several finger movements (difficult grasp) and bring the piece closer to body. This element is applicable for fabric or garment piece. The element 'Pick up the Piece' does not include any straightening or positioning of the piece. The element does include releasing of the piece, which may take place later, after several more elements.

The distance here implies the length covered by hands from the last dispose position to reach the piece assuming the distances covered for reaching and moving the piece closer to body are same. In case of different reaching & moving distance, consider the distance of larger one for the ranges classified.

Breaking down into MTM-2 While GA and GB are for putting the palm of the hand on the side of any object in order to push it and getting an easy-to-handle object having particular shape respectively, getting the plies or garment piece from stack or bin etc. will always be a difficult grasp (**GC**). (Kanawaty, 1992)

This macro-element comprises of two basic MTM-2 Motions. **GC** for getting the piece and **PA** for moving the piece closer to body or working area.

SFD ELEMENT	Proposed Code	Range Classification (cm)	Comprising MTM-2 Elements			TST time(min) for Macro element
Pick up the Piece	PP1	0-15	Element	GC15	PA15	0.015
			Time(min)	0.011	0.004	
	PP2	16-30	Element	GC30	PA30	0.021
			Time(min)	0.014	0.007	
	PP3	31-45	Element	GC45	PA45	0.025
			Time(min)	0.016	0.009	
	PP4	46-80	Element	GC80	PA80	0.031
			Time(min)	0.019	0.012	

Figure 9. Example of detailed documentation of each established macro-element/code

In this way, a database of 50 macro-elements/codes has been created, with what, all manual motions involved in studied 7 operations can be defined ; and thus the Standard Minute Value (SMV), also known as Standard Allowed Minute (SAM) of the operations, can be evaluated.

The entire codes' database has been divided into 3 Data Cards (A data-card contains related macro-elements' names, their code-names, and pre-determined time values for different distance ranges). Data Card 1 helps to define human motions involved in 4 types of finishing operations- 1. Installing/Attaching Rivet, 2. Attaching Waist Button, 3. Attaching Tag to Jeans/Trouser and 4. Belt Loop Trimming. Data Card 2 can be used to analyze 5. Denim Blowing/Topper Pressing operation. Data Card 3 helps to study and evaluate work-content (SAM value) of 6. Scraping and 7. Whiskering Operations.

Table 7. Data-Card for Installing/Attaching Rivet and also Waist Button, Attaching Tag to Jeans/Trouser, Belt Loop Trimming

Data Card for Installing/Attaching Rivets, Waist Button; Attaching Tag to Jeans/Trouser & Belt Loop Trimming Operations							
Category		Macro Elementes	Codes	TST/Normal Time(min) For Distance Ranges (cm)			
				0-15	16-30	31-45	46-80
Pick up and Position	For Piece	Pick up the Piece	PP	0.015	0.021	0.025	0.031
		Pick up the Piece with Turn	PPT	0.019	0.028	0.036	0.043
		Position without Grasp, Easy	POSE	0.009	0.011	0.014	0.018
		Position with Grasp, Difficult	POSD	0.023	0.025	0.028	0.032
		Position Accurately without Grasp, Easy	POSAE	0.016	0.018	0.022	0.025
		Position Accurately with Grasp, Difficult	POSAD	0.030	0.032	0.036	0.039
	For Rivet/ Button/Tack	Pick-up and Positioning Rivet & Tack (Seperately)	PPRT	0.027	0.032		
		Pick-up & Position Rivet & Tack Simultaneously	PPRTS	0.035	0.040		
		Pick-up and Positioning Button & Tack Simultaneously	PPBTS	0.048	0.053		
Handling		Move or Straightening Piece without Grasp, Easy	MSE	0.006	0.007	0.010	0.012
		Move or Straightening Piece with Grasp, Difficult	MSD	0.010	0.015	0.020	0.026
		Regrasp with Fingers	RF	0.004			
		Regrasp with Hand Movement	RHM	0.006	0.007	0.010	0.012
		Fold without Grasp, Easy	FE	0.008	0.011	0.013	0.016
		Fold with Grasp, Difficult	FD	0.019	0.022	0.024	0.027
		Creasing or Nail Pressing without Grasp, Easy	CNPE	0.014	0.017	0.019	0.022
		Creasing or Nail Pressing with Grasp, Difficult	CNPD	0.022	0.025	0.027	0.030
		Close Button	CB	0.022	0.024	0.027	0.030
		Open Button	OB	0.019	0.022	0.024	0.027
		Push Button for Trimming	PBT	0.008			
Leg Motion		Foot Motion	F	0.005			
Dispose		Dispose	D	0.010	0.013	0.015	0.018
		Dispose with Folding & Straightening	DFS		0.041	0.043	0.046

Table 8. Data-card for Denim Blowing/Topper Pressing

Data Card for Denim Blowing/Topper Pressing Operation							
Category		Macro Elementes	Codes	TST/Normal Time(min) For Distance Ranges (cm)			
				0-15	16-30	31-45	46-80
Pick up and Position	For Waist	Pick up Piece for Blowing	PPB	0.018	0.021	0.023	0.026
		Position onto the Machine without Grasp, Easy	POSOME	0.009	0.011	0.014	0.018
		Position onto the Machine with Grasp, Difficult	POSOMD	0.015	0.019		
	For Hems/Legs	Positioning Hems/Legs of Long Pants into the Clamps with Straightening	PHLPCS	0.048	0.052	0.058	
		Positioning Hems/Legs into the Clamps of Short Pants with Straightening	PHSPCS	0.044	0.048	0.054	
Handling		Move or Straightening Piece without Grasp, Easy	MSE	0.006	0.007	0.010	0.012
		Move or Straightening Piece, Difficult	MSD	0.010	0.015	0.020	0.026
		Removing off the Machine	RM		0.013	0.015	
		Fold without Grasp, Easy	FE	0.008	0.011	0.013	0.016
		Close Button	CB	0.022	0.024	0.027	0.030
		Open Button	OB	0.019	0.022	0.024	0.027
Leg Motion		Foot Motion	F	0.005			
		Step	S	0.011			
Dispose		Dispose, Easy, Blowing	DEB	0.004	0.007	0.009	0.012
		Dispose with Straightening	DS	0.014	0.017	0.019	0.022

Table 9. Data-card for Manual Scraping/Whiskering Operations of Denim Wash

Data Card for Denim Manual Scraping and Whiskering Operation							
Category		Macro Elementes	Codes	TST/Normal Time(min) For Distance Ranges (cm)			
				0-15	16-30	31-45	46-80
Pick up and Position	For Piece	Pick up the Piece	PP	0.015	0.021	0.025	0.031
		Draw Piece onto the Machine Legs	DPML	0.009	0.011	0.014	0.018
	For Sand Paper	Pick up Sand Paper with Single Hand	PSSH	0.015	0.021	0.025	0.031
		Pick up Sand Papers Simultaneously with Both Hands	PSSBH	0.023	0.029	0.033	0.039
		Positioning/Repositioning the Sand Paper	POREPSP	0.009	0.011	0.014	0.018
Handling		Adjusting Pocket Bags inside before Positioning	APBBP	0.019			
		Move or Straightening Piece without Grasp, Easy	MSE	0.006	0.007	0.010	0.012
		Move or Straightening Piece with Grasp, Difficult	MSD	0.010	0.015	0.020	0.026
		Holding the Edge of the Whiskering Board/Plate	HEWBP	0.008	0.010	0.013	0.016
		Apply Pressure on Rubber Legs	APRL	0.012	0.013	0.016	0.018
		Rotate Machine legs Pushing Downward	RMLPD	0.011	0.012	0.015	0.017
		Rotate Machine legs Pushing Upward	RMLPU	0.013	0.014	0.017	0.019
		Removing Piece off the Machine Legs	RPOML	0.015	0.018	0.020	0.023
		Move handle	MH	0.008	0.009	0.012	0.014
		Rotate Button	RB	0.015	0.017	0.020	0.023
		Close Button	CB	0.022	0.024	0.027	0.030
		Open Button	OB	0.019	0.022	0.024	0.027
		Push/Pull Button/Switch without Grasp, Easy	PPBSE	0.012	0.013	0.016	0.018
		Push/Pull Button/Switch with Grasp, Difficult	PPBSD	0.014	0.016	0.019	0.022
Scraping/Whiskering (for 'n' of Rubbing)		Scrapping/Whiskering with Single Hand	SWSH	(2n-1).(0.004)	(2n-1).(0.007)	(2n-1).(0.009)	(2n-1).(0.012)
		Scrapping/Whiskering with both Hands	SWBH	n.(0.004)	n.(0.007)	n.(0.009)	n.(0.012)
Leg Motion		Foot Motion	F	0.005			
		Step	S	0.011			
Dispose		Dispose without Grasp, Easy, Piece or Sand Paper	DEPS	0.004	0.007	0.009	0.012
		Dispose with Grasp, Difficult, Piece	DDP	0.010	0.013	0.015	0.018

There are many common macro-elements/codes in data cards to define some motions of the same nature present in different operations. If we consolidate, we will find that 50 distinct codes are present in these 3 data cards. The table next shows the consolidated /summarized data card for combined all seven types of operations.

Table 10. Compiled Data Card of the Macro-elements of all 7 types of operations Studied

Category			Sl No.	Macro Elementes	Codes	TST/Normal Time(min) For Distance Ranges (cm)			
				Compiled Datacard of all Macro-elements		0-15	16-30	31-45	46-80
Pick up and Position	For Installing/Attaching Rivets, Waist Button; Attaching Tag to Jeans/Trouser & Belt Loop Trimming Operations while only Pick up Piece(PP) is used for Manual Scraping and Whiskering Operation	For Piece	1	Pick up the Piece	PP	0.015	0.021	0.025	0.031
			2	Pick up the Piece with Turn	PPT	0.019	0.028	0.036	0.043
			3	Position without Grasp, Easy	POSE	0.009	0.011	0.014	0.018
			4	Position with Grasp, Difficult	POSD	0.023	0.025	0.028	0.032
			5	Position Accurately without Grasp, Easy	POSAE	0.016	0.018	0.022	0.025
			6	Position Accurately with Grasp, Difficult	POSAD	0.030	0.032	0.036	0.039
		For Rivet/ Button/Tack	7	Pick-up and Positioning Rivet & Tack (Seperately)	PPRT	0.027	0.032		
			8	Pick-up & Position Rivet & Tack Simultaneously	PPRTS	0.035	0.040		
			9	Pick-up and Positioning Button & Tack Simultaneously	PPBTS	0.048	0.053		
	For Denim Blowing/ Topper Pressing	For Waist	10	Pick up Piece for Blowing	PPB	0.018	0.021	0.023	0.026
			11	Position onto the Machine without Grasp, Easy	POSOME	0.009	0.011	0.014	0.018
			12	Position onto the Machine with Grasp, Difficult	POSOM D	0.015	0.019		
		For Hems/Legs	13	Positioning Hems/Legs of Long Pants into the Clamps with Straightening	PHLPCS	0.048	0.052	0.058	
			14	Positioning Hems/Legs into the Clamps of Short Pants with Straightening	PHSPCS	0.044	0.048	0.054	
	For Scraping and Whiskering	For Piece	15	Draw Piece onto the Machine Legs	DPML	0.009	0.011	0.014	0.018
		For Sand Paper	16	Pick up Sand Paper with Single Hand	PSSH	0.015	0.021	0.025	0.031
			17	Pick up Sand Papers Simultaneously with Both Hands	PSSBH	0.023	0.029	0.033	0.039
			18	Positioning/Repositioning the Sand Paper	POREPSP	0.009	0.011	0.014	0.018
Handling	Common For all 7 operations		1	Move or Straightening Piece without Grasp, Easy	MSE	0.006	0.007	0.010	0.012
			2	Move or Straightening Piece with Grasp, Difficult	MSD	0.010	0.015	0.020	0.026
			3	Regrasp with Fingers	RF	0.004			
			4	Regrasp with Hand Movement	RHM	0.006	0.007	0.010	0.012
			5	Fold without Grasp, Easy	FE	0.008	0.011	0.013	0.016
			6	Fold with Grasp, Difficult	FD	0.019	0.022	0.024	0.027
			7	Creasing or Nail Pressing without Grasp, Easy	CNPE	0.014	0.017	0.019	0.022
			8	Creasing or Nail Pressing with Grasp, Difficult	CNPD	0.022	0.025	0.027	0.030
			9	Close Button	CB	0.022	0.024	0.027	0.030
			10	Open Button	OB	0.019	0.022	0.024	0.027
	For Especially Loop Trimming		11	Push Button for Trimming	PBT	0.008			
	For Especially Denim Blowing/Topper		12	Removing off the Machine	RM		0.013	0.015	
	For Especially Scraping and Whiskering Operations		13	Adjusting Pocket Bags inside before Positioning	APBBP	0.019			
			14	Holding the Edge of the Whiskering Board/Plate	HEWBP	0.008	0.010	0.013	0.016
			15	Apply Pressure on Rubber Legs	APRL	0.012	0.013	0.016	0.018
			16	Rotate Machine legs Pushing Downward	RMLPD	0.011	0.012	0.015	0.017
			17	Rotate Machine legs Pushing Upward	RMLPU	0.013	0.014	0.017	0.019
			18	Removing Piece off the Machine Legs	RPOML	0.015	0.018	0.020	0.023
			19	Move handle	MH	0.008	0.009	0.012	0.014
			20	Rotate Button	RB	0.015	0.017	0.020	0.023
			21	Push/Pull Button/Switch without Grasp, Easy	PPBSE	0.012	0.013	0.016	0.018
			22	Push/Pull Button/Switch with Grasp, Difficult	PPBSD	0.014	0.016	0.019	0.022
Leg Motion	Common For all 7 operations		1	Foot Motion	F	0.005			
			2	Step	S	0.011			
Dispose	Only for Scraping/ Whiskering (For 'n' of rubbing)		1	Scrapping/Whiskering with Single Hand	SWSH	(2n-1).(0.004)	(2n-1).(0.007)	(2n-1).(0.009)	(2n-1).(0.012)
			2	Scrapping/Whiskering with both Hands	SWBH	n.(0.004)	n.(0.007)	n.(0.009)	n.(0.012)
	For Installing/Attaching Rivets, Waist Button; Attaching Tag to Jeans/Trouser & Belt Loop Trimming		3	Dispose	D	0.010	0.013	0.015	0.018
			4	Dispose with Folding & Straightening	DFS		0.041	0.043	0.046
	For Denim Blowing/Topper Pressing Operation		5	Dispose, Easy, Blowing	DEB	0.004	0.007	0.009	0.012
			6	Dispose with Straightening	DS	0.014	0.017	0.019	0.022
	For Denim Manual Scraping and Whiskering Operations		7	Dispose without Grasp, Easy, Piece or Sand Paper	DEPS	0.004	0.007	0.009	0.012
			8	Dispose with Grasp, Difficult, Piece	DDP	0.010	0.013	0.015	0.018
*Total no of Elements for Manual Motions			50						

8. Analysis and Validation by Experiment

8.1. Experiment for Validation

After establishing the SDS, it is important to check how precisely it is measuring time when real-time challenges come in terms of setting a standard time for given work. To check the applicability of SDS, the most useful way is to measure the variation of time evaluated using SDS and time determined using the time study method. To accomplish the objective, we have performed one experiment here this way-

1. We have collected video-footages of 12 operations of the previously mentioned seven types of operations the SDS developed for, from different industries located in different countries.
2. Then we have carried out Time Study on these operations for 20 cycles to determine the average observed cycle time for these operations.
3. Then we have studied the operations separately with PMTS from recorded videos and then based upon the method followed, we evaluated the standard times (Normal/ Basic Time) for these operations using the established SDS.
4. Finally, we have studied the results obtained statistically and interpreted the data with pie chart.

8.2. Statistical Analysis of The Result Obtained from experimentation

The table below summarizes the observations about the results obtained from the experiment.

Table 11. Statistical Analysis of the Results from Experiment

Serial No	Kind of Operation	Standard Time evaluated using SDS	Average Observed Time	Variation(%)	Variation(%) Considering only the Mod Value	Maximum Variation (%)	Minimum Variation (%)	Average Variation	Operations below +/-3% Variation	Operations below +/-5% Variation	Operations Below +/-7.5% but above +/-5% Variation
1	Snap Button Attaching	0.131	0.133	-1.75	1.75	6.25	0.40	3.54	33%	83%	17%
2	Snap Button Attaching	0.136	0.132	3.03	3.03						
3	Snap Button Attaching	0.123	0.126	-2.38	2.38						
4	Rivet Attaching	0.198	0.190	4.21	4.21						
5	Rivet Attaching	0.496	0.498	-0.40	0.40						
6	Tagging	0.255	0.272	-6.25	6.25						
7	Topper pressing/Denim Blowing (long trousers)	0.490	0.479	2.30	2.30						
8	Topper pressing/Denim Blowing (short Trousers)	0.379	0.400	-5.25	5.25						
9	Scraping (Double Side)	1.140	1.192	-4.36	4.36						
10	Scraping (Single Side)	0.799	0.831	-3.85	3.85						
11	Whiskering (Single Side)	0.764	0.728	4.95	4.95						
12	Whiskering (Single Side)	0.784	0.756	3.70	3.70						

Key Observations-

1. On 50% occasions, (6 out of 12), SDS based analysis has under-estimated ('- 'variation) time than the average observed cycle time. On 8% occasions is has precisely estimated the time (-0.40% variation). On the other hand, on 42% occasions, it has over-estimated ('+ 'variation) the time than the average observed cycle time.

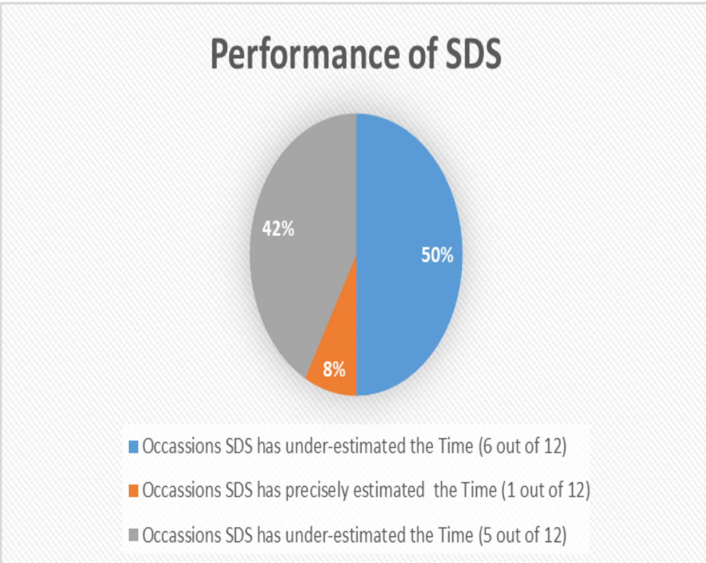

Figure 10. Pie Chart Representing Performance of SDS

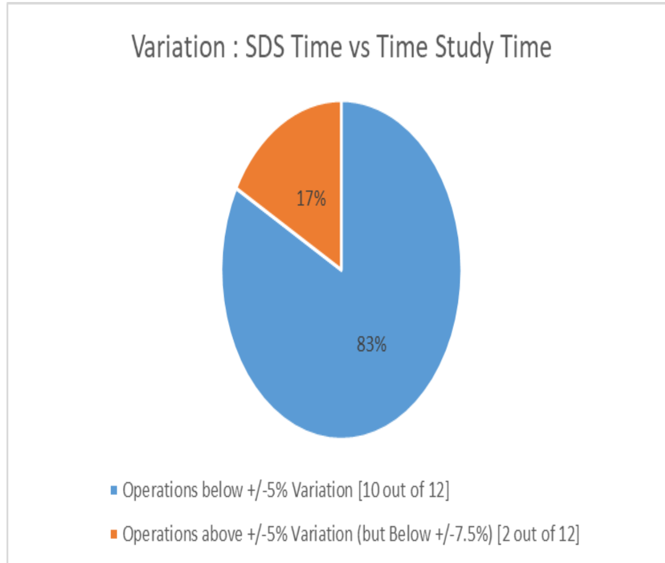

Figure 11. Pie-chart Representing percentage of operations having a certain variation

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2. The purpose of the experiment is to check how accurately SDS can help evaluate the time. Therefore, for analyzing the result, we have considered only the modulus values of the variations to study its closeness to the observed time value- no matter if the variation has a positive or negative value. Here we can see the variation ranges from 0.40% to 6.25%.

3. On 33% occasions, the variations have been below +/- 3%.

4. On 83% occasions, the SDS based standard times have had variations below +/- 5%. Rest 17% occasions only, the variations have been more than +/- 5% but have never gone beyond +/- 7.5 %.

9. Conclusions

Earlier Sauer said that," Experience *shows that variations of 7.5% in the standard times found by stopwatch time study must be expected"* (Sauer, 1950). Here from our experiments, we have seen that the variations in the Standard Times set by SDS have never exceeded 7.5%. This means that the time standard set by the PMTS based SDS have always fallen within the area of the scatter plot of the normal times found by time study.

Based on the level of variations found in our experiments, the results demonstrate that this PMTS based SDS can replace the conventional time study based labor content measurement method in garment finishing departments with a considerable level of accuracy.

However, to put the time constraint for the project and limited exposure of a trousers production facility during our research in perspective, we have to admit that the SDS developed here can be useful for the work measurement of a trousers-finishing-department only.

In addition, there are many other types of garments requiring different kinds of finishing operations, which involve different kinds of manual motions. To name a few of them-

1. Folding of Shirts before packing,
2. Tagging with Tag gun,
3. Thread Trimming off the garments,
4. Barcode Scanning,
5. Attaching Barcode Sticker,
6. Heat Strass/Reinforcement Sticker Attaching by Fusing, and
7. Pearl Attaching etc.

These are some of the operations where it is possible to apply PMTS successfully to measure the time.

Therefore, by extending the research to the finishing operations of other products and with a longer period of time invested in this, it is possible to come up with a PMTS solution of universal application, which could help us to set up work standard for finishing operations of any garment product according to an international benchmark.
As an outcome of the research project, while studying and creating the macro-elements/codes for the simultaneous motions, one another finding discovered was- *overall performance rate, by 2 hands, of doing simultaneous activities of the same nature is more/better than that of the different natures.*

10. Limitations of SDS

The fact we should keep in mind is that- no SDS, as often claimed, actually eliminates the need for the stopwatch fully, any more than they eliminate method study or work sampling. Machine time, process time and waiting time are not measurable with PMTS systems, and occasional or incidental elements are often more economically measured using other techniques. In fact, it is difficult to obtain 100 percent coverage in a plant using only a PMTS solution, and in certain cases- 1. A high volume of different parts, 2. Low production run, 3. Rapid changeover, 4. Batch production or 5. Non-repetitive jobs -the use of such a system can be an expensive proposition and is not always practical to practice without the assistance of any direct measurement technique.

11. Future Scopes of this Research

The finishing section of the garments department is still bereft of any scientific measurement techniques for labor content benchmarking and production planning. This research, therefore, was an endeavor to cater to one for the industry and point out the unexplored possibility harbored in the domain. As already discussed, it is apparent that, by extending the research to the finishing operations of other products and with a longer period of time invested in this, it is possible to come up with a PMTS solution of universal application. This could help us to set up the work standard for finishing operations of any garments products according to an international benchmark. When we will own such SDS, it would help the industry in not only planning efficiently but also taking a giant leap towards Industry 4.0. In this era of digital high-end cameras and drones, it may become possible in the near future to analyze the operations from the videos taken by a drone from different angles and positions. It will save both time, labor, and make it easy to study body part movements without interrupting normal working situation on the shop floor by eliminating the requirement of an IE personnel's real-time presence out there. With the advent of modern improvements and application of Artificial Intelligence, Machine Learning and the Internet of Things etc., it may turn into reality that the AI-enabled system would recognize the motion patterns and be able to evaluate the SAM values using the predetermined set of time-data values from SDS- on its own, without any expert's intervention. Nevertheless, before that, we should at least develop that Standard Database for the scientific work measurement technique as the stepping-stone. Our research here aims to provide that necessary ground as its primary objective to achieve the desired goal.

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